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Chanathip Pharino

Challenges for Sustainable Solid Waste Management

Lessons from Thailand

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Preface

My aim and inspiration to write this book is to share my work and research experience in the past 10 years on improving solid waste management situation in Thailand. I hope this book can be useful to researchers and practitioners who are working and facing challenges on this issue.

I appreciated the opportunity to work with and help from the editor and the team behind this book series. Many thanks to Loyola D'Silva, Almas Schimmel, Ashok Arumairaj, Sooryadeepth Jayakrishnan and Springer staffs who are very supportive and efficient in making this book possible.

This book is possible with continuous supports from my advisors, my graduate students, my colleagues whom I have worked with side by side, shared thoughts and experiences. I thank them all for their intellectual contributions into this book.

I am thankful for the endless supports from my family and friends.

Bangkok, Thailand
May 2017

Chanathip Pharino

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Chapter 1
Integrated Waste Management System Overview

1.1 Overview of the Book

Increasing waste generation under inefficient management systems has become a major challenge in many developing countries facing rapid economic growth. Thailand is suffering from low efficiency throughout the waste management logistics from source to final treatment. This has become a major concern to public health and resource utilization in the country. This book aims to give an overview of the waste management system situation and concepts in different countries. The book focuses on the management of municipal solid waste (MSW) in Thailand and special waste streams such as discarded electrical and electronic equipment and hazardous household waste. System operation, management approaches, and key factors impacting the progress of waste management are explained. The first chapter starts with a brief introduction of the outlook and scope of the waste sector. An integrated sustainable waste management framework is presented, followed by a discussion of challenges and opportunities facing the sector in the future. The second chapter covers waste generation rates, waste sources, and waste characteristics. The third to eighth chapters present how municipal waste, electronic waste, hazardous household waste, and infectious waste are managed in Thailand. Lessons learned from various activities within Thailand aimed at overcoming ongoing challenges are presented. Recommendations promoting a sustainable waste management system in Thailand that could be applied to other countries with a similar background are presented including integration of the polluter pay concept, stringent new laws, good incentive systems for recycle and reuse, waste to energy technology, incorporation in environmental education, and awareness raising in every sector.

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1.2 Challenges in Managing Solid Wastes

Today, more than 50% of the world's population lives in cities and the rate of urbanization is increasing quickly. This adds challenges to current and future waste management systems from waste generation, waste collection, waste treatment and disposal, and waste recycle and recovery. All stakeholders, mainly citizens and corporations, will likely need to take more responsibility for waste reduction, separation, and recycle throughout the waste management lifecycle. For example, urbanization raises the opportunity for "urban mining" as the largest source of materials like metal and paper are found in cities. Technology choices, a new paradigm toward economic growth and policy structure, together with stakeholder involvement are interconnected in the effort to drive significant improvement in waste management as an engine for sustainable development.

As a result of economic growth, more waste is generated and discarded into the environment—the by-product of production and consumption. The rate of waste generation differs according to many factors such as lifestyle, level of income, demographic, and climate. Difference in the consumption behavior and type of economy highly impact waste composition and therefore affect the waste management system. Moreover, the waste management process emits greenhouse gases and causes water pollution. Today, waste managers face many challenges in designing and taking appropriate action to suit local, regional, and global contexts since the issue of waste is closely interconnected to economic, environmental, and social impacts.

There are a number of waste composition types that are more complicated to manage. The complexity of waste is a consequence of advances in production technology and supply that serve various consumption lifestyles. Imports and exports of goods from various countries play a major part. Some waste is easier to manage such as organics and paper, but there are others such as multilaminate, hazardous waste (e.g., syringes), and e-waste that pose disproportionately large problems. Today's waste management paradigm tends to look at waste management in a linear manner with landfill or incineration as the final disposal destination. However, there is a need for a new paradigm that considers management throughout the waste lifecycle by redesigning products to minimize wastage and recovering materials and energy from the waste stream to create co-benefits from waste management.

The design and implementation of integrated sustainable waste management in any country is the greatest challenge. There are many dimensions to consider—financial, technical, legal, environmental, sociocultural, and stakeholder engagement. Many pressures are key drivers to implementing an integrated system on waste management including public and environmental health, climate change, resource scarcity, and limited space for final waste disposal. The waste crisis can actually be turned into a good development and investment opportunity to design a means of effective integration of technological, economic, and social development to improve a waste management system. There are many successful cases of community-based waste management, advanced waste to energy technology, upcycled products, and so on. Lifecycle waste management and integrated waste management are key to promoting more widely a successful circular economy and sustainable development.

