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Faecal sludge emptying in Sub-Saharan Africa, South and Southeast Asia: A systematic review of emptying technology choices, challenges, and improvement initiatives

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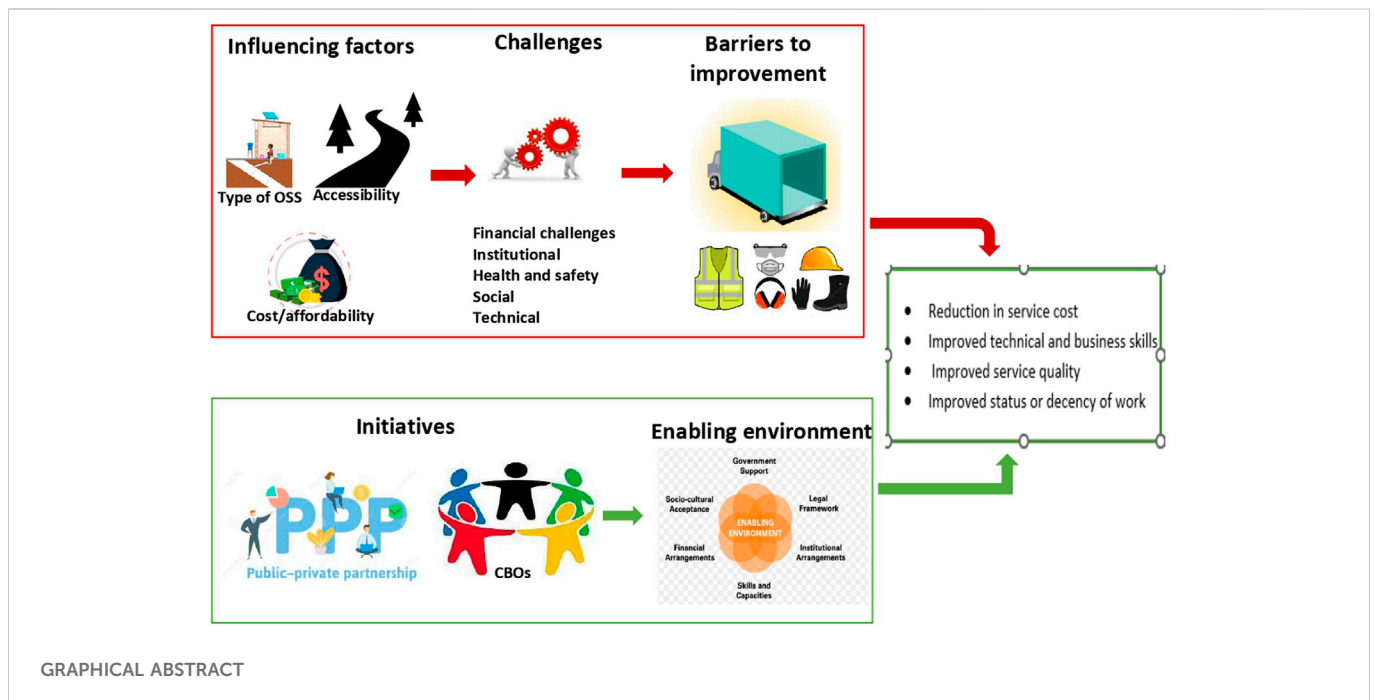
The emptying and transport of faecal sludge (FS) is a fundamental aspect of the sanitation service chain and is mostly carried out by private operators who usually face a lot of challenges. Our review assessed how influencing factors and challenges FS emptiers face are linked and in turn how they act as barriers to improvement initiatives. We conducted a systematic review of peer-reviewed journals on FS emptying in sub-Saharan Africa, South and Southeast Asia published between January 2002 and December 2021. Amongst the 37 journals reviewed, accessibility was mostly documented ($n = 18$) as a factor which affected choice of emptying method, followed by cost ($n = 14$), quality of service ($n = 13$) and then sludge thickness ($n = 8$). We grouped the types of challenges identified from the publications into five categories of financial, technical and institutional ($n = 14$, each), followed by health ($n = 12$) and then social challenges ($n = 8$). Discussions on initiatives ($n = 13$) used to improve the emptying business were limited to Cost/affordability of sanitation services and access to finance by FS emptiers, which were noted to be the major barriers to effective implementation of these strategies. This review identified the need for sensitizing the public on FS emptying, financial modelling of manual emptying business and a need to study the relationship between perceptions and emptying behavior of users.

KEYWORDS

onsite sanitation, pit emptiers, Sub-Saharan Africa, South and Southeast Asia, barriers, initiatives, desludging, faecal sludge management

1 Introduction

Globally, about 3.6 billion people lack access to safely managed sanitation services (UNICEF/WHO, 2020). For Low- and Middle-Income Countries (LMIC), the most common types of sanitation facilities used by people are On-Site Sanitation (OSS) systems, which include pit latrines, flush toilets, aqua privies, and septic tanks (Afolabi and Sohail, 2016; Akumuntu et al., 2017; Manga, et al., 2019; Manga et al., 2022b). The use of OSS leads to the accumulation of Faecal Sludge (FS), which needs to be desludged and transported to the designated disposal sites or the FS treatment facilities for treatment before disposal to ensure the wellbeing of the users as well as the protection of the surrounding environment (Junglen et al., 2020; Manga et al., 2021; Manga et al., 2022a; Tokwaro et al., 2023). The emptying and transport



of FS is carried out by a number of stakeholders which include the private sector, Non-Governmental Organizations (NGOs), local government and municipal authorities (Peal et al., 2014; Manga, 2017; Singh et al., 2021). For over two decades, the private sector has been more responsive than government to the gap in FS emptying and transportation (Bassan, 2014). Private operators usually consist of mechanized, semi-mechanized and manual emptiers or operators (Mbégué et al., 2010). These operators are important because having toilets without a hygienic service chain has dire consequences on the environment and society (Bongi and Morel, 2015; Prasad and Ray, 2019). Though these operators play a fundamental role in faecal sludge management (FSM) chain, they usually face a lot of challenges which limit their efficiency and affect the profitability of their business. These challenges are linked to factors which affect the choice of emptying methods and also serve as barriers to the effectiveness of improvement strategies (Lerebours et al., 2021). To better understand the FS emptying business, this study reviewed: 1) factors which determine the choice of an emptying method, 2) challenges faced by FS emptiers and 3) initiatives that have been implemented to improve FS emptying business in Africa, South and Southeast Asia. This review investigated how the factors which influence the choice of emptying methods are linked to the challenges faced by the emptiers. The review also discusses how the influencing factors and challenges act as barriers to successful implementation of improvement initiatives. The results from this review provide background data on the role of influencing factors and challenges on the improvement of FS emptying, which can be incorporated into policy framing, infrastructure development and targeted behavior change strategies.

2 Methodology

In this review, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009; Sprouse

et al., 2022) were followed to identify all the relevant publications pertaining to FS emptying in Sub-Saharan Africa (SSA), South Asia and Southeast Asia. These regions were chosen because of their wide coverage with OSS and in turn widely spread emptying businesses (Tremolet, 2012). Web of Science, Environmental Complete, Scopus, Global Health, and PubMed were systematically searched for peer-reviewed literature published in English language in the past 20 years (January 2002 to December 2021). Titles and abstracts of all the studies were initially screened, and then full texts of potentially relevant studies were further screened for data on FS emptying and transport using inclusion and exclusion criteria, and search terms which are presented in the [Supplementary Material, Supplementary Tables S1, S2](#), respectively. The data extracted included author, study setting, date of publication, location where the study was carried out, factors which influence choice of emptying method, FS emptying and transport challenges, initiatives to improve FS emptying business.

