Chapter 6

Challenges and Opportunities of Faecal Sludge Management for Global Sanitation

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Abstract Excreta is a part of everyday life. The negative part of all this excreta, is that if it is not managed properly, these waste products cause waterborne diseases and water pollution. And a lack of access to clean, functioning toilets threatens human dignity. However, that is the case for 2.4 billion people worldwide without access to adequate sanitation. Onsite sanitation technologies that are used by 2.7 billion people will play a vital role in solving this global sanitation problem. Faecal sludge is the excreta and wastewater that accumulates in onsite-sanitation technologies. It needs to be safely contained onsite, and then the accumulated faecal sludge needs to be safely emptied, transported to a treatment plant, treated, and used for resource recovery or disposed of safely. However, most faecal sludge is not properly managed with a lack of adequate and safe emptying, no treatment plants, and illegal dumping directly in the environment. How can this faecal sludge management (i.e. FSM) problem be addressed? First we will introduce you to innovations of resource recovery from faecal sludge in low-income countries, providing a promising approach. Second, we show the lessons learned from the experience of unique FSM in Japan, which has around 1000 faecal sludge treatment plants with good enabling environment for FSM. Third we will introduce our collaboration to research and develop solutions for FSM in Asia and Africa with a focus on dewatering of faecal sludge, one of the main process challenges to overcome to achieve efficient and reliable treatment.

6.1 Introduction

Excreta is a part of everyday life! Every adult human being produces 130 g of faeces and 1.4 L of urine every day (Rose et al. 2015). The negative part of all this excreta, is that if it is not managed properly, these waste products cause waterborne diseases and water pollution, and a lack of access to clean, functioning toilets threatens human dignity. And that is the case for 2.4 billion people worldwide without access to sanitary toilets (UNICEF & WHO 2015). It also contributes to the fact that 0.7 billion people worldwide do not have access to safe drinking water, as precious water is polluted with the people's own excreta.

In response to the lack of access to basic sanitation, the United Nations defined the target of Goal 7 of the Millennium Development Goals (i.e., MDGs) to halve the proportion of the population without access to improved sanitation facilities[1] during the period from 1990 to 2015 (United Nations 2015). Unfortunately, it was not achieved. However, now the Sustainable Development Goals (i.e., SDGs) in September 2015 have defined a new target to achieve access to adequate and equitable sanitation and hygiene for all and end open defecation by 2030 (United Nations Department of Economic and Social Affairs 2015).

In achieving this new targets, the management of onsite sanitation technologies will play a vital role. 2.7 billion people worldwide are served by onsite sanitation technologies such as pit latrines, and flush/pour flush toilets connected to septic tanks, and this number is expected to grow to 5 billion by 2030 (The Boston Consulting Group 2013). Onsite sanitation technologies store human excreta under or close to a toilet until it can be removed and treated offsite. Some technologies can also treat and/or dispose of excreta onsite.

Faecal sludge is a slurry or semisolid, and results from the collection, storage or treatment of combinations of excreta and blackwater (i.e. toilet wastewater) from onsite sanitation technologies (Strande et al. 2014). Faecal sludge needs to be safely contained onsite, and then the accumulated faecal sludge needs to be safely emptied, transported to a treatment plant, treated, and used for resource recovery or disposed of safely. However, most faecal sludge is not properly managed with a lack of sanitary emptying, no treatment plants, and illegal dumping directly in the environment.

So how should we solve the problem of this--we might say--most fundamental waste, human excreta and faecal sludge? Faecal sludge management (i.e., FSM) is a new field, which is now being acknowledged globally for its importance. In this

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[1] In the WHO/UNICEF Join Monitoring Programme, an improved sanitation facility is defined as one that hygienically separates human excreta from human contact (WHO & UNICEF 2015).

chapter, we will introduce challenges and opportunities of global sanitation, with a focus on FSM, as one of the most important global environmental problems that needs to be addressed.

6.2 Global Challenges of Excreta and Faecal Sludge Management

What is the current global sanitation situation? How has it been addressed and not addressed? Why are huge efforts still required to provide global sanitation? In this section, we will introduce you to negative health impacts from unsanitary practices, the current status of global sanitation, and the role of onsite sanitation technologies and FSM. Since the impact of sanitation often cannot be separated from that of water supply, we also discuss the impact and current status of sanitation together with water supply.

6.2.1 Impact of Water Supply and Sanitation

The most important outcome of improved sanitation are health benefits. Presented in Table 6.1 and Table 6.2, are the 10 leading causes of global death and leading contributors to disability-adjusted life year (DALY)[2] impacts worldwide, and illustrates the current burden of diseases. In 2000, diarrhea was the 5th largest cause of deaths and 2nd largest burden of diseases in the world. Of diarrheal diseases, 88% are attributable to unsafe water supply, inadequate sanitation, and lack of hygiene (WHO 2004). The establishment of safe water supplies, adequate sanitation, and hygienic practices has a huge impact on the improvement of global health.

