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Sustainable Solutions for Municipal Solid Waste Management in Thailand

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***Abstract*—**General as well as the MSW management in Thailand is reviewed in this paper. Topics include the MSW generation, sources, composition, and trends. The review, then, moves to sustainable solutions for MSW management, sustainable alternative approaches with an emphasis on an integrated MSW management. Information of waste in Thailand is also given at the beginning of this paper for better understanding of later contents.

It is clear that no one single method of MSW disposal can deal with all materials in an environmentally sustainable way. As such, a suitable approach in MSW management should be an integrated approach that could deliver both environmental and economic sustainability. With increasing environmental concerns, the integrated MSW management system has a potential to maximize the useable waste materials as well as produce energy as a by-product.

In Thailand, the compositions of waste (86%) are mainly organic waste, paper, plastic, glass, and metal. As a result, the waste in Thailand is suitable for an integrated MSW management. Currently, the Thai national waste management policy starts to encourage the local administrations to gather into clusters to establish central MSW disposal facilities with suitable technologies and reducing the disposal cost based on the amount of MSW generated.

***Keywords*—** MSW, management, sustainable, Thailand

I. Introduction

WORLD population continues to rise with projections nearing 7.2 billion by 2015 [1]. "The increasing volumes of waste being generated would not be a problem if waste was viewed as a resource and managed properly" [2]. Municipal Solid Waste (MSW) is the most complex solid waste stream, as opposed to more homogeneous waste streams resulting from industrial or agricultural activities [3]. MSW is defined to include refuse from community activities, such as residential households, commercial and business establishments, fresh markets, institutional facilities and construction and demolition activities, and to exclude hazardous and infectious wastes.

The increase of MSW generation rate and the diversity of MSW types cause by the increases of population, changing consumption patterns, economic developments, changing incomes, and urbanization. Increased MSW generation creates more environmental problems. Solid waste has been one of the environmental problems in urban areas of Thailand. The main effect is the environmental degradation, caused by insufficient MSW disposal. The disposed MSW impact is composed of: (i) the odor from landfills, (ii) the groundwater, surface water and soil contamination from leachate, (iii) spreading of diseases by different vectors, (iv) uncontrolling of methane gas from anaerobic decomposition of MSW, (v) burning and explosion of landfill from methane gas. MSW management will be impacted by the huge amount of MSW to be disposed of in densely populated areas. MSW stream in Asian countries is almost similar, that is composed of high fraction of organic material of more than 50% with high moisture content, and the generation rate is increasing with time [4].

In MSW management, there are several technological methods to manage solid waste before landfill. These methods manage solid waste in a sustainable way. For example, incineration produces energy; composting of organic wastes produces fertilizer; anaerobic digestion produces energy (i.e., biogas); usable materials are recovered through recycling. The above methods together reduce the final waste into manageable amount of environmental friendly product such as fly ash. The final product can be disposed to landfill [5].

In recent years, the notion of integrated MSW management has spread. The integrated MSW management has been applied to reduce the waste at the source before the waste even enters the waste stream. That is MSW materials generated must be recovered for reduce, reuse and recycling. The remaining should be disposed at landfill sites.

The main objectives of this paper include:

(1) Reviewing previous work on MSW generation, sources, composition, and trends,

(2) Seeking a sustainable solution for general MSW management,

(3) Discussing the current and future trends of the integrated MSW management in Thailand.

II. MSW Characterization in Thailand

A. Definition of MSW

The source of typical wastes is shown in Table 1. MSW is generated by households, commercial activities, and other sources whose activities are similar to those of households and commercial enterprises, (e.g., wastes from hotels, supermarkets, schools, institutions, offices, shops) and from municipal services (e.g., street cleaning and maintenance of recreational area) [6]. In contrast, the MSW in Thailand are classified into several categories by Pollution Control Division in Thailand. The major MSW types are food wastes, paper, plastic, clothes, wood, rubber and leather, glass, metal, stone, and others such as sand, dust, and ash.