3 Results and discussion

3.1 Selection of reviewed publications

A total of 974 articles were available from the database and when selection criteria were applied, 843 records were excluded of which 333 were duplicates. Of the remaining 131 full text articles assessed for eligibility, 94 articles were further excluded and 37 articles from 25 countries met the inclusion criteria (Figure 1).

3.2 Geographical location and settings of reviewed emptying and transport studies

A higher percentage ($n = 23$, 62%) of the 37 studies reviewed was located in SSA, 11 (30%) in South Asia and six (16%) in South East Asia, with the largest fraction from Bangladesh ($n = 8$, 22%) (Figures 2,

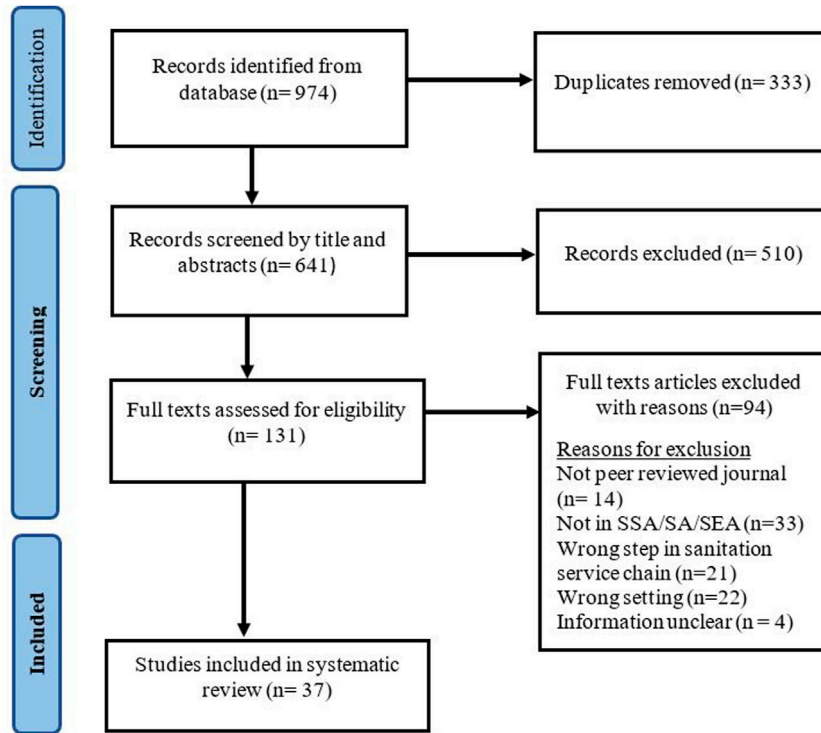


FIGURE 1
PRISMA flow diagram for studies in the systematic review of faecal sludge emptying in sub-Saharan Africa, South and Southeast Asia.

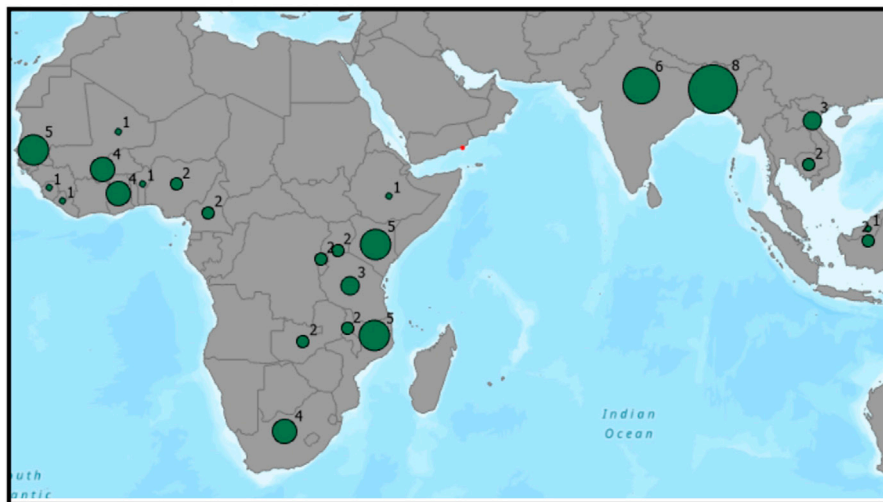


FIGURE 2
Number of studies in countries within Sub-Saharan Africa, South and Southeast Asia selected in the review.

3). Five of the included studies looked at FS emptying and transport in multiple countries; three of these studies considered countries in both Asia and SSA (Eawag and Sandec, 2006; Thye et al., 2009; Chowdry and Kone, 2012), while one looked at some countries in SSA (Lerebours et al., 2021) and the last one looked at some South Asian countries (Anh et al., 2018). Only one study examined FS

emptying business in countries in SSA, South and Southeast Asia together with countries outside these regions (Hawkins et al., 2014).

Most of the studies were located in urban areas ($n = 26, 70\%$), 10 (27%) in peri-urban areas and only one in a rural area (Figure 3). Only studies which were self-described as peri-urban were categorized as such while those which looked at cities were categorized as urban. The

higher number of studies in the urban and peri-urban areas can be attributed to the growing interest of FS emptying in urban areas due to rapid urbanization and high population density, leading to generation of high FS volumes, hence, frequent filling of OSS facilities. The 37 studies included in this review comprised of 17 observational studies, 10 practitioner papers (journals and publications which aim at conveying research, models or even theory to practitioners and stakeholders in the FSM field, such as, FS emptiers, municipal authorities, households, non-governmental, community based organizations, 10 case studies and there were no experimental studies (Figure 3). It was also noted that there is increasing awareness on the importance of FS emptying, which has brought about increase in the number of studies published over time. For the 20 years considered, more than half of the studies were published in the last decade ($n = 27$; 73%).

3.3 Factors influencing choice of an emptying method

The prevalence of emptying methods shows that manual emptying was presented by majority of the studies ($n = 32$, 86%), followed by mechanical emptying ($n = 26$, 70%) and then emptying by other

methods (gravitational or flooding out/pit diversion) ($n = 4$, 11%) (Figure 3). A total of 25 studies reported on emptying by both manual and mechanical methods, though four of these studies presented gravitational emptying or FS flooding out of the containment. Manual emptying involves the use of human power and hand tools such as spades, forks and containers/scopes (Mikhael et al., 2014) for the removal of FS while mechanical emptying involves the use of mechanized technologies like vacuum trucks (Thye et al., 2009; Chowdry and Kone, 2012). Gravitational emptying involves intentional release of FS to the environment by unplugging a drainpipe installed in an elevated or exposed portion of the pit, especially during heavy rains (Jenkins et al., 2015). The type of emptying method employed depends on cost/affordability of the service, accessibility, quality of the service, availability, and the thickness of the FS to be emptied (Figure 2). Figure 4 and Figure 5 show the frequency of discussing the aforementioned factors in relation to the emptying methods and region, respectively. From Figure 4, it can be observed that the number of papers which discussed each emptying factor in relation to mechanical emptying (Figure 4A) are the same with those that discussed each factor in relation to manual emptying (Figure 4B) except for cost/affordability of the service which was higher for manual emptying. The equal number of studies give an indication that the factors which negatively