The rational of the investment to improve water and sanitation was further supported by a cost-benefit study of water and sanitation interventions, reporting that for each 1 USD of investment for both water supply and sanitation, it would provide economic returns of between 3 USD and 34 USD depending on the region (Hutton & Haller 2004). Thus, impacts of water supply and sanitation not only include public health and environmental health, but also have significant economic benefits. These are more than enough reasons to push forward safe water supplies and global access to sanitation.

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[2] The definition of DALYs are as follows (WHO 2015): “One DALY can be thought of as one lost year of ‘healthy’ life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.”

Table 6.1 10 Leading Causes of Death

	2012		2000	
Rank	Cause	% deaths	Cause	% deaths
0	All Causes	100.0	All Causes	100.0
1	Ischaemic heart disease	13.2	Ischaemic heart disease	11.3
2	Stroke	11.9	Stroke	10.7
3	Chronic obstructive pulmonary disease	5.6	Lower respiratory infections	6.6
4	Lower respiratory infections	5.5	Chronic obstructive pulmonary disease	5.8
5	Trachea, bronchus, lung cancers	2.9	Diarrhoeal diseases	4.1
6	HIV/AIDS	2.8	HIV/AIDS	3.2
7	Diarrhoeal diseases	2.7	Tuberculosis	2.5
8	Diabetes mellitus	2.7	Preterm birth complications	2.5
9	Road injury	2.3	Trachea, bronchus, lung cancers	2.2
10	Hypertensive heart disease	2.0	Diabetes mellitus	2.0

Data source: WHO (2014b)

6.2.2 *The Current Coverage of Sanitation Technologies Worldwide*

Worldwide, huge efforts have been put into improving water supply and access to sanitation. The United Nations initiated the decade of International Drinking Water Supply and Sanitation (1981–1990), and the decade for International Action for ‘Water for Life’ (2005–2015), as well as the MDGs and SDGs targets on water supply and sanitation.

However, the improvement of water supply and sanitation has not progressed well, sanitation more so than drinking water. Global progress is reported by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (i.e., JMP), who have been tracking access to improved sources of water[3] and sanitation facilities since 1990 (WHO & UNICEF 2015). As illustrated in Fig. 6.1,

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[3] In Join Monitoring Programme, an improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter (WHO & UNICEF 2015).

Table 6.2 10 Leading Causes of DALYs

	2012		2000	
Rank	Cause	% DALYs	Cause	% DALYs
0	All Causes	100.0	All Causes	100.0
1	Ischaemic heart disease	6.0	Lower respiratory infections	7.3
2	Lower respiratory infections	5.4	Diarrhoeal diseases	5.6
3	Stroke	5.2	Ischaemic heart disease	5.0
4	Preterm birth complications	3.9	Stroke	4.4
5	Diarrhoeal diseases	3.6	Preterm birth complications	4.3
6	Chronic obstructive pulmonary disease	3.4	Birth asphyxia and birth trauma	3.6
7	HIV/AIDS	3.4	HIV/AIDS	3.5
8	Road injury	2.9	Chronic obstructive pulmonary disease	3.1
9	Unipolar depressive disorders	2.8	Malaria	2.7
10	Birth asphyxia and birth trauma	2.7	Road injury	2.4

Data source: WHO (2014a)
Note: DALYs is the disability-adjusted life year, which indicate the burden of diseases

from 1990 to 2015, access to improved drinking water increased from 76% to 91%, meaning the target to halve the population without access to improved water source was successfully achieved. However, even a single person without access to water is still too many, water is as necessary for life as air!

In contrast, during the same period, sanitation access only increased from 54% to 68%, meaning the sanitation target was not met. In addition to the sanitation target not being met, the global population is also increasing. During this 15 year period, the global population increased by 2.00 billion, with the greatest growth in low-income countries. Therefore, the population without access to improved sanitation facilities only decreased from 2.45 billion to 2.37 billion during the MDG period. It is shocking to think that one-third of the world's population still lacks access to adequate sanitation!

Reported in Fig. 6.2, is the progress of the sanitation target by country. This illustrates that the lack of sanitation not only has a divide among income, but also regionally. Many countries in South America successfully met the target,