TABLE I
SOURCES AND TYPES OF MSW [7]

Sources	Typical Waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil, and tires) and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, government center, hospitals, prisons	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Municipal services	Street cleaning, landscaping, parks, beaches, recreational areas	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches and other recreational areas

TABLE II
WASTE GENERATION RATE IN THAILAND [8]

Area	Waste generation rate (ton/day)						
	2000	2001	2002	2003	2004	2005	2006
Bangkok	9,130	9,137	9,617	9,340	9,356	8,340	8,473
Municipality	11,785	11,903	11,976	12,100	12,500	12,635	12,912
Outside municipality	17,255	17,423	17,632	17,800	18,100	18,295	18,697
Total	37,170	38,643	39,225	39,240	39,956	39,270	40,082

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A. MSW Generation

Thailand has the common MSW generation rate of typical developing countries at the range of 0.3 to 1.44 kg/capita/day with the average of 1.443 kg/capita/day [5]. Several different elements directly affect the quantity of waste generated in Thailand such as geographical location, season, income, household structure, pattern of living, pattern of commodity buying, behavior of consumption, attitude of living, and regulation. The relationship between MSW generation and income varies with respect to the developmental stage of a nation [9]. Some factors are briefly discussed below.

The lifestyle associated with certain incomes can influence consumption rates and patterns [10-11]. The number of people in a household has shown a correlation to per capita waste generation such that a higher number of people in a given household results in less waste generation per person per day [12]. Socio-economic development and the degree of industrialization influence waste generate rates by generally affecting income and consumption patterns [13]. Climate and seasonal changes impact waste generation by having an effect on the amount of organic material generated as a waste product of preparing fresh foods in the seasons or climates that allow such preparation [13].

The amount of waste generated outside and inside municipality areas are different due to the incomes, lifestyle and population. The outside municipality area, wastes are mainly agricultural. For example, the amount of MSW generated in Thailand in 2006 is shown in Table II. Approximately 40,082 tons/day or 14.66 million tons per year, is generated, of which 21.1% of total MSW quantities were generated from Bangkok metropolitan area, 32.2% from municipality area, and 46.7% from outside municipality area.

B. MSW Sources and Composition

Those factors that influence the amount of waste generated are also influenced the MSW composition. The most fundamental step in MSW source management is quantifying and qualifying the different types of MSW being generated. It is important to have a system of the collection, separation, and analysis of MSW basic information. The MSW basic information includes the sources of MSW, the quantities of MSW generated, their composition and characteristics, the seasonal variations and future trends of generation.

TABLE III
COMPOSITION OF MSW IN THAILAND [14]

Type	Waste Composition (%)
Organic waste	48
Paper cardboard	15
Plastic	14
Glass	5
Metal	4
Others	14

In Thailand, the composition of MSW in 2007 is shown in Table III. According to the table, the organic waste was the largest portion of MSW. The moisture content was generally about 40-60% with a little difference between dry and wet seasons throughout country as shown in Table IV. The above information indicates the benefit of composting methods in managing waste in Thailand. More details will be discussed later. In addition the heating value (shown in Table IV) was in the ranges of 5,163 to 6,121 kJ/kg.

C. MSW trends

Due to increasing economic development growth, the trend in MSW generation is predicted to increase. The estimate volume of waste will be 15.25 million ton/year in 2011 or increasing rate of 2% annually. Even though the increase is in a small percent, the amount of waste can still cause environment problem in Thailand due to the limited landfill space and the odor. Therefore, the environmental friendly MSW management should be deployed early to prevent such problems to grow. However, the current implementation of

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MSW in Thailand addressed only immediate problems. There is a lack of long-term master planning, and no cooperative planning among communities that might benefit from joint use of facilities, and disposal systems. Moreover, the increasing percentage of plastic and paper materials in the MSW stream will contribute to the growing MSW amount.