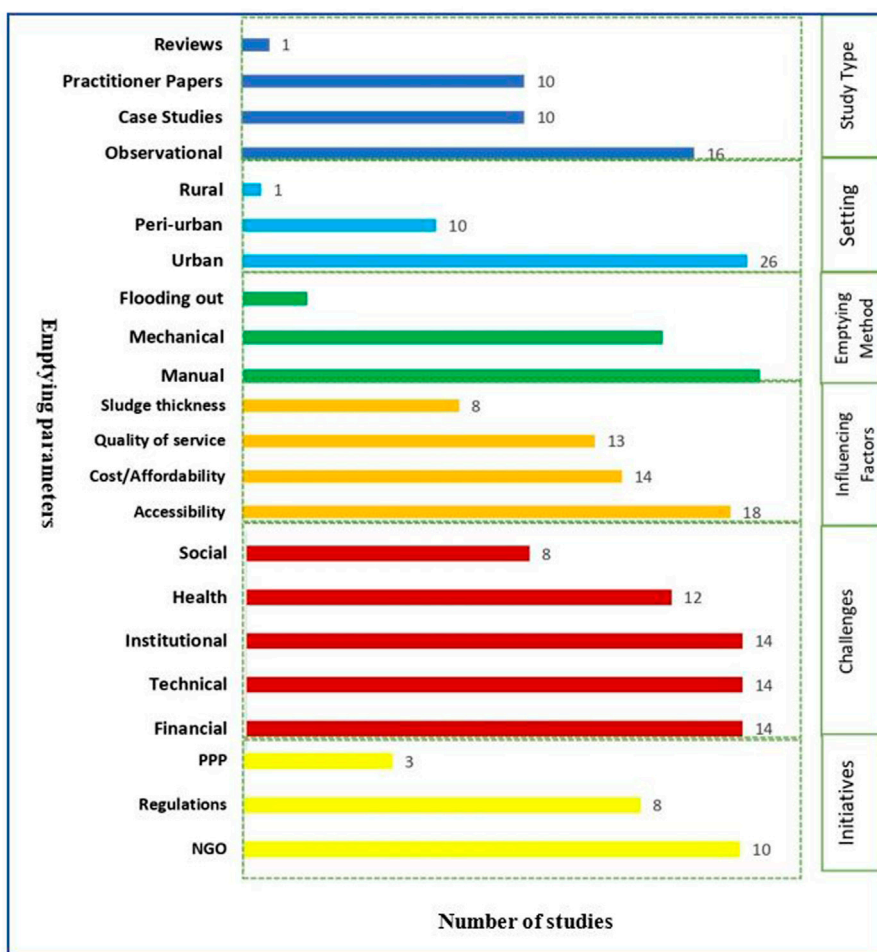
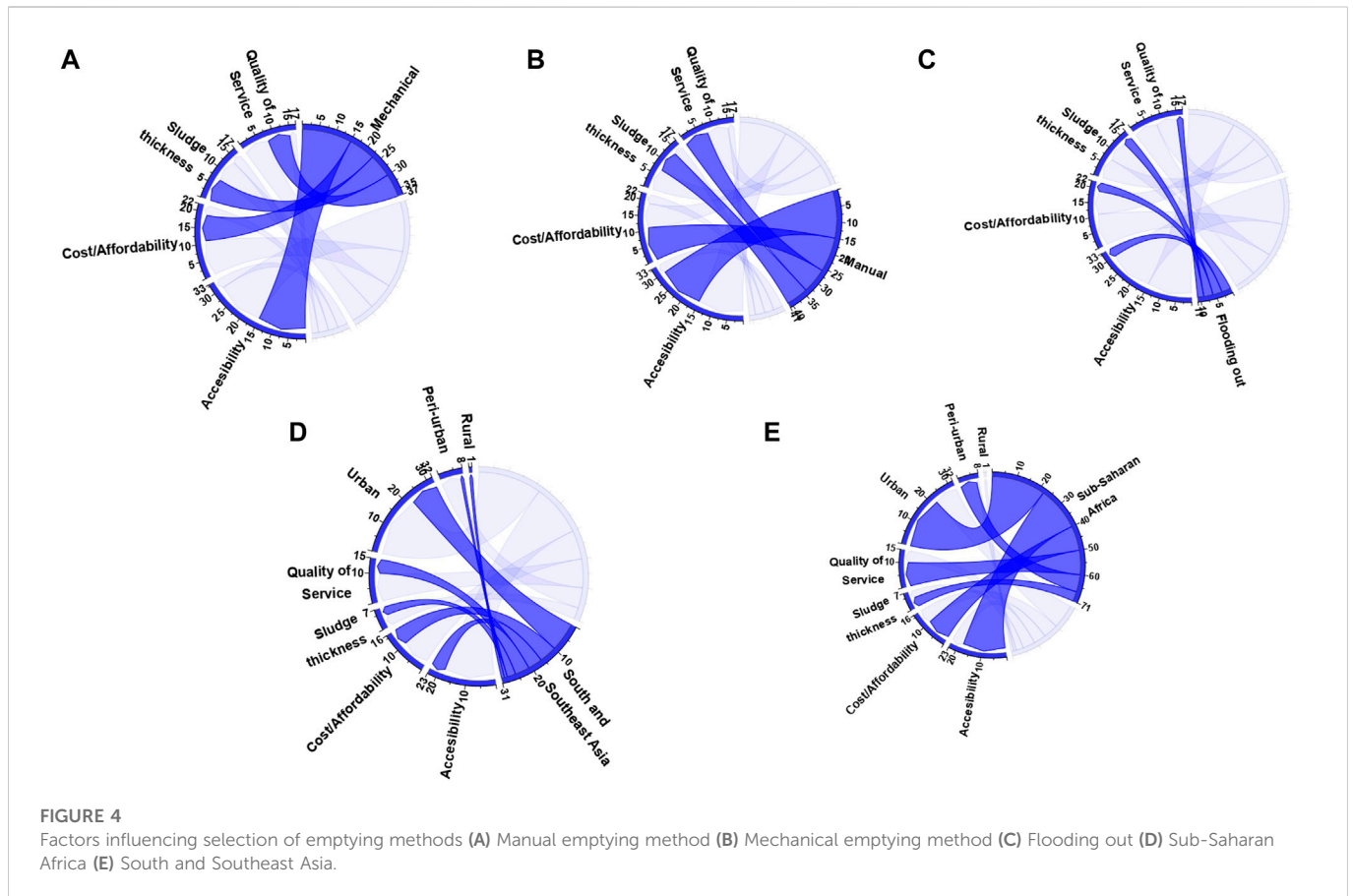


FIGURE 3 Characteristics of studies included in the review of fecal sludge emptying in Sub-Saharan Africa, South and Southeast Asia.



affect mechanical emptying could have positive impact on manual emptying and *vice versa*.

3.3.1 Accessibility to containment facilities and/or emptying means

Accessibility was discussed by 18 studies as a major factor influencing the choice of an emptying method. 12 of the 18 studies discussed accessibility in terms of access to sanitation facilities while 10 discussed access in terms of availability of service providers. It was observed that accessibility is a major factor which negatively affects mechanical emptying. This is mainly found in unplanned informal settlements with poor road conditions, making it difficult to traverse the narrow streets (Owusu, 2013; Kennedy-walker, 2015). This presents the need for long hose pipes thereby adding to the cost of emptying. Another problem is poor design and construction of containment facilities, which either have no or limited access for emptying as some dwellers construct other structures on top of them or too close (Holm et al., 2018). Such inaccessibility to sanitation facilities by mechanical emptiers necessitates the use of manual emptying, which is often discouraged. Chowdry and Kone (2012) reported manual emptying of public sanitation facilities in low-income areas of Kenya due to inaccessibility by trucks due to narrow paths. Jenkins et al. (2015) reported that in Tanzania, households with accessible plots and service availability were on average 23 times more likely to use a higher hygienic service than those without access.