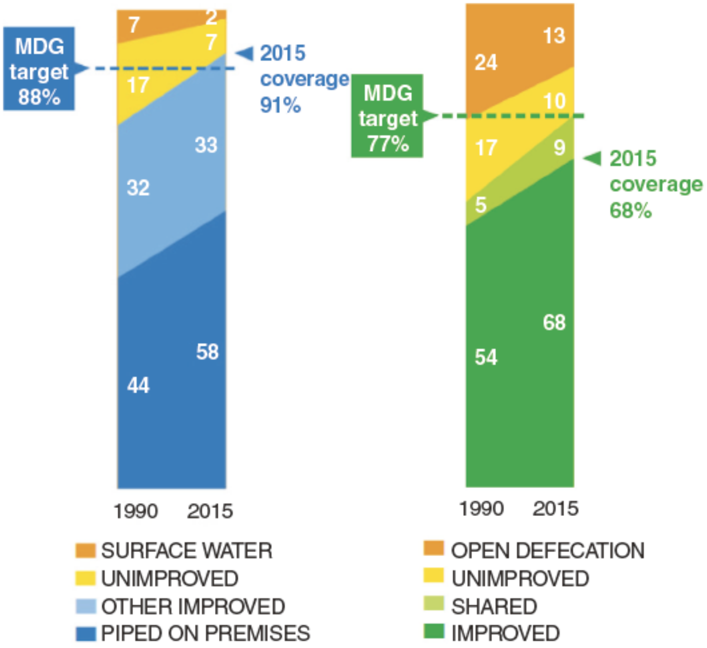

Fig. 6.1 Change of the population coverage with the access to improved water and improved sanitation (adapted from UNICEF & WHO 2015, with permission from WHO press)

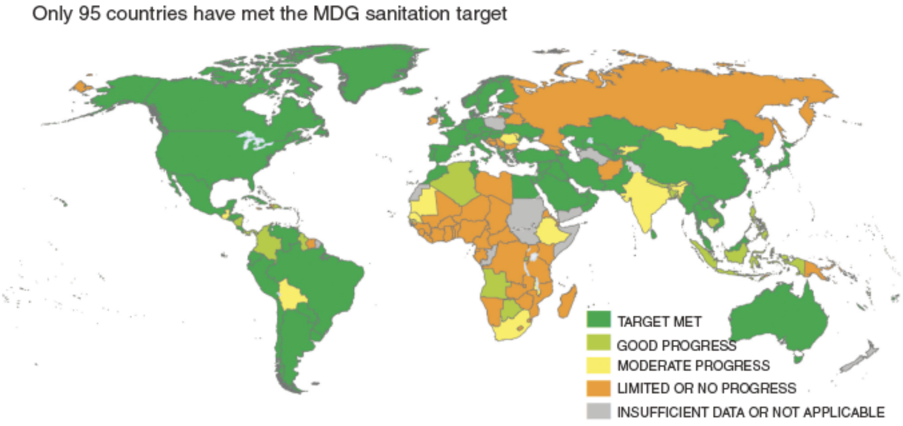

Fig. 6.2 MDGs sanitation target progress by countries (adapted from UNICEF & WHO 2015, with permission from WHO press)

whereas many countries in Africa have the lowest access, with limited or no progress. These gaps are continuing to increase.

6.2.3 Role of Onsite Sanitation Technology

Obviously adequate sanitation is a global need. What kind of sanitation facilities are used worldwide, and what will be used in the future? What role can onsite sanitation technologies play, as opposed to centralized sewer systems? First we will present the situation in Japan, and then discuss a bit about the rest of the world.

6.2.3.1 Sanitation Systems in Japan

The population of Japan is approximately 120 million. 72% of the population's excreta is transported in sewers, and treated at centralized wastewater treatment plants. The sewer transports blackwater (wastewater from toilets) and greywater (wastewater from household other than blackwater) through pipes to wastewater treatment plants. Another 21%–mostly in suburbs and rural villages, but also in urban areas like Tokyo Metropolis–are processed through *johkasou* systems, which is a packaged onsite wastewater treatment unit installed at each house. The *johkasou* systems collect and accumulate faecal sludge, which is then emptied and transported by vacuum trucks, and processed at faecal sludge treatment plants (referred to as night soil treatment plants in Japan). The remaining 7% of excreta is managed by onsite sanitation technologies (referred to as night-soil treatment in Japan). This includes toilets draining to fully lined tanks that accumulate but do not treat the faecal sludge. They are also emptied and the faecal sludge is transported by vacuum trucks to night-soil treatment plants (Ministry of the Environment 2015). This means that basically 100% of human excreta in Japan is processed in a safe and sanitary manner.

6.2.3.2 Sanitation Systems in the World

Shown in Fig. 6.3 schematically is the status of onsite, centralized, or no management of human excreta worldwide in 2010. It can be seen that the situation in Japan is not representative of the global situation. Human excreta was treated by centralized sewer systems (with secondary treatment or better) for 2.8 billion people (Baum et al. 2013), onsite sanitation technologies (Fig. 6.4) for 2.7 billion (The Boston Consulting Group 2013), and the remaining 2.5 billion lack access to adequate toilet facilities (UNICEF & WHO 2012).

