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RESEARCH PAPER

Faecal sludge management practice in informal settlements of Bangladesh

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Abstract. Informal settlements suffer sanitation challenges of inadequate toilet facilities and a high accumulation rate of faecal sludge due to land crises and dense populations. However, people who struggle with informal living, either way, manage to keep their toilets running. This research explores faecal sludge management practices by people living in informal settlements. It took Notun-Bazar Char Khulna as a case, purposefully sampled toilets and populations and conducted interviews and group discussions among informal settlers, sweepers, key persons and detailed observations of settlement premises. It also mapped excreta flows and discharge locations in drawings and diagrams. It illustrates how faecal sludge from all types of containment ending in the water is unsafe. This study analytically found practices related to periodical containment management, collective emptying mechanism and faecal sludge's conditional conveyance available in the informal settlement. It suggests developing environmentally safe faecal sludge management in informal settlements with an appreciation of the identified practices.

Keywords: Containment; conveyance; emptying; environmental safety; faecal-sludge management (FSM); informal settlement.

1. Introduction

Sanitation introduces a range of facilities and services for all settlements, where faecal sludge management (FSM) is an essential part and inevitable challenge aroused with achievements of the remarkable growth of On-site Sanitation facilities in developing countries (Bain et al., 2015; ISF-UTS and SNV, 2019; WHO, 2018). However, cities are home to more than half of the world's population, with 30% of all city dwellers living in informal settlements (UN-Water, 2018), and the number is continuously increasing. Informal settlements can spread diseases over less crowded areas but suffer sanitation challenges of inadequate toilet facilities and a high accumulation rate of faecal sludge (FS) due to land crises and dense population (Katukiza et al., 2012; Simiyu, 2017). Due to the lack of available spaces to build proper sanitation facilities with appropriate on-site containment and ease of sharing, informal settlers mostly prefer pit latrines, resulting in a high filling rate of FS, difficulties in emptying and fewer septic tanks in the settlement (Simiyu, 2015; Thye et al., 2011). Septic tanks are only available with a few shared toilets, and city authorities or NGOs provide different sanitation projects to achieve the sanitation

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targets of the Millennium Development Goals (MDG). In Bangladesh, open defecation has been reduced to less than 1% of the population with MDG's sanitation target (WHO & UNICEF, 2015). Additionally, only 2% of urban faecal sludge is managed and processed by sewerage systems, which are lacking in many areas, making FSM a second-generation sanitation challenge (Library, 2015). However, it increases the reliability of on-site sanitation, including pit latrines and septic tanks, and only 12-30% of informal settlers have access to safely managed sanitation facilities, including FSM (WHO & UNICEF, 2015).

Informal settlers struggle with tenure and food security difficulties, yet they manage to maintain their toilets running despite all these challenges (McFarlane, 2008; Rahman, 2014). This study also found that a lack of proper sanitation infrastructure causes untreated FS to end up directly in the environment. Previous research claimed that the lack of information on the whole FSM scenario in informal settlements (Peal et al., 2014) affects detailed long-term plans and decision-support tools (Kennedy-Walker et al., 2016). Meanwhile, in Bangladesh, vacutug-based services were specifically adopted for urban slums (Ross et al., 2016). However, its service attracted few demands from formal residential and commercial areas, and informal settlements were never availing of this service, implying that they are not included in that system (Jakariya et al., 2018). The cities offer a variety of demand-based FS emptying services. Long ago, sweepers used informal manual methods to empty the FS, but officials only implemented vacutug-based mechanized emptying. (Opel & Bashar, 2013; SNV, 2017). Though sweepers have unconstrained access in varied settlements with unsafe emptying methods, their informal roles on FSM are not adequately addressed in formal models. Besides, the self-management system of people living in informal settlements remained unexplored. This research explores practices by settlers and sweepers in informal settlements and tries to reduce information gaps to develop decision support tools for city-wide FSM in Bangladesh.

This paper is a systematic literature review (SLR) to develop a more systematic understanding of the effects of climate change on food security. SLR can describe areas of research, and to identify research gaps (Snyder, 2019). SLR allowed the researcher to investigate the literature and answer: the relevant literature that could be found; the themes discussed; and research gaps identified. The structure of this research consists of an introduction, materials and methods, results, discussion and finally a conclusion.

2. Literature Review

2.1. Faecal Sludge Management and Environmental Safety

Faecal sludge is liquid and semi-liquid contents accumulate in storage facilities such as pits and septic tanks of on-site sanitation systems within the dwelling plot (Hemkend-Reis et al., 2008; Tilley et al., 2014). However, to keep these systems running, the sludge has to be collected and treated off-site (Hemkend-Reis et al., 2008), and FSM deals with it. The sanitation service chain is a widely accepted de-facto framework that devices a better understanding of faecal sludge's physical flow through the sanitation systems (Bain et al., 2015; Rao et al., 2017; Scott, 2019). The chain consists of five steps: containment, emptying, transport, treatment, and disposal (Figure 1). Containments are storages that contain human excreta safely; emptying is to vacate FS from containment, and transportation signifies carrying FS to safe locations; treatment is to convert FS into a non-harmful condition; and disposal is to discharge FS safely to the environment (Rao et al., 2017). This study borrows the sanitation service chain concept to report FSM practices step by step in an informal settlement with environmental safety concerns. The environmental safety during FSM practice was categorized according to where the FS was conveyed after emptying and the type of containment used (Kabir & Salahuddin, 2014; Shahriar et al., 2022). By demonstrating how improper management at each stage of the sanitation chain spreads excreta in the environment, the f-diagram; (WHO, 2018) published by WHO in 2018 emphasizes the importance of safe sanitation systems as a fundamental barrier to transmission. The diagram captures that

transmission routes are not only fecal-oral but have complex ways where different risks and risky events correlate (WHO, 2018). This study prepared a checklist (Table 1) based on existing literature to consider whether the explored FSM activities were safe or unsafe for environmental health.