Manual emptiers are known locally, easy to locate and can easily access the densely populated informal settlements, making them the most commonly used (Choudry and Kone, 2012; Hawkins and

Muximpua, 2015). In Dhaka, the capital city of Bangladesh, it was observed that most people use manual emptying due to cost, flexibility of timing and the ease of availing the service. They find the process of accessing mechanical emptying services from the municipality to be lengthy and bureaucratic (Opel et al., 2011). This situation is not peculiar to Dhaka. A study by Singh et al. (2021) in Khulna Bangladesh, revealed that in many cases, households made use of manual emptiers as emptying service by the city corporation (Khulna city corporation, KCC) is not timely as households call for emptying only when the pit/tank is full and starts overflowing. This suggests that if municipal authorities make their procedures less bureaucratic and more friendly, accessibility will be increased, and this will in turn increase their profit.

3.3.2 Cost and/or affordability of the emptying service

Emptying cost was cited in 14 (38%) studies as the most influential factor affecting the choice of emptying method (Figure 2). Cost of mechanical emptying is reported to be higher than that of manual emptying in most of the studies. In the study by Balasubramanya et al. (2017) in Bhaluka Bangladesh, it was reported that mechanical emptying (13 USD) cost more than manual emptying (5 USD). The higher cost is attributed to high operation and maintenance costs as well as the cost of discharging FS at treatment plants or legal disposal sites (Mougoue et al., 2012; Hawkins and Muximpua, 2015; Prasad and Ray, 2019; Manga et al., 2020). Long distance to the disposal sites and the poor road conditions also contributes to the high operating costs (Mougoue et al., 2012; Oduro Kwarteng et al., 2019). Due to the

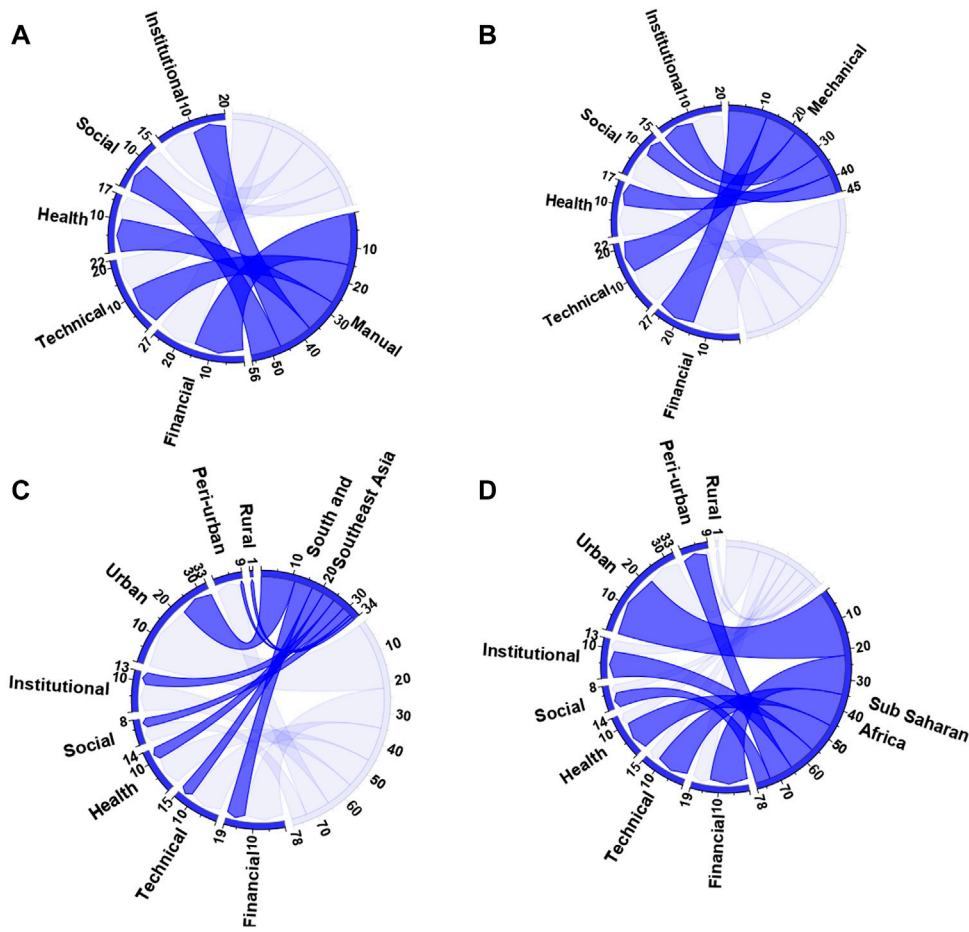


FIGURE 5 Challenges faced by fecal sludge emptiers (A) Manual emptying method (B) Mechanical emptying method (C) Sub-Saharan Africa (D) South and Southeast Asia.

absence of government support in most of these countries, it is the households to meet the higher cost of mechanical emptying, tempting them to employ manual emptying methods, despite having knowledge of risks involved. Hawkins and Muximpua (2015) reported the price of emptying services rendered as the most common disincentive to using hygienic mechanical emptying among pit latrine users in Maputo (Mozambique), and most people continue to use cheap and unhygienic manual emptying, where there is local burial and open dumping of FS. Even where road access is available, slum dwellers prefer manual emptiers as their charges are considerably lower than mechanical emptiers (Mallory et al., 2021). Some households which have little or no money to pay for emptying services have resorted to gravitational emptying which is the most dangerous method as large volumes of untreated FS are discharged into the environment (Jenkins et al., 2020; Rotowa and Ayadi, 2020). Though manual emptying is a cheaper method of emptying, the potential health effects to the users, emptiers and the environment in the long run makes it an inapt method.

Although most studies reported mechanical emptying to be more expensive than manual emptying, some studies reported otherwise. Parkinson and Quader (2008) in their study in Bangladesh noted that manual emptiers demand exorbitant prices from households especially in areas that are inaccessible by mechanical emptiers as they know that households have no alternative. Peletz et al. (2020)

reported that in Kisumu Kenya, formal manual emptying was about four times more costly (6,169 KES or 62 USD) than mechanical emptying (by vacutugs) (1,630 KES or 16 USD).

3.3.3 Faecal sludge density or thickness

Eight studies reported on how variation in density or thickness of FS in OSS facilities affects the choice of emptying method (Figure 3). The thickness of FS depends on the quantity of solid wastes deposited in sanitation facilities, water addition, infiltration or exfiltration of water and the extent of compaction/solidification that has occurred (Manga et al., 2016; Simwambi et al., 2017; Semiyaga et al., 2022). FS from lined pit latrines and septic tanks is less thick compared to that from unlined pit latrines. This is because unlined pit latrines allow for the exfiltration of the liquid fraction of FS into the surrounding soils through the permeable sidewalls and open bottom (Tilley et al., 2008; Manga et al., 2022a).