1.3 What Is Waste?

Waste is defined in general terms as any substance or object which the holder discards, or intends or is required to discard. From an economic aspect, waste is a negative externality. Production and consumption generate waste which has an impact (pollution) on the public (third parties) who do not consume the goods or get benefits from consumption. Waste management systems incur costs for collection, transportation, and treatment to mitigate the impact from waste. However, many types of waste today can be recovered and recycled as material for production. Therefore, the benefit from using waste is now promoted and encouraged to understand waste in terms of "residue" from the production and consumption process which is in transition to be utilized in the next step. The concept of waste and the waste cycle is important to highlighting to consumers that resources can be regenerated from waste as a by-product of production and consumption. The definition of MSW is given by various agencies as the following:

> **OECD**: Municipal waste is collected and treated by, or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden, street sweepings, contents of litter containers, and market cleansing. Waste from municipal sewage networks and treatment, as well as municipal construction and demolition is excluded.
>
> **IPCC**: The IPCC includes the following in MSW: food waste; garden (yard) and park waste; paper and cardboard; wood; textiles; nappies (disposable diapers); rubber and leather; plastics; metal; glass (and pottery and china); and other (e.g., ash, dirt, dust, soil, electronic waste). What a Waste: A Global Review of Solid Waste Management (2012).

Waste can be broken down into the following categories:

- Waste produced from residential and industrial (non-process waste), commercial and institutional sources with the exception of hazardous and universal waste, construction and demolition waste, and liquid waste (water, wastewater, industrial processes) (Tchobanoglous and Kreith 2002).
- Waste produced by households, businesses, and institutions, frequently linked to consumption, and under the responsibility of municipalities including waste originating from economic activity and public agencies (i.e., residents, shops, restaurants, schools, etc.).
- Waste generated by industrial activity, frequently linked directly to production or occurring at the end of life of certain products. There are special categories, such as waste from the construction and demolition sector, mining activity, agricultural activity, and so on.

Table 1.1 provides a summary of types of solid waste and waste generators.

Table 1.1 Generators and types of solid waste

Source	Typical waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastics, textiles, leather, yard waste, wood, glass, metals, ashes, special waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), household hazardous waste (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-waste (e.g., computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process waste when municipalities do not oversee their collection)	Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous waste, ash, special waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food waste, glass, metal, special waste, hazardous waste, e-waste
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal service	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweeping, landscape and tree trimmings, general waste from parks, beaches, and other recreational areas, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food waste, agricultural waste (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous waste (e.g., pesticides)

Source Adapted from *What a Waste: A Global Review of Solid Waste Management* (2012)

1.4 Waste Management Systems

In general, a typical waste management system comprises collection, transportation, treatment, and disposal. Waste is collected by municipal service trucks or by being dropped off at fixed stations. The waste collection capability and efficiency of the municipality highly varies and depends on budgets, manpower, routes, and coverage zones. After collection, waste is transported to waste transfer stations for pretreatment (sorting and reloading on to large vehicles) before being carried to landfill or incineration. Landfill is the dominant method for final disposal of waste in developing countries. However, a variety of material and energy recovery technologies have been developed and widely implemented in modern systems. The informal sector plays an important role in recycle waste collection, sorting, and recovery. Substantial efforts are being made to reorient SWM systems toward sustainability, which is explained in the next section (Fig. 1.1).

From Waste to Resource: World Waste Survey 2009 analyzed the waste management situation around the world and provided an interesting summary in that waste management in developing countries is still most often the responsibility of municipalities. Waste management costs are on the increase; however, public budgets are being trimmed. Municipalities in these countries are confronted with the growing problem of waste management budget deficit. The private sector is increasingly called on to handle this management task. The informal sector has now become a major part of conventional waste management. The poor are engaged in collection and recycling of materials extracted from waste for resale and making a living. Some waste as a resource is handled by the informal sector—not the municipalities. However, these activities are conducted under conditions harmful to the health of workers and the environment. In some countries the informal sector is becoming increasingly organized, benefiting from its social and environmental usefulness and professionalism. Collection in developing countries is the responsibility of municipalities, but is still not very efficient for many reasons. Management and supervision of staff are weak, waste transport vehicles are