TABLE IV
CHARACTERISTICS OF MSW IN THAILAND [15]

Characteristic	Average amount
Density (kg/m^3)	244.32
Moisture (%)	40.40
Combustibles (%)	31.32
Ash (%)	28.29
High heating value (kJ/kg)	6,121
Low heating value (kJ/kg)	5,163

III. MSW MANAGEMENT IN THAILAND

MSW management refers to collection, transfer, separation, biological treatment, recycling, resource recovery and disposal of solid waste.

A. MSW Collection and Transportation

In a typical MSW collection and transportation system, consists of (1) household waste containers, (2) waste collecting equipped trucks, (3) workers with protective suite. In big cities, however, a transfer station may be needed due to the large amount of waste and the long distance to the MSW facilities. A transfer station consists of temporary MSW storage, transfer point, vehicles and equipment for MSW transfer, and the procedures for operating and maintaining these facilities and equipment.

In Thailand, Provincial Administration Offices (PAO) and Tambon Administration Offices (TAO) were responsible for collection, transportation, and disposal. Approximately 36% of total MSW in Thailand were collected in Bangkok (shown in Table V). However, the waste collection in Bangkok is almost 100% thus there are little or no waste left in the Bangkok area. In contrast, only 37% of waste is collected in municipality area and 6% of waste is collected in outside municipality area. Due to the unavailable waste collection services in outside municipality areas, open dumping and burning are typical disposal method for MSW in such areas.

TABLE V
EFFICIENCY OF MSW DISPOSAL IN THAILAND [8]

Area	Amount of MSW (ton/day)	Treatment and Disposal (ton/day)	Collection (%)
Bangkok	8,473	8,473	100
Municipality	12,912	4,780	37.0
Outside municipality	18,697	1,120	6.0

B. MSW Processing and Disposal in Thailand

In Thailand, MSW disposal was still not meeting with sanitary purpose such as open dumping, and open burning. The open dumping is the most commonly used method of MSW disposal (as shown in Fig. 1), due to the unavailable waste collection problem discuss in the previous section. Inaccurated operation and maintenance are the main sources of MSW disposal problems.

The most common methods used for MSW in Thailand are sanitary landfill, composting, open dumping, incineration and others (discuss below). There are only 97 disposal facilities that quite properly designed for serving about 480 local administrations throughout Thailand (i.e., 91 sanitary landfills, 3 incinerators, and 3 integrated-system facilities).

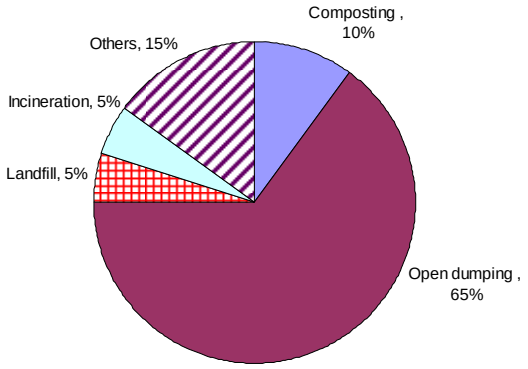


Fig. 1 Waste treatment methods in Thailand [6]

1) Open dumping

Open dumping sites are the most popular MSW management method in Thailand. Open dumping has been applied to manage MSW for many years and it can manage a huge quantity of MSW generated per day. Open dumping site can be utilized with the easily fermented, and low cost but it can also cause visual pollution, and odor. In addition open dumping can probably pollutes to soil and groundwater. Although the Thai government has started working on developing sanitary landfill sites in several municipality areas. The open dumping sites still remain a choice for many areas due to its low cost and its effective performance in getting rid of a huge amount of waste.

However, open dumping should not be allowed because it is unsightly, unhygienic, and potentially disastrous to our environment.

