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Resources Recovery in South and Southeast Asia



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Resources Recovery and Reuse in Sanitation and Wastewater Systems

Options and Investment Climate in Selected South and Southeast Asian Countries

Maksud Bekchanov and Pablo Evia

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Abstract

Properly managed sanitation systems and improved wastewater treatment are important for safeguarding environment and enhancing sustainable livelihoods in vast areas of South and Southeast Asian countries. Recovering nutrients and energy from organic waste and wastewater is an effective option for improving environmental and health security, rehabilitating agricultural soils and improving energy and food access for the poor in these countries. This study addressed the technical potentials and investment climate for wider adoption of resources recovery and reuse (RRR) technologies in this region. Reviewing results and technical calculations indicated poor sanitation in India and Nepal in contrast to high levels of sanitation in Sri Lanka. However, despite comparatively higher levels of fecal sludge and wastewater treatment in Sri Lanka than the remaining countries, levels of waste treatment and recycling are much lower than their potential level in all countries of the region. Lack of financial resources, lack of awareness on hazardous impacts of poor sanitation, poor governance and high corruption levels in the system are pointed out as key barriers for wider implementation of waste and wastewater treatment and recycling technologies. Improving regulatory frameworks and governmental support through establishing subsidy programs, raising the awareness of population on environmental safeguarding, improving the skill capacity and technologies as well as ensuring quality standards can enhance wider implementation of RRR options.

Keywords: composting, biogas, nutrient management, organic waste, wastewater, onsite sanitation, soil rehabilitation, governance, institutional framework

JEL codes: O13, Q53, O44, Q42, D02

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1 Introduction

Poor sanitation and mismanagement of waste under conditions of rapid urbanization are one of the key drivers behind many environmental and human health degradation problems across the developing world (Hutton et al. 2007; UN-HABITAT, 2010; Corcoran et al. 2010; Cairns-Smith et al. 2014; WWAF, 2017; UNEP, 2017). Therefore, improving the governance and infrastructure in the waste and wastewater management sector is essential for better environmental systems and sustainable livelihoods. In addition to improved environment and health impacts, proper handling and recycling waste may turn the waste into asset which can augment water, energy and nutrients supply (UN-WATER, 2016; Strande et al., 2014; UN, 2016; Bekchanov, 2017a). Despite enormous costs of recovering nutrients, producing energy and treated effluents from waste and wastewater streams, the Resources Recovery and Reuse (RRR) options can be feasible under conditions of decreasing stocks of non-renewable minerals (phosphate rocks) and fossil fuels, and increasing water scarcity (Cordel et al., 2011; Höök and Tang, 2013; Lazarova et al., 2013).

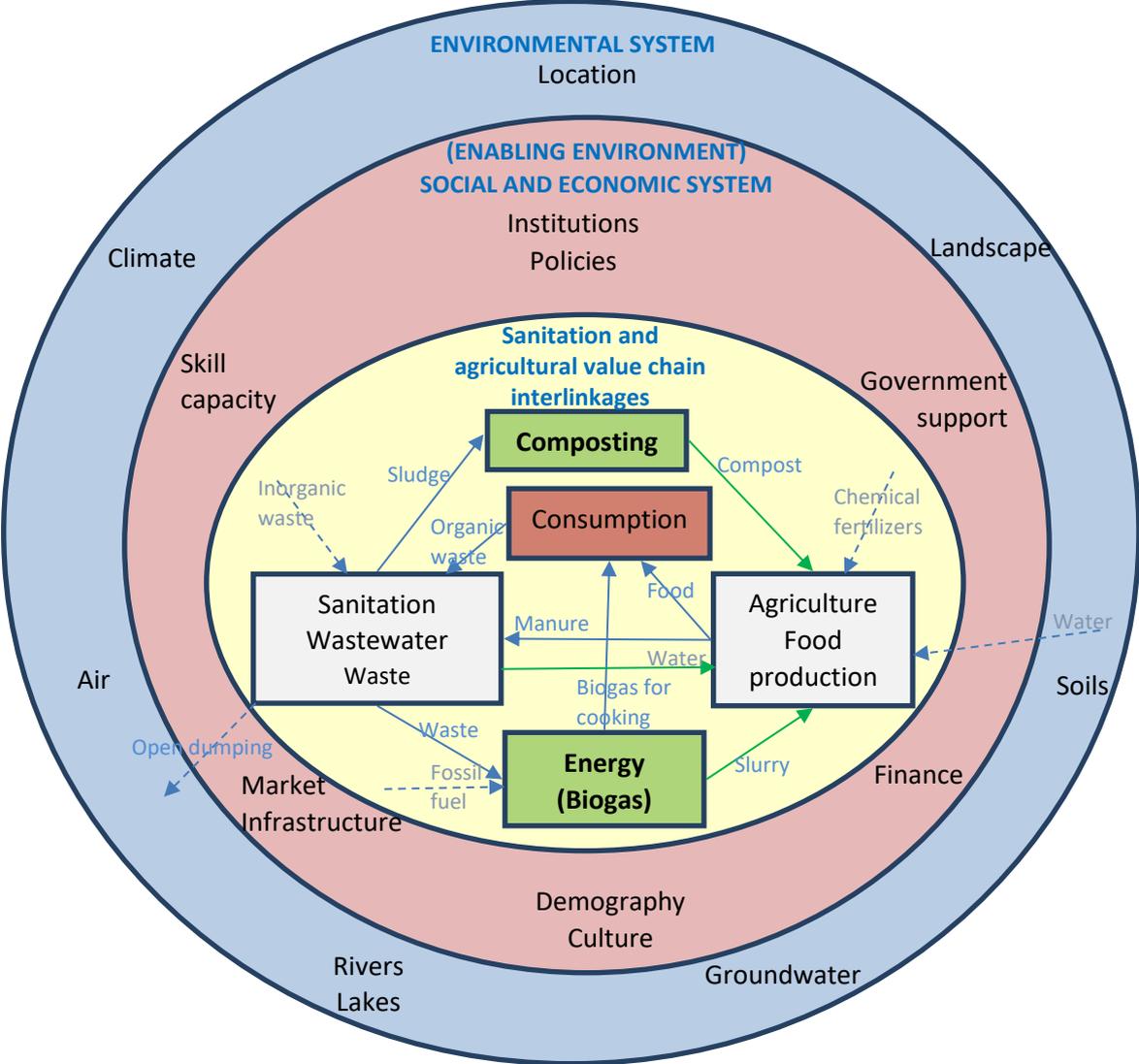
Nowhere is mismanagement of waste and wastewater systems more evident than in South and Southeast Asia. Lack of proper sanitation facilitates and unsafe disposal of waste and wastewater are common problems causing environmental pollution in many parts of this region (Visvanathan and Glawe, 2006). RRR options are highly relevant to enhance sustainable production and prevention of environmental degradation under these circumstances. This study thus aims at reviewing the current status of sanitation and wastewater management systems, and assessing the investment climate for introducing waste recycling options to enhance the sustainable livelihoods in the region. South and Southeast Asian countries considered under the study are India, Sri Lanka, Nepal, Bangladesh, Laos and Myanmar.

Next section presents briefly a conceptual-methodological framework of the study. It is followed by a section on the location and population in the studied countries. Next the current conditions of fecal sludge and wastewater management in these countries are analyzed. After that, RRR options currently applied to manage waste and wastewater are presented. Then, investment opportunities for wider implementation of waste treatment and recycling technologies are discussed. Particularly, affordability of RRR, demand for products produced through recycling, infrastructure, and regulatory and institutional frameworks are considered. The last section summarizes the findings and concludes.

2 Conceptual-methodological framework

Interlinkages between waste management and agricultural value chains and their relationship to general socio-economic framework and environmental system are considered in the conceptual framework presented in Fig. 1. The conceptual framework builds on the previous approaches to business climate assessment developed by World Bank (2015, 2017a), FAO (2013) and EAWAG (Strande et al., 2014). According to the framework, waste management and agricultural value chains as part of a broader economic system is influenced by general socio-economic and institutional conditions (Hasan 2018). The value chains and the socio-economic system functions within the physical environment which plays a pivotal role for the sustainability of the production system and determines the relevance of the production and recycling technologies to a particular location.

Figure 1: Waste management and agricultural production value chains as part of a broader socio-economic, institutional and environmental system



Source: Authors' presentation

The micro environment depicts the specifics of sanitation and agricultural value chains and their interlinkages. If composting and biogas production from organic waste or safe disposal of waste are underdeveloped, large portion of the generated waste ends up in waterways, lakes, and neighboring areas, polluting water sources, causing toxic gas emissions and damaging environmental health. RRR options such as compost and biogas production from organic waste greatly help in reducing the amount of waste to be openly dumped and supply additional energy or fertilizer for production processes and household consumption.