2.2. FSM dynamics in informal settlements

Informal settlements are residential areas that are often situated in hazardous lands where residents lack tenure for land or dwellings; they are usually cut off from city infrastructures, lack a formal supply of essential services and are constantly exposed to disease, violence and evictions (UN-Habitat, 2015). The practice of informality is the management of poverty. As Kim Dovey mentioned, informal urbanism is a complex adaptive assemblage which means; in informal settlements, there exists a complex adaptive system of growth, conservation, release and re-organization, and the system is intermeshed with the chain of whole urbanism (Dovey, 2012). Informal settlers manage their situations with their informal practices without the city's essential services. It was recommended in the UN-Habitat issue paper to first understand the challenges of informal settlements and then adopt a people-centered approach (UN-Habitat, 2016).

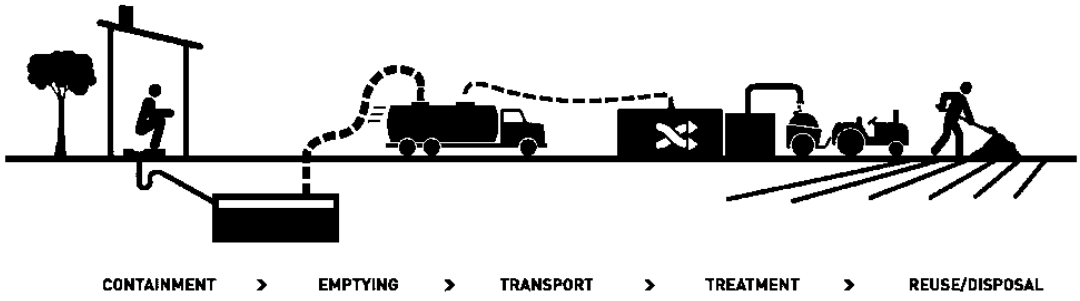

Figure 1. Sanitation Service Chain (Gates Foundation, 2010)

Table 1. Environmentally Safe FSM Activities (Kabir & Salahuddin, 2014; Shahriar et al., 2022; Simanjuntak et al., 2020; Visakhapatnam & Corporation, 2018)

- No open defecation on settlement premises
- Keeping containment impermeable from water and flies
- Regular observation of containment to prevent FS overflow
- Installing well-sealed pipes to connect containments with sewer or digestion systems
- No FS discharge to any surfaces, toilets, settlement premises, drains, or open grounds
- Awareness of users about the timely emptying of containment
- No entering the containment during emptying
- Using protective gear and compatible equipment for emptying
- Keeping people unexposed to direct inhalation of the pathogen
- Disposal practice of compost or FS is only after a minimum of six months of storage
- Not discharging un-treated FS to the water bodies or open environments
- Having sufficient pathogen removal process from FS in treatment facilities
- Practicing the emptying cycle period of three years but more frequently for shared facilities
- Cleaning toilet premises after emptying operations

With a high population density and a lack of traditional toilets, informal settlements may transmit more diseases; instead, they favour pit latrines more than septic tanks, which have a high rate of Faecal Sludge filling and difficulty of FS emptying (Isunju et al., 2011; Simiyu, 2015). Narrow streets and passages, plot divisions, physical diversity, topography, containment type, storage capacity, location of containment, and location of disposal site affect accessibility, mobility, and affordability of availing top-down vacutug based mechanical services for safe emptying (Isunju et al., 2011; Opel & Bashar, 2013; Ross et al., 2016; Thye et al., 2011). On the other hand, sweepers (informal manual service providers) have ease of access regarding physical diversity and economic affordability (Opel & Bashar, 2013). However, due to a lack of skills, the capacity of equipment, constraints related to FS transportation, availability of disposal site, and shortage of on-site facilities causes health risk due to spillage of FS in slum compound, discharging FS into nearest storm drains, water bodies and dug trenches which leads to the nearest ponds (Ross et al., 2016; Thye et al., 2011). Further from informal settler's practices, FS discharging to the nearest storm drains with pipes or drains to avoid emptying not only adds more pollution to the slum surroundings (Ross et al., 2016), but also causes eutrophication of water sources leading downstream, which can affect many other localities (Isunju et al., 2011). Tariff structures and payment mechanisms of existing services primarily affect the affordability of informal informal settlers (Ross et al., 2016). Availing of an emptying service is assumed as an extra cost, where people primarily focus on the survival of living affects their willingness to pay for servicing on-site sanitation facilities (Isunju et al., 2011). The legal status, land tenure system and tenant-landlord relationship dynamics cause people to be transient and have little willingness to manage containment (Isunju et al., 2011; Ross et al., 2016; Simiyu, 2017). Among socio-cultural issues, lack of awareness of FS emptying, knowledge of service availability and social stigma of living in an informal settlement create distances among dwellers from getting safe emptying services (Ross et al., 2016; SNV, 2017; Thye et al., 2011).

Table 2. FSM Dynamics in informal settlements (Isunju et al., 2011; Opel & Bashar, 2013; Peal et al., 2014; Ross et al., 2016; Shahriar et al., 2022; Simiyu, 2015, 2017; SNV, 2017; Thye et al., 2011)

Socio-cultural	Spatial	Economic	technological
• awareness • responsiveness • foul odour • decision making • social stigma • shared duty • social cohesion • political process • extent of sharing • internal conflicts • networkability • population density • time of emptying • emptying duration • user number • emptying refusals • unsafe dumping • transiency	• shred toilets • pit toilets • space allocation • containment location • accessibility • disposal site • plot size • space allocation • narrow road • containment location • space allocation • relocation of containment • discharge site distance • topography	• availability • ability to pay • payment mechanism • tariff structure • affordability • tenure • income effort • affordability • no reuse • ease of availing	• transportation • FS fill rate • containment type • FS spillage • equipment capacity • human contact • equipment capacity • high fill rate • ease of sharing • exposure of FS • quality of sludge • storage capacity • efficiency • sludge mobility • containment quality • treatment facility • solid material in the pit