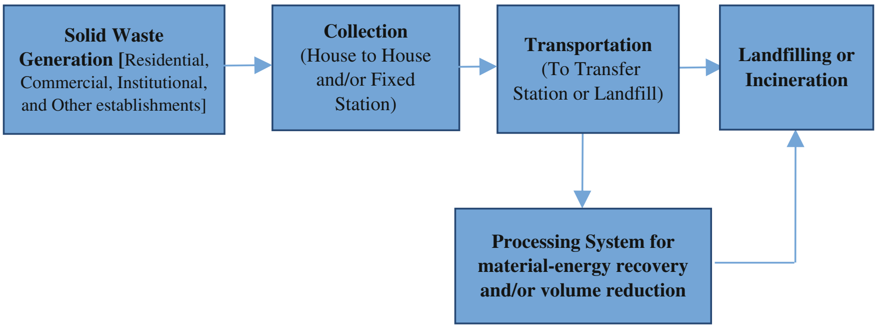

Fig. 1.1 Typical waste management in developing countries. *Source* Adapted from A.V. Shekdar (2009)

inadequate, collection routes are not rational and highly diversified, travel times are not adjusted adequately, and the capacity of most transfer centers is insufficient. The private sector, together with the informal sector, could contribute more efficient and less costly solutions. Landfilling is the dominant waste treatment method in developing countries. Waste transport distances mean collection costs increase and illegal dumping sites increase accordingly. Waste reduction and recycling have been emphasized as solutions to help reduce the burden of finding new landfills and other co-benefits from resource recovery. In developing countries, waste is still sorted for recycling by the informal sector on landfill sites themselves. However, there is no assessment of the quantities sorted in this way. The waste management system challenge is designing the entire system to involve different stakeholders and operating the system as efficiently and cost effectively as possible to meet essential environmental standards.

The Waste Management Hierarchy is an internationally recognized strategy to maximize the upstream waste management hierarchy towards the 3Rs (reduce, reuse, and recycle) and a fourth R (recovery). This aims to shift away from less preferred waste treatment and disposal methods such as incineration (without energy recovery) and landfilling. The Waste Management Hierarchy emphasis is on prioritizing waste avoidance and minimization, practicing segregation, promoting the 3Rs, implementing safe waste transportation, treatment, and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency. This highlights efforts to move away from the usual approach of treatment such as incineration (without energy recovery) and landfilling (see Fig. 1.2).

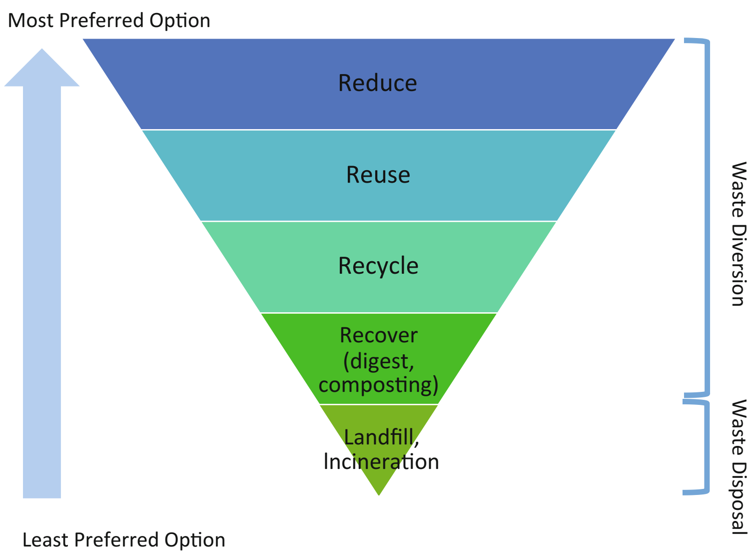

Fig. 1.2 Waste management hierarchy

The waste management vision toward sustainability aims to establish a circular global economy in which the use of materials and generation of waste are minimized, any unavoidable waste recycled or remanufactured, and any remaining waste treated in such a way that causes the least damage to the environment and human health or even creates additional value such as by recovering energy from waste.

Waste reduction: By means of waste prevention, resource wastage is minimized to reduce the quantity of waste at generation points by changing designs and patterns of production and consumption.
Waste reuse: Use products and goods efficiently to circulate waste and avoid the use of virgin resources.
Recycle and recovery: Waste conversion to useful products. Recycling and recovery help reduce the quantities of disposed waste and the return of materials to the economy.
Anaerobic digestion and composting: Anaerobic digestion will generate methane that can either be flared or used to generate heat and/or electricity. Organic waste composting helps reduce contamination of mixed waste and quantity of waste to landfill and generates by-products for soil improvement.
Landfill: Landfills are a common final disposal site for waste and should be engineered and operated to protect the environment and public health.
Incineration: Incineration can reduce the volume of waste by as much as 90%. Final ash will be put in landfills. Incineration without energy recovery (or non-autogenic combustion, the need to regularly add fuel) is not a preferred option due to costs and pollution.

