Short Communication

Inclusion of innovative technology in integrated waste management of a city: case of Bogura, Bangladesh

D. Dey, I. Krukkert and E. Osse

ABSTRACT

Bogura is the largest municipality in Bangladesh by population. Its huge population and agri-industry produces a great deal of solid, faecal and industrial waste which has been a matter of concern for the municipality. IRC started working for a solution and completed a pre-feasibility and feasibility study to find innovative technologies and an operation model. The feasibility study has produced an integrated solution of faecal sludge, municipal solid waste, agri-waste and aerosol can recycling model which also helps to reduce surface and ground water contamination. The solution integrates conventional anaerobic digestion with new torrefaction and aerosol-propellant capture technologies which treats the municipality solid waste and aerosol cans to produce biofuel and liquid petroleum gas, respectively.

Key words | anaerobic digestion, faecal waste, leachate, solid waste, torrefaction, waste-to-energy

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INTRODUCTION

Bangladesh is a densely populated country. With rapid industrialization and urbanization, the influx of migration from the villages towards the towns and cities has increased significantly. Thus, industrial progress in cities and towns has led to an extra population load (Khan 2009). This has resulted in unplanned urbanization which leads to the generation of huge amounts of waste. In most cases, the cities and towns are not capable of processing/treating these extra wastes. Bogura is an ideal example of this. It is the largest municipality town in Bangladesh with a population of 0.6 million. It is situated in the north-western part of Bangladesh. In fact, it is the gateway of northern Bangladesh. The town and its nearby areas are full of agro and mechanical industries. IRC, an international non-governmental organization (NGO), working in Bangladesh since 2007 in the field of water and aanitation (Terpstra 2016) has carried out two studies for faecal sludge management. The studies found the importance and a possible solution of dealing with faecal sludge, but also emphasized the need of integrated waste management.

CONTEXT

Bogura is a major town located in the Bogura District, Rajshahi Division, Bangladesh. It is a major commercial hub. Bougra connects the Rajshahi Division and Rangpur Division.

The town is approximately 69.56 km^2 (26.86 square miles) and is divided into 21 wards. Bogura has a population of around 600,000 people. It is rich in crops such as rice, jute, wheat, potato, mustard, pepper, etc. Many industries are there to process the crops (Bogura 2019). In addition, the town has different chemical and mechanical industries such as agro-mechanical, foundry, soap, etc. Due to that, the town produces a huge amount of waste, which consists of faecal waste, municipal solid waste, agri-waste, scrap aerosol cans, broken glass, etc.

IRC has been working in Bangladesh since 2007. It was the knowledge partner of the BRAC WASH Programme

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from 2007 to 2015 which covered 250 sub-districts of Bangladesh, about half of the entire country. Bogura was one of its focus areas. Along with regular water and sanitation activities, BRAC and IRC included faecal sludge management as an area of innovation and commissioned two action researches. One primarily focused on large-scale faecal sludge management and considered Bogura as a suitable location for the study. It also took agri-waste into consideration for processing with faecal sludge for financial sustainability (IRC 2015).

The research shows that a biogas unit using corn stovers and chicken manure only can be a profitable investment in Bangladesh. The profit from this unit will cross subsidize the logistic cost of collecting the faecal sludge from pit latrines. Its recommendation was, therefore, a granular approach; the unit will be designed and constructed for processing corn stovers (or other agri-waste or even water hyacinth) with chicken manure, and faecal sludge (which requires the installation of a 'hygienic unit' or helminth killer), but the unit starts up only with corn stovers/chicken manure (Mahmud *et al.* 2016). This would allow for an organic growth of the faecal sludge collection from pit latrines, which would gradually replace part of the corn stovers. In the model presented in the report, the initial feedstock would be 7,000 metric ton (MT) of corn stovers/year and 3,000 MT of chicken manure. However, this would gradually (over a period of three to four years) change to 1,000 ton faecal sludge (content of 40,000 pit latrines), 6,000 MT of corn stovers and 3,000 ton of chicken manure (IRC 2015). This replacement would lead to a reduction of roughly 75,000 m^3 biogas which is 3.75 of the overall production (Mazurkiewicz *et al.* 2019). This reduction of production would allow the plant to process pit content of 40,000 households and will act as a subsidy for faecal sludge management.

However, while carrying out the study, IRC found that considering faecal and agri-waste only will just address the problem partially. The town requires an integrated waste management and therefore an integrated solution is required (World Bank 2006). The technical solution often does not work due to the weakness of the system. Thus, IRC designed a feasibility study for integrated waste management in the town of Bogura and carried out the study in 2018.