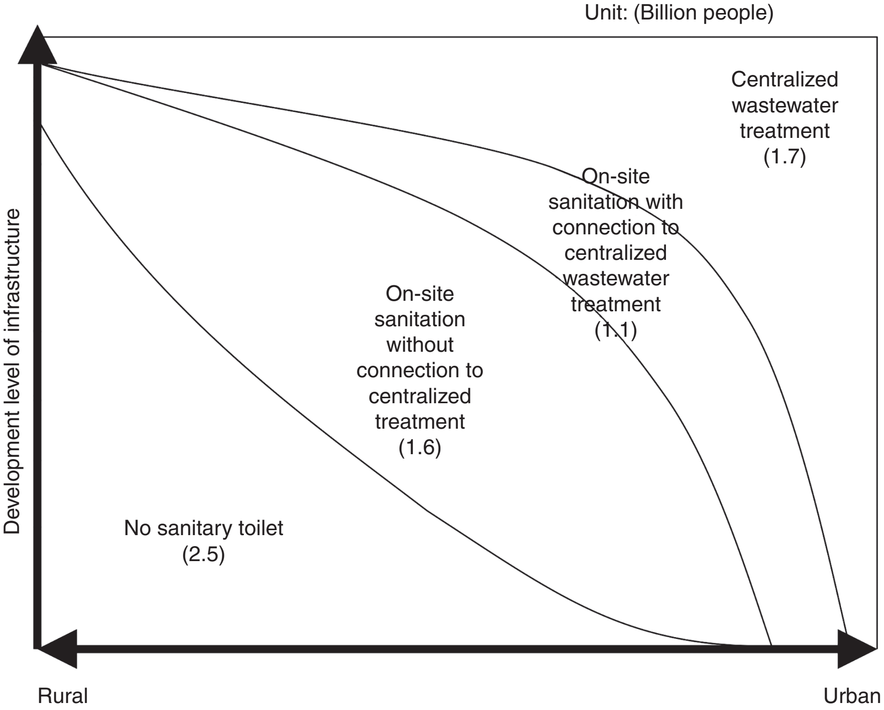

Fig. 6.3 A schematic diagram of the coverage of sanitation technologies worldwide in 2010. The figure made by the authors based on The Boston Consulting Group (2013), Baum et al. (2013) and UNICEF & WHO (2012)

For the past 100 years, sewer systems followed by treatment have been safely and effectively removing excreta from most industrialized cities, greatly contributing to the quality of life in cities. However, they are resource and cost intensive. In addition to making them financially unattainable for many countries, this also means they are not the most sustainable option. Long considered the gold standard, many engineers and scientists are pursuing more sustainable onsite or decentralized options, which will hopefully be the new gold standard in the future. Onsite sanitation technologies can provide adequate access to sanitation if the entire treatment chain is managed properly, can be five times less expensive than sewer systems, and the two solutions can operate in parallel to provide access to entire cities (Dodane et al. 2012). In addition, onsite sanitation technologies will also continue to play a role in rural and peri-urban areas where building sewers is not feasible. Obviously, management of faecal sludge from onsite sanitation

Fig. 6.4 A pit latrine in Kampala, Uganda, an example of onsite sanitation technologies. It stores human excreta in a pit under the toilet and the stored excreta is called faecal sludge (photo credit: Hidenori Harada)

technologies will continue to be of global importance for providing access to sanitation, and protecting human and environmental health.

6.2.4 *Current Status – Poor management of Faecal Sludge*

One third of the world's population is served by onsite sanitation technologies. Proper Management of onsite sanitation technologies is essential to ensure they are functioning properly. As shown in Fig. 6.5, once the faecal sludge is removed, the service chain is much different from centralized wastewater treatment. The faecal sludge service chain includes onsite containment of faecal sludge, followed by some form of emptying/removal, transportation, treatment, and final enduse or safe disposal.

The entire service chain needs adequate management to ensure protection of public and environmental health. However, in the majority of low-income countries, adequate FSM is not in place. Although there are not global statistics on FSM like the MDGs, some recent studies reflect the serious situation and current faecal sludge crisis. The World Bank Water and Sanitation Program reported on FSM in 12 cities in Africa, Latin America, South Asia and East Asia along the entire service chain (World Bank Water Supply and Sanitation Program 2014). According to this study, 64% of the excreta in these cities were processed by onsite sanitation technologies but only 22% was safely managed. The result beings that 42% of excreta from onsite sanitation technologies is directly discharged into the urban environment. Prior to achieving improved FSM, the following need to change: acknowledging the importance of FSM, setting up frameworks and responsibilities, increasing knowledge dissemination and capacity development, creating sustainable business models and fee structures, implementing integrated

