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Assessment of the Status and Characteristics of Faecal Sludge Management in populated unplanned settlements of Dar es Salaam, Tanzania

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ABSTRACT: This study evaluates faecal sludge management in densely populated informal settlements of Dar es Salaam, Tanzania, using suitable standardized methods. The data indicates that latrines are built with less emphasis on quality compared to the construction of houses, resulting in the use of inferior materials and technology. Various techniques are employed for emptying pits, with vacuum trucks and manual pit emptying being the predominant methods. However, lack of access to households poses a significant obstacle to vacuum truck emptying, as 39.67% cannot be reached by transportation means. The pit emptying industry faces high costs and restricted technological accessibility. Semi-manual and semi-mechanized technology innovations for hygiene emptying in less accessible dwellings have not gained sufficient appeal among inhabitants in densely crowded unplanned settlements. DAWASA owns treatment plants for faecal sludge treatment, but these are located far away, increasing transportation expenses. Implementing decentralized faecal sludge treatment plants appears to be a more effective approach. The collection and handling of faecal sludge now overlook the potential for resource recovery and re-use, which might greatly enhance the sustainability of faecal sludge management. Two government ministries have partially incorporated the faecal sludge management or sanitation sector into their health and water policies and programs, but the separation of responsibility has hindered its growth and lack of emphasis on information diffusion in urban areas.

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Faecal sludge management poses a substantial challenge in many developing nations countries (Cross and Buckley, 2016). Many cities in middle and low income countries face pressures to expand sewerage, but are not able to provide adequate collection and treatment systems (Andersson *et al*. (2016). In addition, many urban residents use on-site sanitation options such septic tanks, pit latrines and pour-flush toilets. Periodically, these systems need to be emptied (or changed, in the case of some pit latrines), and in high-density informal settlements, properly disposing off and treating waste may be expensive and challenging for users. This frequently results in improper maintenance of septic tanks and pit latrines, which can contaminate the surrounding area, especially during periods of heavy rainfall (Harada *et al*., 2016; Jenkins *et al*., 2015). A proper faecal sludge management process depends on the efficient operation of a chain from containment, emptying, transport, treatment, disposal or reuse, with each