MATERIAL AND METHODS

The feasibility study team developed a methodology considering two issues as the backbone (Arikan & ÖzalpVayvay 2016): environmental and financial sustainability. It tried to work out the magnitude of the waste management problem. It observed the inhabitants and industries to sketch the full cycle of waste generation, transportation and dumping. It also tried to identify the points of contamination and their scale. It followed the rapid assessment method for data collection. The rapid assessment consisted primarily of quantitative research methods; data were collected mainly through structured interviews and direct observations (Baetings *et al.* 2014). The interviews included people from the municipality, waste collectors, informal waste entrepreneurs, civil society organizations, etc. Visual observations included different waste collections, transportation and dumping process. As well, desk research was carried out on the available regulations and technologies. It identified the complex and interlinked system working for WASH and waste management in the municipality and tried to track the status of the components of the system (Huston & Moriarty 2018). While identifying the technology solution it followed the same approach. It looked at different technologies, their suitability to the local conditions and footprint on the environment. It tried to find an integrated solution that can solve the environmental challenges and can help to gain financial sustainability through income generation.

The key principles of the study were as follows:

- Identify the wastes generated in the town and its surrounding areas.
- Identify the location and pattern of dumping sites.
- Characterization of the waste and identifying the full waste chain.
- Identifying the ideal solution for the problem that matches with the local context.

RESULTS AND DISCUSSION

The team carried out the study by collecting data from different sources. They include observation of the situation, interviewing key personnel, secondary document review and best-case analysis. The team fixed a few objectives while collecting the data. They are as follows:

1. The utilization of agriculture waste and faecal sludge for the production of organic fertilizer, electricity and heat. The latter two are required for the second component of the project.
2. The utilization of municipal solid waste (MSW) for the production of a high calorific biofuel, which can replace fossil coal, and the recycling of glass, metal (ferro and non-ferro), propane, butane and dimethyl ether.
3. Enhanced and/or new service companies to collect agricultural and municipal waste and untreated faecal sludge.
4. Enhancement of the city's administration and management of both its waste, water and sanitation management.

Waste situation – four waste streams

The study has developed a full-scale analysis on the solid waste situation of the town. The town has 524 staff for solid waste collection. The per capita production of waste is around 0.55 kg per day. The daily production of the municipality is around 160 ton. It has three trucks and 102 small vans (manually pulled) for waste collection. The town has two dumping sites and ten transfer stations for solid waste. Apart from the two legitimate dumping sites, there is another site where waste is being dumped illegally. Around 80 ton waste per day is being collected and dumped to those sites. It has a serious impact on the environment. The air quality is 100–150 AQI (PM 2.5) and biochemical oxygen demand (BOD) of the nearby surface water quality is 40–50 mg/L. Due to lack of available equipment in Bogura, the study could not measure the BOD of the nearby groundwater. There is no treatment system available for solid waste in the town. The solid waste mainly includes organic wastes, plastics, glass and scrap metals such as aerosol cans. Figure 1 illustrates a summary of different municipality solid wastes and other wastes dumped per day.

Unlike other areas of the country, Bangladesh Small and Cottage Industries Corporation (BSCIC) has established two sites in Bogura for small industries which has helped to grow 1,000 light engineering factories there. They roughly generate 15,000 empty aerosol cans which contributes to greenhouse gas emission (Ahsan & Nasim 2018).