The presence of very thick FS makes it difficult to empty the OSS facility as materials found in the pit are usually in a partially compacted or solidified form (Bakare, 2019). It has been noted that the mechanical emptiers are not usually effective in removing the heavier and compacted FS at the bottom of pits (Mougoue et al., 2012; Muximpua and Hawkins, 2012). Sometimes, large quantities of water needs to be added to the pit to fluidize and mix its content before

mechanical devices can be used (Bakare, 2019). This usually increases emptying costs as water is in short supply in such low income areas (Krueger et al., 2020). In addition, presence of thick FS usually affects the efficiency and reduces the useful life of the mechanical equipment due to blockage of suction pipes and valves, leading to damage of the equipment. In such cases the most viable emptying technique is to manually dig out the pit content (Bakare, 2019). However, it is imperative that when manual emptiers are called upon to empty the pits, they observe standard operating procedures by putting on personal protective equipment. This is needed to protect them from the hazardous nature of pit content.

3.3.4 Quality of FS emptying service

About one-third of the studies ($n = 13$, 35%) reported how the quality of service provided by the emptiers influenced the choice of emptying method (Figure 2). The quality of service is defined in terms of hygienic methods applied during emptying ($n = 10$, 77%), time spent emptying ($n = 6$, 46%), and complete emptying of FS contents ($n = 5$, 38%). Mechanical operators are found to provide more efficient, hygienic services, and easily accessing treatment plants compared to manual emptiers (Parkinson and Quader, 2008; Thye et al., 2009; Semiyaga et al., 2022). Mechanical operators are usually organized into registered companies, thereby providing safer working conditions than manual emptiers whose method of operation exposes the population to peril associated with poor FS handling (Mbéguééré et al., 2010; Zaquot et al., 2020). Manual emptiers commonly dump the FS into nearby drains, canals or water bodies, leading to severe public health and environmental risks (Boot and Scott, 2008; Jenkins et al., 2014). However, the quality of service was found to not only depend on hygiene, but also on the perceptions of people, income levels and the waiting times to assess the service. In Dar Es Salaam, Tanzania, it was observed that households preferred manual unhygienic methods because these methods removed all the FS from the pit and were more affordable than existing mechanical hygienic services (Jenkins et al., 2015).

3.4 Challenges faced by faecal sludge emptiers

The challenges faced by FS emptiers are categorized into social, health and safety, technical, financial, and institutional (Figure 3). At least a category of challenge faced by FS emptiers was discussed in each of the 37 studies. The frequency of reporting these challenges in relation to emptying methods and sub-region are illustrated in Figure 5. Figures 5A, B shows that in comparison to mechanical emptiers, manual emptiers face more challenges. This can mostly be attributed to the dangerous manner with which they carry out their work and their inability to be organized into groups which can voice out their opinions. From Figures 5C, D, it can be observed that the number of studies carried out in SSA are higher than those in South and South East Asia. The higher number of studies in SSA may be attributed to the fact that onsite sanitation systems are much more expensive in SSA than in South and South East Asia and this contributes to more challenges in SSA and in turn more studies in the region. Sanitation facilities in Africa are on average three times more expensive than in Asia due to factors such as high costs of materials (i.e., cement and bricks), lack of prefabricated or mass produced toilet components (which are common in Asia), and the

informality of the construction sector which is dominated by micro-entrepreneurs (Ulrich et al., 2016).

3.4.1 Social challenges

The stigma associated with FS emptiers was discussed in eight studies, and this was mostly peculiar to manual emptiers. Manual emptying is carried out as an informal activity by poor people who need a form of living (Chowdry and Kone, 2012). Manual emptying is deemed illegal in a number of countries such as India, Kenya, Ghana and Bangladesh (Zaquot et al., 2020). In India, manual emptying is seen as a caste-based practice done by people who are members of the lowest social class (Prasad and Ray, 2019). Manual emptiers are usually socially excluded, very poor, and work under inhumane conditions (Prasad and Ray, 2019). In Kibera, a large slum in Nairobi, manual emptiers usually face violence and extortion in society (Eales, 2005; Parkinson and Quader, 2008; Mallory et al., 2021). Bassan et al. (2013) reported that the emptiers usually face harassment from the citizens in Maputo Mozambique. Manual emptiers are seen as carrying out undignified, demeaning work and most of the times are usually marginalized, hence, they usually carry out their tasks in the middle of the night in order not to be seen by the neighbours (Muximpua and Hawkins, 2012). The problem faced by manual emptiers is further compounded by the fact that they are not formed into organizations, and therefore, do not have any association which could voice out their opinions when required. The stigma they face brings about psychological trauma and as a means of coping with this, the manual emptiers resort to taking intoxicants such as alcohol, opioids, tobacco and cocaine to numb their senses (Muximpua and Hawkins, 2012; Gautam et al., 2021). However, the continuous use of alcohol and hard drugs has detrimental effects on the health of these workers.

3.4.2 Health and safety challenges

FS emptiers are usually exposed to a wide range of hazards while carrying out their work, and they do not usually have health insurance (Zaquot et al., 2020; Gautam et al., 2021). The 14 studies (38%) which documented the health and safety of the FS emptiers mainly discussed exposure to pathogens, musculoskeletal disorders, physical injuries and inhalation of harmful gases. FS is a very hazardous material that contains large amounts of pathogens (bacteria, protozoa, virus and worms) which pose serious health risks (Holm et al., 2015). The common routes through which the pathogens get into the emptiers' bodies are *via* hand-to-mouth contacts (accidental ingestion), inhalation and open cuts in the body (Fracchia et al., 2006). In the study carried out on pit emptiers in eThekweni region, Durban South Africa, pathogens were found in the gloves, bottom of the boots, hands and masks of the pit emptiers (Bonthuys, 2017). Some of these pathogens like *ascaris lumbricoides* (roundworm) eggs can remain viable for months because of their impermeable eggshells (Bonthuys, 2017; Capone et al., 2022; Manga et al., 2023). Infections by these organisms usually have appalling implications; for instance, helminths can cause neurological defects. FS emptiers are susceptible to sanitation related diseases such as dysentery, cholera, diarrhea, hepatitis A, typhoid and polio (Weststrate et al., 2019).

Manual emptiers are reported to develop musculoskeletal disorders due to the heavy work involving pulling, pushing and carrying heavy FS containers (Chumo et al., 2021). In addition, emptiers suffer from physical injuries which mainly occur in the process of accessing the containment system, whereby the workers get

exposed to risk of bruises, wounds and injury mostly on the feet, knees and thighs as they move around bushes which have thorns without slippers; or in the processing of opening the containment systems covers/lids as these are usually heavy to be lifted with bare hands, and this can cause injuries to the workers' extremities (Gautam et al., 2021). It has been reported that a lot of sanitation workers die every year servicing pit latrines (Hawkins et al., 2014; Prasad and Ray, 2019). Furthermore, FS emptiers usually inhale harmful gases which could lead to asthmatic problems, respiratory issues, headaches, irritation and burning of the eyes, and sometimes death from suffocation (Patil and Kamble, 2017).

The health risks to the FS emptiers are a function of: 1) type and quantity of the viable pathogens in the emptied FS; 2) the design of the containment; and 3) operational practices and individual behavior, that is, the attitude to risk or compliance of both the workers and the household users. In a study by Bonthuys (2017), it was observed that while necessary protective gear and code of conduct were not often available, the emptiers did not always make use of the steps available to them for their protection. They posited that it was either because the emptiers did not have an in-depth understanding of the hazards associated with sludge emptying or they were not motivated to apply what they knew. In the study carried out in India by Prasad and Ray (2019), it was noted that the emptiers mentioned gloves and boots, which are available in the market were not suited to the type of job they do, and they did not want the public to perceive that the type of job they do is dangerous. In the study by Gautam et al. (2021), it was observed that some workers were of the belief that their longevity in the profession has helped them develop a certain degree of immunity, and they therefore, carry out pit emptying without using PPE. Households are partly responsible for health risks to workers due to their non-chalant attitude and practices ranging from non-compliance of septic tank construction to design standards, irregular cleaning and improper disposal of inappropriate items in toilets. The aforementioned show that solving the health and safety problems of FS workers goes beyond the use of PPE, it also involves steps such as behavioral change campaigns, improvements in decanting stations, and better access to appropriately designed tools.