A complex decision-making process of informal settlers and the extent and boundary of shared responsibilities always hamper the maintenance of toilets, containments and proper operation of the emptying process in containment sites (Isunju et al., 2011; Simiyu, 2015). These maintenance and operations are also affected by conflicts among tenant and landlord relationships and variations of preferences in selecting service options. The limited social network of the transient population also develops poor linkage with well-managed disposal sites, and difficulties relating to well-managed disposal cause failure of safe emptying (Isunju et al., 2011). Ease of availing service, visibility and smell of FS in the emptying period, emptying duration, flexibility and timeliness of services and preferred time decided from informal settlements also affect preferences of availing services and quality of faecal sludge emptying (Cookey et al., 2020; SNV, 2017). These instances indicate a need to make the sweepers process safe and safer service providers need to address containment and disposal site-bound complexities from slum areas to enhance the quality of emptying (Peletz et al., 2020). This study listed the above dynamics within a group (Table 2) of aspects such as socio-cultural, spatial, economic, and technological.

3. Methods

3.1. Study area

This study considers Notun-Bazar Chor as the least likely case, the largest among 1,134 informal settlements of Khulna, Bangladesh, where 3,480 people (854 households) live (BBS, 2015). Khulna has city-wide vacutug-based emptying services provided by Khulna city corporation (KCC) and community development committees (CDC) and sweepers (manual emptier) provide manual emptying services (SNV, 2017). Notun-Bazar Chor is settled in both government-owned and Christian Service Society (CSS) land, where maximum variations such as pit toilets, hanging toilets and toilets with septic tanks are available. As FS is directly related to water contamination (Isunju et al., 2011), the study area has the potential to observe the relation of FSM with water bodies having internal ponds and the Rupsha river nearby. The existing ponds owned by CSS contain polluted water, scatter foul odor and floating garbage visible on pond water. CSS does not restrict people's pond use; many residents connect their pits or septic tanks with the pond through underground pipes, and some hanging toilets are also constructed over the pond water (Figure 2a). Rupsha river is Khulna city's primary edge, and city people use it as a wastewater discharge place. The study area is beside the Rupsha River and is connected by a big drain with a sluice gate that leads wastewater from all formal and informal settlements toward the river (Figure 2b). Big drains directly face the tidal effects of the river and sometimes overflow water in settlement streets. It has a 23' wide road with the city, but internal alley widths ranged from 1'- 6" to 12' -0" made with concrete pavements and drains with many. People do not pay rent but instead pay the electricity bill and taxes to KCC according to the room's size. A sample household pays 198/- BDT tax per year for a 26'x13' size room bought with 9000/- BDT. Alley-based social organizations of the settlement maintain territorial control and decisions of each alley named by its people, such as Christian alley, Sat-vai alley, Kashem alley, school alley, Masjid alley, etc.

Figure 2. Water bodies where FS and black water is being discharged (a) Pond in Notun Bazar Char settlement (b) city drain and river connection

3.2. Toilets and populations

This study sampled the maximum variations such as two hanging toilets, seven single pit toilets, one twin pit toilet and seven toilets with septic tanks considering the single or shared user, containment types, and alley-based social organizations (Figure 3). Respondents for interviews from four single toilet users were selected, along with toilet selection, and in the case of shared toilets, 13 users were sampled through the snowball method. Household numbers varied from three to 56 as single-premise users of shared toilets. That is why six groups were selected randomly from them for group discussion, and the respondent number varied from three to six persons in each discussion where mainly females participated. A local sweeper was opportunistically interviewed, who participated in several emptying operations within the study area. This study also participated in a group discussion with the sweepers from the Harizan (a caste of Hinduism) community. Besides, it conveniently interviewed a vacutug manager, three CDC members and three NGO personnel to perceive city-wide FSM scenarios and practices among informal settlements. Before starting, the first author clearly explained the research to the participants, and after the interview and discussion sessions, the documented information was briefly conveyed to the respondents and verbal consent was taken for later use.

Figure 3. Sample toilets (a) Single pit toilet; (b) shared septic tank toilet; (c) Shared pit toilet; (d) Hanging toilet

3.3. Data Collection and management

Semi-structured close and open-ended questions were asked to the respondents and recorded to understand the whole FSM scenario of toilet premises, containment construction and condition and management. Respondent's handwritten indications for showing underground infrastructures, FS flows and FS's discharge locations are noted on hand-carried maps. Toilet users' information is triangulated with local sweepers' and NGO personnel's information. This study took photographs and videos to supplement the desktop preparation of built-environmental maps and FS flow diagrams during observation. The streets and toilet infrastructures were also measured with a digital measuring device and listed as field notes on settlement maps from Khulna Development Authority. The site was repeatedly visited throughout the process to produce more reliable transcriptions and drawn maps (with AutoCAD-2017). Interviews and group discussions were recorded on an audio device and transferred to the computer, transcribed verbatim into Microsoft-word, translated into English, read and re-read to gain familiarity with the data. Data analysis followed a thematic content approach where three types of information were analyzed: informant and respondent interviews, built-environmental maps and environmental issues.

4. Results and Discussion

4.1. Results of FSM practices

4.1.1. Hanging toilet users

"We paid for the toilet ourselves, constructed pan slab only; there is no ring under the toilet, and dirt goes to water when the water level rises in the pond; not only us do that; people living near the pond, all do the same" - a hanging toilet user (female)

No containment is found in hanging toilets constructed over the pond water, despite having a street with a drain (Figure 4). People used a concrete squatting pan without a water sill trap over wood, a bamboo frame and a CI sheet or bamboo fence for toilet walls. Excreta emitted from these toilets sometimes accumulates as a high pile under the pan when the pond becomes dry. They pour buckets of water from the nearest tube well to eliminate an increased accumulation of sludge that can block their squatting pan. To avoid emergency overflow, users monitor sludge fill-ups periodically.

