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# Anaerobic Digestion (AD) for MSWM: Development of a simple guideline for policy makers and practitioners in emerging countries

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## ABSTRACT

Organic waste presents a significant portion of MSW compositions in many cities. A proper treatment of organic waste is therefore an important concern, particularly in low and middle-income countries. Biological treatment methods are widely accepted as technical option to get the full advantage of organic waste as a resource. The most popular treatment options for the biological fractions of MSW are either an aerobic treatment such as composting or an anaerobic treatment such as fermentation or anaerobic digestion (AD). Considering the demand and some advantages of applying AD method in MSW, this paper aims to present the framework for development of a guideline for policy makers and implementers to be able to anticipate and manage risks as well as planning the related matters when they consider implementing AD technology for waste management. The guideline development is based on literature reviews, focus group discussions with practitioners and stakeholders and some field visits. In the guideline, we present the key elements, technical planning steps, sustainability aspects, and case studies from various countries.

**Keywords:** anaerobic digestion (AD), biogas, municipal solid waste management (MSWM), technical guide, sustainability factors

## INTRODUCTION

The composition of municipal solid waste (MSW) usually depends on the level of national income and the local urbanization level. It can be estimated that the lower income countries usually have a higher percentage of organic waste amounting 60% of total waste generation (World Bank, 2018; UNEP/ISWA, 2015). These estimations also revealed that even in the high-income countries, organic waste still accounts for the biggest individual fraction of MSW (approximately 30%) when compared to other types of waste such as plastics, paper, glass, metal and others. This implies that finding the most appropriate methods and technologies to manage organic waste is important regardless of development and economic level of a country.

To get the full advantage of the resource potentials from organic waste, there are some biological treatment methods widely recognized and practiced, such as composting and AD. Considering its advantages in addressing both energy and material recovery (soil conditioner), AD method is the main focus of this study.

AD process captures the Greenhouse Gases (GHG) emitted by organic waste that would otherwise be released to the atmosphere if waste is being landfilled. It will then generate biogas with a $CH_4$ concentration of 50 to 65% (which could be used in thermal or co-generation process to produce thermal and electrical energy or upgraded towards natural gas quality). AD-based energy contributes to the world's effort in avoiding fossil-fuel based energy by providing clean and renewable energy. Depending on the process (dry or wet fermentation) AD produces slurry with a dry matter content of 6 to 20% dry matter. By dewatering the slurry, fertigation water and landscape conditioner could be produced. Despite of the seemingly perfect solution of using AD to treat organic waste, both decision-makers and practitioners found it difficult to start or sustain AD plants using MSW. This study therefore aims to develop a simple guideline for policy makers and practitioners, especially in low and middle-income countries to build their decision-making capacity in applying AD into city or national waste management systems. The guideline covers key sustainable aspects, including geographical conditions, social conditions, institutional aspects, governance, financial, and technical in the planning and operation of the technology. It also presents some selected case studies from both the lower- and upper-income countries and various scale of AD plants and projects.

## MATERIALS AND METHODS

The study applies the literature review, interviews, focus group discussions, case study analysis and field observations as a key method to collect relevant information on AD methods and its sustainability aspects such as technical, financial, and other aspects that lead to the success or failures of an AD plant planning for MSW. In the literature review, more than 50 studies on the subject of AD and its practices worldwide was reviewed using including scientific journals, private sector websites, and governmental reports. Among them, few case studies will be selected for in-depth analysis. This will be conducted in various forms such as interviews, written correspondences, focus group discussions and site visits.

## RESULTS AND DISCUSSION

The findings so far highlight that the majority of successful AD plants in the emerging countries are practiced in the smaller scale in rural areas. However, large-scale plants in the urban areas are facing some challenges in sustaining its operation, such as 1) High initial investment, 2) Fluctuations of feedstocks due to seasonal availability, 3) Finding appropriate market for the soil conditioner and fertigation water, and 4) The problem of feedstock impurity. Our findings revealed that some of the solutions could be: 1) Green energy tariffs that could support for the financial the success of an AD projects, 2) High volume of digestate should be anticipated by securing market for soil conditioners and fertigation water, and 3) Better waste separation at source and collection is necessary. These findings highlighted the importance of having well preparation by the policy-makers and practitioners before introducing the AD into their waste management system.

## OUTLINE OF THE GUIDELINE

Based on the preliminary findings, the following guideline outline was determined: 1) Introduction, 2) Background and objectives, 3) Key elements, 4) Technical planning, 5) Sustainability aspects, and 6) Case studies. In the *Introduction* part, the definition and importance of AD will be elaborated. In the *Background and objective* part, the development of AD in various regions, especially in Asia will be presented and the technical variety such as different types, feedstocks, scale, and use of outputs will be summarized. In the *Key elements* part (Table 1), the "soft-elements" that need to be checked for decision-making is discussed. These are including social conditions, institutional aspects, governance capacity, technical and financial aspects, and public awareness.