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component playing a vital role. Looking at faecal sludge management chain, the first component which is latrine structures and associated containment structure play a crucial role in establishing and ensuring an effective faecal sludge management system. It is observed that Latrines are built with varying degrees of utility and durability, which are determined by the financial resources available to each home (Seleman *et al*., 2020). Empirical evidence suggests that the design construction of on-site systems in impoverished households often fails to consider the need for future emptying, resulting into a major problem when emptying is needed (Jenkins *et al*., 2015). The process of emptying pits is essential for effectively management of faecal sludge. However, many households encounter several barriers when trying to acquire this service, such as difficulties in reaching houses and their individual pits, as well as the lack of appropriate emptying technology in such situations (Cairncross *et al*., 2014; Thye *et al*., 2011). In such, some individuals resort to dangerous methods of manual extraction of waste using buckets and ropes. These methods are generally termed as unhygienic and unsafe (Cross and Buckley, 2016; Seleman et al., 2020). Consequently, this results in heightened health risks and contamination of the surrounding ecosystem. Delivering pit emptying services in urban slums is frequently hindered by the presence of high poverty rates, limited household accessibility, and unstable pit structures. Consequently, people living in slums sometimes use dangerous and makeshift methods to get rid of toilet waste, such as flooding trenches or indulging in careless hand disposal of waste. The ongoing use of unsanitary pit emptying methods can be attributed to factors such as limited physical access, shortcomings in current emptying technologies, and insufficient enforcement of rules and regulations (Seleman *et al.*, 2020). Informal settlements frequently exhibit uncontrolled and haphazard discharge and disposal of faecal sludge, especially during periods of rainfall. This approach entails utilizing open drainage systems or connecting pipes to local rivers or storm-water networks, which presents a substantial hazard and is associated with cholera epidemics. Prior studies emphasizes the necessity of having secure and functional latrines in locations with high population density, although there are shortcomings in comprehending the building and functioning of latrines (Chipeta *et al*., 2017; Chiposa *et al*., 2017). Faecal sludge treatment is crucial to render it harmless to health and environment however, in developing nations with limited financial resources, as there no comprehensive treatment systems (Atwijukye *et al*., 2016; Semiyaga *et al*., 2015). The existing practice in many cities is the co-treatment of faecal sludge with limited number of wastewater treatment facilities. However, the potency of septage and faecal sludge makes it difficult to treat them effectively (Ingallinella *et al*., 2002). Effective treatment of faecal sludge is essential to eliminate its potential harm to human health and the environment. However, in poor countries with limited financial resources, there is a lack of complete treatment systems (Atwijukye *et al*., 2016; Semiyaga *et al*., 2015). Many cities now practice the co-treatment of faecal sludge with a small number of wastewater treatment plants. Nevertheless, the high concentration of septage and faecal sludge is a challenge in achieving successful treatment (Ingallinella *et al*., 2002). Legislation plays a crucial role in the implementation of septage management, which includes environmental legislation, waste discharge regulations, and institutional powers and responsibilities. These frameworks can manifest at various levels, including national laws, directives, rules, and standards, as well as localized forms like municipal directives and by-laws (Ingallinella *et al*., 2002). The effectiveness of legislation depends on its enforcement, which relies on monitoring systems that oversee actions of homes and sanitation service providers and the ability to impose penalties on non-compliance. The distribution of responsibility for sanitation services, including septage treatment, is influenced by institutional frameworks. The allocation of duties can be categorized into spatial and functional dimensions. National and regional organizations bear the responsibility of establishing standards and overseeing the discharge of effluents. The provision of faecal sludge and septage removal and transport services is typically undertaken by municipalities, the private sector, or a combination thereof. However, there are instances where such regulation is either lacking or fails to effectively govern these services. In cases where current service providers fail to offer satisfactory faecal sludge management, it is worth considering the establishment of an entity that can deliver these services across multiple local government or utility service regions. This entity might operate as a publicly traded firm, a specialized division within a sewage utility or solid waste management agency, or a privately-owned organization engaged in a management contract with multiple municipalities. The entity in question potentially assumes responsibility for the provision of services over an entire region or province, or a specifically delineated area within such region or province (Andersson *et al*., 2016). Furthermore, numerous studies have assessed the faecal sludge management throughout its different stages in the process. The existing interconnections, capabilities, and limitations among the components of the FSM chain in cities of the developing countries, like Dar es Salaam, have not been addressed yet. This lack of

understanding has the potential to impede the smooth functioning of the chain. Hence, the objective of this paper was to assess the status and characteristics of faecal sludge management in populated unplanned settlements of Dar es Salaam, Tanzania

MATERIAL AND METHODS

Case study description: Dar es Salaam, a commercial and industrial city in the Tanzania, has a population of 5.3 million, causing significant strain on urban infrastructure and services. The city's mix of planned and unplanned settlements has led to poor services, unemployment and poverty. The government's pace of service delivery has not kept pace with population growth, with 75% of the population residing in unplanned settlements. Sanitation is a significant issue, with a high-water table affecting over 45% of the city's area. A significant proportion of the population relies on onsite sanitation systems, with pit latrines accounting for 90% of the total. Only 10% of the population has access to sewer systems, which are primarily limited to the central business district such as Upanga, Kariakoo and a few scattered institutional areas. The sewerage system, built between 1945 and 1948, has not been adequately integrated with the growing population and number of high-rise buildings, leading to challenges such as the insufficiency of the faecal sludge management (FSM).

Data Collection: The study employed a mixed approach to gather information about the design, usage, and management of HH latrine structures in Dar es Salaam. A cross-sectional survey of 342 residential households was done using questionnaire interviews in densely populated unplanned settlements in four Municipal authorities of Ubungo, Kinondoni, Ilala and Temeke. More data were also collected through key informant interviews with a variety of faecal sludge management practitioners, including pit emptying service providers, administrators from the local government, the Water Supply and Sanitation Authority, and operators of faecal sludge treatment facilities. The survey examined latrine systems, resident latrine uses and care, pit emptying, transportation and treatment and faecal sludge management practices.