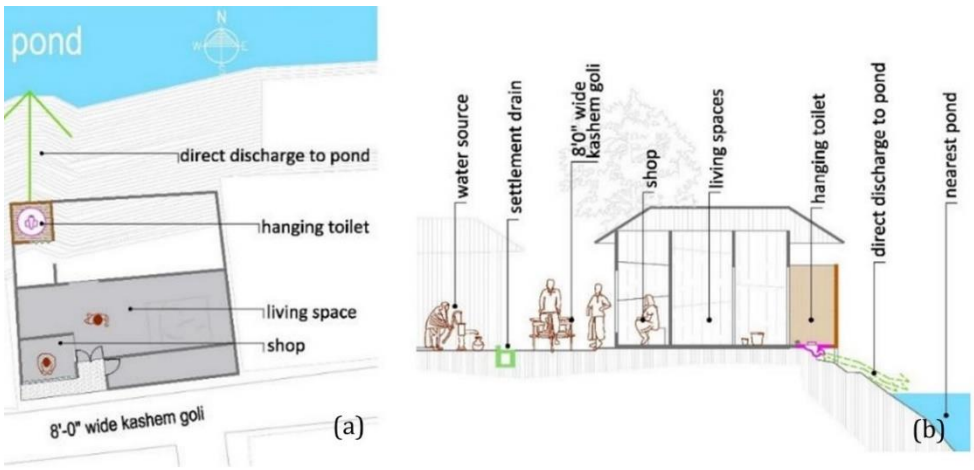

Figure 4. FS discharge from hanging toilets (a) plan; (b) section of a sample

4.1.2. Single-pit toilet users

"*My pit does not require emptying; the pit has a piped connection with the pond; 16-18 households of this street have done it, for not having a drain, everyone built roadside toilet because it is less costly" - a pit toilet user (male)*

Individual households using single pit toilets are common in informal settlements; they were built at the users' expense and rarely practice FS emptying operations. This research found two types of single toilets; one with a pit under the pan slab (Figure 5a), and another without (Figure 5b). People usually connect pits with settlement drains using PVC pipes, and households near the pond connect them with the pond using pipes under the concrete pavement of the street. Almost all containments have never been emptied before, which do not contain the sludge and discharge periodically to nearby drains or water bodies (Figure 5). Only one containment was emptied four-five years ago because of the pipe blockage with hard sludge. During that time, users uncovered the drain slab and tried to clear the pipe blockage using wooden sticks but failed. No service hole was visible with the pit to conduct any emptying operation and constructed with locally made concrete rings with local masons. Besides not having brick-sole or concrete casting at the bottom, those unlined pits do not adequately contain the FS. People used six to eight rings, which added eight to ten fit depths.

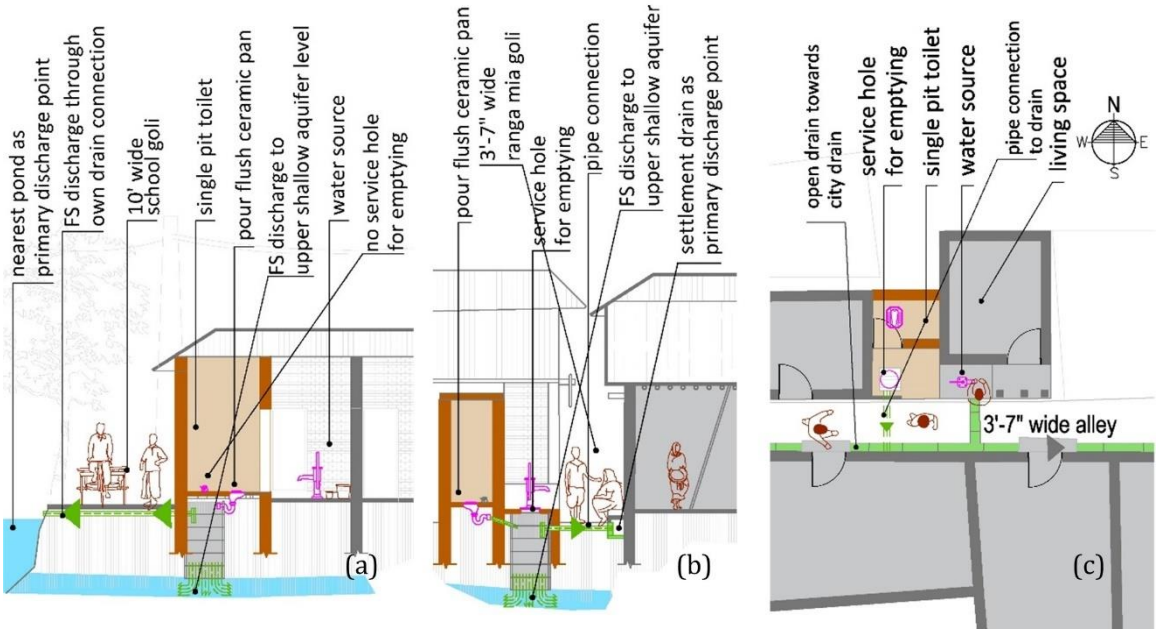

Figure 5. FS discharge from pit toilets (a) Single HH pit section; Shared pit (b) section (c) plan

People who emptied their pits paid a great price because their pit had no service hole. Pit rings are not big enough to place the hole over them. Toilet holders use a pour-flush ceramic pan over the pit and it takes much space to connect with the pit. Due to the space constraints within the house, they cannot split the position of the pit from the pan. As a result, they had to break the slab while they needed emptying to clear the blockage, which added extra cost for emptying. The containment operated for FS emptying was aligned under the pan slab having no emptying hole (Figure 5a). That caused an extra cost to break the slab. As they have unemptiable containment, they are conscious of FS accumulation and periodical discharge of FS through pipes to the drains.

However, they expressed a willingness to adapt infrastructural changes with their containment to make it an emptiable slab and repair it.