3.4.3 Technical challenges

The technical challenges faced by FS emptiers were reported in 14 studies. The major technical challenge cited was poor construction of sanitation facilities. In Maputo Mozambique, sanitation facilities are built by the households who do not follow technical standards or guidelines, making them a source of threat to the emptiers (Muximpua and Hawkins, 2012). In addition, poorly constructed pit latrines by untrained builders have been reported in Duala and Yaoundé in Cameroon (Mougoue et al., 2012). This has also been confirmed by Semiyaga et al. (2015) and Manga et al. (2022b). One factor that contributes to this is inadequate implementation of urban planning which brings about construction of residential dwellings with low quality sanitation facilities (Holm et al., 2015).

3.4.4 Financial challenges

The 14 studies discussed financial challenges in terms of accessing capital to start the emptying business and the profitability of the business. Starting the FS emptying and transport business requires a great investment in purchasing a truck, acquiring administrative documents such as insurance, technical inspection, and operation or parking permit (Mougoue et al., 2012). Though

financial assistance is usually obtained in the form of loans either from banks, thrift and loans from relations; accessing the money is usually difficult as banks, financial institutions and private entrepreneurs are not ready to invest in pit-emptying business (Opel et al., 2011). Most of the entrepreneurs are reported to only manage investing in second-hand mechanical trucks which have outlived most part of their useful lives and often breakdown, making it difficult for them to honour the deed of agreements when the credit was obtained (Mougoue et al., 2012).

Apart from the uncertainty and variability in the costs of leasing and buying equipment, the wages from FS emptying is low and irregular (Zaqout et al., 2020). The demand for the services of FS emptiers is subjected to seasonal variations as they can only depend on FS services during the rainy season (Nkasah et al., 2012; Zaqout et al., 2020). In the study by Chowdry and Kone (2012) on sanitation service providers in some countries in Africa and Southeast Asia, it was observed that the private service providers usually operate the FS business as an additional source of income rather than as their principal business. In this same study, it was noted that the manual emptiers are also engaged in other manual labor like construction, road sweeping, and cleaning public toilets (Chowdry and Kone, 2012). Muximpua and Hawkins (2012) observed that though the manual emptiers in Maputo Mozambique usually take the business seriously, they usually carry out other side jobs as they stated that the FS services alone cannot sustain them. Also, the emptiers usually have considerable financial burdens from high healthcare expenditure especially as they have neither health insurance nor compensation for days lost due to illness (Zaqout et al., 2020).

3.4.5 Institutional challenges

The institutional challenges faced by FS emptiers were presented in 14 (38%) of the papers. The results show that there are either no institutional frameworks or the ones that exist are not properly enforced in a number of LMICs (Akumuntu et al., 2017). For these countries implementing the framework, there are usually challenges such as: lack of capacity (technical or financial) of the stakeholders involved to enforce the regulations (Holm et al., 2018; Kohlitz et al., 2018); inadequate sanitation-related regulations (Sinharoy et al., 2019; Weststrate et al., 2019); and inadequate data on the available sanitation facilities, service providers and their operations (Sinharoy et al., 2019). Prasad and Ray (2019) stated that in India, the emptying of pits and handling of wastes to a great extent, remains undiscussed in policy documents. The lack of credibility and consistency in the institutional framework leads to a situation whereby FS emptying and transport services are provided without adequate technology, regulations and safety precautions (Jayathilake et al., 2019).

The lack of regulation usually leads to imbalanced competition among the FS emptiers as those who operate as companies pay taxes while those who operate as individuals do not (Akumuntu et al., 2017). In Yaoundé Cameroon, it was observed that the public authorities impose tax at the disposal sites, but the money realized is not put back into sustenance of the system but rather used for the selfish gains of the authority. Moreover, there are no fixed prices as they depend on the bargaining power of the operator (Mougoue et al., 2012). In another study in Nkobikok, Yaoundé Cameroon, it was noted that the prices for emptying usually fluctuate due to undue obligatory or unofficial fees and bribes paid to officials by the emptiers (Noumba et al., 2017). In Vietnam and Thailand, the legislation for FS collection and

transport is still neglected (Anh et al., 2018). Another example is in Accra Ghana where the responsibility of FSM falls under the Waste Management Department (WMD), but many private mechanical truck operators complain about their activities not being monitored regularly and effectively by WMD (Boot and Scott, 2008). In a study by Lerebours et al. (2021), where the opinions of different pit emptiers across sub-Saharan Africa were sought about the regulatory framework in place, the respondents said that rules and sanctions should be applicable to all operators including public operators to ensure fair competition. The emptiers who provide unsanitary services charge a lesser amount than the compliant service providers, thereby disturbing the market and reducing the financial viability of safe services.

For successful implementation of FSM, there is need for the development of institutional frameworks based on the specifics of the local situation (Kone, 2010; de La Brosse et al., 2016). The framework usually covers five aspects which include: 1) design and construction of onsite facilities; 2) demand of emptying and transport services; 3) operations through licenses and permits; 4) transport and disposal of faecal sludge; and 5) service tariffs (Trémolet, 2012; Cross and Coombes, 2014; Rao and Otoo, 2017). For successful implementation of institutional frameworks to occur, apart from laws and strategies being clearly defined, the roles and responsibilities of each stakeholder involved should be regulated and enforced, and the government should show strong dedication through consistent funding and training schemes. Included in these frameworks should be provisions for worker training and certificates through incentives by the sanitation authorities in order to improve the services rendered by these workers, allow for limited environmental impact and bring about safe work conduct. Also, monitoring, record keeping and performance evaluation should be incorporated into these frameworks as this will aid in informed decision-making in the long run.

3.5 Initiatives to improve faecal sludge emptying business

In order to reduce some of the challenges faced by pit emptiers and make the pit emptying business more sustainable and lucrative in LMICs, certain initiatives have been implemented. These initiatives which were presented in 13 (35%) of the papers reviewed include the use of private public partnership (PPP), Involvement of Non-Governmental Organizations (NGOs)/International Donor Agencies (IDAs)/Community Based Organizations (CBOs).

3.5.1 Private public partnership

Nijkamp et al. (2002) defines Private Public Partnership (PPP) as an institutionalized form of cooperation between public and private actors, who based on their specific objectives, work together towards a joint target. In the collection and transport of FS, the public sector is characterized by the local authorities which could be metropolitan, municipal or district while the private sector is a private company or private operator (Scott et al., 2013). Three of the studies in this review cited examples of where PPP have been implemented. In Marikina city in the Philippines, the water utilities, the city municipality and the private sector organizations worked together to implement a 5-year cycle sludge removal program. During the time for sludge removal, the city authorities provide support for the private sector organizations by

sending trucks into the areas where the sludge removal will occur to advertise (through announcements by loudspeakers) the private companies in order to involve more households (Bassan, 2014). This initiative brought about 95% compliance with sludge removal in the areas involved through the generation of a working system that is supported by the public and private sectors and the household users (Bassan, 2014). Another area where this has been implemented is in Dakar Senegal, where the government regulated the activities of the private sector and helped to manage the FS treatment facilities. The private sector provided the emptying services to the population (its main customers) and the government contracted out part of the collective sewage network to the private sector and them with the task of pit emptying in religious cities on the eve of national ceremonies (Scott et al., 2013).