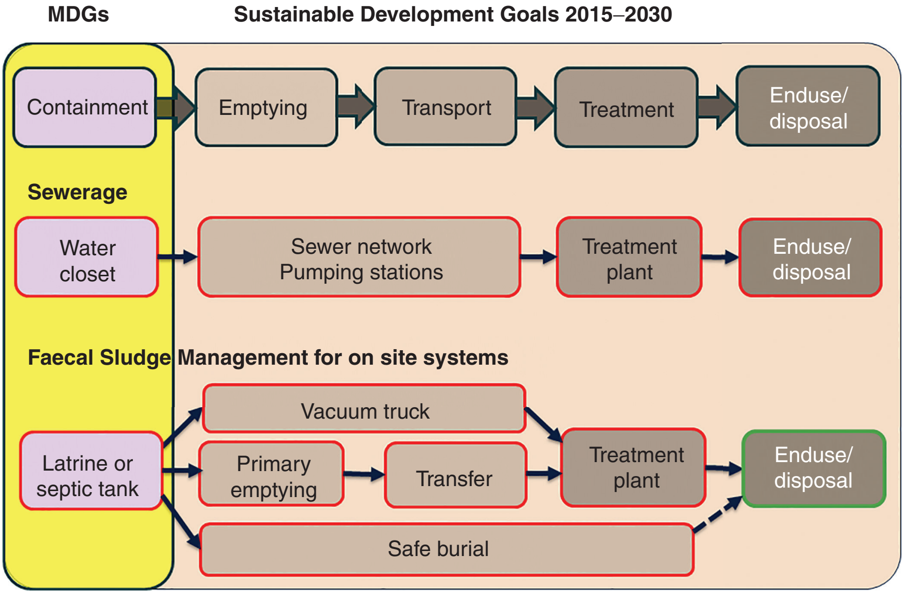

Fig. 6.5 Sanitation service chain of on-site sanitation technologies and centralized wastewater management technologies (reproduced with permission from World Bank – Water and Sanitation Program)

planning methodologies, and developing appropriate technologies (Strande et al. 2014).

Another tool to develop awareness of the global FSM problem, is the Shit-Flow Diagram (SFD, refer to www.sfd.susana.org/). A method is being developed and tested in over 40 cities worldwide, that illustrates the proportion of excreta on a city-wide scale that is safely treated, or ends up directly in the urban environment. The project, which Sandec (Sanitation, Water and Solid Waste for Development) at Eawag (the Swiss Federal Institute of Aquatic Science and Technology) is a part of, is led by GIZ (the German Federal Enterprise for International Cooperation) with support from the Bill & Melinda Gates Foundation, in cooperation with Leeds University, Loughborough University, Center for Science and Environment, and the World Bank Water and Sanitation Program.

Initial results include Dar es Salaam, Tanzania, where 90% of excreta is managed by onsite systems, but 23% of excreta is discharged to the environment without treatment (Eawag/Sandec 2015a) and Danang, Vietnam, where 100% of excreta is managed by onsite systems, but 37% is discharged to the environment without treatment (Eawag/Sandec 2015b). In many cities, private emptying service providers operate either legally or illegally, but with no legal discharge location, or no existing treatment facilities, resulting in no option but to discharge faecal sludge directly into the urban environment.

In addition, the lack of adequate FSM results in poor performance of onsite sanitation technologies. In Hanoi, a city that is served almost entirely by septic tanks, many residents have never had their systems desludged following installation, with an average emptying interval of eight years. Residents tend to only call a company to empty the faecal sludge from their septic tank if there is an emergency, like blockage resulting in backing up of the tank into the household. The lack of proper emptying maintenance results in significantly deteriorated performance of septic tanks. If emptied annually, around 80% of the organic pollution load, as measured by COD, can be expected to be reduced, compared to the eight-year interval of emptying which results in a COD removal of 40% (Harada et al. 2008). Also in Kampala, a city that is served mostly by pit latrines, a hole at the bottom of pit latrines is frequently made during the rainy season so that the faecal sludge directly drains out, resulting in direct discharge of faecal sludge in the environment (Eawag/Sandec 2015a).

Thus, FSM which is required for one-third of the global population, has not yet been addressed for the majority of people using onsite sanitation technologies. The result is direct discharge in the environment with significant deterioration of human and public health.

6.3 Can Resource Recovery Provide a Solution for Faecal Sludge Management?

FSM is a global need. How can it be addressed? Can resource recovery from faecal sludge provide a solution for FSM? In this section, we will introduce you to innovations of resource recovery from faecal sludge in low-income countries.

Summarized in Table 6.3 are potential resource recovery end-products from faecal sludge treatment technologies. In addition to recognized forms of recovering nutrients, an additional safe form of resource recovery can be from heat or energy. As shown in Fig. 6.6, Sandec's research has demonstrated that the calorific value of faecal sludge, a metric of energy potential, is as high as many other commonly used organic fuels. As shown in Fig. 6.7, pelletizing of faecal sludge is an example of a technology for energy recovery which produces dried pellets following dewatering of faecal sludge. Pellets are easy to transport and to market and use as a biofuel or soil conditioner (Strande et al. 2014). As shown in Fig. 6.8, research is also demonstrating the possibility of other forms of resource

Table 6.3 Summary of potential resource recovery options from faecal sludge

End-product	Treatment technology
Soil conditioner	Untreated faecal sludge Sludge from drying beds Compost Pelletizing process Digestate from anaerobic digestion Residual from Black Soldier fly
Reclaimed water	Untreated liquid faecal sludge Treatment plant effluent
Protein	Black Soldier fly process
Fodder and plants	Planted drying beds
Fish and plants	Stabilization ponds or effluent for aquaculture
Building materials	Incorporation of dried sludge
Biofuels	Biogas from anaerobic digestion Incineration/co-combustion of dried sludge Pyrolysis of faecal sludge Biodiesel from faecal sludge Pelletized faecal sludge

Data source: Strande et al. (2014)

recovery, such as protein. The Black Soldier fly (*Hermetia illucens*) can grow on and process faecal sludge and municipal solid waste. The larvae of the fly can then be harvested to use as a protein and fat source for animal feed (Strande et al. 2014).