Understanding the interlinkages between sanitation and agricultural value chains is essential to assess the amount and value added of input and output flows along the chains concurrently determining any issues related with input supply, high costs, low productivity, demand and competition for the outputs. For instance, aiming at introducing composting technologies may not yield the expected results due to lack of proper sanitation and waste collection facilities. Or, in water abundant conditions characterized with heavy rainfall, a reuse of treated wastewater is less likely to be an economically viable option. Likewise, if the costs of chemical fertilizers are much cheaper than producing and applying compost in crop production, promoting demand for compost cannot be easy. Similarly, biogas plants may not be preferred by households and businesses if cheap electricity or gas is available as an energy source.

In addition to production system characteristics, the consideration of geographic conditions is essential for assessing the relevance of any RRR option for particular location. Groundwater levels influence on the choice of sanitation facility, for instance. Fertilizer application requirements may vary depending on soil type and thus it may determine overall compost demand in particular area. Cold temperature may reduce the technical and economic feasibility of biogas plants. Since compost plants require large area and may cause unpleasant odor in the neighborhood this option can be less recommendable in densely populated areas.

Except technological and environmental conditions, socio-economic and institutional factors also play an important role for the choice of appropriate RRR option. Lack of proper laws, policies and institutions to incentivize the implementation of improved sanitation and RRR options may lead the continuation of unsustainable waste management practices and environmental degradation. Even if proper laws for safeguarding environment exist, enforcement of these laws and monitoring can be limited. High corruption levels and lack of transparency are key barriers for maintaining the rule of law. In case the laws are supportive to enhance sustainable production and adoption of RRR options, financial feasibility of such changes may depend on income levels of people, access to credit, and subsidization rates. Infrastructural conditions such as access to energy, water, roads, education services, and information and communication technologies (ICT) are also important for the feasibility of RRR options. Availability of affordable technologies (mechanized compost application) and skilled workers are required for the continuation of the RRR processes. Socio-cultural factors play an important role for wider implementation of RRR options. For instance, the use of fecal sludge for biogas generation and biogas use for cooking can be unacceptable in some societies because of social stigma attached to excreta.

Based on this conceptual framework, this study systematically collects data related to processes along the sanitation, waste management and recovered commodity value chains. The study also considered socio-economic and institutional factors determining the enabling environment for RRR options and physical - environmental conditions across the studies South and Southeast Asian countries.

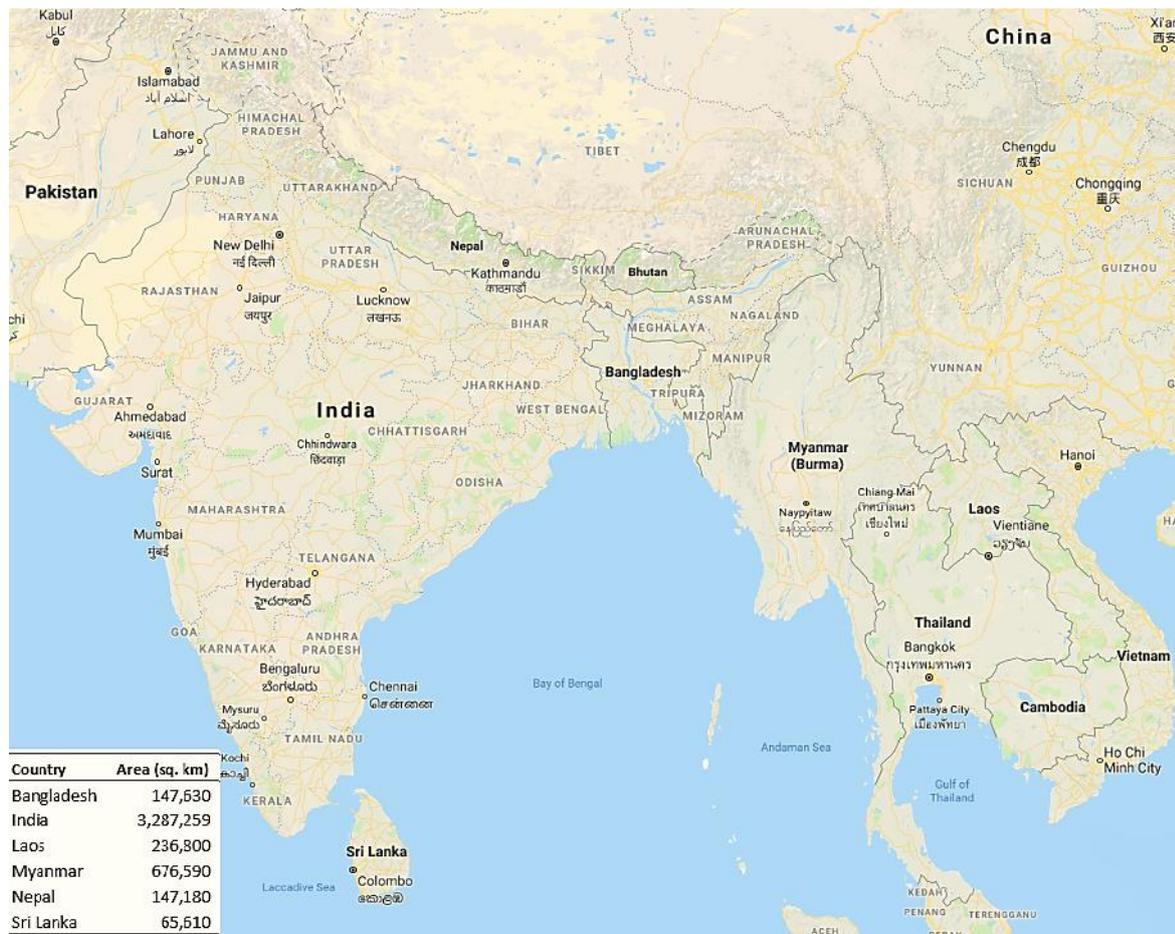
Technological processes along waste management and agricultural value chains are depicted based on technical documents prepared by experts and researchers. Data on natural conditions are mostly collected from the reports of statistical and environmental agencies of the respective countries. Socio-economic and institutional factors (enabling environment) are evaluated based on expert survey analysis results and the database of the World Bank on World Development Indicators. Additionally, information was obtained from the research reports of other international organizations such as Asian Development Bank (ADB), International Centre for Integrated Mountain Development (ICIMOD) and Japan International Cooperation Agency (JICA).

3 Study area – location and population of South and Southeast Asia

South and Southeast Asia region is bordered on Middle East in Northwest and China in Northeast (Figure 1). Among South Asian countries, India is the largest with a territory of about 3.3 million km². An island country – Sri Lanka is the smallest with the territory of 65.5 thousand km². Despite their different sizes population densities are similar in these two countries (338 and 445 people per km² respectively; Table 1). Bangladesh is the most densely populated (1,250 people per km²) among the studied countries while population density is very low in Laos and Myanmar.

Total population in the South Asian countries under this study are 1.6 billion which accounts for 21% of global population (Table 1). India with population of over 1.3 billion is the most populous country in South Asia and the second most populous in the world (after China). Over 160 million people reside in Bangladesh while Laos has only 6.8 million population despite its larger territory. More than 80% of population lives in rural areas in Nepal and Sri Lanka. In the remaining countries, people residing in rural areas exceed 60%. Taking into account the average global proportion of rural population (45%), the relatively higher proportion of rural population in the studied countries could represent a need for decentralized sanitation facilities and an opportunity to implement RRR technologies in order to decrease environmental and health hazards.

Figure 1: Map of South and Southeast Asia



Source: Google maps

Table 1: Population (2016)

Country	Population (million people)			%		Population density People per sq. km
	Total	Urban	Rural	Urban	Rural	
Bangladesh	163.0	57.1	105.9	35.0	65.0	1,252
India	1,324.2	438.8	885.4	33.1	66.9	445
Laos	6.8	2.7	4.1	39.7	60.3	29
Myanmar	52.9	18.3	34.6	34.7	65.3	81
Nepal	29.0	5.5	23.5	19.0	81.0	202
Sri Lanka	21.2	3.9	17.3	18.4	81.6	338
Total	1.597.1	526.3	1070.8	32.9	62.1	

Source: Based on World Bank (2017b)

4 Sanitation and wastewater management chain

Densely located population and lack of infrastructure for proper sanitation are behind the major environmental and water pollution problems in most countries of South and Southeast Asia. High rates of open defecation and essentially psychological preference for such behavior are key barriers for safe management of waste and implementation of RRR technologies. As shown in Table 2, in contrast to very low levels of open defecation in Bangladesh and Sri Lanka, open defecation rates are enormously high – reaching almost 40% - in India in spite of so many efforts to provide cheap toilets and improving the sanitation. High rates of open defecation and low sanitation access rates are also specific to Nepal and Laos. Higher prevalence of open defecation is strongly correlated with lower quality of drinking water and higher rates of diarrhea related morbidity and stunting in children (Vangani et al. 2016, Hasan 2018). Open defecation has spillover effects even on the households that use improved sanitation facilities as the children from these households face stunting issues similar to the children of neighboring households without access to improved sanitation (Vangani et al. 2016).