Data Analysis: The study utilized a descriptive analysis to explore individuals' perceptions of sanitation issues, practices in managing faecal sludge pits, and their knowledge and attitudes towards latrines design and utilization.

RESULTS AND DISCUSSION

Socioeconomic characteristics of households and service access: The study surveyed households in Dar es Salaam, Tanzania, focusing on permanent residences built using durable materials such as cement block walls and iron sheet roofs. A significant proportion of households opt for alternative materials like bricks made from clay or traditional mud houses for construction. Approximately 88.21% of floor finishes are achieved through cement slurry surfacing, while the remaining proportion is allocated to alternative materials like ceramic tiles or leaving the floor unsurfaced. The households have a diverse range of family sizes, with an average of four families per household. The type of construction materials used in housing are commendable, with a significant proportion of households having durable dwellings constructed with cement blocks for walls and iron sheets for roofs to indicate that their households are permanent.

Owner occupancy accounts for 72.47% of residential properties lived by owners, while the remaining residences are either inhabited by the owning household and tenants or solely by tenants. Only 8.52% of the properties are collectively owned by multiple individuals and are subjected to rental agreements. Access to residential properties is challenging, with 60.33% of households accessible by car, despite difficulties such as narrow road width, steep slopes, and rough surface conditions. A notable 5.94% can be accessed through alternative modes of transportation, such as bajajis. Approximately (39.67%) of residential dwellings are inaccessible due to narrow pathways, steep inclines and construction along riverbanks. The survey reveals that a significant proportion of households in the surveyed region generate income from formal enterprises, small-scale trading, wages from sporadic labor, stable employment, agricultural or horticultural activities, fishing and trading sea products. Income sources among households in Dar es Salaam include 19.2% through petty trading, 38.2% temporal employment in formal business enterprises, 13.6% through allowances acquired from casual labour and 29% from salaries of permanent employments. Gardening and fishing are additional income sources, but a significant proportion of individuals lack reliable and consistent income sources. Water services vary among households, with 78% linked to the main water supply, while rest rely on alternative sources such as public kiosks or neighbouring water supplies. A small percentage of households use shallow wells as secondary sources during intermittent water supply interruptions. Energy sources for lighting and cooking are varied, with 95% obtaining electricity from the national grid. A significant percentage of households

use charcoal as their primary cooking fuel, followed by cylinder gas and kerosene.

