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Fecal sludge management: Insights from selected cities in Sub-Saharan Africa

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Abstract: Recent studies have shown that over half of the world's population lives in urban areas, with the number of people living in slums growing by over 20 million per year and people living in urban areas lacking access to adequate sanitation. This study presents a review of the challenges facing fecal sludge management (FSM). A globally relevant issue in developing urban centers, especially in selected developing countries in West Africa was discussed. Some key findings of the review are that effective sanitation in developing areas depends on the chain of services and that one of the largest problems in sanitation is FSM. This study presents the initial steps toward understanding the main issues involving FSM in developing cities of West Africa. Results are intended to be used as a support for decisions on policies, strategies for FSM, and investments for improved treatment facilities in the region. The study suggests that governments and private sector organizations should develop adequate measures for handling fecal sludge.

Introduction

The need to work toward effective and sustainable fecal sludge management (FSM) on a global scale has recently been highlighted and understood (Debela et al. 2018). FSM is a fairly new field that is developing rapidly and gaining recognition (Strande et al. 2014). Fecal sludge (FS) refers to the raw, slurry, or partially digested semisolids resulting from the collection of a combination of black water and human excrement with or without the combination of gray water (Strande et al. 2014, Zhou et al. 2018). Fecal management includes the storage, collection, transportation, treatment, disposal and/or safe end use of FS in several areas, such as in biogas recovery, soil amendment, and liquid or dry fuel (Gomaa and Abed 2017). FS is highly variable in concentration and quantity (Werner et al. 2009).

Onsite treatment technologies serve the sanitation needs of 2.7 billion people worldwide; however, the world population is expected to grow to over 5 billion by the year 2030 (Bracken 2005, World Health Organization and UNICEF 2014). While onsite technologies are usually perceived to fulfill the sanitation needs of rural areas, in reality, around 1 billion onsite sanitation facilities globally are located in urban cities (Hu et al. 2016, Katukiza et al. 2012). In many areas, onsite technologies have much greater coverage than sewer systems. For instance, in Sub-Saharan Africa, 65–100% of sanitation access in the urban centers is provided by onsite technology (Koottatep et al. 2001, Odey et al. 2017). Regardless of the fact that sanitation needs are generally met through onsite technologies for many people living in urban areas of low- and mid-income countries, no general management system is yet available for the subsequent collection, transportation, treatment, and use or disposal of FS (Abila 2014, Chinyama et al. 2012, Huda et al. 2012). FSM is a critical environmental issue in Sub-Saharan Africa that requires attention and will continue to play a relevant role in the management of future sanitation issues in the region.

Onsite technologies are traditionally viewed as temporary solutions until permanent sewers can be constructed. However, the development of standard functioning sewer networks cannot match the speed of urban expansion, especially in low-income cities. Moreover, the recognition that vital resources from FS, such as organic matter and nutrients, can be used for soil amendment in agriculture has led to the development of resource-oriented sanitation approaches (Jayawardhana et al. 2016, Jepsen et al. 1997, Kah et al. 2016, Lau et al. 2017). FS can be managed more efficiently through a resource-oriented sanitation approach that can recover organic matter and nutrients available in FS to be utilized in agriculture and close the loop in the nutrient cycle (Schönning et al. 2002). Such sanitation systems could provide efficient resources, sustainable sanitation, and an economically sound alternative that protects both humans and the environment. A homogenous solution to various environmental problems, such as food security, water scarcity, soil degradation, poor energy, and sanitation, may provide a sustainable ecosystem to humans (Odey et al. 2017).

The use of a sustainable sanitation process to produce rich organic fertilizers after proper treatment for agricultural use is one of the mechanisms for topsoil quality and improvement of degraded soil (Esrey et al. 2001). Resource-oriented sanitation approaches provide solutions to crucial challenges in developing countries, such as environmental degradation, water scarcity, and the need to recover and recycle nutrients for the improvement of agricultural products (Esrey et al. 2001). Dry toilet sanitation systems are a resource-oriented sanitation approach specifically considered being an acceptable option for the rapid improvement of sanitation treatment in developing areas, especially in areas without these systems that affect fresh water resources by eliminating the demand for toilet flushing water. Nevertheless, the dry toilet sanitation process enables easy nutrient recovery from source-controlled undiluted sanitation flows (Strande et al. 2014).