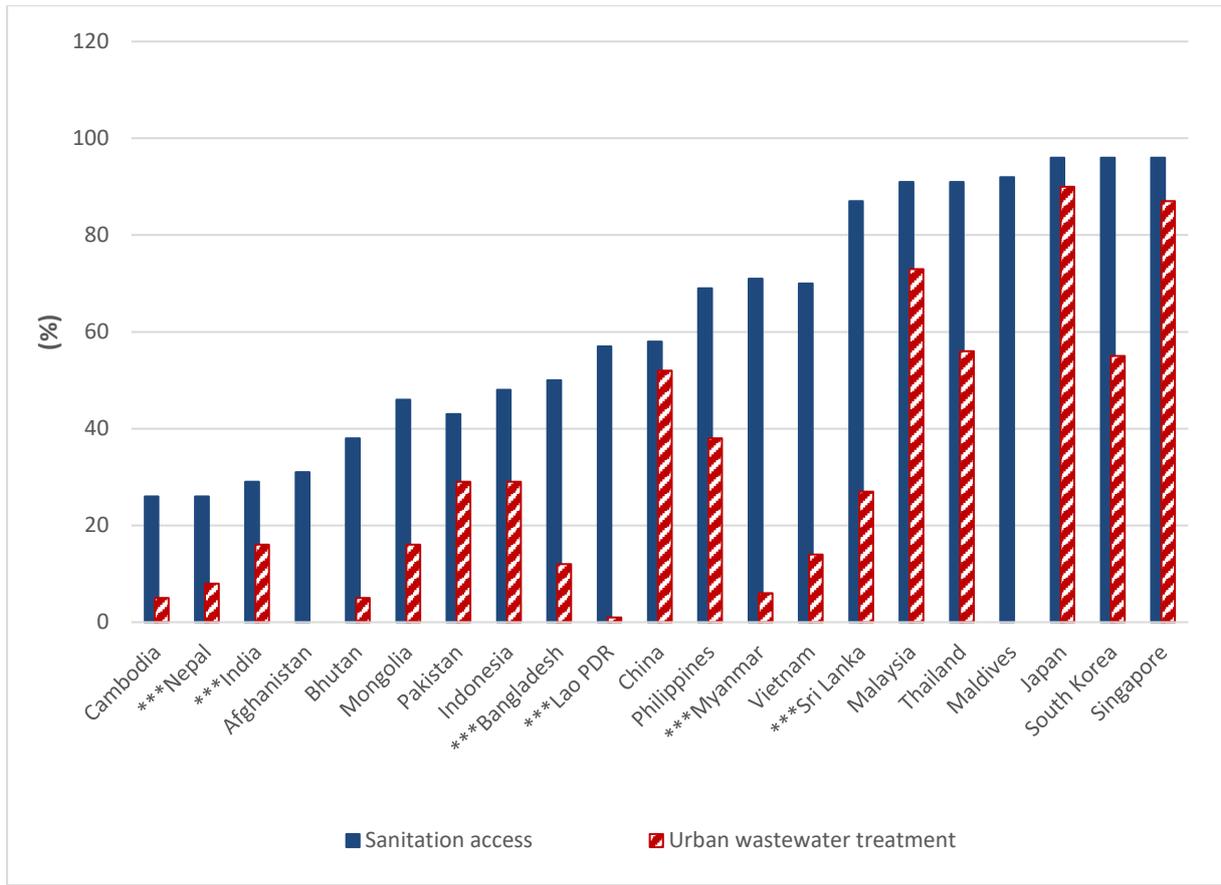
Table 2: Sanitation (2015)

Country	Access to sanitation	Open defecation rate
Bangladesh	60.6	0.1
India	39.6	39.8
Laos	70.9	22.1
Myanmar	79.6	4.7
Nepal	45.8	29.8
Sri Lanka	95.1	2.6

Source: Based on World Bank (2017b)

Fecal sludge and wastewater treatment levels in the South and Southeast Asian countries are quite low compared to the sanitation rates and the average wastewater treatment levels in other Asian countries with high income levels. Figure 2 illustrates the ranks of the studied countries among Asian countries according to access to sanitation (availability of sanitary toilets) and the level of wastewater treatment. According to UNEP (2017), sanitation access is quite low in Nepal and India and leveled at less than 30% though low wastewater treatment levels are comparable with Bangladesh. Bangladesh and Laos have similar sanitation access at levels of 50-60% but wastewater treatment almost lacks in Laos. Wastewater treatment levels are also quite low in neighboring Myanmar though sanitation rates are higher than 70% in this country. Sri Lanka performs best among the studied countries reaching high sanitation access comparable to in the developed countries of the region but wastewater treatment levels in urban areas are quite low compared to those in the developed countries.

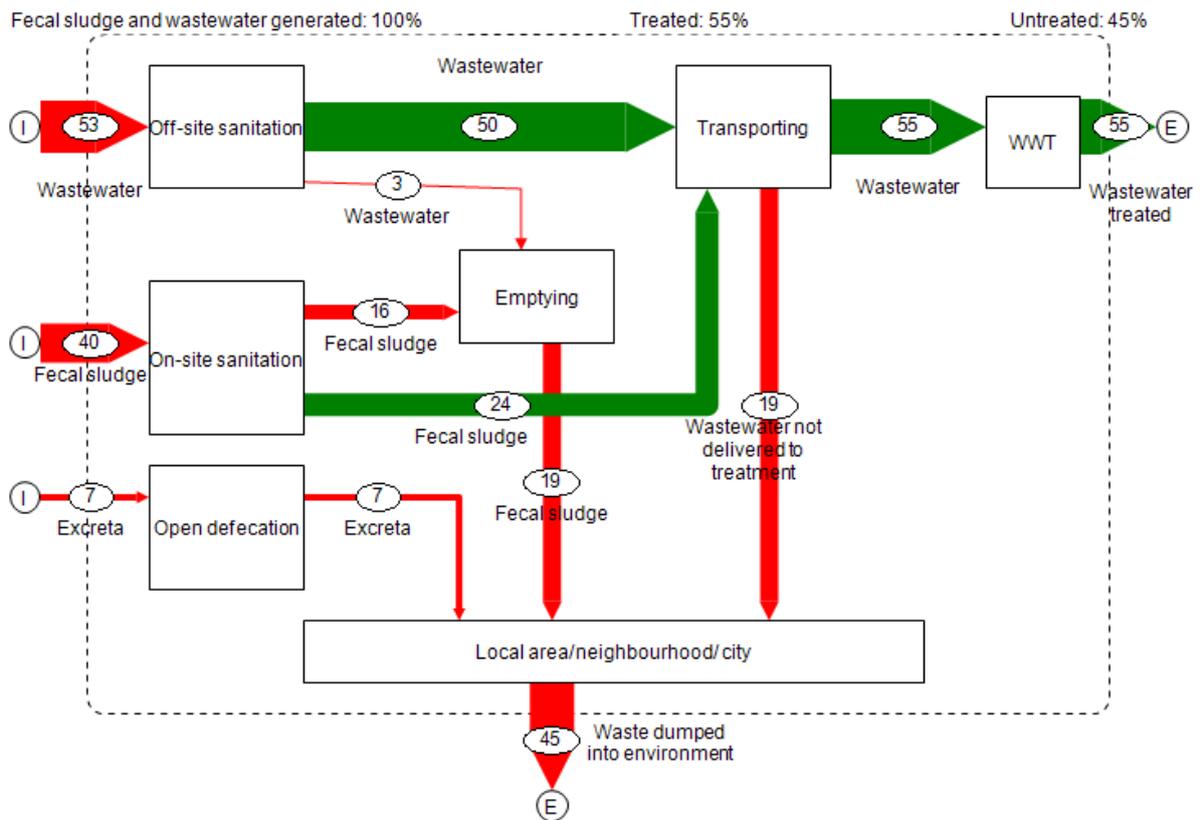
Figure 2: Access to sanitation by households and wastewater treatment levels across Asia



Source: Based on UNEP (2017)

Example of fecal sludge management in Tumkur city of India (located 70 km away from Bangalore – the capital of the state of Karnataka) was shown in Figure 3. Half of the population in the city is provided with sewerage system which conveys 50% of wastewater generated to treatment plants. Small portion of wastewater joins to drainage waters due to leakage or failure in the sewerage system. 19% of fecal sludge from on-site facilities is dumped directly into the drainage system. Despite 24% of the fecal sludge from the on-site facilities are collected only 5% of the sludge is treated and the rest is released into neighborhoods without a proper treatment. Open defecation rate is 7%. Overall, almost half of the wastewater and fecal sludge generated end up in open fields and drainage system without any prior treatment and thus contributes to heavy environmental pollution, groundwater contamination and spread of the diseases (Gunawan et al. 2015, Vangani et al. 2016).