Latrine structures quality characteristics and maintenance: The survey results in (table 1) reveal that, households (HHs) use a variety of latrine technologies, with traditional pit latrines accounting for 40% of the total, followed by pour-flush latrines (37.1%) and VIP latrines (21.8%). A small percentage of HHs use cistern flush latrines and composting toilets. A significant percentage of households have latrines equipped with containment pits situated directly at the base of the latrine structure. The study's findings revealed that the distribution of latrine technologies in Dar es Salaam has remained relatively stable throughout time. The data, as reported by (Chaggu *et al*., 2002; Jenkins *et al*., 2015), show that there have been no advances in better sanitation over the previous two decades, despite nearly twenty years and nine years having passed since the respective studies were conducted. There is a significant disparity in the selection of construction materials used for latrine structures within individual households. Sand cement blocks are the primary material commonly used for the construction of latrine superstructure walls, constituting approximately 82.2% of instances. The remaining latrines, which lack walls, are located in the backyard. Other materials employed include thatches, sacks, textiles, or a composite amalgamation thereof. A considerable percentage of latrines, 55.4%, lack a roof, and the roofed ones with corrugated iron sheets emerging as the prevailing material in the subset of latrines that possess a roofing structure. A small proportion of latrines, 3.8%, utilize alternative materials such as thatches, sacks and canvas. The main constituent of latrine slabs is reinforced concrete, although logs are occasionally utilized as an alternative reinforcing material. Although households in surveyed unplanned settlements have relatively permanent houses, the construction of latrines in these settlements does not demonstrate the same level of permanence and does not adhere to appropriate construction standards. This can be attributed to factors such as poverty perception, limited knowledge, inadequate access to skills and a lack of well-established information on sanitation standards. (Adriana *et al*., 2010; Owusu, 2010) have noted that communities often overlook the significance of constructing high-quality latrines, in contrast to the attention they give to building their houses. The existing norms on latrine construction are primarily known by local masons, who lack awareness of them. As a consequence, certain pits may have a restricted ability to be emptied, especially when utilizing machinery or necessitating the removal of a section of the latrine structure part. Households display a diverse range of pits, characterized by varying sizes and depths that span from 1 to 4 meters. As indicated in table 1, the majority of these excavations (95%) exhibit depths ranging from 2 to 4 meters, whereas the remaining excavations, comprising less than 5% of the total, possess depths below 2 meters. The majority of the excavated pits are located at depths where the presence of groundwater is evident, as reported by the respondents who encountered groundwater during the excavation process. The majority of these pits takes between 1-5years to fill up (66%). In latrine pits, 81% of latrine pits are outfitted with protective lining because of the weak soil profile of Dar es salaam. The primary method employed for lining the pits is the utilization of cement sand blocks, which constitutes 83.9% of the instances. Additional lining techniques that can be employed include stone pitching, the use of old tires or drums, and the option of leaving the pits unlined, representing 7.3% of pits. It was observed that approximately half of the households dispose different types of waste into latrine pits. A significant percentage of households (74%) indicated that they used their latrine facilities for excretion and bathing activities together, with all wastewater produced from these activities directed into a shared pit. No evidence was found to suggest that any of the households surveyed implemented the practice of segregating wastewater from toilets or bathrooms into separate pits. Water is the major cleansing material used (88%) while the few others using also toilet papers and normal papers. In order to address the issue of odour and minimize the risk of insect vectors, a waste seal mechanism has been integrated into specific latrine designs, constituting approximately 37.2% of these sanitation facilities having water seals at a latrine pans. The remaining percent of latrines had no water seal. A significant proportion of latrines (69.9%) were observed to be in a sanitary condition, but a significant percentage (21.0% and 9.0% correspondingly) displayed indications of faecal or urinary contamination on latrine flow and floor surfaces. The survey also noted that 39.67% of the latrines were not able to be emptied by vacuum trucks. The primary reasons for inaccessibility or lack of temporary access to pits for emptying, which exceeds 30% as stated by (EWURA, 2021), include the presence of latrines in the city of Dar es Salaam that cannot be emptied. The presence of non-emptiable latrines is a major problem in numerous areas of sub-Saharan Africa, where pits cannot be emptied. The same has been observed also by (Chipeta *et al*., 2017; Jenkins et al., 2015). In addition, numerous containment facilities in Dar es Salaam suffer from inadequate access points, resulting in higher expenses related to the emptying procedure (Seleman *et al*., 2021; Seleman *et al*., 2020). When latrines are affected by environmental conditions such

as shallow groundwater tables, it is essential to use certain building precautions to protect groundwater from being contaminated by faecal sludge and to prevent flies from reaching the sludge. It is crucial to regularly remove faecal sludge when it reaches a depth of one metre below the top of the squatting slab. Non-compliance with these guidelines can result in substandard sanitation practices and living circumstances, which have been found to be substantial. Similar findings were noted by (Jenkins *et al.*, 2015).

Table 1: Latrine technologies used in Dar es Salaam and their operations

Type of latrine	**%**	**Time taken to fill up (years)**	**%**
Automatic cistern flush	0.9	Less than 0.9	7.6
Pour flush	37.1	1-5	66.0
VIP	21.8	5-10	16.8
Traditional Pit latrine	40.0	10-15	4.6
composting toilet	0.3	15-20	3.6
Containment pit type		**Pit depths (metres)**	
Pit	61.8	1-2	5
Septic tank+Soakway	11.4	2-4	95
Cesspit	26.8	>4	-
		Greater than 20	1.5
Cleansing materials	**%**		
Water only	88.0	**Pit additives application timing**	**%**
Toilet papers only	5.1	when the pit is full	11.3
Both water and toilet paper	6.9	when the pit is about full	10.6
		With a regular interval	77.8
		DK	0.3