FSM and FS treatments are becoming very relevant to achieve safe sanitation approaches that ensure hygiene and well-being by inactivating pathogens and the infection cycle. Human excreta have been utilized for many years in agriculture to increase soil fertility. However, FS is very rich in microorganisms and pathogens that could pose a threat to public and environmental health. Developing terra preta from pretreated human excreta could be effective in replenishing and promoting plant growth and maintaining a hygienic environment. The process could also foster sustainable soil fertility, which is a major challenge all over the world. Therefore, this review provides insights into FSM in Sub-Saharan Africa with focus on the types of toilet systems and sanitation approaches employed for resource recovery.

Sanitation situation and development approach

Recognizing the importance of adequate sanitation as the best approach to solve environmental problems and developing an environmental sanitation system to reduce the risk to pathogen associated with FS in the environment is the current global goal (Dickin et al. 2017, Dickin et al. 2018). Wastewater management systems consisting of sewer networks that collect human waste from households and directly transport them to the treatment system could be a suitable approach to FSM. For over 100 years of research and development in the area of sanitation, wastewater management systems have evolved from collection and open disposal to collection and central disposal to collection and central treatment before disposal and to collection, treatment, and resource recovery.

Fecal sludge management in Sub-Saharan Africa

In West Africa, non-collective sanitation facilities consist mainly of latrines (traditional and improved latrines) and septic tanks associated with infiltration wells and other pits that receive domestic or assimilated wastewater.

Organizational and regulatory framework

In West Africa, only Cote d'Ivoire and Sierra Leone did not have an approved sanitation policy in 2011 (World Health Organization 2012). All countries of the subregion have an organization responsible for the management of wastewater and excreta in urban and semi-urban areas. One of the mandates of these organizations is to define, coordinate, and implement guidelines in their area. However, Nigeria, Liberia, and Gambia are lagging behind in terms of implementation of the coordination of actions by the responsible agencies (World Health Organization 2012). Ministries in charge of water, sanitation, hygiene, public health, and the environment share the leadership management of sewage and excreta in rural areas. Stakeholders in wastewater management and excreta are associated with consultation and decision-making, but their participation is not systematic in all countries (African Ministers' Council on Water et al. 2011).

Steps of the management chain

The stages of FSM include production, collection, transport, treatment, and disposal or upgrade of FS.

Production of FS

Assessment of the quantity of FS produced remains difficult and poorly documented in West Africa. The quantities of FS produced are poorly known or uncontrolled in West African countries due to variability in the type of existing non-collective sanitation facility (Koné et al. 2007). Standardization of the dimensions of the built installations is also lacking. Thus, estimating the sludge production for each type of plant and the overall deposit of FS produced in the localities is difficult. While the specific productions found in the literature range from 0.05 L/day/inhabitant to 2 L/day/inhabitant of FS in urban areas of developing countries (Heinss et al. 1998), the methods of evaluation used by the authors are not always clearly described. In general, the quantities of FS encountered in the literature do not correspond to the exact amount of sludge produced but to the quantities collected or emptied.

Collection and transport

The collection (emptying) of sludge from non-collective sanitation facilities in West Africa is performed mechanically by hydro-scrubber trucks or other mechanized or semi--mechanized machineries or manually by shovel and bucket (Koanda 2006). Manual emptying is performed by "professional" manual drainers, and mechanical emptying is ensured by (mostly) private and public companies (Koanda 2006, Koné 2010).