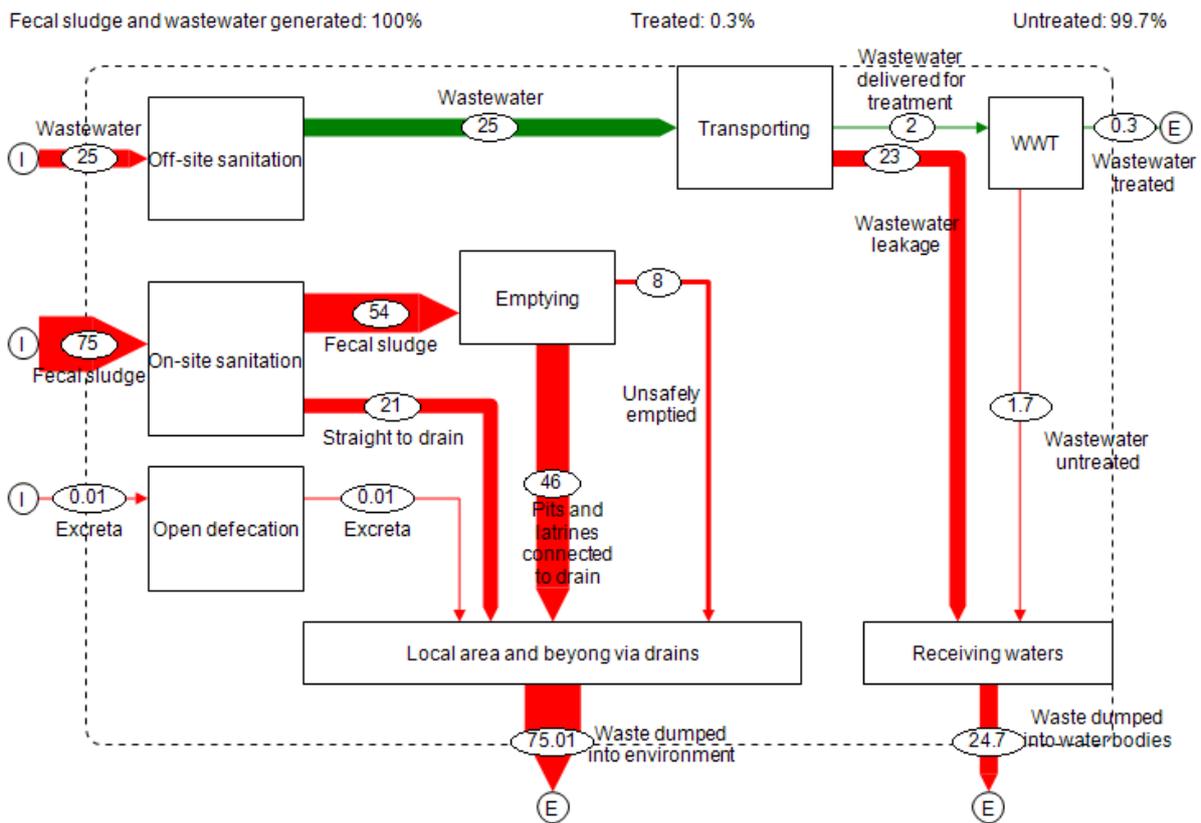
Figure 3: Fecal sludge and wastewater management in India (the case of Tumkur city)



Source: Based on Gunawan et al. (2015)

Although open defecation is not a big problem in Dakka, Bangladesh, and flush toilets are commonly used for collecting fecal sludge, only 0.3% of total wastewater and fecal sludge generated are treated (Figure 4). Most water from sewerage system (which serves only 25% of the city population) are leaked into water bodies. Large portion of fecal sludge is dumped into open drainage which conveys it beyond the local area and discharges into environment without a proper treatment (Opel et al., 2012). Mechanical emptying on-site facilities such as pit latrine and septic tanks are rare and manual emptying characterized with high disease risks is common practice across the country. The situation in other cities, where sewerage system lacks and on-site fecal sludge collection facilities are commonly in use, is even worse than in the capital city. Thus, since surface and groundwater sources are often contaminated with chemical pollutants and pathogenic microorganisms such as *E. coli*, withdrawing water from untapped sources for drinking increases diarrhea incidents and causes stunting in children (Hasan and Gerber 2016). Households with irrigating areas are more likely to use water mixed with wastewater and fecal sludge consequently facing with diarrhea issues and income losses due to productive time lost (Hasan 2018).

Figure 4: Fecal sludge and wastewater management in Bangladesh (the case of Dakka)



Source: Based on World Bank (2016)

Water supply and sanitation is underdeveloped in urban areas and lacks in rural areas of Nepal. For instance, in the Kathmandu Valley it has been reported that only 40% of households are connected to the sewerage system (ICIMOD et al., 2007). Across the country, only 12% of households in municipal areas have an access to sewerage system (Shrestha, 1999). In municipal areas without connection to sewerage system, septic tanks and pit latrines are in common usage (HPCIDBC, 2011). Effluents from these septic tanks and pit latrines are discharged into drainage system or soak pits where they are gradually absorbed into soil. Although private companies or municipalities are in charge of cleaning of the septic tanks, the cleaning is rarely conducted in time. Consequently, these septic tanks are filled up easily, do not function properly and cause heavy air, water and soil pollution. If 370 million liters per day (MLD) of wastewater is generated in Nepal, only 5% of this volume can be treated since the overall capacity of wastewater treatment plants (WWTPs) is 37 MLD and only 50% of these plants are operational (Nyachhyon, 2006).

In Colombo, the capital of Sri Lanka, the sewerage network covers only some parts of the city and comprises 320 km of sewers, 18 pumping stations, and two long outfalls into the deep sea (ADB, 2015). Given the lack of pipe-borne sanitation infrastructure in many parts of the country, fecal sludge in some areas is collected by special trucks to deliver them into treatment plant (Figure 5). Wastewater is recycled through passing several ponds in wastewater treatment plants and treated water is safely disposed into a lagoon or sea. In some places like Rathmalana in the South of the Colombo Municipality, a very modern wastewater treatment plant functions using advanced computer technologies for monitoring and managing wastewater treatment process. Treated wastewater is safely released into the sea thus not polluting the coastal area. Sediments are dried several days before being delivered to a compost plant for co-composting together with organic waste (food waste, crop residues, etc.) or dumped into landfills. In some cases, dried sediments were supplied to cement production factories for burning in cement kilns (Maheshi et al., 2015). In the areas without adequate access to sanitation services, disposal of wastewater and sewage sludge without proper treatment is

a key reason for eutrophication and the spread of diseases in inland water bodies and coastal areas. Increased eutrophication may also damage coral reefs in the coastal zone and negatively effect on fishing industry (Sunday Times, 09 April 2017). Improper management of solid waste, such as dumping waste into wetlands or constructing inefficient landfills close to fresh water streams, causes organic and chemical contamination of water bodies and leads to the consequent loss of aquatic species and human health degradation (Lagerblad, 2010).

In Laos, fecal sludge management is quite undeveloped as only 35% of fecal sludge generated is stored in septic tanks and various poorly maintained latrines are in use for containing the remaining excreta (Opel and Cheuasongkham, 2015). Although open defecation rate is 4% in urban areas and 70% of population uses some type of toilets, open defecation rates are 40% in rural areas in this country (WHO/UNICEF, 2014). Fecal sludge collected in septic tanks is accumulated over 1 to 5 years for further collection. Since public service for collecting fecal sludge is quite limited, fecal sludge collection are mostly conducted by private companies. Because of long distance to the official dumping site and expensiveness of discharging the collected waste into the dumping sites, the collected fecal sludge is mostly dumped into waterways and the ditches along the roadside (Opel and Cheuasongkham, 2015). No regulation, monitoring and control exist for the illegal dumping of fecal sludge. At present, some cheap wastewater treatment plants based on planted reed beds are under way of construction which can lessen the environmental burden of the illegal dumping at least in some parts of the capital city (The Laotian Times, 2018).