DK = Don't know; n = 342

Latrine use and material disposal in latrine pits: Latrine pits are specifically engineered to assist the efficient disposal of human waste, as well as cleansing agents and bathing water. Various substances, such as soaps, detergents, and germicides, are used in varying amounts to maintain cleanliness in latrines. Household members have a tendency to dispose of various waste materials in toilet pits. A substantial majority (87.1%) choose to discard hazardous trash into latrine pits as a means of safely containing them. In addition, certain homes also discard household waste, such as baby nappies and sanitary napkins, into latrine pits. Inadequate handling of these materials presents a substantial obstacle in the management of wastewater infrastructure and during the process of pit emptying. Certain households choose to engage in garbage burning, while others opt to dispose of their waste in latrine pits in areas where municipal solid waste collection services are not accessible. Latrine pits are also used for the disposal of a variety of materials, including broken glass or ceramic objects, sharp metal needles or razors, expired prescription compounds, substances used for rodent extermination, and used condoms. The vast majority (84.2%) of participants were aware of the potential obstruction it can create to the process of emptying and the heightened expenses linked to emptying owing to the dumping of unnecessary debris in toilet pits. Furthermore, pit additives are used for a variety of reasons, and at least 85.5% of families are already familiar with the use of pit additives. A significant proportion (77.8%) of households regularly utilize pit additives primarily to alleviate smells, deter insects, or facilitate the sinking of sludge. Additionally, it was observed that 23.9% of families believe that pit additives can serve as a viable substitute for pit emptying. This implies that these consumers think that they can rely on the use of pit additives to sink sludge and avoid the expenses associated with emptying. Out of the pit additive users for the purpose of sinking sludge, 94.8% confirm that the use additives were successful in causing the sludge to sink. Commonly employed pit additives encompass commercial additives, salts, ashes, diesel, paraffin, battery acids and spent motor oils. The disposal of solid wastes in latrine pits is a significant issue in many developing towns, as shown by previous studies conducted by (Bakare *et al*., 2012; Zuma *et al*., 2015). Disposing of these things adds complexity to the task of emptying and presents a difficulty for the management of wastewater infrastructure. Some homes employ pit additives for different purposes, but just a few consider them a feasible alternative to pit emptying. Nevertheless, previous studies have not demonstrated the effectiveness of using pit additives to sink sludge (Grolle *et al.,* 2018).Therefore, they are not considered an appropriate method for managing sludge

Existing pit emptying and transportation and treatment arrangements: The survey findings indicate

that families employ a range of technologies to empty sanitation facilities, including vacuum trucks (33.9%), manual pit emptying methods (27.2%), and alternative ways such as hand pumps (Gulper) or a compact vacuum system known as Vuctug. Nevertheless, vacuum trucks are incapable of efficiently managing thick sludge or deep pits. The cost of emptying ranges from 50,000 to 300,000 Tanzanian shillings (equal to USD 20-120), depending on the geographical location and the distance to disposal facilities. Currently, there are over 110 privately owned vacuum trucks that are used to provide emptying services for the entire city. In addition, there are 5 vacuum trucks owned by LGAs and 7 vacuum trucks owned by Dar es Salaam Water Supply and Sanitation Authority (DAWASA) that also give the same service. The duty for waste disposal fees is usually shouldered by the homeowner or divided among each family resident within the property. Occasionally, when there is a significant amount of dense or solid sludge in the pit especially at the bottom, it may be necessary to have an additional agreement in place. This agreement would involve adding water to the pit and agitation before it the pit is emptied. The client would incur extra fees for this process. Occasionally, in situations where the sludge is very thick, the vacuum truck operators and manual pit emptiers collaborate to empty the pit, solid sludge that accumulates at the pit's bottom. When the task of managing the emptying service becomes challenging, certain households resort to surreptitiously disposing of the contents of their pits into the surrounding environment as a means of coping with the perceived financial burden associated with a correct emptying procedure. Out of the households surveyed, at least 15% reported experiencing instances where their latrine pits were flooded. The reasons for this included financial constraints preventing timely emptying (60.4%), blockage issues (8.3%), an increase in the water table within the pits (29.2%), or a lack of access to pit emptying services.