4.1.3. Single-pit shared toilet users

"We are 50 people of seven families using the single toilet, and it gets blocked very frequently, suppose three to four months consecutively. People from NGO came to us for toilet, but we could not avail for lack of land, each room of this alley has toilets connected with this narrow drain" - a single pit shared toilet user (female)

Shared toilets with single pit users practice the same as the single HHs but face a high FS fill rate, and their frequency of blockage is high. Sweepers emptied one single pit toilet (Figure 5c) three years ago. Seven households used it, and they did not get an improved one because of the lack of land. To manage the overestimated frequency of emptying, sometimes households empty their own pit to reduce the extra cost. They can empty it quickly because the pit is not under the pan, and they discharge FS in the nearest narrow drain and pour buckets of water to get rid of sludge and pour kerosene oil to get rid of odours. Sweeper worked with a spade and bucket in this alley, carried FS to drop to a big drum kept in a van in the main street and worked only at night as their neighbours allowed it.

4.1.4. Twin pit shared toilet users

"If we want to call a sweeper, they do not need to carry the sludge to any other places after emptying; we can easily dump it into the pond at night, there is no problem with that dumping" - a twin pit shared toilet user (female)

Few twin-pit shared toilets were found only in Christian alleys, used by the Christian cluster, and occupied more settlement space than others. Connecting alley is only 5' wide, but a regular-sized van can enter. They got the toilet from CDC, constructed with twin pits in locally available methods. From these four households, three households use one toilet, one household uses one toilet that can be accessed through their room, but a Y junction connects both toilets with twin pits. Both pits do not work now; one pit became non-functional soon after the construction as the concrete ring collapsed. No service hole was observed over the pit despite having the opportunity to have it. They have not attached pits with the drain or pond but never emptied after construction, i.e., 13 years.

4.1.5. Shared septic tank toilet users

CDC or NGO provided shared toilets with septic tanks in the settlement. Three types of shared toilets with septic tanks have been observed, i.e., toilet blocks used by single alley users (Figure 6), toilets used by two alley users and have two separate containments (Figure 7) and toilet blocks used by two alleys with single containment. NGO personnel informed that the septic tank's sidewall and bottom are adequately lined.

"Availing a toilet (from NGO) we survived, what we had earlier the slab was broke down, and drop into the pit" – a shared toilet with septic tank user (female)

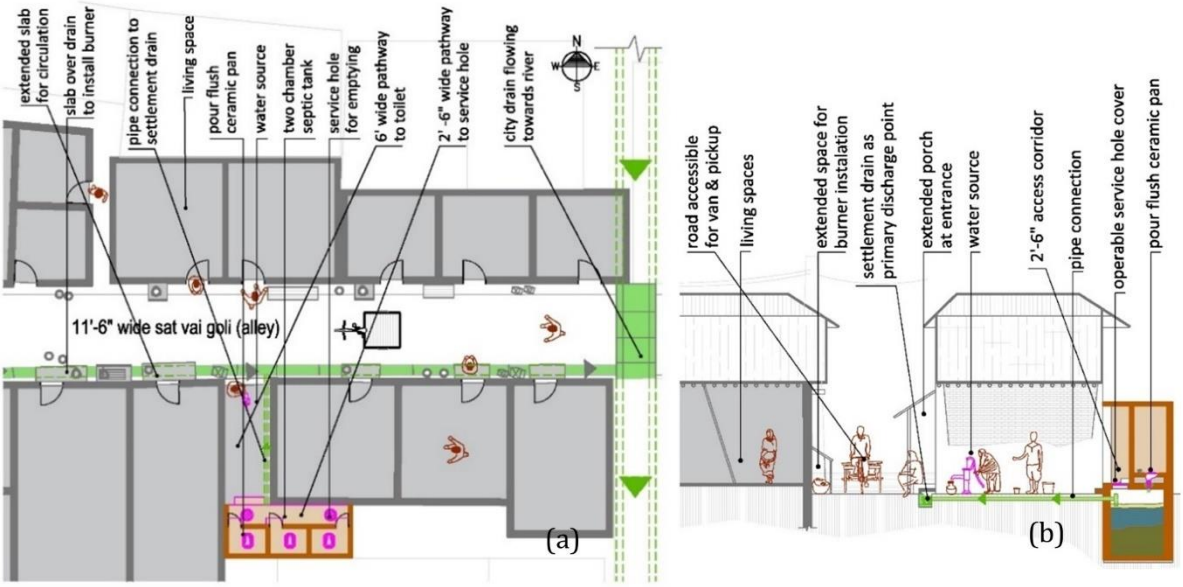

Figure 6. FS discharge from 20 HH's shared toilet with septic tank (a) plan; (b) section.