Figure 5: Delivering the fecal sludge to the wastewater treatment plant (Sri Lanka, 2017)



Source: Photo by Bekchanov

According to the official statistics, Myanmar is well equipped with sanitary means of disposing excreta (Zaw, n.d.). The Ministry of Health provides subsidies to construct latrines in rural areas (ADB, 2013). Thus, improved toilets are used by 80% of population in rural areas and 94% in urban areas (Zaw, n.d.). Majority of population uses pit latrines with slabs for excreta containment. However, only 3-4% of households are connected to centralized sewerage system. Even in main urban areas such as Yandong, only key business districts are equipped with the centralized sewerage system. Sanitation services are below acceptable levels in the remaining areas. In Yandong city, only 7% of wastewater generated is treated before its release into environment and activated sludge from the plant is used as soil amendment (Premakumara et al., 2017). The remaining waste is mostly discharged into storm water

canals or open waterways without proper treatment. These water ways are often blocked due to heavy loading of suspended solids or mismanagement, increasing the health risks such as malaria and dengue. Poor governance, lack of data and planning, financial shortcomings are key barriers for constructing a proper urban sanitation facilities in the country.

5 RRR options for treating organic waste and wastewater

5.1 Overview of RRR options

Technologies of treating and recycling fecal sludge vary depending on the purpose of the treatment (Table 3). Some municipal areas of South and Southeast Asia are equipped with cheap options of wastewater treatment such as planted or unplanted drying beds. The application of the advanced wastewater treatment technologies are very limited. Although Reverse Osmosis (RO) technique is effective in wastewater treatment and has positive effects on drinking water quality, high costs of the technique prevent its wider implementation (Vangani et al. 2016). Incineration is also applied yet at limited level (mostly in metropolitan cities of India) because of high operation and investment cost requirements. Studies on cultivating fly larvae and deep row entrenchment were not found. Resource recovery and reuse technologies are quite underdeveloped in Myanmar and Laos but composting and biogas plants are more common practices which are supported by various governmental policies across Sri Lanka, India, Nepal, and Bangladesh. Thus, we mainly focused on composting and biogas generation options across these four countries in this section.

Table 3: Fecal sludge treatment objectives and technologies

Treatment objective	Treatment technology
Solid-liquid separation	Unplanted drying beds
	Planted drying beds
	Mechanical dewatering technologies
	Settling tanks
Sludge stabilization	Composting
	Anaerobic digestion (biogas)
	Fly larvae (Soldier Fly)
	Incineration
Nutrient management	Vermicomposting
	Deep row entrenchment
Pathogen inactivation	Lime treatment
	Ammonia treatment

Source: Based on Strande et al. (2014)

5.2 Composting

Compost is a dark colored matter rich in nutrients and thus useful for improving soil fertility. As estimated, overall composting potential from organic waste is about 4.3 million tons in India (Chandran, 2012). Windrow composting is main type of composting across the country. Initial plans for composting organic waste were implemented as early as 1970s and thus several semi-mechanical composting plants have been constructed in many states of India at that time. However, most of these plants were also shut down due to lack of spare parts for machinery which are mainly imported. Even a malicious fault in the machines could prevent the entire process given the unavailability of spare parts for quick fixation of the mechanical problem. Frequent shortcuts in electricity also interrupted the process. Mixed waste with high content of glass, metal and rubber also frequently clogged the pulvetizers (grinders). It was not possible or very difficult to continue the composting process in rainy

seasons. Demand for the produced compost was also low because of very low quality and contamination with various hazardous material (Ahluwalia and Patel 2018).

Given the increased environmental consciousness and with the support of the government program, compost plants started to grow since 2008 and were constructed in many cities. Composting plants in Bangalore, Nashik and Pimpri can recycle 100, 300 and 500 tons of organic waste daily. However, contamination of the produced compost with heavy metals is dangerous for soil health and might have consequences in the long term. Especially, compost made from municipal organic waste may contain batteries, glass particles and other harmful materials due to poor segregation of waste. Consequently, demand for such low quality compost is quite low (Ahluwalia and Patel 2018). At present, 95 commercial compost plants exist across India and these plants can recycle about 2.4 million tons of organic waste per annum. Yet, only 14% of their capacity is used due to low demand for compost (Ahluwalia and Patel 2018).

Most of the farmers in Bangladesh produce compost in their premises based on traditional ways and apply it for vegetables production. However, the application of modern ways of composting including vermicomposting are very limited (Mamun-ur-Rashid, 2013). Large-scale composting plants are rare and mostly run by a few commercialized organizations such as Waste Concern, Annapurna Agro Service, Grameen Shakti and Rural Development Academy (Rashid, 2011). Although most farmers are less aware of the soil productivity enhancement properties of the compost, some farmers in rural areas of Bangladesh prefer using compost for reducing external environmental effects of chemical fertilizer application, improving soil structure, avoiding high expenditures for inorganic fertilizers, and ensuring safe disposal of organic waste. Crop residues, kitchen waste, dry leaves, hay, ashes, and manure are main types of organic waste for composting. Both men and women are widely involved in processing compost in rural areas across the country.

Composting organic waste is also limited in Nepal. There have been efforts to establish a composting plant in Kathmandu municipality in Nepal. GIZ supported and funded the construction of compost plant with an annual capacity of producing 30 tons of compost in Teku transfer station in Kathmandu (Dangi et al. 2013). However, the project was stopped by the municipal council citing to malodor, lack of market for composts, and the complaints about the low quality and glass hazards of compost. Instead, Kathmandu municipality provided 600 households (out of 150,000) with compost bins with a volume of 100 l, for promoting mini-scale composting.

It was reported that there was a single large-scale composting plant in Bhaktapur region of Kathmandu municipality before 2007 (ICIMOD et al., 2007). The plant received about three tons of waste per day. However, the composting in this plant was based on a simple methods and most operations are carried out manually. Other private initiatives to establish composting plants did not have much progress until the recent past since low priority was given for these programs (ICIMOD et al., 2007). At present, some NGO initiatives to raise awareness on recycling waste and not to pollute environment are there through international donor support¹. Since 2014, Biocomp company also started running a composting plant in Khokana². The composting process is largely mechanized and some positive signs of progress have been recognized. Rather than waste treatment and recycling, some initiations on safe disposal of waste became successful (Dangi et al., 2013). For instance, GIZ supported the construction of Gokarna landfill. JICA similarly financed the establishment of Sisdol landfill.

In many areas of Sri Lanka, composting at household level was supported by sharing composting bins by local governments or NGOs. Centralized composting, especially using windrow composting technology, is also becoming common. Following the Pilisaru Program adopted by the national government in 2008, over 110 compost plants were planned to be established (JICA 2006, Table 4). 94 composting plants out of 119 are under operation at present and 17 are under construction (Bekchanov, 2017b). In districts such as Kurunegala, Anuradapura, Polonnaruwa, and Badulla where agriculture is a backbone for rural livelihoods, the targeted rates of waste recycling are substantial.

¹ <http://cleanupnepal.org.np/>

² <http://www.biocompnepal.com/>

Some plant operations even faced to public protests over malodor and water pollution in some areas. Lack of technical skills to operate the plant, low quality of compost, and underdeveloped marketing system for compost also hinder successful performance of composting plants (Pandyaswargo and Premakumara, 2012).

Table 4: Municipal solid waste collection and composting rate across Sri Lanka

Provinces	Districts	Waste collection (tons per day)	Number of compost plants	Targeted waste (tons per day)	Targeted waste (%)
Northern	Jaffna	78.5	3	11	14.0
North-central	Anuradapura	64.7	14	46.5	71.9
	Polonnaruwa	17.5	2	12	68.6
	Total	160.7	19	69.5	154.5
Northwestern	Kurunegala	113	16	88	77.9
	Puttalam	87.9	5	30	34.1
	Total	200.9	21	118	58.7
Central	Kandy	209.5	4	17	8.1
	Matale	47.3	4	8	16.9
	Nuwara Eliya	58	2	5	8.6
	Total	314.8	0	30	9.5
Western	Colombo	1,284	2	7.3	0.6
	Kalutara	126.5	7	69	54.6
	Gampaha	372.5	8	40.5	10.9
	Total	1783	17	116.8	6.6
Southern	Hambantota	50	8	30	60
	Matara	92	7	51	55.4
	Galle	107.5	9	13	12.1
	Total	249.5	24	94	37.7
Sabaragamuwa	Kegalle	65.5	6	34	51.9
	Ratnapura	88	2	2	2.3
	Total	153.5	8	36	23.5
Uva	Badulla	75.6	5	52	68.8
	Monaragala	35	2	4	11.4
	Total	110.6	7	56	50.6
Eastern	Ampara	142.5	5	13	9.1
	Batticaloa	136	1	9	6.6
	Total	278.5	6	22	7.9
Sri Lanka	Overall	3,424	119	656.8	19.2

Source: Based on Central Environmental Authority

5.3 Biogas generation

Biogas production from organic waste is getting momentum across the world. China and India are the leaders in the implementation of the biogas technology (Halder et al., 2016). Promotion of biogas plants started since 1970s in India following the first global energy crisis which decreased energy access and its economic feasibility in rural areas (Deo et al., 1991). At present, about 5 million biogas plants have been constructed across the country (Mittal et al., 2018). As estimated, total potential of constructing biogas plants is about 12 million (CSO, 2014). Despite quite large number of biogas plants, the share of biogas in energy consumption of households is low and the dissemination rate of biogas plants is slow. Total amount of biogas generated currently at the level of 2.1 billion m³ per annum is also quite low compared to its overall potential of 29-48 billion m³ (Mittal et al., 2018). Recycling municipal organic waste using anaerobic technologies is currently quite low because of expensive investment requirements and low profitability of such options (Mittal et al., 2018). Biogas based power generation plants are rare and only 56 plants operate across the country. Most of these plants are located in Maharashtra, Kerala, and Karnataka states (CPCB, 2013). Production of briquettes (Refuse Derived Fuel – RDF) from organic waste for further use as fuel is limited due to high costs of production, and bulky mass of the fuel and the residual ash (Ahluwalia and Patel 2018).