On a small-scale emptying, only four small enterprises in Dar es Salaam employ the Gulper technology for delivering faecal sludge emptying services. The cart has a tank capacity of 1 cubic meter. The manual hand pump operates by transferring pit content into jerricans, which are lifted by hand to a three-wheel cart stationed at a certain distance from inaccessible households. The transportation of faecal sludge over long distances incurs significant expenses due to the low volume of sludge being transported, resulting in elevated unit costs. The unit cost for emptying with small scale emptying equipment is 25,000Tsh (10 USD) per cubic meter of sludge emptied. DAWASA possesses one compact cart that is outfitted with a pump designed for the purpose of emptying pits which offers a service a relatively lower cost of 15,000Tsh (6 USD).

The frequency at which pits are filled plays a crucial role in assessing the financial implications and practicality of pit emptying. The challenges encountered by households in accessing pit emptying services underscore the importance of considering the wider context of sanitation systems. Challenges in pit emptying can arise due to factors such as narrow household entrance gates, poor road conditions, and a scarcity of service providers. Enhancing accessibility of services requires addressing system-level concerns and improving technical aspects. The management of faecal sludge in Dar es Salaam is primarily managed by private enterprises using vacuum tankers and small businesses using Gulper technology.

In Dar es es salaam city, only two DAWASA-owned treatment facilities exist, in the Vingunguti and Kurasini wards to handle the treatment of bulk faecal sludge. Co-treating FS with sewage is how the treatment is carried out using waste stabilization ponds (WSPs). Even though DAWASA has seven treatment facilities which are mainly WSPs, only two of them are specifically for treating FS. Recently, a third waste stabilization pond was added to the FS for treatment. It is not accessible to the public, but it is used by DAWASA themselves to handle FS collected by their vacuum trucks only. The current infrastructure for treating faecal sludge has a capacity of approximately 149,526 cubic meters per year (EWURA, 2021).

At small scale, small piloted faecal sludge treatment facilities have been established to treat faecal sludge at capacities ranging from 4-20 cubic metres per day in different parts of the city. The established facilities treat FS with anaerobic technologies with option for resource recovery. In addition to the small anaerobic treatment facilities that were created based on research experiments in the city, the study did not address the potential for recovering resources from the majority of the faecal sludge (FS) that is collected and treated. After co-treating the faecal sludge with wastewater, the resulting effluents are released into water streams, while the sludge is stored in ponds for an extended period of time. Eventually, the sludge is dried, removed, and disposed of in isolated areas, such as reserved wood lands owned by some institutions in the city.

Faecal sludge management policy and regulation environment: In Tanzania, faecal sludge management policies and regulations are fragmented across various government sectors, with responsibilities spanning across different ministries. The Ministry of Water

(MOW) and Ministry of Health (MoH) are two major entities spearheading sanitation policies, but there is not a single policy covering sanitation as a whole. The National Water Policy (NAWAPO, 2002) focuses on fostering sustainable development and effectively managing water resources, emphasizing the preservation of water quality and regulation of water pollution. Inadequate sanitation practices and inadequate management of faecal waste can lead to contamination of water sources and bodies, causing a deterioration in water quality. From the policy the ministry developed the Water and Sanitation Act (2009) (URT, 2009) to regulates community-owned water supply organizations and decentralizes their governance, making them subject to regulation by Energy and Water Utilities Regulation Authority (EWURA).

