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A Planning Framework for Municipal Solid Waste Disposal Decision-Making

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Abstract

This study presents a framework for sustainable planning and decision-making for municipal solid waste (MSW) disposal in the context of developing countries. The framework was developed through a detailed study of MSW disposal in Ghana, using the Wa Municipality as a case study. The methodology and research design for the study was a descriptive and interpretive case study that was analysed through both qualitative and quantitative research methods. The developed framework consists of three main pillars of solid waste management (SWM) elements: MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW disposal environmental performance. The framework can assist waste management decision-makers to take the guesswork out of decisions for waste management planning in developing countries, as the framework incorporates a better picture of how a current waste management system works and what effects changes could have, through an integrated environmental performance evaluation. Furthermore, the application of the framework has the potential to increase the level of decision-makers' awareness of the environmental burdens of MSW disposal and possibly lead to the reduction of the future undesirable environmental effects of MSW disposal in some developing countries.

Keywords: Municipal Solid Waste; Planning Framework; Decision-making Framework; Waste Management; Developing Countries.

1.0 Introduction

Several waste management technologies are available at the current time with different waste management capacities (Das *et al.*, 2019). Cities in the developing world are besieged by private vendors selling technologies, most of which are inappropriate (Dedinec *et al.*, 2015), however, these cities usually have a limited technical capacity and analytical tools for assessing their claims and viability. Many times unsuitable systems have been built, only to close within months of costly start-up operations (Kamali *et al.*, 2016).

The variables affecting municipal authorities' decision-making on solid waste (SW) technology and management choices in developing countries have become more complicated, especially when consideration for greenhouse gases (GHG) reduction and avoidance, landfill-minimisation, and land reclamation are involved (Soltani *et al.*, 2015; ThiKimOanh *et al.*, 2015; Adipah and Kwame, 2019). These have made the waste sector a specialised industry, with high technological standards; therefore, engagement with the sector requires in-depth experience, thorough research and engineering expertise.

Many of the technologies applied in reprocessing and recycling waste, extracting energy and producing other products from waste and gas captured from landfills, may have been tested in commercial use in industrialised countries, but the effort required to adopt these technologies to local conditions in developing countries is usually underestimated (Ouda *et al.*, 2016). For example, an old technology like landfill gas extraction does not work in a developing country such as Ghana in the same manner as it does in Germany

(Bos and Gupta, 2019; Präger *et al.*, 2019). Therefore, knowledge of the local context and the appropriate adaption to local conditions are just as important as technological knowledge.

The equipment used must match with the composition, quantities and qualities of waste delivered to the facilities, the local climatic conditions and the potential demand for products derived from the waste (Mutz *et al.*, 2017). However, many city authorities in developing countries are overwhelmed with the magnitude of the waste problem, and often tend to seek out environmentally friendly but costly win-win technologies via public-private partnerships with investors often from the North, regardless of the fact that these technologies may be inappropriate for their local conditions (De Clercq, Vats and Biel, 2018). The authorities' intentions may be out of goodwill, but the approach most often is born out of an empirical vacuum.

Decision-making in waste management is a complex issue and requires clear goals, appropriate methods, and reliable data of known uncertainty (Stanisavljevic and Brunner, 2014). The objectives of waste management are multidisciplinary: protection of humans and the environment, conservation of resources and no export of waste management problems into the future. These goals cover hygienic, environmental, engineering, socio-economic and ethical aspects. Hence, methods to support decision-making in waste management must be able to cope with all these topics.

In this regard, this study presents a developed and validated framework for sustainable planning and decision-making for MSW disposal in the context of developing countries using Ghana as a case study. The framework proposes the integration of both MSW management and operational performances evaluation to obtain a holistic environmental performance (which is currently non-existent in the case study area and many other developing countries) to aid decision-makers to base their MSW disposal planning and decision-making on the environmental exchanges of the disposal system.

2.0 Materials and Methods

The planning framework for municipal solid waste disposal decision-making was developed based on the findings of one conference paper and three journal papers: An Investigation on Municipal Solid Waste Generation and Characteristics (Bowan *et al.*, 2018); Municipal Solid Waste Disposal Operational Performance (Bowan *et al.*, 2019); A Baseline Scenario of Municipal Solid Waste Management (Bowan, Kayaga and Fisher, 2020); and Municipal Solid Waste Management Performance (Bowan *et al.*, 2020).