In Bangladesh, Bangladesh Agricultural University constructed the first biogas plant in 1972 for research purposes. Several organizations such as Government Engineering Department, the Bangladesh Council of Scientific and Industrial Research, and the Infrastructure Developing Company Limited (IDCOL) became active in supporting the adoption of small-scale biogas digesters by households. At present, about 80,000 small-scale biogas digesters have been installed already across the country yet over 4 million biogas digesters can be built to recycle the entire organic waste (Bahauddin et al., 2012). Thus, over 2.7 billion m³ biogas which is equivalent to 1.5 tons kerosene can be produced just recycling the livestock manure. IDCOL financed also to construct several biogas based power generation plants. A plant established by Paragon Agro Ltd using the IDCOL funds, for instance, produces 2,400 m³ biogas from litter and uses it for generating 3,840 kWh electricity daily (IDCOL, 2016).

The first biogas plant in Nepal was introduced by Father B.R. Saubolle in 1955 (Gautam et al. 2009) and several years were required to draw the attention of government officials for promoting biogas plants. Starting from 1975, the Nepal government offered interest free loans for biogas plant construction. Under the initiation of the Department of Agriculture, Gobar Gas Thata Agricultural Equipment Development Company (GGC) was established in 1977 and 250 biogas plants were built. In 1990, modified Chinese fixed-dome model of generating biogas has been accepted as a suitable model across Nepal. Given the expansion of biogas plant sector, Biogas Support Program (BSP) was established with the support and funding by the Netherland Development Organization (SNV) to develop the biogas sector in 1992. The BSP was realized in four phases and over 200,000 biogas plants were constructed across Nepal till 2010. Number of biogas plants constructed reached to almost 270,000 coming 2012 (Table 5). Biogas plants were installed mainly in households for recycling cattle and buffalo dung, and thus have small size (4-10 m³). Biogas plant implementation took place in majority of districts across Nepal except some few northern districts where biogas generation is not efficient due to cold temperature (Table 5). Several environmental and health benefits of biogas use are encountered. Earlier agricultural residues and cattle dung cakes were used in inefficient cooking stoves, causing heavy indoor pollution and leading to increased incidents of respiratory system illnesses (Pandey, 1984). Biogas uses reduced smoke exposure in the indoor environments and thus reduced exposure to acute respiratory illnesses. Additionally, child mortality rates and eye ailments were reduced.

Table 5: Number of biogas plants constructed across Nepal (in 1992-2012)

Regions	Years				Total	Technical potential of biogas plant construction	Actual to potential ratio (%)
	1992- 1999	2000- 2004	2005- 2009	2010- 2012			
Remote Hill	153	427	584	278	1442	43,255	3.3
Hill	33,661	40,433	39,019	20,445	133,558	344,008	38.8
Terai	27,857	37,926	49,699	17,917	133,399	636,107	21.0
Total	61,671	78,786	89,302	38,640	268,399	1,023,370	26.2

Source: Based on BSP (2012)

In Sri Lanka, initial experimental projects of implementing aerobic digestion technology primarily aiming at energy recovery have been conducted in Kirulapone and Matale (UNEP 2001, Pandyaswargo and Premakumara 2012). Household biogas plants were also introduced in some regions (De Alwis, 2002). Despite failures due to low financial and technical feasibility in some cases, waste-to-biogas project became successful when implemented in hotels. Treated wastewater and compost through waste recycling were also effectively used for gardens in some hotels such as Jetwing Blue. More recently, researchers of Moratuwa demonstrated also waste-generated-biofuel for using in three-wheels (De Alwis, personal communication, 30.08.2017). At present, several commercial companies such as BIOGAS Ltd and BIOFUEL LANKA Ltd are engaged in installation of waste-to-biogas plants throughout the country. Incineration of waste is less common and can be operating only in few hospitals and industries. Unfortunately, incinerations are not equipped with emission control devices (UNEP, 2001). A wider adoption of incineration technology to treat municipal waste across the country is very limited because of a high share of organic matter, high moisture content and low calorific value of municipal waste. In case of Sri Lanka, the incineration may require supplementary fuel since the calorific value of waste in the country is 2 to 3 times lower than in developed countries where the incineration treatment of waste is commonly used.

6 Economy and financial capability

The adoption rates of improved sanitation facilities and RRR options are largely determined by financial capability and income levels. Thus, income levels and stability as reflected through GDP per capita, inflation rates and access to credit are discussed in this section.

Given its big territory and population size, India is also the most voluminous in terms of economy earning annually over US\$ 8 trillion (Table 6). However, per capita income is the highest in Sri Lanka compared to the remaining countries of South Asia and reaches US\$ 11,400. It is also noticeable that the inflation rate in Sri Lanka leveled at 3.7% is one of the smallest, reflecting a greater macroeconomic stability after the end of civil war in 2009. Bangladesh and Nepal are the poorest in terms of income per capita which are leveled at US\$ 3,320 and 2,300 respectively.

Table 6: GDP and inflation rates (2016)

Country	GDP (US\$ Billion)	GDP per capita (US\$)	Inflation rate
Bangladesh	540.9	3,319.4	5.5
India	8,067.7	6,092.6	4.9
Laos	38.8	5,734.5	1.5
Myanmar	280.6	5,305.0	10.8
Nepal	66.6	2,297.7	7.9
Sri Lanka	242.1	11,417.3	3.7
TOTAL	9,236.7	5,783.8	-

Source: Based on World Bank (2017b)

Note: GDP figures are at constant prices for 2011. Inflation rates for Myanmar and Nepal are for 2015.

In addition to income levels, interest rates and access to credit is also essential for assessing financial viability of technology upgrading. Table 7 shows the interest rate for 2016 and the 'Easiness of getting credit' (EGC) index for 2018. Both measures are meant to reflect in some way the possibility of financing investment projects in each of the six economies studied. As shown, the cases of India and Nepal are the most notorious, as these economies reflect the highest EGC index and the lowest lending interest rate, respectively. Difficulty in obtaining credit in Myanmar and high interest rates in Laos are main problems related with financial viability of technological changes.

Table 7: Interest rates and Easiness of Getting Credit (EGC) index (2016)

Country	Interest rate (%)	Easiness of getting credit (EGC) index
Bangladesh	10.4	25
India	9.7	75
Laos	22.6	55
Myanmar	13.0	10
Nepal	8.0	50
Sri Lanka	11.7	40

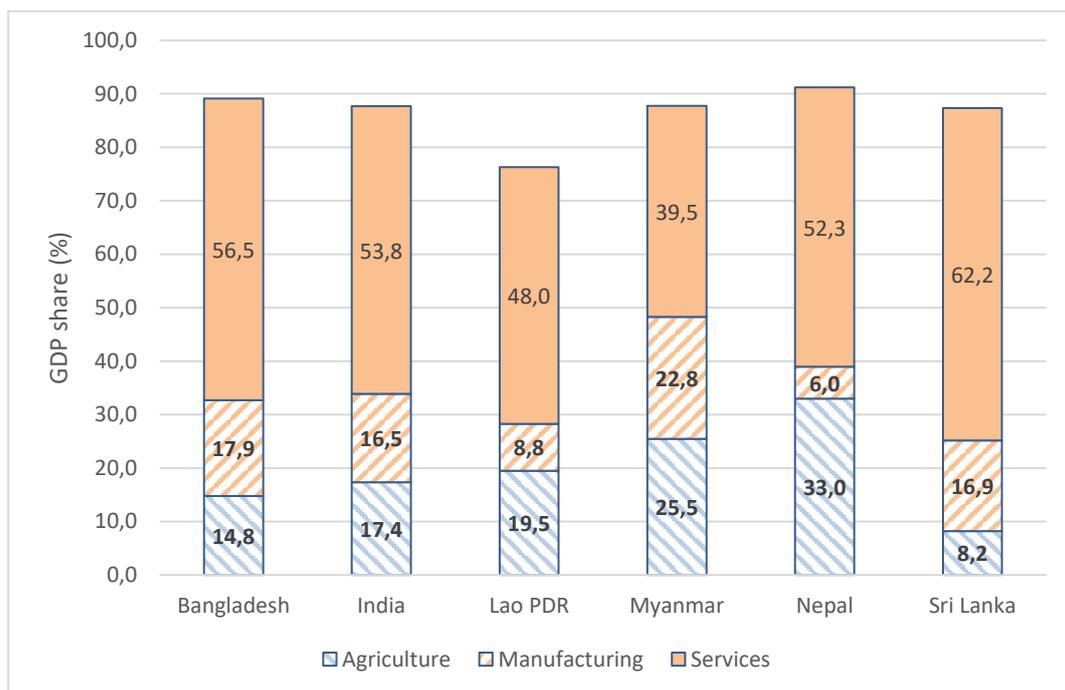
Source: Based on World Bank (2017b, 2018)

Note: Interest rates are average lending rates as of 2016. 'Easiness of getting credit' index is expressed as the 'Distance to the frontier' (DTF), i.e., a low score represents a more adverse scenario in terms of financing enterprises.