The economic benefit of end-products from faecal sludge can potentially increase the sustainability of FSM by off-setting a portion of the treatment and disposal costs. However, as shown in Fig. 6.9, the potential market values of the same end-products in different countries vary significantly, and so the local context and markets must be considered. For example, in Dakar, Senegal protein recovery appears to be more financially viable (21.6 USD/ton), in Accra, Ghana fuel as biogas (up to 31.8 USD/ton), and in Kampala, Uganda fuel as incineration (up to 32.3 USD/ton). This indicates the importance of market attractiveness as one of the most important criteria for selecting resource recovery technologies. This should be considered together with the many other challenges remaining to make end-products from faecal sludge acceptable for use. The value of resource recovery from excreta should not be over-looked to increase the sustainability of excreta management in any country.

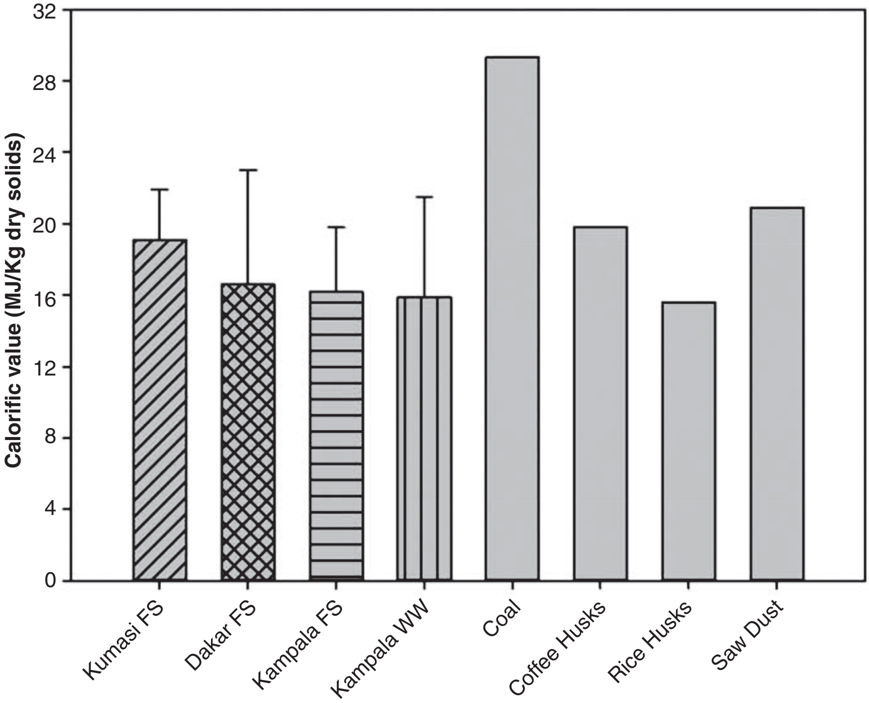

Fig. 6.6 Calorific value of raw faecal sludge in Uganda, Ghana, Senegal. FS: faecal sludge, and WW: wastewater sludge (adapted from Muspratt et al. 2014, with permission from IWA Publishing)

6.4 Learning From Night-Soil Treatment Systems in Japan

Japan is a unique example of an industrialized country with a long history of faecal sludge treatment plants. In Japan, there are around 1,000 faecal sludge treatment plants. In contrast, many other countries rely on centralized, sewer based solutions, and co-treatment of faecal sludge with centralized wastewater. What are the lessons learned from the experience in Japan that could provide a model of successful FSM?

The success of FSM in Japan is due to a number of factors. The long historical use of faecal sludge in agriculture means that it is accepted, and was in wide practice until the 1930s (Japan Association of Drainage and Environment 2003). Following World War II, the country rapidly established a unique nationwide system of FSM, that was well-established by the 1960s - 1970s, the basis of the current night-soil treatment system including containment, collection and transport of faecal sludge. At this time the majority of onsite systems were lined pit

Fig. 6.7 Dried pellet from faecal sludge in Kampala, Uganda (photo credit: Moritz Gold)

Fig. 6.8 Larvae of Black Soldier fly growing on organic waste. Potentially faecal sludge can be converted to a protein source (photo credit: Samuel Blyth)