For the Investigation on Municipal Solid Waste Generation and Characteristics in Ghana, the data was obtained from secondary data sources, using qualitative and quantitative research methods, through documentary analysis and content analysis of published literature and official documents. The secondary data obtained for the study was deemed valid, reliable, and accurate since the research design and methodology and data analysis of the documents viewed followed research protocols. The paper on Municipal Solid Waste Disposal Operation Performance applied both qualitative and quantitative research methods and modelled the Wa Municipality's MSW disposal system using the municipal solid waste decision support tool (MSW DST).

Furthermore, baseline scenario of municipal solid waste management (MSWM) in Ghana was established through material flow analysis and understanding of MSW handling practices, using the Wa Municipality as a case study. The study was theoretically based on empirical observation and an exploratory design. The methodology and research design for the Municipal Solid Waste Management Performance evaluation was an exploratory and interpretive case study that was analysed through both qualitative and quantitative research methods.

The Investigation on Municipal Solid Waste Generation and Characteristics in Ghana revealed that MSW composition in Ghana was more organic (60%). Also, Municipal Solid Waste Disposal Operation Performance evaluation indicated that separation, composting, incineration, refuse derived fuels (RDF) and landfill disposal; and separation, transfer, material recovery, composting, incineration, RDF and landfill disposal in an integrated SWM system, produced the least engineering cost and the least average health impacts, whereas, composting and landfill disposal of MSW generated the highest engineering cost and equally produced the highest average health impacts.

The findings on the Baseline Scenario of Municipal Solid Waste Management showed that sustainable waste management has remained elusive because MSWM in the case study area and Ghana in general, consist of some waste collection, transportation and open dumping, where the entire amount of waste is open dumped without pre-treatment. The Municipal Solid Waste Management Performance evaluation also revealed that Ghana has a good institutional framework, sufficient and robust legislation, existing bylaws, policies and programmes regarding MSWM. However, the challenge was the non-enforcement of and non-compliance with the laws and regulations governing MSWM.

These research findings formed the basis for the development of the framework for sustainable planning and decision-making for municipal solid waste (MSW) disposal in the context of developing countries.

3.0 Discussion

3.1 Conceptual Formulation of the Framework

The developed framework consists of three main pillars of SWM elements: MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW disposal environmental performance, as illustrated in Figure 1. There is a continuous-reversal sequence and an intrinsic relation between the three pillars, with equal importance placed on each pillar in the framework.