Surveys conducted in some West African countries revealed that 30–50% of non-collective sanitation facilities are manually drained (Blunier et al. 2004, CREPA 2004) due to the inability of some households to pay for mechanical drain services, the type of infrastructure and its modalities of use, or the difficulty of access to the sanitation facilities of some households by drainers. Fuel and maintenance costs for drain trucks account for more than 60% of the cost of a drain service (Koanda 2006). These costs are high for low-income households and often make service inaccessible to them. Traditional latrines allow for the infiltration of liquids into the soil because these solutions are non-watertight. Therefore, the sludge produced from these structures has high dry-matter concentrations. Even if water is used for cleaning, 20–50% of the contents of the lower part of the non-watertight latrine cannot be emptied mechanically due to its consolidation over time. In comparison, the dry matter content of a septic tank is generally less than 2% and, therefore, more easily drained by pumping. As a result, depending on the dry matter content of the sludge in the plants, emptying of an installation may be complete or partial, and the sludge field produced may not be extractable. Therefore, the type of sanitary facility promoted and put in place has a direct impact on the quantity and quality of the sludge collected and transported. Narrowness of the streets and the location of the latrines in some houses prohibits hydro-scrubber trucks from performing draining services (Koanda 2006).

FS treatment and disposal/recovery of by-products

In nearly all West African countries, the sludge collected and transported is mostly displaced without any treatment. Areas of depression, streams and ocean, agricultural land, lakes and fish ponds, and even housing and streets receive untreated sewage sludge (CREPA 2004, Koanda 2006). Nevertheless, over the past 15 years, several encouraging initiatives for the treatment of FS have emerged in the countries of West Africa, especially Senegal, Mali, Côte d'Ivoire, Burkina Faso, Ghana, Benin, and Guinea. These initiatives (Table 1) range from small-scale pilot experiments to research projects and the construction of a full--size processing station (Koanda 2006).

Table 1 shows that Senegal is strongly involved in research and development activities, particularly in the treatment and enhancement of treated sewage sludge. Other countries in the subregion also have similar initiatives, but discontinuity of efforts hinders their advancement.

Even in cities where large-scale FS processing systems are present, a considerable amount of FS remains untreated. In Dakar, for example, collected and transported sewage sludge is estimated to amount to 1500 m^3/day, but treatment plants receive only 22–70% of this amount. In Dori, a station was put into service in 2012 but attendance statistics are not available. In Ouagadougou, FS deposit is estimated to range between 700 and 1203 m^3/day, but the Kossodo and Zagtouli stations are designed to receive only 250 m^3/day. In Bamako, the processing stations are not active and the sludge collected is not treated. The FS treatment plant in Cotonou has been in service since 1994 and is remarkably overloaded. The cities of Niamey, Abidjan, and most of the capital cities and towns of the countries of the subregion have no functional infrastructure for the treatment of FS on a large scale. The FS collected and transported in these cities is, therefore, disused into nature without treatment.

The upgrade of FS as fertilizer is a common practice in West African cities as a result of the development of urban

Table 1. Station/initiatives for the treatment of FS encountered in West Africa

Cities (Countries)	Treatment	Observation (ref.)
Accra (Ghana)	Lagooning	Koanda 2006
	Sedimentation Basin + lagooning of the supernatant and Co-Composting of thickened sludge	Heinss et al. 1998
Kumasi (Ghana)	Lagooning	Koanda 2006
	Biodigester	FSM2, 2012
Cotonou (Benin)	Sedimentation Basin + lagooning	Koanda 2006
Dori (Burkina Faso)	Non-planted drying beds + treatment of Percolât by lagooning	Established in 2013
Dakar (Senegal)	Decantation + co-treatment of the supernatant by sludge activated with sewage and thickened mud (Sludge residue at the bottom) on drying beds non-planted	Station in service Koanda 2006
	Non-planted drying beds	Station in service
	Drying beds planted	Experimental Station – Ongoing research work
	Non-planted drying beds + sludge incineration dry	Experimental Station – Ongoing research work
	Decantation-sedimentation/thickening	Experimental Station – research work Mbêguêrê et al. 2011
Keur Massar (Senegal)	Biodigester	Project Pilot Station Koanda 2006
Abidjan (Cote d'Ivoire)	Unsaturated flow drying bed	Experimental Station
Bamako (Mali)	Non-planted drying beds + treatment of Percolât by lagooning	Abandoned Station
	Decantation + treatment of Percolât by lagooning	Station not in service
Conakry (Guinea)	Sedimentation + degasification + anaerobic basin	Koanda 2006