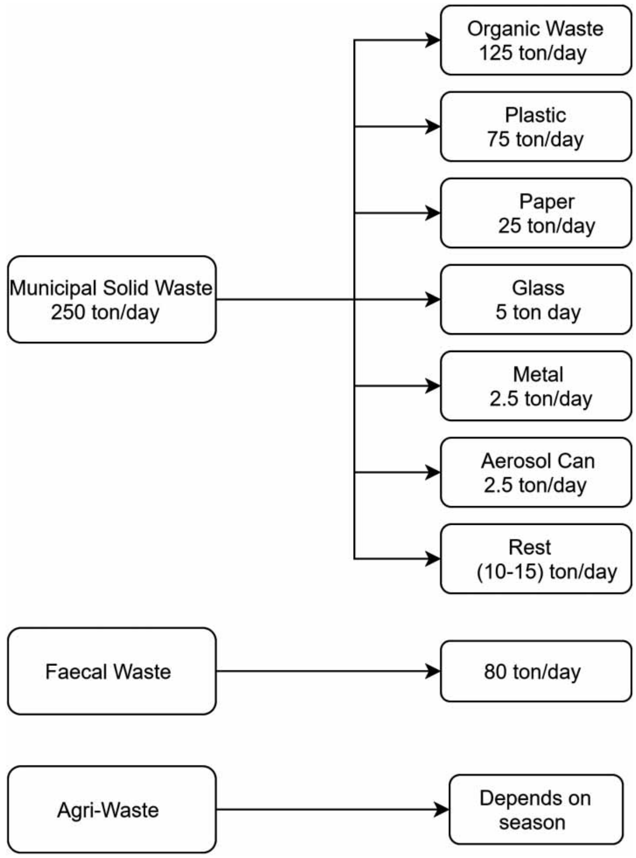

Figure 1 | Volume of the different types of wastes generated per day in Bogura town.

There are around 55,000 households in the town. Thirty-five per cent of the households have septic tanks, 45% of the latrines are single pit latrines and the rest are double pit latrines. Most of the septic tanks have faulty designs so work only for confinement not treatment. The town has no sewer system, neither does it have a safe sludge collection and treatment system. Observations and interviews found that a large proportion of the latrine pits and septic tanks are connected to nearby water bodies and drains. Other people manually empty their pits/tanks with the help of pit emptiers and dump the sludge in nearby water bodies.

Another waste stream identified during the study is agri-waste. There are croplands available near the town and some agri-processing industries are situated in the town. This generates approximately 40 ton of agri-wastes that contribute to greenhouse gas (GHG) emission. Around 1 million ton of waste was dumped in Kalitola dumping yard which is no longer used, but the waste is still there and generating leachate to contaminate the groundwater. Additionally, at least 900 MT CO_2 equivalent is being emitted per day due to methane generation from it (Park *et al.* 2017).

Exploring the service delivery system

The WASH and waste service delivery system relies on an entire, complex and interlinked WASH system, and that WASH sector reform requires the ability to engage with and strengthen that system as a whole (Schouten & Moriarty 2013). Delivering access to sustainable services requires a strong and capable system. The system strengthening process is demonstrated in Figure 2.

Actors range from individuals in a rural household to large institutions, including the private sector, civil society and public agencies, all of which play a part in delivering or using WASH services and thus in achieving the goal of universal access. In the context of Bogura, the municipality is primarily responsible for waste management under the Municipality Act 2009. As such, common actors in the process are:

- Municipality
- Public Health Engineering
- Department of Environment
- Local Government Division.

Visual observation of the process found some other actors playing a role in the system. They are:

- Informal entrepreneurs
- Water resources management
- Investors
- NGOs/CSOs.

Factors are system elements and influences: technologies, markets, cultural and social norms, and aid mechanisms, all of which are complex and interlinked (Schouten & Moriarty 2013). Identified factors of this process are:

- Knowledge on policy
- Willingness to invest
- Policy and integration
- Political leadership
- Lack of awareness
- Community
- Participation.

The building blocks of the system were also looked at and they are as follows:

- Institutions: municipality, Local Government Division of the Ministry, Department of Environment, Department of Health.
- Policy and legislation: the Municipality Act 2009, Bangladesh environment policy 2018, Bangladesh water rule 2018.
- Finance: national allocation, municipalities income, private investment.
- Regulation and accountability: role and responsibilities of the concerned departments mentioned above.
- Monitoring: process of environmental data collection and its effectiveness.
- Planning: the ability to set out pathways to achieving policy goals.
- Infrastructure: hardware present at this moment to manage the generated waste.
- Water resource management: managing the ground and surface water being contaminated by the generated waste.

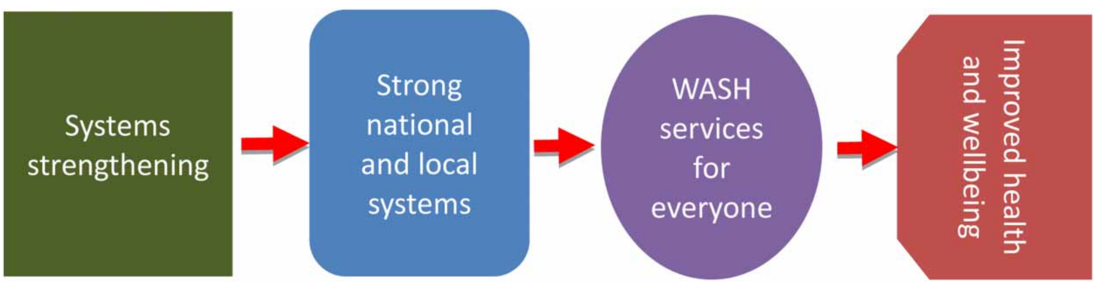

Figure 2 | System strengthening process pathway.