Today, despite the increasing volume and complexity of waste as a result of economic growth, there is the potential to turn crisis into opportunity for green growth. The minimization of waste should be the first priority. Recovery of material and energy from waste as well as remanufacturing and recycling waste into usable products should be the second priority. Reducing the amount of waste entering the environment will help lessen human health and environmental impacts. Recycling can lead to significant resource saving and generating more revenues. Moreover, recycling helps create more jobs and hence income distribution. A range of economic instruments can serve as incentives to better improve the outcome and performance of waste management systems.

1.5 Integrated Sustainable Waste Management (ISWM) Framework

> Integrated solid waste management (ISWM) reflects the need to approach solid waste in a comprehensive manner with careful selection and sustained application of appropriate technology, working conditions, and establishment of a 'social license' between the

> community and designated waste management authorities (most commonly local government)… ISWM should be driven by clear objectives and is based on the hierarchy of waste management: reduce, reuse, recycle — often adding a fourth 'R' for recovery. What a Waste: A Global Review of Solid Waste Management (2012).

There are four principles in the ISWM framework proposed by van de Klundert and Anschütz (2001) (see Fig. 1.3), including:

(1) ***Equity*** for all citizens to have access to waste management systems
(2) ***Effectiveness*** of the waste management system to safely dispose and treat the waste
(3) ***Efficiency*** to maximize benefits, minimize costs, and optimize the use of resources
(4) ***Sustainability*** of the system from technical, environmental, social (cultural), economic, financial, institutional, and political perspectives.

Three interconnected dimensions in the ISWM framework are (1) stakeholders, (2) processes, (3) policy and impacts. Stakeholders play different roles in SWM such as legal authorities, service users, formal and informal sector, donor agencies,

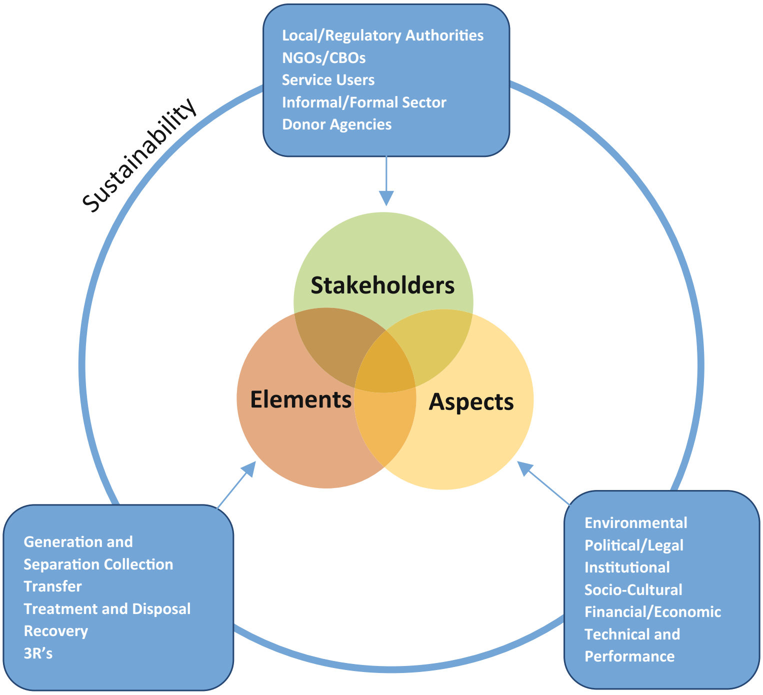

Fig. 1.3 Integrated sustainable waste management framework. *Source* Adapted from van de Klundert and Anschütz (2001)

and NGOs. Not only do stakeholders play different roles they make different contributions. All of which should be identified and engaged into ISWM. Elements (processes) are technical aspects in SWM that need to be considered simultaneously when creating an SWM program to have an efficient and effective system throughout the waste management lifecycle from the point of generation to collection, treatment, and recovery until final disposal. Aspects (policies and impacts) refer to the regulatory, environmental, and financial realities in which the waste management system operates. Political, institutional, sociocultural, economic, and technical aspects have a major influence on priority levels and implementability toward a different level of performance from ISWM. Measures and priorities are also linked and created based on these various local, national, and global aspects.

UN-Habitat provided an alternative framework of ISWM in 2009. This identified three key system elements in ISWM: public health, environmental protection, and resource management (UN-Habitat 2009). Public health concerns and protection define a need for integrated solid waste management systems. Whereas ISWM programs can stop environmental degradation and contamination of water resources, air quality, and livelihood of the community, MSW can become a potential resource which can contribute to cost savings in production and green growth.

The integrated approach to sustainable solid waste management is recommended and has gained acceptance internationally. The improvement in achieving sustainable SWM in Asian countries in the context of national policy and legal frameworks, institutional arrangement, appropriate technology, operational and financial management, and public awareness and participation is explained in Fig. 1.4.