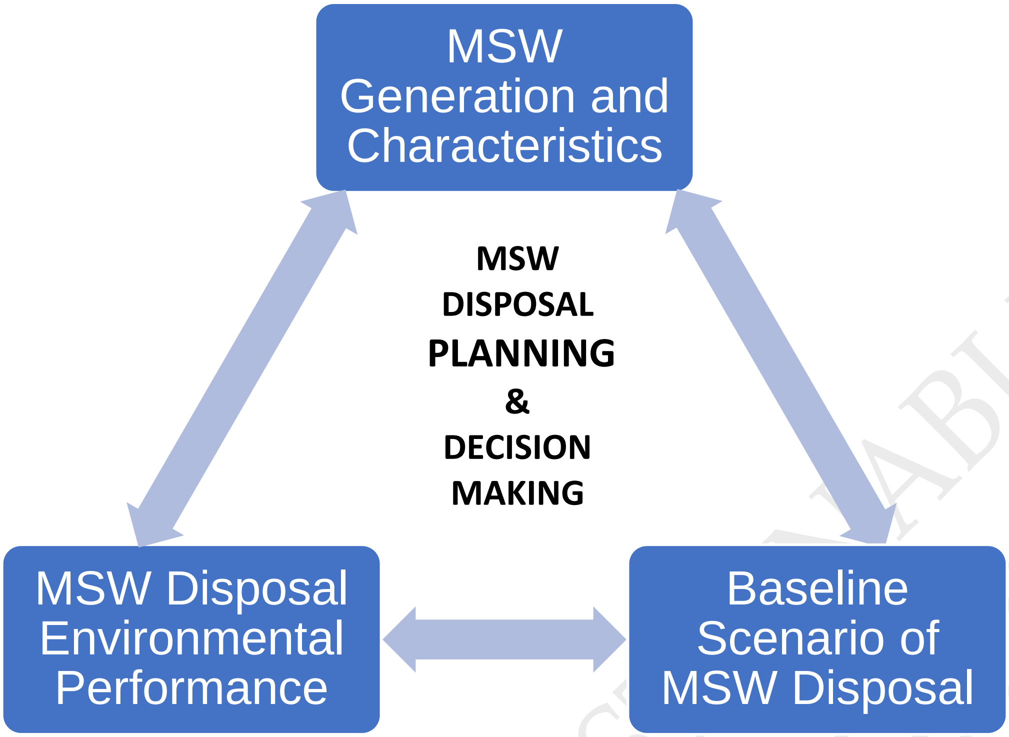

Figure 1: Planning framework for MSW disposal decision-making

3.1.1 MSW Generation and Characteristics

Many researchers indicate that accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated (Miezah *et al.*, 2015; Abbasi and El Hanandeh, 2016; Asante-Darko, Adabor and Amponsah, 2017; Singh, 2019). Sound waste management and optimisation of resource recovery from waste, equally, require reliable data on the generation rates and characteristics of waste (Edjabou *et al.*, 2015; Ferronato *et al.*, 2019). Thus, the MSW generation rates and characteristics, which depend on urban population, economic development, consumption rate, geographic location, and administrative systems (Saidan *et al.*, 2020), have a direct impact on the baseline scenario of MSW disposal in a location. MSW disposal activities include MSW segregation at the point of generation, MSW reduction, storage, collection, transportation, processing/treatment, and final disposal.

Also, the adequate knowledge of the MSW generation and characteristics, assist in the formulation of targets for waste reduction and material recovery. These reduce the environmental effects of MSW and lead to the overall improvement of MSW disposal environmental performance (emissions from MSWM activities).

Furthermore, the handling and processing/treatment (operational performance) of organic and inorganic waste are quite different. For instance, waste-to-energy technologies such as incineration are not appropriate for the processing/treatment of organic waste which are high in moisture content, since the moisture content influences the calorific value of waste (Zhao *et al.*, 2014; Tom, et al., 2016). Thus, organic and inorganic MSW produce different environmental impacts, which in turn influence the overall MSW disposal environmental performance differently, especially MSW disposal operational performance (emissions).

On the other hand, MSW disposal environmental performance, particularly MSWM performance indicators such as policy, legal, institutional, and financial arrangements for SWM also affect MSW generation and characteristics. For instance, the enforcement of and compliance with SWM policies, regulation, and laws will determine the quantity and composition of MSW generated (in a particular location).

3.1.2 Baseline Scenario of MSW Disposal

The baseline scenario of MSW disposal include the handling practices of MSW, such as waste segregation, storage, collection, transfer/transport and processing/treatment, and the attitude of waste management stakeholders (waste generators, regulators, and service providers). The baseline scenario of MSW disposal depends on the MSW generation and characteristics and stimulates the overall MSW disposal environmental performance and vice-versa.

Effective waste management laws enforcement compels waste generators, especially households to comply with waste management laws and regulations, such as segregation of SW at the generation point. Waste segregation is the first step in material recovery from waste and waste reduction programmes. Material recovery from waste usually leads to a reduction in the quantity of MSW that must be properly disposed of, and this eventual improves the overall MSW disposal environmental performance.

3.1.3 MSW Disposal Environmental Performance

The efficient operation of SWM systems (operational performance) is dependent on good MSW streams analysis and accurate predictions of SW quantities, the baseline scenario of MSW disposal, and good MSWM performance. For instance, the equipment used for waste management must match with the composition, quantities and qualities of waste delivered to waste management facilities, the local climatic conditions and the potential demand for products derived from waste (Mutz *et al.*, 2017).

MSW disposal environmental performance evaluation integrates environmental and human health risks in the assessment process, consequently ensuring that new policies are adopted by decision-makers under the concept of continuous improvement of waste management systems (Ansari *et al.*, 2019; Lam *et al.*, 2020). Waste management environmental performance is divided into two components: management performance (MP) and operational performance (OP).