The Ministry of Health has a National Environmental Health, Hygiene and Sanitation Strategy (NEHHASS) to effectively execute the National Health Policy while adhering to the Tanzania Development Vision for 2025 and the Strategic Development Goals (SDGs). The President's office, specifically the Regional Administration and Local Government (PMO-RALG), serves as the primary governing body for Local Government Authorities (LGAs). The PMO-RALG's jurisdiction extends to the grassroots level and bears the responsibility of executing sanitation and faecal sludge management. The role of LGAs in excreta management, specifically safe disposal, is outlined in the Local Government (Urban Authorities) Act of 2000 in Tanzania. The responsibility for the provision of latrine and containment facilities is outlined in the Public Health Act (PHA). LGAs play a crucial role in ensuring the enforcement of appropriate sanitation technologies and emptying methods. The process commences with routine latrine inspections conducted by environmental health officers (EHOs), who are responsible for ensuring compliance with sanitation standards. In cases where latrines are found to be full and unemptied, or instances of unauthorized emptying and improper disposal of wastewater are observed, fines are imposed as a means of enforcement. The Ministry of Education, Vocational Education and Training (MoEVT) formulated a policy in 1996 with the objective of incorporating environmental health, hygiene, and sanitation into educational curricula and programs. The national strategic plan for school water, sanitation, and hygiene (SWASH) from 2012 to 2017 aimed to ensure universal access to WASH facilities and comprehensive hygiene education in educational institutions. The Vice President office in Tanzania has the National Environmental Policy (URT, 1997), which focuses on protecting the environment and fostering sustainable utilization of natural resources. The policy emphasizes the mitigation of pollution in both urban and rural settings, as well as the promotion of technological innovations in the treatment and recycling of wastewater and sludge. The Environment Management Council (NEMC) was vested powers by the National Environmental Management Act of 2004 to establish a comprehensive legal and institutional framework that facilitates sustainable environmental management in alignment with the National Environmental Policy of 1997 (URT, 2004). The Sludge Management Policy, developed by the Dar es Salaam Water Supply and Sewerage Authority in 2003, is designed to establish a framework for the efficient management and appropriate disposal of faecal waste within Tanzania (URT, 2003). EWURA oversees the operations of Water Supply and Sanitation Authorities, including the management of liquid waste. In such, it has developed the guidelines for onsite sanitation and faecal sludge management for water and sanitation authorities of 2020 (EWURA, 2020).

Existing Faecal sludge management typologies across the chain: Notably, there are primarily three different chains of alternatives for pit emptying to dispose of FS in the city: vacuum trucks (VT), small-scale emptying equipment (SsEE), and small-scale transport equipment (SsTE) as seen in figure 1. VT is frequently used to empty pits at agreements reached between the public and private sectors. To specific faecal sludge treatment plants, FS is carried using small-scale transportation and emptying equipment. Utilizing vacuum trucks that automatically empty and deliver FS to approved treatment facilities is the second option. The final choice entails manually emptying and burring FS in a trench dug nearby because there is either no way to access the pit via transportation or it is regarded expensive for the household to bear. In the street, each of these techniques runs simultaneously. While using VT for transport and emptying is more convenient and hygienic, the charges must be paid for up front by the household. When compared to VT, using SsEEs is less hygienic and convenient. The initial cost of emptying is low, but the cost per unit is higher. Although it is less expensive, manually emptying pits and burying FS poses a risk to public health and hygiene. It is noted that private owners have full responsibility for managing latrines and sludge containment facilities from building to emptying, with minimal to no supervision from the government. The government's involvement in this matter is minimal, specifically limited to inspections of latrine hygiene undertaken by health officers. While government rules do exist, they have not been widely disseminated to the public nor strongly emphasized. The private sector primarily controls the process of pit emptying and

transportation of material to disposal, while the government, through DAWASA, offers a limited number of emptying services. These private suppliers of pit emptying services are officially recognized by DAWASA, but their pricing is not subject to regulation. As a result, their fees are often considered to be higher than what DAWASA charges for the same service. The government, through DAWASA, has a dominant role in the treatment of faecal sludge as they own and run the official treatment facilities. There are only a limited number of small-scale treatment facilities available, but their capacities are insignificant when compared to the real volume of sludge that needs to be treated each day. When municipalities lack the capacity or when managing septage is not a top concern for local policymakers, it may be advantageous to consider alternative methods for handling the removal, transportation, and treatment of faecal sludge (Klingel *et al*., 2002). Several potential alternatives can be considered, such as assigning the responsibility of managing septage and faecal sludge to a government entity at a higher administrative level, implementing management practices through contractual arrangements with individual local government bodies or a collective agreement with a group of local government bodies, or delegating authority to an established specialized organization for providing these services.