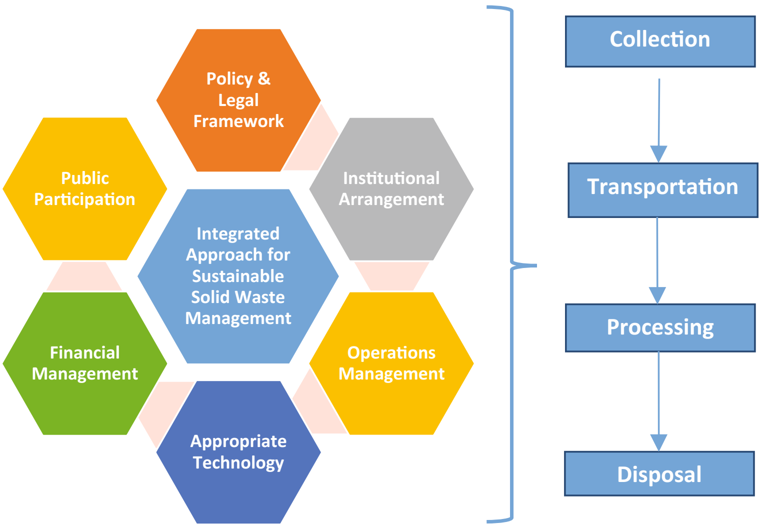

Fig. 1.4 Integrated sustainable solid waste management framework. *Source* Adapted from A.V. Shekdar (2009)

Policy and legal frameworks: should address the boundary conditions in which the waste management system exists, such as setting goals and priorities, determining roles and jurisdiction, determining the existing or planned legal and regulatory framework as well as the basic decision-making processes. The legal framework should ensure that the targets defined in the policy documents are met within specified timeframes. The framework should also facilitate the planning and operation of the system.

Institutional arrangement: relates to the political and social structures that control and implement waste management, the distribution of functions and responsibilities, the organizational structures, procedures, and methods implicated, available institutional capacities, and the actors (such as the private sector) who could become involved.

Appropriate technology: concerns the implementation of best practice technology, what equipment and facilities are in use, how they are designed, what they are designed to do. Waste management technology has to be designed in accordance with waste characteristics and quantities and must be compatible with usual operating conditions.

Operation management: systems include material handling and treatment processes through which the waste generated from different sources is collected, transported, processed, and disposed of regularly. Procedures and practices should be clearly defined and integrated into monitoring and control operations.

Financial management: A vital ISWM system requires resources in the form of manpower, vehicles, machinery, and land. The system must be adequately financed with respect to capital investment and recurring expenditure. Budgeting procedures need to consider sustainability issues (long term). Subsidies to improve the commercial viability of technologies to enable resource recovery or increased fees for handling waste collection and disposal should be considered.

Public participation and awareness: It is necessary to make the public aware of ISWM and participate or take actions based on the waste management hierarchy from reduction to proper disposal.

The sociocultural aspect affects waste generation and its involvement in waste management. The relations between groups and communities, between people of various ages, gender, and ethnicity, and the social conditions of waste workers.

Marshall and Farahbakhsh (2013) applied a system approach to analyze integrated solid waste management in developing countries. The researchers made the interesting observation that, in industrialized countries, public health, the environment, resource scarcity, climate change, and public awareness and participation have acted as SWM drivers toward the current paradigm of integrated SWM. Whereas, in developing countries, urbanization, inequality, and economic growth; cultural and socioeconomic aspects; policy, governance, and institutional issues; and international influences have complicated SWM. Marshall and Farahbakhsh (2013) demonstrated the importance of founding new SWM approaches to developing country contexts in adaptive systems thinking (see Fig. 1.5).