MP indicators are generally related to the sustainability aspects (social indicators), which are the governance features (institutional, political, and financial issues) and the various groups of stakeholders involved in waste management, whereas the OP indicators are usually concerned with the physical system and its technological components, with more focus on the environmental sustainability (environmental indicators, such as emissions) aspect of the system (Bowan *et al.*, 2019; Serrano *et al.*, 2019).

Thus, MSW disposal environmental performance covers not only operational aspects, such as the handling, transfer, transport, separation, processing, and disposal of waste, but also aspects on public perception, environmental, economic, and social issues (Bowan *et al.*, 2020). Waste management activities are apparently impossible to implement without high consciousness within the communities as well as a strong commitment and support from waste management authorities (Bowan and Ziblim, 2020). Thus, a good/bad MSW disposal environmental performance depends on the MSW generation and characteristics, and the baseline scenario of MSW disposal.

3.2 Framework Validation

The framework was validated by senior staff of Ghana's Environmental Protection Agency (EPA), who regulates waste management, in the Upper West Region (UWR) and a Municipal Engineer each (in a focused group) from *Wa*, *Lawra*, *Jirapa* and *Sissala East* Municipalities in UWR, Ghana. Given that, the best practice in managing SWM is through an integrated solid waste management (ISWM) system, and waste management regulators (such as EPA in Ghana) and service providers (local authorities) are solely responsible for MSW disposal decision-making in most developing countries, it was essential for the staff of EPA and Municipal Waste Engineers to confirm or challenge the findings.

Therefore, waste management regulators and service providers were selected to validate the framework in order to ascertain the theoretical perspectives of the framework. This ensured that the developed framework is theoretically fit for purpose and provides a theoretical standpoint for the concept of MSW disposal and contributes to theories in ISWM. Answers to the framework validation questions are presented in Table 1.

Table 1: Findings from Framework Validation

Question	Responses	
	EPA	**Municipal Engineers**
How important are all the elements of the framework to effective MSW disposal?	Very important	Very important
How easy is it to understand the framework?	Arrows show a continuous sequence of the relationship between the elements of the framework	Explanation of the elements of the framework makes it easily understandable
To what extent will you say this framework is adequate for effective MSW disposal decision-making?	Very adequate	For MSW disposal, the framework is adequate but how the MSW generation and characteristics will be determined is challenging in the current circumstances
To what extent is this framework logical?	Logical	Very logical
Do the elements suggested in the framework address MSW disposal problems?	Yes	Yes
How transferrable is this framework to other MSWM activities?	It is transferable	Very transferable
What do you consider as the strengths and weakness of the framework?	Strength: sequence relationship and vivid description of elements Weakness: how to easily determine the adequacy of the framework elements	Strength: it is quite simple Weakness: needs resources to implement
What can be added to and/or removed from the framework?	Add: details of the framework elements Remove: nothing	Add: nothing Remove: nothing

From the answers in Table 1, the validators of the framework agreed that elements of the framework are very important to effective MSW disposal and MSWM in general. They also approved that the framework is logical, addresses MSW disposal problems, adequate, and transferable to locations and other MSWM challenges. However, there was a suggestion by EPA validators that the details of the elements of the framework (MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW disposal environmental performance), should be added to the framework. Thus, the researcher added the details of the elements of the framework as suggested by the EPA validators and produced the validated framework for MSW disposal planning and decision-making in developing countries, as shown in Figure 2.