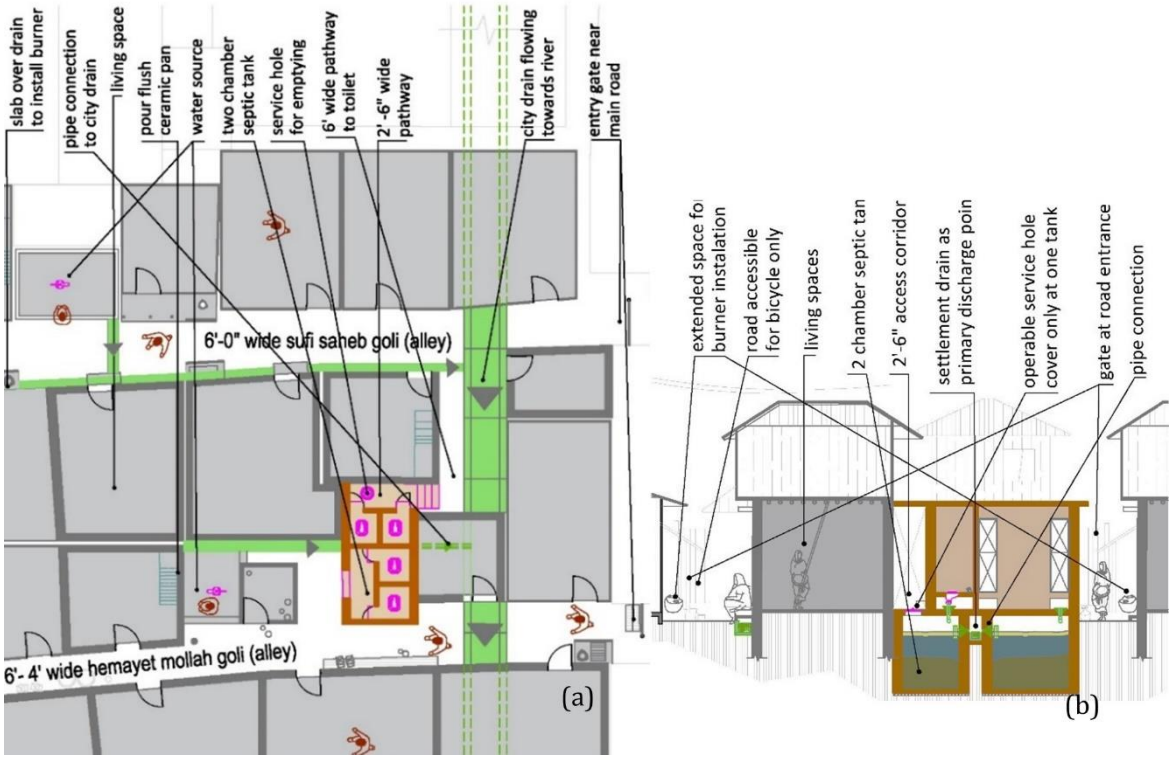

Figure 7. FS discharge from 56 HH's (2 alleys) shared toilet with septic tank (a) plan; (b) section

After the septic tank toilet construction, people linked the tank with drains to manage FS increase and three types of connections were noticed in the community. Tank linked with city drain, tank attached to settlement drain and tank connected to pond; typical scenario is that the

tanks were never emptied after construction. That is causing almost no containment; FS intermittently goes directly to the alley side open drain, pond and river through the city drain and the sanitary purpose is not operational.

"*People usually connect their tanks with nearest drains, but people of Khristan alley living at the west side of the pond linked their tank with pond, they do not have a drain" – a male sweeper from the settlement*

Usually, black water goes frequently to the drain, and sludge goes periodically. Tanks connected with city drains are not affected by foul odour because the city drain has a tidal effect created by the Rupsha River, which cleans the drain every day; however, in settlement drain, which has a shallow depth and outspreads terrible smell to the premises when FS emits from the containments.

"*People scold us after excreta emits to the drain; the nearby gutter is not deep enough, just one wrist span; if dirt comes out, we pour water promptly, sometimes throw kerosene oil to remove the bad odor" – a shared septic tank toilet user (female)*

Tanks become full of FS when a connecting pipe becomes clogged with any hard sludge or cloth accidentally dropped into the pan. Primarily, people try to manage the condition self-handed using wooden or bamboo sticks by pricking or pouring buckets of water. However, the worst situation happens when their system fails and only then do they search for a sweeper. While people from one alley call sweepers, they collect money from every household. That is their practice of paying for emptying a containment. However, in single containments of two alleys, it is sometimes impacted by alley disputes.

"*Suppose one piece of cloth been poured with water into the pan, after washing cloth they forgot to pick it from the bucket, it went through the pipe and clogged it, sometimes chamber becomes jammed, then we need to uncover the manhole and clear the jam" – a male local sweeper*

Sweepers who empty FS in this settlement sometimes discharge sludge to the nearest settlement drains, sometimes to the city drains and occasionally to the river or sluice gate where multiple city-level drains are linked near the river (Figure 2b). However, no matter what is done, all the FS ends up in the river.

4.2. Discussion

Out of 17 toilet samples, this study found only six containments emptied at the emergency but not within three years, breaking the safe emptying standards. Pits are constructed using locally available 12" high, 2" thick and 3'-2" diameter concrete rings with local mason without the involvement of professionals. CDC provides shared toilets with pits and shared toilets with septic tanks provided by NGOs and KCC; both provisions come with a borrowing payment system. Studied pits are lined, but the bottom is not sealed with brick sole or concrete casting; as people know, even NGO construction drawings do not suggest that. Institute of Water Modelling identified that Khulna's groundwater level of the upper shallow aquifer fluctuates from .56m or 1'-9" to 2.16m or 7'1" below ground level (Asian Development Bank, 2011). Surveyed pits are constructed with 6-10 concrete rings that get six to ten feet deep and directly touch the upper shallow aquifer. It means FS contained in pits gets dissolved with the top groundwater level. Each containment has

a pipe connection to discharge FS with black water. As containments are connected with drains or the nearest pond as a primary discharge point, FS does not fill up containments. According to the primary concern, people manage to keep their containment functional from their practice. However, it is reducing sanitation barriers of the faecal-oral contamination pathways, causing FS to dissolve with water and increasing people's health risks of being affected by flies and foul odours.