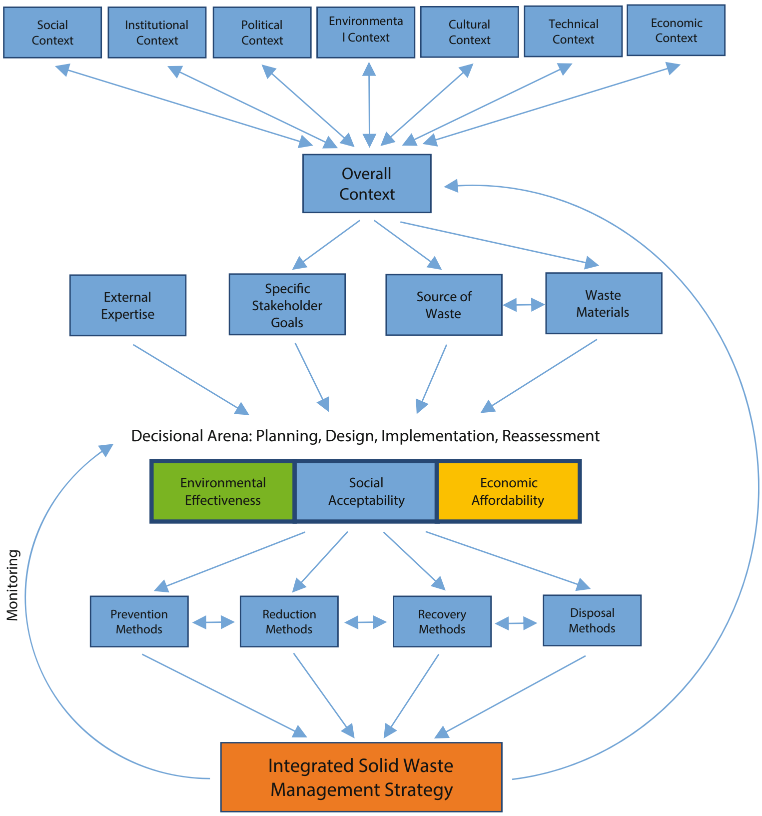

Fig. 1.5 Integrated solid waste management. *Source* Adapted from Marshall and Farahbakhsh (2013)

Marshall and Farahbakhsh (2013, p. 995) described that "… the ISWM concept attempts to balance between three dimensions of waste management: environmental effectiveness, social acceptability, and economic affordability (McDougall et al. 2001; Morrissey and Browne 2004; Petts 2000; Thomas and McDougall 2005; van de Klundert and Anschutz 2001). ISWM also focuses on the integration of the many inter-related processes and entities that make up a waste management system (McDougall et al. 2001). To reduce environmental impacts and drive costs down, a system should be integrated (in waste materials, sources of waste, and treatment methods), market oriented (i.e. energy and materials have end uses), and flexible, allowing for continual improvement (McDougall et al. 2001). ISWM systems are tailored to specific community goals by incorporating stakeholders' perspectives and needs; the local context (from the technical, such as waste characteristics, to the cultural, political, social, environmental, economic and institutional); and the optimal combination of available, appropriate methods of prevention, reduction, recovery and disposal (Kollikkathara et al. 2009; McDougall et al. 2001; van de Klundert and Anschutz 2001) …".

To put in place an action plan based on an integrated waste management system needs to be carefully done. This is very specific to local contexts. Hoornweg and Bhada-Tata (2012) established the components that any community can adopt to develop their own integrated waste management plan, as described below.

Components of an integrated solid waste management plan [What a waste: a global review of solid waste management (2012)]
1. All municipal policies, aims, objectives, and initiatives related to waste management
2. The character and scale of the city, natural conditions, climate, development and distribution of population
3. Data on all waste generation, including data covering both recent years and projections over the lifetime of the plan (usually 15–25 years). This should include data on MSW composition and other characteristics, such as moisture content and density (dry weight), present and predicted
4. Identify all proposed options (and combination of options) for waste collection, transportation, treatment, and disposal of the defined types and quantities of solid wastes (this must address options for all types of solid waste arising)
5. Evaluation of the Best Practical Environmental Option(s), integrating balanced assessments of all technical, environmental, social, and financial issues
6. The proposed plan, specifying the amount, scale, and distribution of collection, transportation, treatment and disposal systems to be developed, with proposed waste mass flows proposed through each system
7. Specifications on the proposed ongoing monitoring and controls that will be implemented in conjunction with facilities and practices and ways in which this information will be regularly reported
8. Associated institutional reforms and regulatory arrangements needed to support the plan
9. Financial assessment of the plan, including analysis of both investment and recurrent costs associated with the proposed facilities and services, over the lifetime of the plan (or facilities)
10. All the sources of finance and revenues associated with developing and operating the plan including estimated subsidy transfers and user fees
11. The requirements for managing all non-MSW arisings, what facilities are required, who will provide them and the related services, and how such facilities and services will be paid for
12. The proposed implementation plan covering a period of at least 5–10 years, with an immediate action plan detailing actions set out for the first 2–3 years
13. Outline of public consultations carried out during preparation of the plan and proposed in future
14. Outline of the detailed program to be used to site key waste management facilities, e.g. landfills, compost plants, and transfer stations
15. An assessment of GHG emissions and the role of MSW in the city's overall urban metabolism

Source Adapted from Hoornweg and Bhada-Tata (2012)

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Chapter 2
Waste Characteristics and Practices

This chapter presents an overview of the trend of the waste generation rate in different countries. The sources and characteristics of waste are presented to provide a snapshot of the waste situation in different regions. The makeup of waste affects how it should be managed. The common practice of waste management is explained and its performance is compared between low-income and high-income countries. Formal and informal waste recycling play increasingly important roles in the resource recovery system. Recycling practices are discussed. The local community is key to managing waste at source (waste reduction and separation). Therefore, community-based waste management is also highlighted in the chapter.