2) Landfill

Sanitary landfills are usually located far from sources, resulting in increasing of the transfer costs and additional investments for infrastructure. Direct landfilling of such waste creates the nuisance owing to the generation of highly concentrated leachate, methane gas emission, and extreme waste settlement in landfill. Rapid waste decomposition eventually affects the landfill stability. Even though there are 91 sanitary landfill sites in Thailand, more sites are still required to decrease the amount of open dumping and open burning waste.

3) Composting

Composting is the most promising area for the recovery of organic wastes. Volume of waste good for composting (i.e., organic waste) was about 48% of the total MSW in Thailand

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(Table III) making it a good choice for Thailand sustainable MSW management method. Moreover composting generates a valuable fertilizer or a soil conditioner for agricultural and horticultural uses. However, composting is not well practiced in Thailand due to the lack of knowledge and the high cost in maintenance.

4) Incineration

Incineration is one of the methods for MSW management in Thailand. This method is used for the huge municipality and tourist municipality area because sanitary landfill is not enough for disposed MSW. Currently there were 3 incinerations for communities' wastes: Phuket province (250 ton/day), Samui Island (75 ton/day), and Lamphun province (10 ton/day). Even though the incineration can rapidly reduce the amount of waste, it can cause an air pollution concern especially in the tourist areas.

C. MSW Situation

Thailand has volume of community waste around 14.66 ton/year. The volume of waste was increased every year due to expansion of tourism developments, communities, and business. Waste management at all levels was still a key problem. The problem of MSW management is usually caused by various forms and components of waste making it difficult to dispose, resistance from the people to construct the landfill, lack of landfill, insufficient equipment for collection, transportation and disposal, limited budget for operation, and public participation.

1) Waste from Bangkok

Waste in Bangkok was about 8,473 ton/day. Bangkok was able to collect close to 100% of its total waste disposed in the area. For the disposal, a private company was contracted to collect and transport the waste from Tha Reng, Nong Khem, and On-nut Transfer Stations to be landfilled at Tambon Rachathewa, and Amphur Bangplee in Samut Prakan province. Each of landfill sites gets around 3,300 ton/day and 5,173 ton/day, respectively.

2) Municipality waste

Volume of municipality waste was about 32% of the total MSW in Thailand. Due to a large service area, most people dispose wastes themselves such as dumping and burning in an open area. Thus, the problem of waste disposal was inaccurated operation and maintenance.

3) Outside municipality waste

Tambon Administration Offices (TAO) was responsible for collection, transportation, and disposal of waste outside municipality areas. Waste disposal method (such as open dumping site and open burning site) in this area was still not met with sanitary purposes.

IV. The Solutions for MSW Management

MSW management aims to promote environmental conditions by controlling pollution (including air, soil, groundwater, surface water, and cross media pollution), protecting environmental health, and ensuring the sustainability of ecosystems in the urban region.

A. Sustainable Solutions for MSW management

The principles of sustainable MSW management strategies are to: (i) minimize MSW generation, (ii) maximize waste recycling and reuse, and (iii) ensure the safe and environmentally sound disposal of MSW. The sustainable MSW management depends on the overall effectiveness and efficiency of urban managements, and the capacity of responsible municipal authorities.

Integrated MSW management is one of the holistic approaches to environmental and resource management which is emerging from applying the concept of sustainable development. The long term efficiently management of MSW wan integrated MSW management center. The objective of integrated MSW management is to deal with society's waste in an environmentally and economically sustainable way.

The integrated MSW management system includes four main processes resulting in zero waste. Before all processes the waste must be collected and sorted. The first process is to recover secondary materials which require an access to reprocessing facilities. This process also required an adequate sorting. The second process is the biological treatment of organic materials. For example, organic wastes can be composted to produce fertilizers (Aerobic process); anaerobic digestion method (Anaerobic process) can be used to transform organic waste into liquid fertilizers. Methane, a by-product of the anaerobic digestion, can be used to produce energy. The third process is the thermal treatment focusing on ways to reduce the volume of wastes such as burning of mixed MSW, burning of selected parts of the MSW stream that is Refuse-Derived Fuel (RDF), and separating materials from household collections such as plastic and paper. This process can be regarded as a pre-treatment to stabilize waste and reduce the volume of waste for disposal in landfill. Also, this process can be viewed as a waste valorization method by means of compost and biogas production. The only remaining of this process is fly ash which is disposed off in landfill (Fig. 2). By doing so, the area of landfill can be greatly reduced. In addition, the problems of methane and the contamination of surface and ground water can be reduced. Some integrated MSW systems may not contain all four processes described above which may result in remaining wastes.