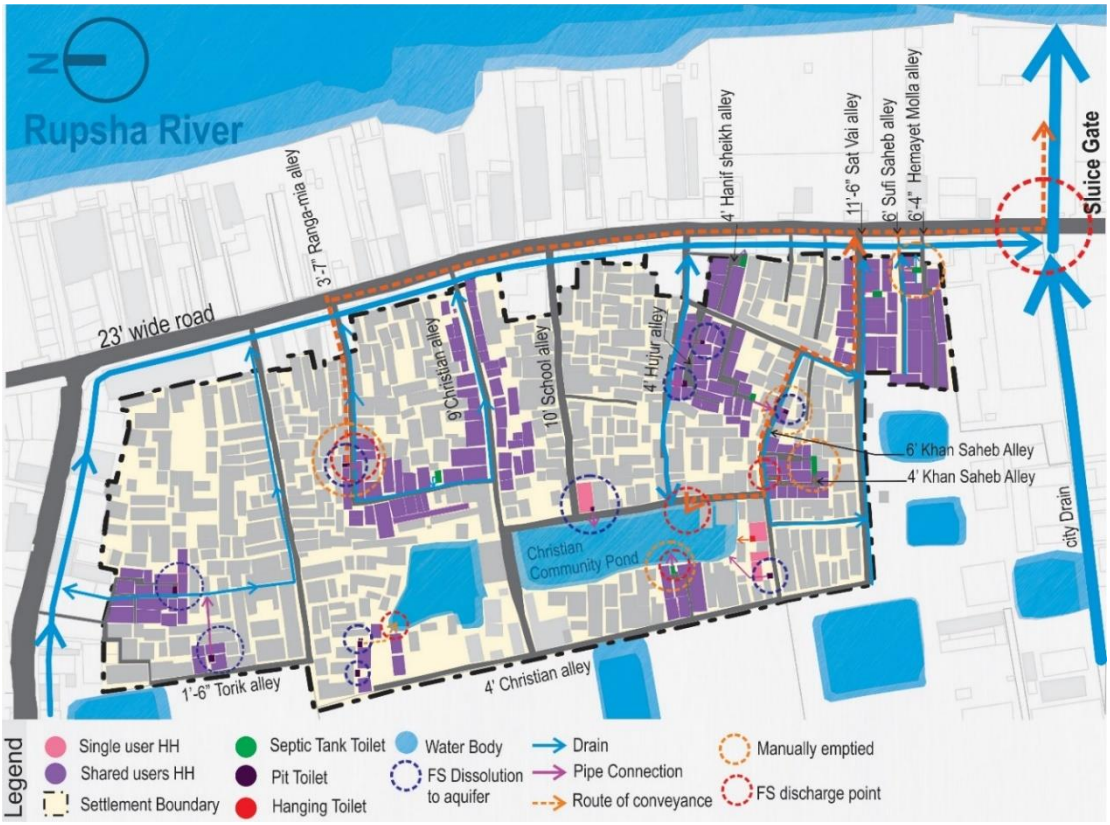

Figure 8. FS flow from Notun-Bazar Chor, Khulna; Base map source Shahriar et al. (2022)

General FSM practice found in the settlement results; FS is finally going into the water. People practice emptying or call a sweeper if a blockage occurs in connecting pipes. Initially, they tried to unclog the pipe by pouring buckets of water or pricking it with wooden or bamboo sticks. However, they call a local sweeper when they fail to unclog it. The concept of environmentally safe emptying and conveyance prescribes that periodic emptying of FS is necessary every three years (WHO, 2018). However, emptying was not practiced among the sample containment users except at Ranga-Mia alley. The local sweeper emptied that pit unsafely by entering it and removing hard sludge with a spade. Primary discharge locations of carried FS used by sweepers are the nearest drain, pond, storm drain, river and sluice gate (figure 8). These activities increase the probability of faecal-borne disease transmission with flies to people's living spaces, floor and furniture surfaces, and foods. People prefer to call sweepers at night to avoid foul odour, which increases the risk of unsafe working conditions due to insufficient lighting. Sweepers work with bare hands without any safety gear and face health risks such as skin diseases, stomach disorders and toxic gas inhalation. Working with open buckets to carry sludge causes FS spillage on the streets. Streets of informal settlements have multipurpose activities. People conduct cooking activities over drain

slabs, spend leisure time and children play. Spillage on streets increases the risk of spreading fecal-borne diseases in the community.

"Sweepers do not work appropriately; often they spill excreta into streets, intentionally or unintentionally, we cannot argue, if we do, they drop the dirt to the alleys" – a CDC member

People spoke that dealing with sweepers is difficult, but they have become accustomed to it. Sweepers charge less for emptying and are widely accepted. A settlement sweeper is particularly effective in unclogging the pipe in an emergency. However, he no longer works as a sweeper, instead repairing the pipes and toilet fixtures. Sometimes, he arranges jobs, calls other sweepers and organizes a team for emptying work. Although, they cannot maintain the cleanliness and safety of emptying due to a lack of proper emptying equipment. The vacutug manager informed us that vacutug never entered this settlement of narrow roads, and people did not know about it and never saw it enter.

"Streets are very narrow; the pickup vehicle cannot enter the street, requiring a minimum of 8'; still, some roads are recently expanded, but how do you turn it around? Again how will it go through because there are cooking burners, lengthy slabs on the street"- a vacutug manager

The adaptive growth of household spaces happens regularly in this area. People extend kitchens and cliff storage over the streets, making the streets narrower. They often get restrictions from electricity providers or councilors about extending, but they listen for some days only. Several alley residents build gates near main roads to create privacy for their alleys. Those alleys have dead ends and gates that allow them more utility and privacy, but these gates make the streets narrower. The toilets of these alleys are well maintained in comparison to other alleys. The maintanance is used commonly for strong bonding in their alley-based social organizationstructure.

4.3. Key Concerns

According to the results, it is evident that people do have a management system against FS accumulation with some environmentally unsafe practices (Table 2) (Figure 8). Some opinions about their management system can be traced as key concern areas.

Table 2: Environmentally unsafe FSM activities in informal settlement of Bangladesh

Containment	• not applying any containment and direct discharge of FS from hanging toilets • using an unlined bottom pit that reaches FS to water at the upper shallow aquifer • connecting pipe to discharge FS periodically to drain, which leads to the water bodies • connecting pipe to discharge FS periodically to the pond • not emptying containment within three years • not using any protective gear while operating management work
Emptying	• people and sweeper both not using any protective gear during emptying • sweeper entering the containment during the emptying • sweepers not using safe equipment during emptying
Conveyance	• sweepers not carrying FS to the safe discharge location • sweepers spilling sludges on settlement premises