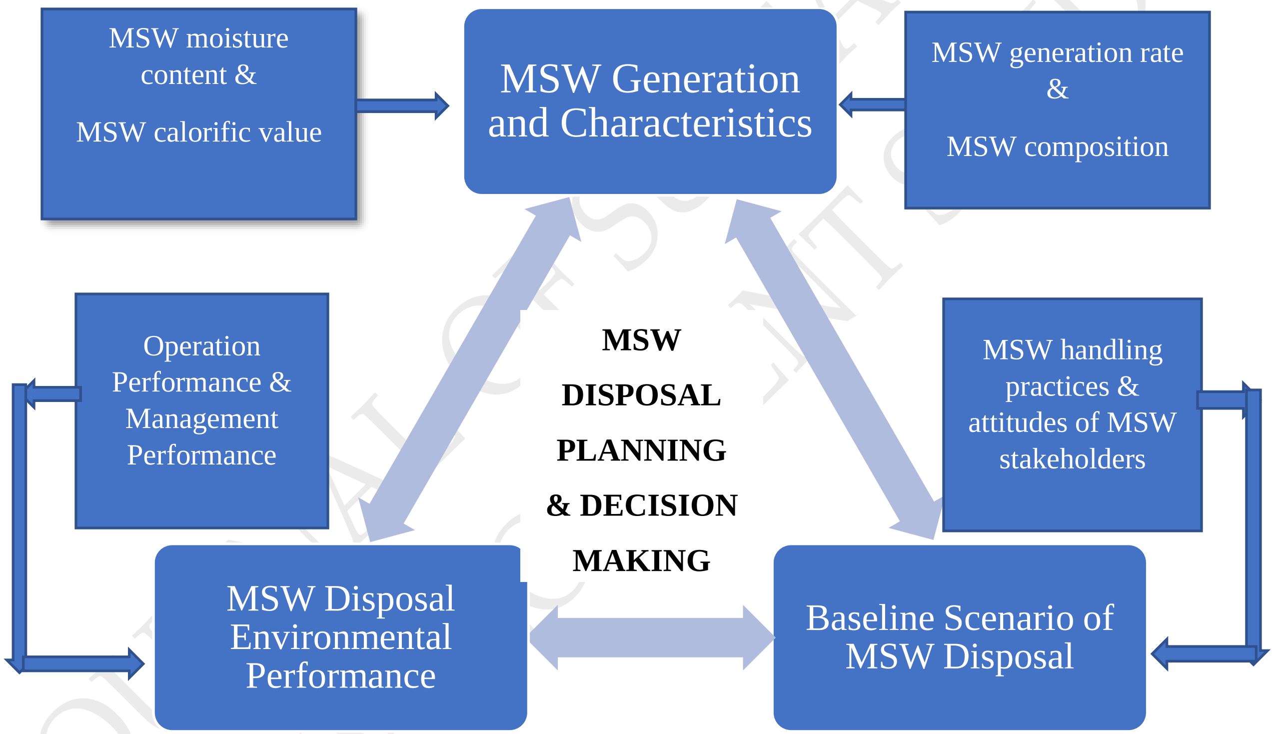

Figure 2: Validated planning framework for MSW disposal decision-making

This framework can assist waste management decision-makers to take the guesswork out of decisions for waste management planning in developing countries, as the framework incorporates a better picture of how a current waste management system works and what effects changes could have, through an integrated environmental performance evaluation. Thus, the application of this framework has the potential to increase the level of decision-makers' awareness of the environmental burdens of MSW disposal and possibly lead to the reduction of the future undesirable environmental effects of MSW disposal in developing countries.

4.0 Conclusion

Concerns of sustainable development (SD) has made sustainable MSWM, especially in developing countries, prominent in the current time. Consequently, the United Nations (UN) General Assembly, included MSWM in the 2030 Agenda for SD. The specific goals which focus on waste management include:

- sustainable development goal (SDG) 11 - "*Make cities and human settlements inclusive, safe, resilient and sustaina*ble". This is properly delineated in target 11.6: *"By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management*.
- SGD 12 – "*Ensure sustainable consumption and production patterns*", and appropriately outlined in targets:

  12.2 - "*By 2030, achieve the sustainable management and efficient use of natural resources*",

  12.3 – "*By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*"

  12.4 – "*By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment*", and

  12.5 – "*By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse*". (UN, 2018).

This developed and validated framework for MSW disposal planning and decision-making, together with its three main pillars (accurate prediction of MSW generation rates and characteristics, a good knowledge of the baseline scenario of MSW disposal, and a good MSW disposal environmental performance), has the potential of contributing to the attainment of the above mentioned targets and some of the other 2030 SDGs, through the improvement of planning and decision-making for MSW disposal in developing countries.

Competing Interests

The author declare no competing financial interests.

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