The complete integrated MSW management system includes:

(i) Waste selection
(ii) Material recovery facilities
(iii) Incineration and energy recovery
(iv) Biological treatment of organic waste
(v) Landfill of final inert waste

Notice that the landfill is still the final destination of final remaining product of any MSW management method. Instead of regular waste to be filled, the remaining product of MSW is only inert wastes which produce no odor and require small space. Thus, the life time of landfill can be extended.

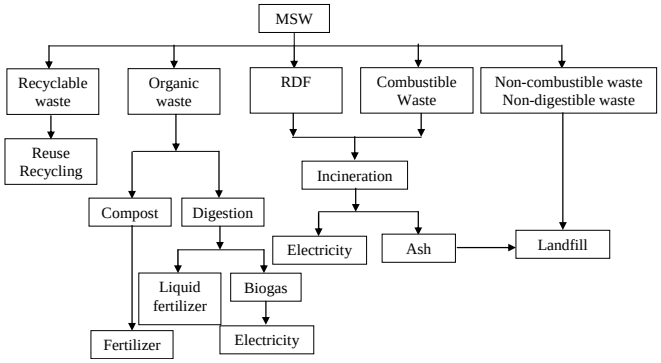


Fig. 2 Components of an Integrated MSW Management System

B. Key sustainable solutions for MSW management

Currently, the amount of waste increase due to the increasing in population and changes in environment, making it difficult to manage. Ways to limit the impact on the environment is by (1) reducing the amount of MSW that is generated, and (2) using sustainable solutions for MSW management.

The aim of 'sustainability' should be a solution for MSW management that produces zero waste. Such solution should be based on waste minimization, reuse, recycling, bio-digestion, composting, cleaner production, and sanitary disposal. The starting point of such solutions can be identified by: (i) environmentally sound management, (ii) recycling, (iii) reuse, and (iv) developing of the green productions and bio-product productions, (discussed below).

1) Environmentally Sound Management of MSW

Environmentally sound MSW management should be considered as the first method approaching sustainable solutions for MSW management. However, it must go beyond the mere safe disposal or recovery of MSW generated. Also, it must seek to address the root causes of the problem by attempting to change unsustainable patterns of production and consumption.

2) Recycling of MSW

In Thailand, recovery of recyclable materials – mainly paper, plastics, glass and metals – is normally undertaken by private sector workers. Information in Table III indicated that more than 38% of MSW were potentially recyclable materials. Therefore, a number of incentive campaigns with the cooperation among public and private sectors as well as NGOs have been encouraged in the recycling activities to reduce the MSW volume from sources. The main problem of recycling in Thailand is the sorting and collecting of reusable materials from wastes. The two existing systems in Thailand are (i) collecting and sorting works – doing it by hands at the collecting points, (ii) collecting and sorting scavengers doing it by hands at the disposal facilities. It can be seen that these two methods are not only ineffective but also unhealthy.

3) Reuse of MSW

Reuse is considered the most appropriated method for MSW management because there is no extra cost associated with this method. Approximately 14% of waste collected in Thailand is plastic. Plastic is actually used for packaging, cans, boxes, tools, containers, equipment etc. It requires a long time to dispose. Therefore the suitable method for handling products with plastic composition is reuse.