- Learning and adaptation: the ability to adapt in the face of change, to monitor and maintain progress towards a vision.

Solution

Based on the study, the team designed an integrated waste management solution for the municipality. To treat the faecal sludge and wastewater, anaerobic digestion was found to be the best solution, a proven technology and when integrated with agri-waste, a feasible solution. It will produce biogas, which will subsequently be used to generate electricity. However, making the faecal sludge and wastewater pathogen free was still a challenge. Thus, IRC together with ICDDR'B carried out another study and developed a protocol to make the waste free of risky pathogens (Dey *et al.* 2016; Mahmud *et al.* 2016). Having tackled faecal waste, MSW remains the key challenge. The MSW contains a combination of wastes that are difficult to treat by one technology. The team has considered different technology options for the MSW management such as gasification, thermal depolymerization, pyrolysis, torrefaction and plasma arc gasification. There were three criteria for selection: process safety, input efficiency and product demand. Based on these, torrefaction was selected as the best model to be implemented. The reasons are the process complies with the safety guideline of the Department of Environment and it can utilize a mix of solid wastes (kitchen waste, green market waste, plastics and papers). It will produce biofuel (bio-coal or green coal) by processing the organic and plastic part of the MSW (Energy-expert 2019). It is being used in Germany, Indonesia and some other countries with different commercial models (Gent *et al.* 2017). The remaining elements (i.e., glass and metal) will be used for recycling. This will significantly contribute to reduce leachate generation and thus help to reduce groundwater contamination at a significant level. Another key