2.1 Waste Generation Rate

Globally, the composition of municipal solid waste (MSW) can be classified according to each country's income level. Hoornweg and Bhada-Tata (2012) provided a review of the global MSW situation and reported that the annual global MSW generation amount was at 1.3 billion tons and the global MSW generation rate at 1.2 kg/capita/day. By 2025, this will likely increase to about 1.42 kg/capita/day ($\sim$2.2 billion tonnes of MSW per year). The report estimates that actual per capita rates, however, are highly variable, as there are considerable differences in waste generation rates across countries, between cities, and even within cities.

> MSW generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced. Income level and urbanization are highly correlated and as disposable incomes and living standards increase, consumption of goods and services correspondingly increases, as does the amount of waste generated. Urban residents produce about twice as much waste as their rural counterparts. What a Waste (2012).

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The higher the income level and rate of urbanization, the greater the amount of solid waste produced. High-income countries produce MSW at the highest rate of 2.13 kg/capita/day while lower income countries produce MSW at lower rates. When lower and lower middle-income strata are combined, the average of combined urban waste generation is 0.84 kg/capita/day. Generation rates in upper middle-income and high-income countries are increased (largely from urban residents). The rate of MSW generation is likely to escalate in the same direction once countries engage in higher economic activity.

Considering the MSW composition from countries with different income levels, the percentage of organic waste in MSW and income levels are often inversely correlated while other MSW constituents tend to correlate directly with income levels. Hoornweg and Bhada-Tata (2012) revealed that low to upper middle-income strata often process the highest percentage of organic waste (64, 59, and 54%, respectively) while the high-income strata has paper waste (31%) as the highest proportion in MSW composition with organic waste ranked as second (28%). The percentage of plastic, glass, and metal waste does not wildly differ among income strata. In all income strata, organic, paper, and plastic waste tend to be the highest constituents in MSW.

Hoornweg and Bhada-Tata (2012) forecast and reported the amount of MSW in different regions (see Table 2.1). They indicated the current waste generation per capita by region, the lower and upper boundary for each region, as well as average kilogram per capita per day of waste generated within each region (see Table 2.1). It was observed that countries in the OECD have the highest waste generation rate of around 2.2 kg/capita/day while countries in Africa have the lowest waste generation rate of around 0.65 kg/capita/day. This matches expectations in that waste generation increases with economic growth. Africa has relatively smaller economic activity compared with other regions. When categorizing the waste generation rate based on the incomes of countries, it is found that the larger the national income, the bigger the MSW generated (see Table 2.2). The low-income country group has an average waste generation rate of around 0.6 kg/capita/day while the high-income country group has a rate of around 2.13 kg/capita/day.

Table 2.1 Waste generation rate per capita in different regions

Region	Waste generation per capita (kg/capita/day)		
	Lower boundary	Upper boundary	Average
Africa	0.09	3	0.65
East Asia and Pacific	0.44	4.3	0.95
Europe and Central Asia	0.29	2.1	1.1
Latin America and the Caribbean	0.11	142	1.1
Middle East and North Africa	0.16	5.7	1.1
OECD	1.1	3.7	2.2
South Asia	0.12	5.1	0.45

Source Adapted from *What a Waste* (2012)

Table 2.2 Different income strata at the global scale and MSW data

Region	Total urban population (millions)	Urban waste generation	
		Per capita (kg/capita/day)	Total (tons/day)
Lower income	343	0.6	204,802
Lower middle income	1293	0.78	1,012,321
Upper middle income	572	1.16	665,586
High income	774	2.13	1,649,547
Total	2982	1.19	3,532,256
Level of income	Waste generation per capita (kg/capita/day)		
	Lower boundary	Upper boundary	Average
High	0.7	14	2.1
Upper middle	0.11	5.5	1.2
Lower middle	0.16	5.3	0.79
Lower	0.09	4.3	0.6

Source Adapted from *What a Waste* (2012)

2.2 Waste Composition

Production and consumption have a direct correlation with the sources and types of waste generated. The main sources of waste typically come from residential, industrial, commercial, and institutional sources. However, there are some specific types of sources including construction and demolition, municipal services, agricultural, and medical that need special treatment. The typical source likely generates certain types of solid waste (see Table 2.3). These sources (especially medical) produce a specific type of waste that requires a specific procedure for handling and treatment. The major purpose and advantage of classifying waste types is to facilitate appropriate waste management and better utilize recovery from the waste cycle. The makeup of waste impacts how waste is collected and disposed as well as the potential to recover it (Table 2.4).