4) Developing the Green Production and Bio-products production

Sustainable MSW management in Thailand should consider bio-products and green products due to their environmentally friendly traits as well as their advantages. Thailand is mainly an agricultural country, resulting in a huge amount of agricultural waste and by-product of crop residues. Thus, these materials are being considerable for production of green and bio-products. For example, bio-plastic bags and green packaging are made from plant or crop starch. After use, the green products and bio-products can be disposed together with organic waste and can be broken down when exposed to sunlight. In recent years, degradable plastic bags have been used successfully in supermarkets and superstores.

C. Integrated MSW Management System in Thailand

The Thai national waste management policy encourages local administrations to establish central MSW disposal facilities with integrated concept of appropriate technologies and beneficial utilization of MSW such as energy recovery and compost material (Fig. 3). The purpose of area clustering approach is to encourage local administrations to gather into cluster to establish central MSW disposal facilities. There are approximately 300 clusters formed throughout the country [8]. It is expected that about 28 clusters have MSW generated more than 250 ton/day, and less than that for the remaining clusters (Table VI).

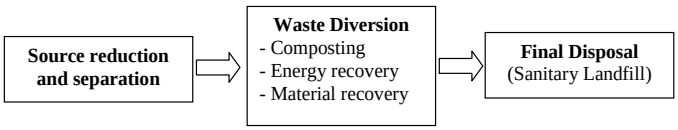


Fig. 3 Integrated MSW Management Systems in Thailand [8]

TABLE VI
CLUSTERS IN THAILAND [8]

Area size	Amount of MSW (ton/day)	Number of areas
Large Cluster	> 500	3
Medium Cluster		206
- M1	250-500	26
- M2	100-250	89
- M3	50-100	91
Small Cluster	<50	90

Currently three centers of integrated-system facilities in Thailand are operating: (i) Wieng Fang Municipality (Chiang Mai province) – 150 ton/day (ii) Rayong Municipality (Rayong province) – 80 ton/day (iii) Chonburi Provincial Administration (Chonburi province) – 300 to 400 ton/day.

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TABLE VII
SUSTAINABLE TECHNOLOGIES FOR EACH CLUSTER IN THAILAND [8]

Cluster	Technology
Large Cluster	Separation + Biological decomposition + Incineration + Landfill
Medium 1 Cluster	Separation + Biological decomposition + RDF/Incineration + Landfill
Medium 2 Cluster	Separation + Biological decomposition/RDF + Landfill
Medium 3 Cluster	Separation + Biological decomposition/RDF + Landfill
Small Cluster	Separation + Biological decomposition + Landfill

In conclusion, an appropriate alternative method for Thailand should be a biological decomposition process such as anaerobic digestion due to the characteristics of MSW in Thailand. Since the highly biodegradable waste contains high moisture content due to a large amount of food waste. Biogas and waste residue are valuable by-products of anaerobic digestion technology. The stabilized waste residue can be used as a fertilizer or soil conditioner, or can be safely disposed of in landfill. Furthermore, the remaining waste from the anaerobic digestion technology can indirectly extend the life-time of landfill space in Thailand as well.

V. CONCLUSION

It is clear that no one single method of MSW disposal can deal with all materials in an environmentally sustainable way. The "sustainability" is a popular word today and it is not a new topic. The requirement for a reasonable and sustainable MSW management is one of the most common complaints, especially when there is a growing concern of the increasing rate of waste generation due to varying income levels and the extent of urbanization. A suitable approach in MSW management should be an integrated approach that could deliver both environmental and economic sustainability. With increasing environmental concerns, the integrated MSW management system has a potential to maximize the useable waste materials as well as produce energy as a by-product.

In Thailand, the compositions of waste (86%) are mainly organic waste, paper, plastic, glass, and metal. As a result, the waste in Thailand is very suitable for an integrated MSW management. With this knowledge in mind, the Thai national waste management policy starts to encourage the local administrations to gather into clusters to establish central MSW disposal facilities with suitable technologies and reducing the disposal cost based on the amount of MSW generated.

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