agriculture (Koanda 2006). Sewage trucks from several cities often dump crude FS into the fields at the request of farmers. In some cases, FS from manually drained pits is buried in the soil before being reused as an agricultural amendment (CREPA 2004). Co-composting of FS with household refuse in an artisanal or semi-artisanal manner can also valorize the FS in the subregion (Koanda 2006). In addition to agricultural valuation, energy recovery from FS is developing in some countries of the subregion, notably in Ghana and Senegal. For example, Muspratt et al. (2014) assessed the high-energy potential of FS in ACCRA and Dakar BV, while Gold et al. (2014) showed the feasibility of using dehydrated sludge on drying beds as industrial fuel through pilot trials in the same cities. The study of Diener et al. (2014) showed the potential use of ACCRA FS for biogas production.

In summary, in the last decade, improved sanitation (wastewater management) in West Africa was driven by the commitments undertaken by states at the Millennium Summits. These commitments have resulted in the establishment of national policies primarily geared toward the construction of non-collective sanitation works without considering the management of the by-products of FS. Internal and external financial support has been allocated for this purpose. However, less than half of the funding needs have been mobilized despite the absence of the FSM component in national policies. While the collection and transport processes of the waste are relatively developed, collection and transport of FS is done manually by bucket and shovel or mechanically by hydro--scrubbing trucks, and the means implemented for this service are inadequate. Nearly all of the FS collected in West African countries is disposed in the wild without any treatment. Initiatives have been undertaken to treat the sludge but very few efforts can address the scale of a city. In municipalities or cities where treatment systems exist, establishing a regulatory and organizational framework following a participatory and concerted process with all players involved in the management of the FS remains necessary to ensure the sustainability of the industry. Valuation of FS in agriculture is common and research on energy recovery is emerging. Figure 1 shows the flow chart of sanitation model proposed in this study

Type of toilet systems in West Africa

Pit latrine sanitation system

The pit latrine sanitation system is a common traditional sanitation technology in developing countries. However, pit latrines cause the most pollution among the toilet systems. The pathogens and nutrients available in FS are easily transported and deposited in the soil beneath the pit and to the groundwater. When the groundwater table water is high, FS directly contaminates the drinking water (Nakagiri et al. 2016, Rifkin 1981). Odor nuisance usually exists, no interest is taken in treating the discharged FS, and the resources available in FS eventually cause environmental pollution (Grimason et al. 2000).

Urine diversion dry toilets

UDDTs are regarded as the most available resource-oriented sanitation system in urban and semi-urban areas of developing countries (Lalander et al. 2013, Senecal and Vinnerås 2017, Zakaria et al. 2018). In this method, urine and fecal matter are collected directly from different containers placed in a chamber below the toilet seat. The toilet is built in such way that urine is collected and drained from the front area of the toilet, while the feces fall through a large hole at the back (Lamichhane and Babcock 2013, Simha and Ganesapillai 2017). The liquids are separated from the feces to keep the processing chamber contents dry. Drying materials, such as ash and lime, are added to the hole after defecating. The addition of drying materials reduces the moisture content and increases the pH of the FS to create conditions for drying and increase the pH variation and time for inactivation of pathogens. This type of toilet system is a waterless system that is particularly suitable for conditions where water is scarce or unavailable (Uddin et al. 2014). The products of UDDTs and collected urine and FS can become valuable fertilizer if appropriately treated with on-site technology or transported to a site where they can be properly used or discharged. Hence, UDDTs are usually adopted in households or communities in need of such types of organic compost.