In Dhaka, the capital city of Bangladesh, a model with the brand name SWEEP was used for PPP whereby the local government or authority bought a vacuum tanker and leased it out to a private party. The local authority was also responsible for infrequent maintenance of the vehicle, marketing, regulation and FS disposal at a designated site. On its part, the private party paid a security deposit and a monthly lease fee to the government, carried out the emptying and transport services, and did regular operation and maintenance of the tanker. This initiative was reported to be profitable and successful (WSUP, 2016). In Kumasi Ghana, the Kumasi Metropolitan Assembly (KMA) mobilized revenue to finance FS collection, provided treatment plants, monitored the activities and operation of the private emptiers, and also helped to subsidize taxes on the importation of trucks' spare parts. The private sector helped in the collection of FS and contributed to the maintenance of the treatment plant (Owusu, 2013).

In sum, it can be seen that the use of PPP gives room for the local government to help the private sector through advertisements, subcontracting jobs, leasing equipment, provision of subsidies and also formulation and implementation of policies. This has helped to improve the profitability of FS emptying business and provide better working conditions for the emptiers.

3.5.2 Involvement of non-governmental organizations and international donor agencies in faecal sludge emptying business

Of the 37 studies reviewed, 10 (27%) documented the involvement of non-governmental organizations (NGOs), Community Based Organizations (CBOs) and International Donor Agencies (IDAs) in educating the emptiers and raising awareness on FSM. This helps to reduce the social stigma associated with FS emptying business. In Mukuru slum (Kenya), two NGOs (i.e. Sanergy and Umande Trust) helped in providing sanitation services to the residents. Sanergy is a private company which provides container-based sanitation services in Mukuru with regular emptying (Tilmans et al., 2015). Umande Trust worked closely with informal pit emptiers to provide 'bio-centres' which are public toilets based on anaerobic digestion technology, hence producing biogas that is used for cooking (Binale, 2011). The involvement of these organizations helped to reduce the violence sanitation workers face from hoodlums in order to carry out their work during the day rather than in the night.

In Maputo Mozambique, the Japanese Social Development Fund (JSDF), World Sanitation Program (WSP) of World Bank and World Sanitation for Urban Poor (WSUP) carried out a project-Maputo Sanitation Project - which involved equipping private service providers with technical, managerial and business skills, and

equipment needed to provide FS emptying and transport services in a more hygienic manner (Hawkins and Muximpua, 2015). These operators were equipped with plastic water tanks mounted on handcarts and other equipment such as buckets, gulper (hand pump designed for desludging pit latrines), a diesel-powered trash pump for more liquid sludge and Personal Protective Equipment (PPE). The use of gulper equipment helped reduce the health and safety risks that the manual workers are usually exposed to.

Apart from the involvement of NGOs and IDAs, city corporations provide emptying services. For instance, the Kampala Capital City Authority (KCCA) in Kampala Uganda and Khulna City Corporation (KCC) in Bangladesh collaborate with local stakeholders to provide and improve FSM (Singh et al., 2021; Semiyaga et al., 2022; Singh et al., 2022). The city corporations help in subsidizing emptying price as well as encourage scheduled desludging. Scheduled desludging helps to reduce public health risks as residents do not have to wait till their tanks are full and overflowing (which can cause surface and ground water pollution).

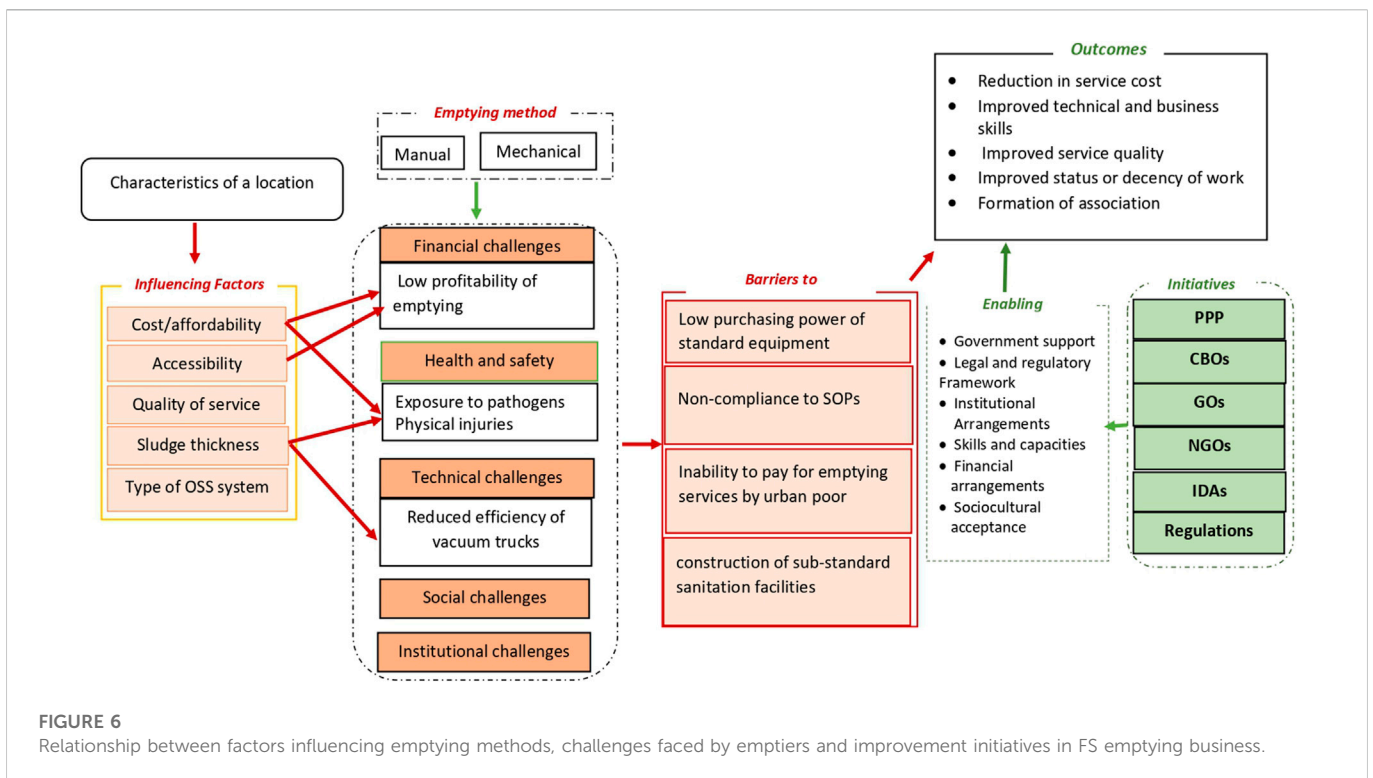
From the aforementioned, it can be seen that the involvement of organizations in the emptying business has not only helped in improving the profitability but has also improving the quality of service provided by the emptiers. It has also brought about the subsidization of services thereby making it more affordable to the urban poor.