4.3.1. Periodical containment management

Informal settlers are primarily concerned about the periodical management of containments. This attitude exists in every alley of the settlement. Periodical management activities cover the monitoring of each toilet component on a regular basis to avoid emergency overflow due to sludge fill-ups. Monitoring pipe blockages and blockage removal are also frequent. Unempty containment users are more aware of it. If sludge comes out from the pipe, they immediately pour buckets of water, and use kerosene oil to prevent odours from spreading. To avoid conflicts from adjacent alleys, people do these activities consciously; sometimes, they restrict guest visits to their rooms to reduce the toilet use and fill rate of excreta. Households sometimes empty their pit independently to manage the overestimated frequency of emptying. All these routine activities have environmentally unsafe consequences, such as FS transmission to water, damaging sanitation barriers and increased risk of faecal-borne disease on human health. Avoiding emptying costs causes unsafe consequences of FS transmission to ponds, drains and rivers through the pipe from containments. However, low-cost, informal emptying services of sweepers are popular among them. Those informal emptying can be safe with proper safety gear and equipment. Adding a pipe for reducing FS accumulation in containment breaks the sanitation barriers of the containment from the environment. Still, those activities can be a safe practice considering the strength of the alley-based territorial organization and adaptive attitude to accept instrumental changes. The alley-based territorial organization acts as a powerful social instrument for changing existing practices into a safe one. People are already unified with these organizations, and it is easy to make them aware of the need of maintaining sanitation barriers for their healthy living. People are willing to identify certain areas where toilets may be built to ensure a safe, sanitary environment with proper emptiability of pits or septic tanks. With the negotiation with alley-based organizations, more equitable toilets can be constructed by prioritizing transient populations that will reduce hanging toilets in the settlement. Separate containment with separate service holes for each alley can be installed to reduce the social conflict as people agree to allocate space for more emptiable and manageable infrastructure within their alley. To improve the sanitation barrier infrastructure, people agreed to renovate their pits with a more impenetrable module of pit design that will reduce FS transmission to water. People need knowledge about sanitary information regarding containments where participatory installation can mitigate the knowledge gap. People showed their interest in participating in the installation of the more safe sanitary infrastructure.

4.3.2. Collective emptying mechanism

People usually do not empty pits or tanks; periodic management keeps their toilets running. They empty only in emergencies when containments become full due to pipe blockage with hard sludge or cloth. However, alley-based organizations take quick action to bring toilets back into function. When forced to emergency emptying, one calls a sweeper, estimates the cost of the total emptying job and FS discharge. He then informs the total cost to all alley members, collects equally divided money and employs a sweeper team for the emptying job. Such actions are found in this settlement in their solid waste management systems, and they pay per month to CDC to take their solid waste away. All the FS emptying jobs are held at night as all organizations accept the time, but more responsible organization plays more role in keeping the settlement premises clean. They prepare adequate lighting and water systems and involve themselves in some parts of emptying work. This collective emptying mechanism can be a clue to including informal settlements in a

city-wide FS conveyance system. The emptying job of sweepers gets burdened when they face the difficulty of emptying older hard sludge. Sweepers prefer more convenient, localized and familiar technological solutions for emptying, such as hand-powered small pumping equipment and fluidiser for hard sludge. Since people only conduct emergency emptying, that situation brings some unsafe consequences of emptying quality; but with the participation of alley-based organizations, the scheduled emptying can be possible by utilizing people's monitoring awareness.

4.3.3. Conditional conveyance of FS

These existing conditions have influenced the whole FS conveyance of informal settlement. Primarily, people are concerned with the emptying cost and disregard the matter of safe discharge. They want to send FS away from the settlement and complete the task within the contract limit with sweepers. Usually, sweepers discharge FS to the nearest river. When sweepers face difficulty emptying hard sludge, informal settlers try to keep the job within the budget, making sweepers more ignorant about safe conveyance. That situation often conflicts with sweepers and causes unfinished and unmanaged discharge in settlement drains, ponds and spillage in alleys. Beyond that, there is a treatment plant at Rajband of Khulna, the only one in the city. It is situated on KCC-owned land and used for garbage dumping. However, it is far from the city, and the study area is almost 11km. SNV personnel informed that it is accessible for all sweepers, but the remoteness adds to the cost, and the sweepers are unfamiliar with the location. Besides, there is no such place where sweepers can discharge FS safely. Sweepers discharge FS to water bodies or the nearest rivers for not having a safe discharge site, but if they get any, they want to take that option if it does not cost more. There are opportunities to install decentralized transfer stations in the nearest government land that can be serviced with vacutug-based formal services which can carry FS to the treatment plant. They struggle to carry heavy plastic drums of sludge for lack of vehicles and use only local rickshaw vans, which causes more conveyance costs. If people can find any nearby safe discharge location within their conveyance cost limit, they are interested in using it.

5. Conclusion

This study highlighted FSM's potential and unsafe practices in the informal settlement. Other than the hanging toilets, the use of three alternative methods of containment, including single pits, twin pits and septic tanks. Typically, pits are constructed locally with concrete rings with unlined bottoms that dissolve FS with water at the upper shallow aquifer underground. The alley-based social organization stretches septic tanks into two types: single-alley users and two-alley users, which create two different realities at FS fill rate, mechanism of emptying and containment management. Connecting pipes with every type of containment is a common practice that leads FS to drains, ponds and rivers. Pipe monitoring and unclogging became the primary instruments of their running toilets, and toilets no longer require emptying. It causes hard sludge at the bottom and makes emptying more difficult. People try to empty themselves only in an emergency; if they fail, they call a sweeper. People and sweepers do not wear any protective gear during emptying operations. Even professional sweepers do not have any safety equipment for emptying operations. Due to the lack of adequate carrying facilities, sweepers often spill FS on-premises. Conveyance of FS to a safe discharge location is absent because of the unavailable nearby safe discharge location and all discharge contaminates the pond and river water, but there are some

familiar places along the main road and river, such as sluice gates. This study claims a) Periodical containment management, b) Collective emptying mechanism, and c) Conditional conveyance of FS as the most promising FSM devices listed from the settlement, which can include an informal settlement with a city-wide faecal sludge conveyance network. The role of the CDC in an informal settlement also can be instrumental to that extension. Many factors contribute to environmentally unsafe FSM activities which require more investigation. Considering all the management activities people conduct in informal settlements, this study believes existing practices can be instrumental in developing an environmentally safe FSM model.

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