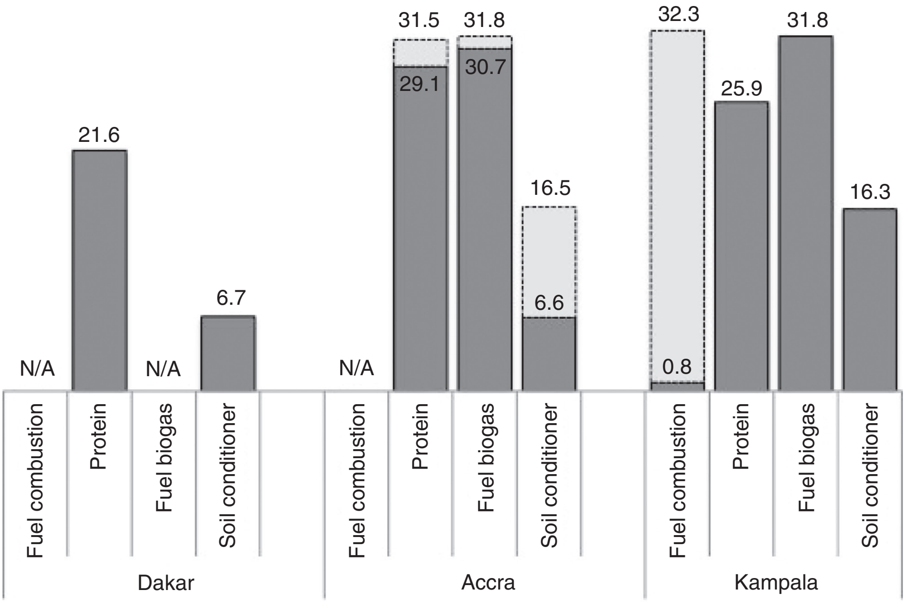

Fig. 6.9 Potential market value (in USD) of different products derived from faecal sludge processing technologies per ton faecal sludge (dry weight) in three African cities. Values are variable based on available data (upper range in lighter shade of grey) (adapted from Diener et al. 2014, with permission from Elsevier)

latrines. By the late 1970s less than 35% of the Japanese population was served by sewers, but the country had established nationwide safe excreta management thanks to night-soil treatment systems (Magara, 2003).

Another factor of success is the development of technology specifically for FSM. Currently, 38% of excreta from the Japanese population is treated at night-soil treatment plants. That is comprised of 21% faecal sludge from *johkasou* systems (package onsite wastewater treatment units), and the remaining 7% from modernized lined pit-latrines with low flush (micro-flush) toilets (200–500 mL/flush) (Ministry of the Environment 2015). As shown in Table 6.4, night-soil treatment technologies have been developed independently and are different from wastewater treatment technologies due to the highly concentrated nature of night soil compared to wastewater. Resource recovery is promoted from treated sludge, although incineration is the main method of disposal for treated sludge in Japan. Other forms of resource recovery from faecal sludge are presented in Table 6.5.

Another very important factor of success is the strong enabling environment for FSM in Japan. Onsite sanitation technologies will never succeed without a

Table 6.4 Technology development of night-soil treatment plants in Japan

Development time	Process type	Main objective
Old	Anaerobic digestion process	Disease control
↓	Aerobic digestion process	Pollution control (Foul odor, organic pollution, color)
	Nitrification-denitrification process	Nutrient removal
	High-loading nitrification-denitrification process, without dilution	Downsizing
New	Membrane-type high-loading nitrification-denitrification process, without dilution	Further downsizing

Table 6.5 Disposal type of excess sludge from night-soil treatment plants in Japan

Type of excess sludge treatment	No. of plant
Incineration	586
Composting	243
Direct landfill of dewatered sludge	31
Fuel	20
Biogas recovery + composting	18
Biogas recovery	15
Carbonization	12
Phosphorus recovery	4

Data source: Ministry of the Environment (2014)

strong management system in place. This includes the 1983 *Johkasou* Law that provides for certification of *johkasou* installation workers and operators, and for registration and licensing of *johkasou* businesses, installation, operation and maintenance, and desludging (Fig. 6.10) (Government of Japan 1983; Gaulke 2006; JECES 2012). Faecal sludge emptying requires the mayor's approval in each municipality, and annual emptying is required for each *johkasou*. Also, the 1970 Waste Disposal and Public Cleansing Law enforces municipalities to collect faecal sludge in a sanitary manner, and treat and enduse/dispose of in accordance with regulations of the law (Government of Japan 1970; JECES 2012). Furthermore, subsidies for faecal sludge discharge at night-soil treatment plants