4 Links between challenges, influencing factors and barriers to improvement initiatives

Figure 6 is an illustration of the relationship between challenges faced by FS emptiers, factors which affect the choice of emptying

methods and initiatives used in improving the emptying business. The characteristics of a particular location usually influences the type of setting (rural/urban) that would be found in the area, accessibility to the area, type of onsite sanitation facility found in the area and the quality of service affordable by residents of the area. The cost of emptying is a major factor which negatively affects mechanical emptiers as most people in poor communities cannot afford their services, which reduces the profitability of their business. Also, in order to save costs, most people do not carry out regular desludging but only request for the services of the emptiers when their onsite sanitation facilities are overflowing. This brings about health hazards to FS emptiers who have to come in direct contact with pathogenic FS littered all over the place. Lack of solid waste management systems in certain areas has propelled people to dump solid waste materials into sanitation facilities which causes physical injuries to manual emptiers. This also affects the useful life and efficiency of vacuum equipment due to blockage of suction pipes and valves. Accessibility as a factor negatively affects the profitability of mechanical trucks, which cannot operate in unplanned settlements with poor road conditions (Figure 6).

The use of PPPs and the involvement of NGOs, governmental organizations (GOs) or CBOs brings about the enabling environment required for the success of FS emptying business (Graphical Abstract). The six dimensions of the enabling environment for FSM include: government support, legal and regulatory framework, institutional arrangements, skills and capacities, financial arrangements, and sociocultural acceptance (Bassan, 2014). Governmental organizations through the introduction of subsidies can make improved sanitation services affordable to the poorest users. In addition, the government can provide regulations which will bring about standards for the construction of sanitation facilities, thereby eliminating the challenges faced by emptiers in



accessing the facilities (Holm et al., 2015). Since the private sector plays a key role in FS emptying, the government should provide enabling environment for the private sector members through technical and business support (i.e., trainings on technical knowhow and financial management), financial assistance, provision and proper implementation of policies, strategies, institutional and regulatory frameworks. Also, governments through national health insurance schemes should provide access to healthcare services for the sanitation workers especially informal manual emptiers. The introduction of PPP into FS emptying business is beneficial to both customers and FS emptiers. The customers get access to quality service while the emptiers have access to safe and clean collection machinery and PPE which improves the status and decency of the work (Hawkins and Muximpua, 2015; Holm et al., 2018). Also, PPP provides a platform through which emptiers (especially manual emptiers) can form associations which can give them an identity and propagate their voices when required. The involvement of NGOs and CBOs who usually hold regular workshops and trainings provides a platform for educating the emptiers on technical, business and behavioral skills which will help to improve the viability of their business (Kohlitz et al., 2018).

Though the aforementioned initiatives help to improve the working conditions of FS emptiers, certain influencing factors and challenges faced by the pit emptiers act as barriers to effective implementation of these initiatives. Challenges faced by FS emptiers especially limited access to finance affect their ability to comply with regulations and standard operating procedures. For instance, due to lack of financial resources, some emptiers especially manual operators cannot afford to buy standard equipment or PPE. Also, due to social challenges, some emptiers might not want to put on PPE as they do not want the public to perceive that the type of job they do is dangerous (Prasad and Ray, 2019). Furthermore, even if standards are put in place towards the construction of proper sanitation facilities, some poor households cannot afford to construct the facilities to design standards, they thereby make use of cheap and unethical methods. In addition, the provision of improved services by the emptiers has the implication that customers will be charged more for the services, which might not be viable as the urban poor might not be able to afford such services.

5 Implications of the review on faecal sludge emptying services

The results from this review show that cost is the most significant factor in influencing the choice of emptying method, hence, a major barrier to effective implementation of improvement strategies. Initiatives and regulations provided by the government and also trainings by NGOs, CBOs cannot be effective unless extra steps are taken to ensure that the emptiers have access to finance and services are subsidized for poor households. First, local authorities should help in bankrolling part of the services to enable FS emptying become a commercially viable business. If FS emptying services become viable, banks and financial institutions as well as private entrepreneurs may come forward to invest in it. In addition, bank loans should be made accessible to potential entrepreneurs in the sanitation sector. The loan conditions should be made more favorable with special consideration for small-scale enterprises and reduced interest charges over the short term. The health and safety budget for a

municipality should include provision for health insurance for FS workers in order to make treatment affordable for these workers. In subsidizing sanitation services for households, government should identify sustainable resources for these subsidies which could be from government budgets, pro-poor sanitation surcharges imposed on utility bills, or higher fees charged to the wealthy (cross-subsidies). Though cost is the major factor which influences the choice of emptying method, use of cost reduction initiatives is not the sole solution to the challenges faced by FS emptiers. The combination of policies and regulations by the government, cost reduction initiatives, financial and technical trainings as well as awareness raising will help in overcoming the challenges faced by FS emptiers.

This review identified some gray areas which provide basis for future research work. Only one study was carried out in a rural area implying that studies in rural areas are limited. This is because emptying in rural areas are limited as most people rely on digging more latrines when the ones in use fill up due to availability of space in these areas. However, with increasing process of land use, there will be limited space for dig and cover method for full pits and there is potential of slipping back temporarily or even permanently to open defecation. Thus, there is need to sensitize the people in rural areas on the need for emptyable sanitation facilities.

Further, there is need to financially model FS emptying business in different communities especially for manual emptiers. The creation of viable business models for manual emptiers involving the use of suitable small-scale pit emptying technologies operated and supported through the provision of decentralized FS discharge points under a municipal framework will help in making their work more hygienic and also improve the profitability of their business.

Finally, there is need for studies on how user perception is related to emptying behavior. Understanding the link between peoples' perceptions towards risks/hazards and FSM in general, and their emptying behavior will enable the development of perception management strategies needed for successful implementation of effective behavioral change intervention programmes with focus on scheduled emptying. It is recommended that behavior change studies to gain insight on drivers and barriers to wearing PPE which will help in potential design options should be carried out. The mental health needs of FS emptiers should be investigated to provide better understanding of issues surrounding substance abuse and what steps can be taken to help improve their mental health.

6 Conclusion

Rapid urbanization in low- and middle-income countries amidst poverty shows that on-site sanitation systems are not likely to disappear anytime soon. Faecal sludge which accumulates in these facilities have to be emptied always; thus, emptying services would still be needed for a long time. The challenges faced by these emptiers mostly discussed in the reviewed papers were financial, technical and institutional challenges with social and health challenges being peculiar to manual emptiers. Though accessibility was the mostly discussed factor which influences the choice of emptying method, cost was observed to have the most influence as it overrides accessibility and service quality when it comes to the selection of an emptying method. Cost/affordability of the service and access to finance by FS emptiers were observed to be the major barriers to effective

implementation of improvement initiatives. Very few studies discussed on initiatives which have been put in place to make emptying business more lucrative and sustainable. The limited number of studies imply that a lot still has to be done to improve FS emptying business. Research gaps identified in the study include the need for sensitization for those in rural areas on importance of FS emptying, financial modelling of manual emptying and studies on perceptions towards emptying for both users and FS emptiers. Addressing these research gaps will provide critical information needed by stakeholders in the sanitation sector to improve FS emptying business.

Author contributions

CM: Conceptualization; Methodology; Software; Formal Analysis; Investigation; Resources; Writing-original draft preparation; Visualization; SS: Formal Analysis; Investigation; Writing-Review and Editing; Visualization. MM: Conceptualization; Methodology; Software; Formal Analysis; Investigation; Resources; Writing-Review and Editing; Visualization; Supervision; Project Administration. All authors read and approved the final manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2023.1097716/full#supplementary-material>

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