7 Agricultural production capacity and demand for fertilizer

Agriculture plays a pivotal role in the studied countries (Figure 6), implying a substantial demand for fertilizers which can be also met through nutrient recovery from organic waste streams. Agriculture contributes over 15% of GDP in India and Bangladesh but this sector accounts for more than 25% of GDP in Nepal and Myanmar. The smallest share of agriculture in GDP among the studied countries is 8% and for Sri Lanka. Nevertheless, agriculture dominates in rural areas and majority of the population resides in these areas. Thus, sustainability of agriculture and adequate supply of irrigation water and soil fertility are essential for food and income security in this region.

Figure 6: Sectorial structure of the national economies (2016)



Source: Based on World Bank (2017b)

Agricultural land areas are mostly used for producing cereals such as paddy rice in the studied countries (Table 8). Half of the croplands are irrigated in Bangladesh and only 10% in Laos. Given the high precipitation rates, rainfed agriculture dominates in most of the areas in the region. Forests cover 80% of total land area in Laos but only 10% of Bangladesh. Given the low population density, high precipitation and high forest coverage of the territory, expensive technologies for centralized fecal sludge recovery are less feasible in Laos and Myanmar (except in their central urbanized regions). Thus, perhaps only safe disposal of fecal sludge with less damage to human and environmental health or deep entrenchment for enhancing forestry can be an option for these countries. Given the high population density and extensive irrigated areas, adoption of nutrient technologies seems more important to Bangladesh and India but their economic feasibility should be further clarified.

Both nitrogen and phosphorus chemical fertilizers are largely imported in all South Asian countries considered (Table 9). India, for instance, imports over 4.8 million tons of nitrogen and produces 12.3 million tons domestically (as of 2014). Nepal and Sri Lanka solely depend on the imports of nitrogen fertilizers, while substantial portion of nitrogen uses is based on imports in Myanmar and Bangladesh. Phosphorus is also solely imported in all countries except India and Bangladesh (as of 2014). Even in Bangladesh, import of phosphorus is 7-8 times higher than its domestic production.

Table 8: Agricultural land uses in South and Southeast Asia (2014)

	Agricultural land (million ha)	Cereals area (million ha)	Irrigated area (% of total cropland)	Forest area (% of total land area)
Bangladesh	9.1	12.1	52.6	11.0
India	179.7	99.0	36.8	23.8
Laos	2.4	1.2	11.5	81.3
Myanmar	12.6	7.7	24.8	44.5
Nepal	4.1	3.5	29.7	25.4
Sri Lanka	2.7	1.0	n.a.	33.0

Source: Based on World Bank (2017b)

Demand for fertilizer is also increasing substantially in some South Asian countries (Table 9). For instance, phosphorus exports increased from 255 thousand to 454 thousand tons in Bangladesh during the period between 2010 and 2014. Similar rates of both phosphorus and nitrogen exports occurred in Sri Lanka at the same period. In Myanmar and Nepal, demand for fertilizers increased more than five times in the period between 2005 and 2014. Rapidly increasing demand for fertilizers in these countries indicate a large market potentials for the soil amendments and compost recovered from organic waste and wastewater.

Table 9: Domestic production, exports and imports of chemical fertilizers (tons)

	Year	Nitrogen			Phosphorus		
		Production quantity in nutrients	Exports quantity in nutrients	Imports quantity in nutrients	Production quantity in nutrients	Exports quantity in nutrients	Imports quantity in nutrients
Bangladesh	2005	880,646	179,962	292,643	69,022	0	257,691
	2010	491,520	40,916	716,206	50,140	0	245,946
	2014	394,580	0	881,420	61,640	0	454,480
India	2005	11,218,193	10,127	1,389,864	4,092,561	10,869	1,144,742
	2010	12,087,720	17,396	4,547,810	4,303,880	5,563	3,698,990
	2014	12,329,482	19,136	4,809,303	4,097,197	20,553	1,886,750
Laos	2005	0	0	0	0	0	0
	2010	0	0	0	0	0	0
	2014	0	0	0	0	0	0
Myanmar	2005	46,058	0	7,736	0	0	8,051
	2010	16,235	0	35,064	0	0	10,476
	2014	76,368	0	83,015	0	0	27,145
Nepal	2005	0	0	9,000	0	0	7,000
	2010	0	0	43,148	0	0	10,130
	2014	0	0	96,718	0	0	41,940
Sri Lanka	2005	0	0	159,595	11,042	0	22,639
	2010	0	0	166,096	10,000	0	40,679
	2014	0	0	227,403	1,000	0	45,403

Source: Based on FAO (2018), data was not found for Laos

8 Infrastructure

Access on specific public services such as safe water and electricity is essential for technical feasibility of waste and wastewater management and recycling technologies. Sri Lanka is very well equipped with potable water and electricity provision services (Table 10). Water and electricity is also high in India and Nepal. Electricity access is low in Bangladesh and Myanmar which means potential difficulties in mechanical operations related with waste treatment and recycling. The development of ICT, which is essential in marketing the RRR products and improve the relationship between producers and consumers, is quite low in Sri Lanka in contrast to India where ICT are quite well developed.

Table 10. Access to infrastructure (% , 2015)

Country	Access to water	Access to electricity	Information & communication technology index (0-9)
Bangladesh	86.9	62.4	4.5
India	94.1	79.2	6.0
Laos	75.7	78.1	2.5
Myanmar	80.6	52.0	4.5
Nepal	91.6	84.9	4.0
Sri Lanka	95.6	92.2	2.5

Source: Based on World Bank (2017b)

9 Governance and regulatory framework

Quality of public policies are important in order to carry forward entrepreneurship projects in general, and RRR projects in particular. In this sense, it is important to assess the general governance status in the countries in which these projects are meant to be driven. Table 11 shows some indicators that could reflect in some way the quality of public policies and the good governance standing. Regarding corruption, the indicators show that in general all the countries perform poorly (all the indicators are negative). With respect to transparency and general governance quality, the situation in the countries is not satisfactory, although in comparative terms India outperform its peer countries by having relatively higher scores.

Table 11: Governance indicators (2016)

Country	Corruption index	Transparency index (voice and accountability score)	Governance quality (Government effectiveness)
Bangladesh	-0.80	-0.56	-0.69
India	-0.30	0.41	0.10
Laos	-0.93	-1.73	-0.39
Myanmar	-0.65	-0.85	-0.98
Nepal	-0.76	-0.23	-0.81
Sri Lanka	-0.28	-0.11	-0.21

Source: Based on Worldwide Governance Indicators (WGI) of World Bank

Note: Indices range from -2.5 to 2.5, the most negative values reflect the worst condition.

Corruption rates and governance quality also somehow affect the costs of doing business. As shown in Table 12, the indexes for the cost and time to start business across the studied countries varied between 72 and 88. In terms of the costs and time to start, Sri Lanka is identified as the top performer among the six. The index reflecting the cost of closing business is more heterogeneous varying between 20 and 48 across the studied countries. Finally, the positions of the countries in the Ease of Doing Business ranking reflect in general a weak business environment, as none of these economies lie among the top 100 performers across the globe. However, in South Asian region, business climate is more favorable in India, Nepal and Sri Lanka than the remaining countries.

Table 12: Business environment

Country	Cost and time to start business	Cost to close business	Enabling environment [Ease of doing Business rank among 190 countries (1 is best)]
Bangladesh	80.7	27.7	177
India	75.4	40.8	100
Laos	72.6	No data	141
Myanmar	75.4	20.4	171
Nepal	84.0	48.2	105
Sri Lanka	87.7	44.9	111

Source: Based on World Bank (2018)

Note: 'Cost and Time to start a business' and 'Cost to close business' indices are expressed as the 'Distance to the frontier' (DTF), i.e., a low score represents a more adverse scenario in terms of starting and closing businesses.