Water-based resource recovery sanitation approach

Water-based sanitation technology is also regarded as an important resource-recovery technology on account of its low--water usage and high resource recovery (Cheng et al. 2017). A vacuum toilet is a type of water-based resource recovery toilet system that is presently used in many areas globally. Vacuum toilets provide a similar level of comfort as traditional flush toilets but use less water because of the air sucked into the toilet when flushing, which produces a vacuum and minimizes water requirements (i.e., 0.5 L to 1.5 L) for the transport of urine and feces (Bracken 2005, World Health Organization and UNICEF 2014). Vacuum toilets can be installed in a single household and communities, adapted for train, airplanes, and ships,. Unfortunately, vacuum toilets require space for connection depending on the electric power supply, command a relatively high investment cost, and easily clog when bulky materials, such as sanitary napkins, are disposed in them.

Composting toilets

Composting toilets, also referred to as dry toilets, have been used as a resource recovery approach; here, human excreta can be treated at high temperatures to promote organic matter decay (Anand and Apul 2011, Anand and Apul 2014). Composting

Fig. 1. Sanitation flow-chart model

toilets treat human excrement using biological processes and turn it into organic compost that can be used in agriculture as fertilizer (Davies-Colley and Smith 2012, Tønner-Klank et al. 2007). Composting toilets decompose waste by creating the aerobic conditions necessary for bacteria and other micro and macroorganisms to exist. These toilets are developed to eliminate harmful organisms and pathogens, reduce or completely eliminate the risk to human and environmental health, and change the waste into fertile soil for agricultural use. These toilets typically break down waste materials to a small percentage of their original volume (Sánchez et al. 2017). The correct balance between moisture, organic matter, oxygen, and heat is required to ensure a rich environment for aerobic bacteria breakdown. The nutrient-rich fertilizer can be used in agriculture as part of the natural cycling of nutrients, it reduces the need for commercial fertilizers and improves local water quality (Godlewska et al. 2017). Human waste does not contain pathogens when properly treated and composted (Vázquez and Soto 2017). However, problems associated with composting toilets exist. Inappropriate maintenance of a composting toilet may lead to several issues. Some core concerns related to the improper maintenance of composting toilets include health issues and contamination of the system by disease-causing organisms (Cerda et al. 2018). Maintenance of these toilets requires more time, work, and attention than that required by a traditional toilet system. Poor management is another problem. Composting toilets require a set schedule of adding and removing materials for transport to the composting unit. The correct treatment materials must be known so that the process is executed correctly. Unprocessed solids and improperly drained liquids can cause biohazards. Most single household composting toilets do not heat to thermophilic temperatures and do not employ a proven pathogen reduction mechanism. Other reports show that resistant pathogens, such as hookworms and viruses, can survive long periods of time in cool saturated compost piles (Hill and Baldwin 2012, Jensen et al. 2017).

What can we do to solve the problem of FSM in Sub-Saharan Africa?

The challenges of FSM are generally underestimated in Sub--Saharan Africa. However, if adequate tools can be provided for FSM, practitioners can take adequate measures to improve sanitation in the areas of concern. This improvement could be done by systematically assessing the quantity of FS generated and various steps it takes from containment to recovery, transportation, and disposal or treatment for reuse. Knowledge gaps must be addressed to design sustainable technologies for FSM. These gaps include:

1. Development of viable market and business models along the FSM service chain from toilet construction to emptying and transport to reuse.
2. Identification of regulatory approaches and instruments across the service chain that could best incentivize optimum behaviors by users and service providers of FSM and effectively link the elements of the service chain together. Establishment of innovative institutional and management arrangements that allow for clear responsibility of FSM and also tie this initiative into the broader local government, utility, and community systems of governance, participation, and feedback.
3. Extent and economic value of public health, environmental, and financial benefits arising from effective containment of FS within the sanitation service chain from containment to reuse.

Measures to address FS issues in Sub-Saharan African

- There should be adequate management of public sanitation facilities in both rural and urban areas, to safely manage their FS.
- The government and rural communities should promote the idea of FSM wherever necessary, for group of households.

Sanitary and safe disposal

- People in the region should promote proper FSM design and the construction of onsite sanitation facilities.
- Recycling and reuse of treated FS for soil amendment wherever possible should be encouraged.
- Proper functioning of FSM systems and ensuring proper collection, transportation, treatment and disposal/reuse of the FS should be promoted.