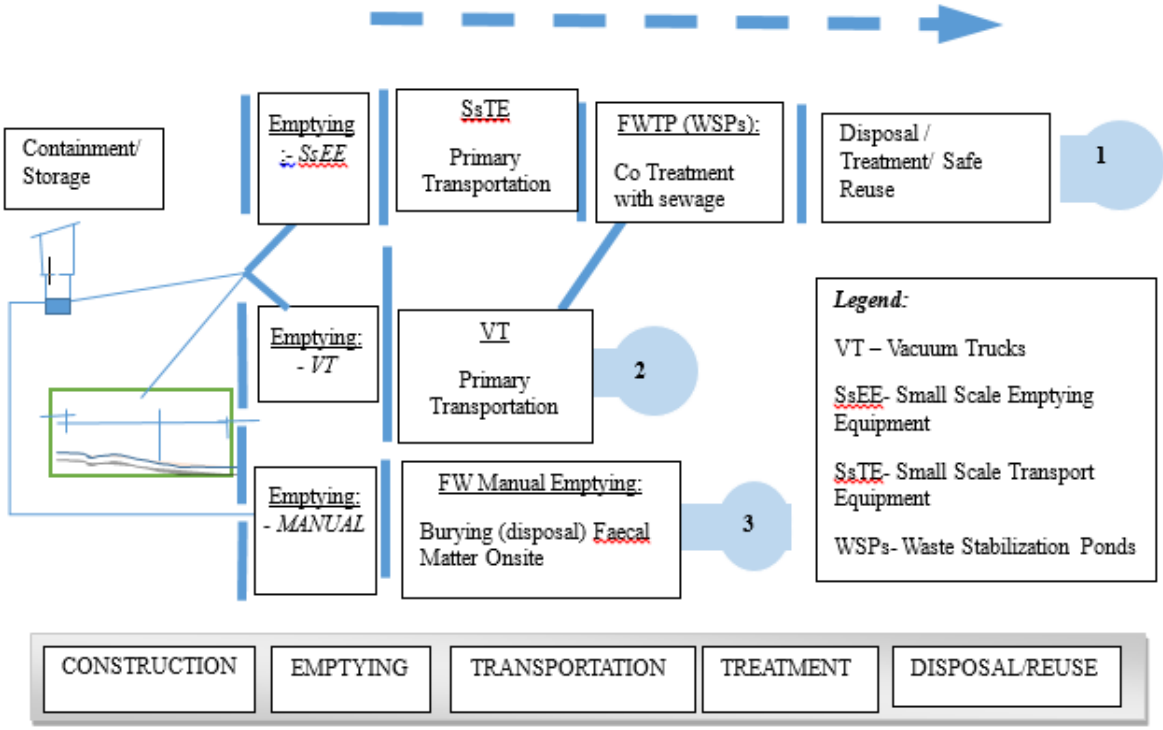

Fig 1: Existing typologies for Faecal sludge management across the chain in Dar es Salaam

Conclusion: The study reveals that Dar es Salaam's faecal sludge management chain involves various stakeholders, including individuals, businesses and government entities. The chain's proper functioning starts with the construction of toilet structures and containment pits, with a lack of knowledge on appropriate construction standards leading to dysfunction. The development and maintenance of latrines require a combination of mindset, expertise, and governance, with government involvement crucial. More than one-third of latrines cannot be emptied, posing a challenge to sanitation and hygiene in unplanned settlements. Current constraints on capacity and localization of treatment facilities lead to higher disposal costs. Decentralization is needed to reduce transportation expenses. The current rules, legislation and regulations regarding faecal sludge management lack clarity and are scattered across various sectors, hindering progress in the sector.

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