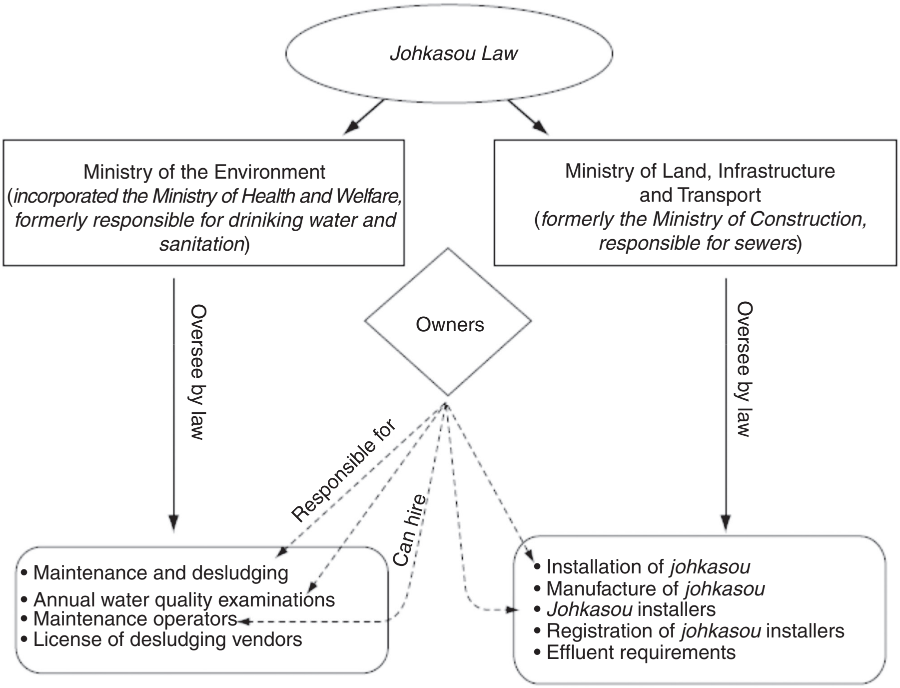

Fig. 6.10 Organization of the government structure responsible for implementing and enforcing the *Johkasou* Law (adapted from Gaulke 2006, with permission from ICE Publishing)

are in place in many municipalities, making affordable for faecal sludge emptying companies.

6.5 Way Forward

Hopefully we can learn from the lessons learned from the unique FSM experiences in Japan together with innovations in resource recovery, and apply them in other countries. Unfortunately, so far, these experiences have not been shared widely enough, or taken up by other countries. Although technology alone will never provide a solution, Japan has experience in developing technologies within the framework of an enabling environment, which has made the parallel growth of sewer based and FSM solutions possible.

The authors started collaboration to research and develop solutions for FSM in Asia and Africa in 2014. Currently, our main collaborative focus is on dewatering of faecal sludge. Faecal sludge is typically over 90–95% water, and so dewatering is one of the main process challenges to overcome to achieve efficient and reliable treatment. Improved technologies for dewatering will increase treatment plant capacities, and reduce the required footprint. This is critical for treatment in urban areas where available land is expensive and very limited. Dewatering is also a key step to producing treatment end-products that can be used for resource recovery.

Our ongoing projects include the development of fundamental knowledge of the dewaterability of faecal sludge, which is a requirement for the optimization of dewatering processes. Faecal sludge is highly variable, as it comes from individual onsite sanitation technologies, which are all constructed differently, and have different usage patterns by individual users. This is quite different from the homogenized excreta that is transported collectively in sewers. In addition, there is a lack of knowledge and expertise of faecal sludge characteristics, in contrast to sewage sludge which has been studied extensively. Our preliminary results are already highlighting the difference between the dewaterability characteristics of faecal sludge and sewage sludge. The high variability of faecal sludge characteristics remains one of the main challenges to optimize treatment processes. We are drawing from the existing experiences from night- soil and wastewater treatment plants to provide hints for understanding dewaterability characteristics of faecal sludge. We are currently investigating parameters that can be used as reliable predictors of faecal sludge dewaterability, and mechanisms to enhance dewatering performance. These will be used to investigate how to improve and develop affordable and reliable dewatering processes in the context of low-income countries, and how that can be used to develop more efficient and reliable resource recovery from faecal sludge.

Another fundamental challenge is that standard methods of faecal sludge analyses do not exist. Currently, researchers modify standard methods from wastewater or soil science for faecal sludge analyses. In addition, many of these methods are not feasible in limited laboratory conditions in low-income countries. With our focus on analyses for faecal sludge dewatering, we are using this experience to develop standard methods for the analyses of faecal sludge. This is based on our current ongoing research in Asia, Africa, Europe, and the United States. We have developed a set of preliminarily standard methods, which we will revise based on our experiences to better allow data comparison from multiple, global locations.

6.6 Conclusions

Developing solutions for FSM will be an ongoing need into the future, if we are to achieve solutions for global sanitation. Resource recovery based solutions for

FSM provide a promising approach. However, technology based solutions by engineers will only succeed within an enabling environment framework—as we have learned from night-soil treatment systems in Japan. An enabling environment will include legal and regulatory setup, economic impact, social acceptance, institutional arrangement, risk management, and strategic planning of FSM. Solving the FSM problem will require global and interdisciplinary collaborations, hopefully future students with diverse backgrounds will also embrace this exciting and challenging field!

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