Behavior change and awareness generation

Sub-Saharan African countries should promote the mechanisms to bring about sustainable behavioral changes that will aim at the adoption of healthy sanitation designs and practices, including the responsibility to ensure safe and healthy containment and management of FS by urban households. Generating awareness about FSM amongst communities and institutions will help to facilitate the process of FSM for hygienic environment.

The success of FSM techniques would be effective with the participation of all layers of society. This is through awareness-raising, intense population education by instilling a sense of civic sense through diversified strategies and also by mass media available. In this case, by the proliferating radio stations, by the written and visual presses, by organizing televised debates, broadcasts, relating to the protection of the urban framework; by the proximity campaigns for advice, organized with the households of their neighborhood by the associations on the dangers related to the degradation of the living environment; strengthening manual and intellectual work on the preservation of the environment through primary, secondary and university curricula. These educational actions would focus on the need to drain sanitary structures, the extension of standards for the construction, use and drainage of these structures. The respect of the urbanization plan in the neighborhoods would facilitate the creation of the access roads and consequently the reduction of the costs of draining.

Financing plan

The Government may provide assistance for funding projects proposed as part of FSM Plans through urban development schemes and programs including gender budgeting of FSM projects. However, the emphasis should be on improving the efficiency of existing sanitation service delivery and infrastructure. Local and state governments should prioritize funds to implement the FSM plan in rural and urban areas. Private sector participation should be promoted across sanitation service chain. Local and state government should provide a reliable means to start levying sanitation tax/user charges for effective FSM operation at rural and urban city areas. They should also facilitate the involvement of private sector participation through an easy relationship framework, to ensure adequate financing and sustainability of FSM projects.

The polluter pays principle must be applied. This principle must not stop at the level of the population; it should extend to the drainers who practice the wild discharge of the sludge in the nature. To stop these sludge spills in the wild, a sewage sludge treatment plant would have to be built. Sludge from the sewage treatment plant may be marketed as a fertilizer in agriculture. With the support of the Ministry of Public Works, roads should be built in all areas of the city to facilitate the movement of trucks and the installation of water supply and electrification.

Monitoring and evaluation

At the national level, the government should adopt feasible framework for sanitation that assess performance of local and citywide sanitation, that will also capture sewage management and onsite sanitation. Local and state government should be responsible for evaluation and monitoring of the sanitation scheme to ensure homogenous sanitation process, and hence needs to devise a suitable reporting and data collection systems using indicator framework to develop database, registry of certified onsite sanitation system, robust reporting format to track compliance of households with outcomes and process standards.

Systematic control of hygiene and sanitation should be rigorous to remind household heads of their duty (emptying of pits). In order to make the draining service more operational, the urban commune should create a self-draining cell, to be accountable to the hierarchy on the basis of transparency. In addition, the drain capacity would be multiplied by acquiring other gear and setting up a maintenance program. Draining agents should be more encouraged: risk and disease insurance, regular payment of premiums, provision of regulatory outfits to reduce the intoxications they complain about regularly. Moreover, in long-term strategies, it would be preferable to use improved and ventilated latrines instead of simple or traditional latrines. These latrines do not pollute the table water and also do not release bad odors because they are ventilated and also they do not promote the proliferation of mosquitoes and cockroaches. In addition, the municipality must encourage and support the action of NGOs in the communities without shirking its responsibilities.

Capacity building and training

Government should help to formulate a strategy on capacity building and treatment on FSM to help rural and urban centers to build their organizational system and personal capacities for delivery of sanitation services. Governments should make effort to integrate the FSM components in capacity building program. The rural and urban centers need to identify agencies that will train their staff and orientation of elected representatives on issues related to FSM. The government needs to set up and develop strategies for citizen engagement through city sanitation task forces. They could be specialist agencies of the government, academic institutions and private sectors. This will also need to focus on capacity building in sanitation, which will be in line with the rural and urban sector reforms. Government needs to provide training on sanitation to their own staff. Figure 2 depicts a dual sanitation and licensing model suitable for adequate sanitation process

Expected outcomes

If this policy is implemented across Sub-Saharan Africa countries, it is expected to provide adequate benefits in terms