**Table 1 Key elements to be checked before implementation of an AD project**

| Classification | Items |
|---|---|
| Social Conditions | Target city population, social needs, infrastructure, residence cooperation and awareness |
| Institutional aspects | Laws and regulations enforcement, administrative effectiveness, construction cite adequacy |
| Governance Capability | Government roles, capacity, and leadership |
| Financial aspects | Capital funds, tipping fee, revenues, financial risks |
| Technical aspects | Local MSW basic data, technical capacity of manufacturing, implementing, operation, and maintenance |

In the *Technical planning* part (Figure 1), basic technical planning steps for an AD project will be discussed. These are including: 1) source of inputs, 2) calculation of biogas amount, 3) selection of technology, 4) size of digester, 5) size of engine, 6) site layout, 7) flow chart, 8) estimate of costs, 9) use of outputs (energy and liquid fertilizer), and 10) operation and monitoring. In the *Sustainability aspects* part, the social, environmental, and economic effects of AD projects will be discussed. And finally, in the *Case study* part, good practices from different countries will be presented so that lessons could be learnt, and good strategies can be replicated. Some of the featured case studies are from Japan, Indonesia, and Germany (Table 2).

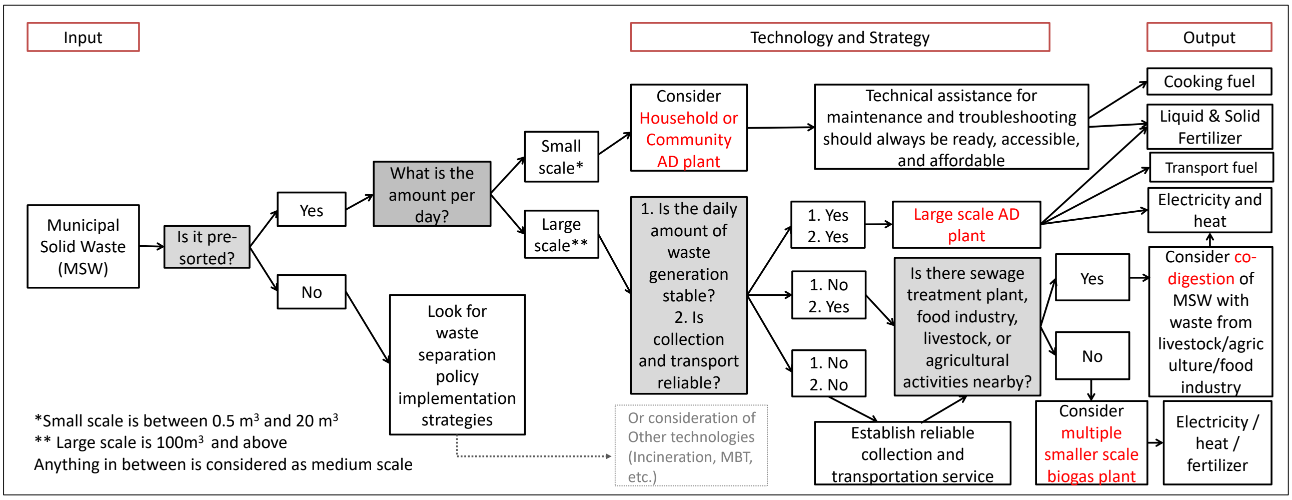


**Figure 1 Project technical planning flow recommendation for MSWM with AD**

**Table 2 Good Practice of MSWM using AD Technology**

| Location | Feedstock | Capacity | Technology Specification | Output | Notes |
|---|---|---|---|---|---|
| East Java, West Nusa Tenggara, Central Java, Jogjakarta, West Java, Bali, East Nusa Tenggara, South Sulawesi, and Lampung, Indonesia | Animal farming / small-scale food industry organic waste | Small scale | Fixed Dome Bio-digester | Equivalent to daily rural household needs for lighting and cooking | The country-wide project is taking place mainly in the rural area where access to highly subsidized LPG tank is limited |
| Oki Town, Fukuoka, Japan | Kitchen waste, Human Waste, Septic Tank Sludge | Kitchen waste (3.8 TPD), Human Waste (7 TPD), Septic Tank Sludge (30.6 TPD) | Medium temperature(37°C) methane fermentation tank | Electricity (752 kWh per day) | Interlinked with local agricultural production using the effluent liquid manure |
| Gütersloh City, Northrhine-Westfalia, Germany | Source-separated household organic waste | 30,000 TPY | Dry Fermentation | approx. 5.7 million kWh / year | The attached composting plant uses park and garden waste in addition to the household waste |

## CONCLUSION

This study responds to the critical issue in addressing the appropriate technology and treatment methods to manage the organic fraction of MSW especially utilizing the advantages of AD technology. A simple guideline covering the basic knowledge, most important success factors, and pitfalls is being developed through discussions among experts, literature reviews, and interview with the AD practitioners. The results help to develop more practical, appropriate and user-friendly guideline for policy-makers and practitioners in developing countries including a flow chart to make decisions in planning, and important information about aspects affecting and resulting in implementation socially, environmentally, and economically. The guideline also elaborates factors that will influence the future of AD such as technology development, trends of national policies and agenda, and business and international collaboration opportunities.

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