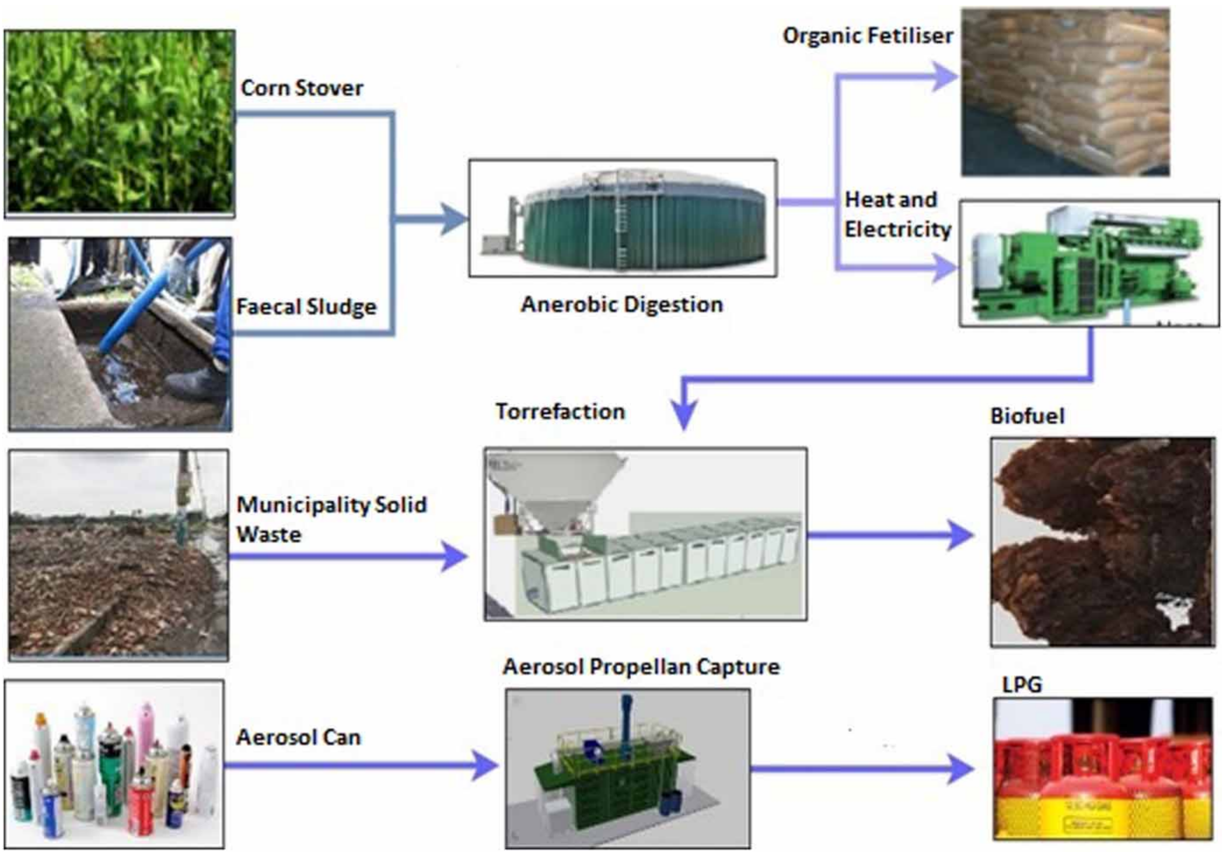

Figure 3 | Overview of the project design.

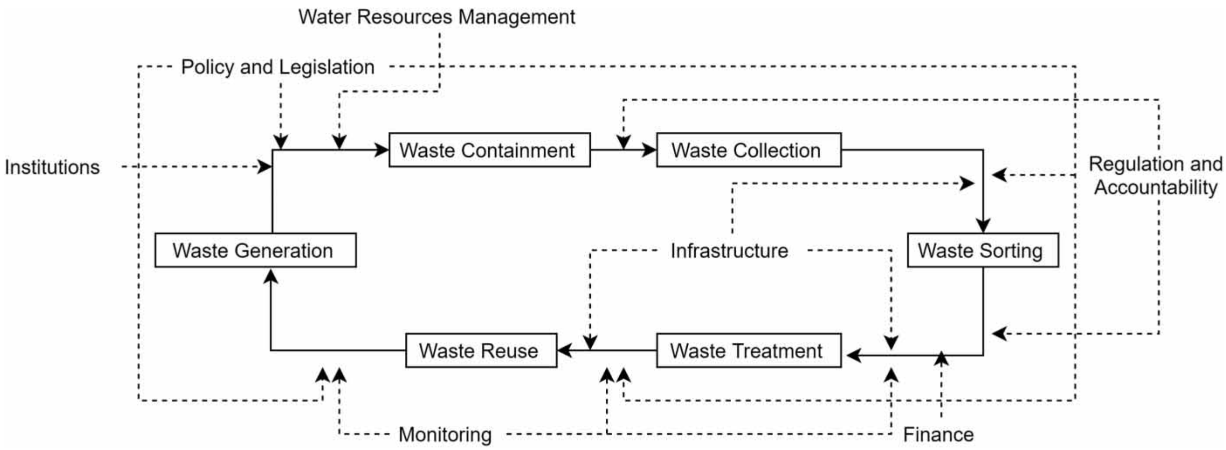

Figure 4 | Proposed involvement of different stakeholders to strengthen the system.

challenge was the aerosol cans, thus the design integrated aerosol propellant capture technology which collects gas from the aerosol cans which can be used for refilling LPG cylinders. The Department of Environment has developed guidelines for sludge management which include recommendations for such aerosols and the proposed solution complies with that (DoE 2015), which makes it a zero waste model. Figure 3 describes the insertion of different wastes in the system.

However, to operate such a process, system strengthening is necessary and so the study looked into the process and identified areas where system strengthening is needed. It identified the lack of integrated thinking about different wastes and water streams. It found that existing policy and regulation is strong but requires more involvement of different stakeholders in planning and especially monitoring. Thus, the study proposes the involvement of different stakeholders at different levels (Figure 4).

CONCLUSIONS

Altogether, this model provides a zero waste solution of waste management for a city. It started with the idea of addressing the water and waste management problems of the town and expanded to overall improvement of the environment. It will contribute to waste and wastewater management, ground and surface water quality improvement, and air quality improvement. Another objective of this initiative is to gain financial sustainability of the integrated waste management model. This model addressed different waste streams of the municipality and proposed to address them with different solutions. The strength of the integrated model is that some streams are highly profitable (biocoal and biogas), whereas some are not (such as faecal sludge collection and transportation). Integrating these different streams means they can support one another to result in financial sustainability. However, the point of the study is not just to propose a technical solution. It looked at the existing system and also looked at the points where the system can be strengthened so that it can address all the WASH and waste issues together. The model has the strength to be replicated in other similar cities. It has the flexibility to be adjusted to different contexts based on the availability of feedstock, management structure and product demand. Thus, it has the potential of scale-up in different cities.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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