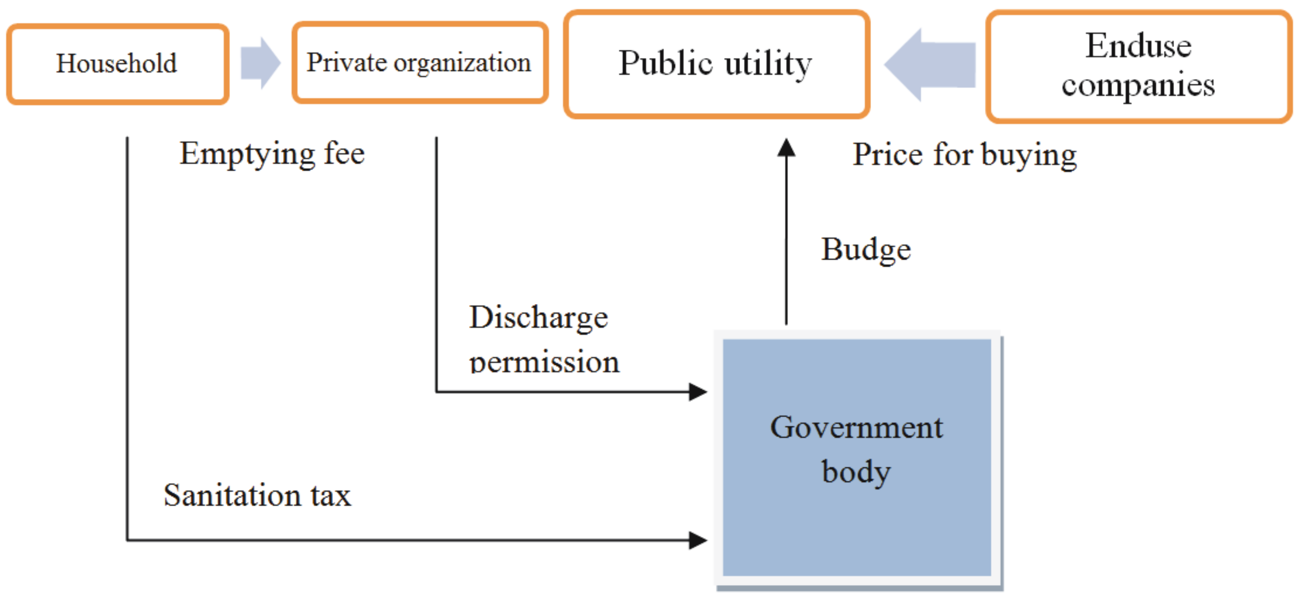

Fig. 2. Dual sanitation process and licensing model for FSM (Strande et al. 2014)

of resource recovery leading to the reuse of treated FS for soil amended and for biogas recovery, public health indicator, reduced pollution of groundwater and water bodies. The following highlights the proper steps for FSM:

- Technical capability among the stakeholders to effectively implement FSM
- Cost-effective solution for management of human waste through integrated network FS, sewerage management
- Containment of all human waste in 100% of the towns and cities
- Clarity among different stakeholders on identifying and implementing best and economically viable sanitation solutions
- Safe disposal of all collected FS and septage at designated sites, FS treatment facilities, lined pits for safe and scientific
- Scheduled emptying of septic tanks or other containment systems at an interval of 2–3 years as recommended
- Proper collection and conveyance of human waste to treatment and disposal sites.

Conclusion

This study reveals that most cities in Sub-Saharan Africa lack the proper FSM strategy, and most cities give low priority to FSM. FSM is viewed as an unimportant aspect of environmental sanitation, and discharging FS in water bodies, lagoons, and the environment is often considered the normal and proper way of dealing with FS. Unhygienic manual emptying methods predominate in most developing cities. This study shows that FSM is the long-term solution to addressing FS issues and public policymakers should recognize these findings. One of the limitations of this study is the poor availability of data on FSM in Sub-Saharan Africa including its current status in any given area and field-based technical data on delivering effective FSM services.

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