Given that organic fertilizer from biodegradable waste is attractive RRR option in South Asia because of high share of rural population, dominance of agriculture among economic activities, and high levels of fertilizer imports, the costs and time for registering new fertilizer was also discussed here (Table 13). Costs and time for registering new fertilizer or soil amendment are quite unfavorable in Nepal as it may take almost four years. Though costs are not so much high, time for registration takes almost three years in India and Bangladesh. In Sri Lanka, one year can be sufficient to test new fertilizer effectiveness and the costs for registration is only 4% of average per capita income.

Table 13: Easiness of registering new fertilizer

Economy	Fertilizer registration index (0-7)	Quality control of fertilizer index (0-7)	Time to register a new fertilizer product (days)	Cost to register a new fertilizer product (% income per capita)
Bangladesh	4.4	4.5	945	58.8
India	5.0	3.5	804	17.1
Lao PDR	3.4	5.0	No Data	0.5
Myanmar	4.4	3.0	41	7.3
Nepal	3.4	5.0	1125	645.2
Sri Lanka	2.4	3.5	365	3.7

Source: Based on World Bank (2017a)

10 Institutional framework for supporting organic waste management

10.1 Central government

Institutional framework and clear distribution of roles and responsibilities are essential for proper functioning of the waste management system. The role of institutions in South Asia regarding waste management could be distinguished in three levels: central government, regional/local governments and NGOs and civil society organizations (ADB 2011). The role of central government institutions consists of setting standards and policies and establishing coordination across different governance levels. However, the ministries involved are diverse and they have different roles related with the waste management activities.

In a broad perspective, the Ministry of Environment is the institution in charge of setting the national policy on waste management and the compliance of the subnational governments and other institutions with these regulations. In addition, in some countries, the Ministry of Environment is the ruling organization in charge of policies and measures on pollution control and environmental regulations. The Ministry of Agriculture has the role of setting an effective policy in the sector, setting the standards for soil preparation, and certifying the uses of organic and inorganic fertilizers. In this sense, this Ministry plays a key role in order to incentivize the use of organic fertilizers through subsidies, information campaigns and regulatory guidelines.

Other important Ministries that could play a role in the waste management are the Ministry of Urban Development and the Ministry of Energy. The Ministry of Urban Development deals with the management of waste in urban areas and plays pivotal role in developing policies for enabling recycling organic waste. The Ministry of Energy, in turn, deals with providing incentives and guidelines for generating renewable energy from organic waste and facilitating the related infrastructural setup. In addition to set policies, the Ministry could also impose the provision of subsidies or other incentives for triggering the implementation of RRR technologies.

The Ministry of Finance and the Ministry of Information have broader roles in terms of facilitating the process of adopting RRR options. Since the Ministry of Finance is in charge of the budget and tax policy overall the ministry provides institutional framework for improving the financial feasibility of RRR options. The Ministry of Information is in charge of the ample communicational policy of the government in general and it could launch the outreach and awareness campaigns regarding sustainable waste and wastewater management options.

Expert surveys indicated lack of cooperation among the ministries and the disputes over conflicting interests prevent successful reforms in the sanitation and environmental protection. Furthermore, since issues of proper sanitation and environmental safeguarding are not prioritized in governmental budget allocation policies investments and subsidies to construct large scale plants to recycle organic waste are very limited.

10.2 Regional/local governments

While the role of central government institutions lies on setting the rules for a proper waste management, the regional governments are actually the ones that potentially carry out the waste reduction, re-use, recycling activities at the local level. In this sense, their tasks are much more diverse than the tasks of the specialized agencies of central government. Some of the tasks for local governments related with waste management are the following (ADB 2011):

- Ensuring land policies for organic waste management;
- Establishing incentives for the private participation in RRR activities;

- Promoting the use of RRR technologies, by creating public awareness;
- Providing infrastructural support (e.g., municipal roads) to enhance the RRR activities;
- Collecting and managing information regarding waste management in order to enhance the process and adjust the procedures.

10.3 Civil Society and NGOs

Civil Society organizations and NGOs are entities in charge of facilitating and implementing the policies addressed to promote the waste management process. Their roles are rather framed in the functions of local governments. For example, they might help to raise community awareness regarding a proper waste behavior (e.g., separating garbage and correct disposal), manage information campaigns and work together with local governments to incentivize the waste reduction, re-use and recycling process. Unwillingness of the government to cooperate with NGOs, legislate the initiatives for sustainable environment, and recognize the private sector initiatives in some countries such as Nepal were earlier reported (Dangi et al. 2013). This attitude prevented the flow of sufficient funds for implementing RRR options and ensuring environmental security.

11 Summary and conclusions

Improved sanitation and wastewater management are important for environmental sustainability and health security in vast areas of South and Southeast Asia. As review results indicated, open defecation is a major problem in India and Nepal due to lack of proper sanitation facilities and psychological barriers. In Laos and Myanmar, sludge and wastewater collection and treatment was quite underdeveloped. Although sanitation facilities are available, wastewater treatment are not adequate or sufficient to meet health and environmental safety guidelines in Bangladesh and Sri Lanka. Underdevelopment and mismanagement along sanitation value chain processes before pre-treatment may dramatically reduce the feasibility of adopting advanced RRR options.

Some level of recycling sludge and organic waste through producing biogas or compost exist in India, Bangladesh, Nepal and Sri Lanka. Lack of spare parts for machines in mechanical composting and inadequate access to electricity in India, government interventions to prevent NGO support for big size compost plants in Nepal, and public protests over malodor in Sri Lanka were found out as main issues. Acceptance of organic waste mixed with inorganic waste, difficulties in obtaining or expanding land for compost plants and lack of demand due to low quality of the compost are common problems in all countries under the study.

Biogas was initially promoted in South and Southeast Asia as a response to skyrocketing energy prices across the globe during the energy crisis in 1970s. Hot temperature in the tropical areas of these regions is very favorable for efficient functioning of biogas plants. Biogas digesters are implemented by many households in plain and hill regions of Nepal with the support of government subsidies. Mostly hotels, some hospitals and farmers adopted biogas technology because of its high construction and utilization costs in Sri Lanka. Installation of biogas digestion units are also enhanced through sanitation and environmental protection laws, which require enterprises and new houses to manage and recycle their waste for obtaining construction and operation permits.

Analysis of demand for fertilizer and energy indicated rapidly growing uses of fertilizers and energy in the studied countries. Nepal, Sri Lanka and Myanmar are fully dependent on imports of phosphate fertilizers. Energy imports or firewood collection for cooking in rural areas are also substantial in this region. Thus, compost and biogas from organic waste can considerably lower deforestation and the expenditures to fossil fuel and chemical fertilizers. Since majority of population lives in rural areas and their livelihoods are heavily dependent on agricultural sector, increased use of organic fertilizer may also play a pivotal role for improving food security and alleviating poverty in these locations.

Insufficient financial resources, inadequate access to bank loans, high levels of corruption and lack of transparency are key barriers for a wider adoption of RRR options in the studied countries. General lack of awareness on environmental safeguarding and indifference towards environmental security impeded the potential technological changes, maintaining the continuity of waste and wastewater related pollution. Manual scavenging and improper handling the composting and biogas generating facilities may increase health risks. Lack of adequate demand for fertilizer or biogas in urban areas where most of the organic waste is generated may limit the feasibility of RRR technologies. Underdevelopment of ICT limits interactions between producers and customers, consequently preventing efficient functioning of markets for compost and biogas.

For a wider implementation of RRR options, first of all, a proper accounting, planning and management along the entire sanitation and waste management chain should be established to prevent leakages and ensure a safe disposal of the waste. Because of high poverty rates, the governments may consider subsidizing the implementation of composting and anaerobic digesters. The governments should be also supportive of non-governmental organizations and international donors in their efforts for maintaining sustainable environment and livelihoods through increased recycling waste and wastewater. Since public services along sanitation and recycling chains are not efficient in most of the places, public-private collaborations in the sector should be promoted. Obtaining permissions to land use for constructing compost or biogas plants as well as registering fertilizer products should be easier

and more transparent. Enforcing the environmental and sanitation laws to reduce open dumping of waste may result in a wider adoption of RRR options. For raising the awareness of population on environmental and health risks and the relevance of RRR technologies for addressing such issues, organization of education and extension programs can be effective as demonstrated in the example of food hygiene education in Bangladesh (Hasan 2018). Improved ICT could support not only a wider outreach of RRR options but also fruitful interactions of producers and consumers, consequently enhancing the marketability of the RRR products. Finally yet importantly, certifying and monitoring the quality of the RRR facilities and recovered products (e.g., compost, biogas, etc.) are important for nurturing trust and maintaining the continuity of demand for RRR products.

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