A number of studies indicated that waste composition is influenced by socioeconomic factors such as level of economic development, culture, demographic, geographic location, environmental condition such as climate, and energy sources. MSW in high-income countries has paper, plastics, and other inorganic materials sharing the highest proprotion. Whereas low-income countries have the highest proportion of organic waste.

Generally, low and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85% of the total. The paper, plastic, glass, and metal fractions increase in the waste stream of middle and

Table 2.3 Sources and types of waste

Source	Typical waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastics, textiles, leather, yard waste, wood, glass, metals, ash, special waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), household hazardous waste (e.g., paint, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-waste (e.g., computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process waste when the municipality does not oversee their collection)	Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous waste, ash, special waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food waste, glass, metals, special waste, hazardous waste, e-waste
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweeping, landscape and tree trimmings, general waste from parks, beaches, and other recreational areas, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious waste (bandages, gloves, cultures, swabs, blood and body fluids), hazardous waste (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food waste, agricultural waste (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous waste (e.g., pesticides)

Source Adapted from *What a Waste* (2012)

high-income countries. Figure 2.1 shows the makeup of global waste. Organic waste makes up the highest proportion (46%) among all types of waste followed by paper (17%), plastic (10%), glass (5%), metal (4%), and other (18%).

Table 2.4 Type of waste composition linked to sources

Composition	Sources
Organic	Food scraps, yard (leaves, grass, brush) waste, wood, process residues
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cups
Plastic	Bottles, packaging, containers, bags, lids, cups
Glass	Bottles, broken glassware, light bulbs, colored glass
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles
Other	Textiles, leather, rubber, multilaminates, e-waste, appliances, ash, other inert materials

Source Adopted from *What a waste,* 2012

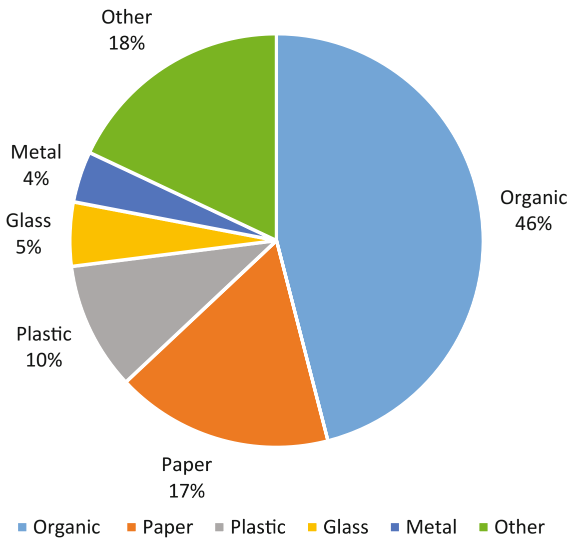

Fig. 2.1 Global solid waste composition. *Source* Adapted from *What a Waste* (2012)

In addition to the impact of waste composition on waste management, waste weight and volume are also important to the management system. This is because they affect the entire waste management lifecycle from frequency of collection, numbers of transportation vehicles and schedule, sizes and location of transfer stations, temporary storage and pretreatment, and distance to final disposal.

Table 2.5 summarizes the makeup of MSW in different groups of countries based on income and in selected cities. It shows that the makeup of Thailand's MSW is similar to other developing countries in which organic waste is the dominant waste type in almost all groups of countries. Plastic and paper, however, have a higher share in the waste stream in more urbanized towns/higher income countries.

Table 2.5 Composition of MSW in countries and selected cities

Country/location	Gen rate (kg/cap.day	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)	Source
Average low income	0.6	64	5	8	3	3	17	Hoornweg and Bhada-Tata (2012)
Average lower middle income	0.79	59	9	12	3	2	15	Hoornweg and Bhada-Tata (2012)
Average upper middle income	1.2	54	14	11	5	3	13	Hoornweg and Bhada-Tata (2012)
High income	2.1	28	31	11	7	6	17	Hoornweg and Bhada-Tata (2012)
Bangkok, Thailand	1.57	50	11.3	22.5	2.7	1.7	12	BMA (2012)
Delhi, India	0.5	38.6	5.6	6	1	0.2	49	Talyan et al. (2008)
Beijing, China	0.85	63.4	11.1	12.7	1.8	0.3	11	Zhen-shan et al. (2009)

2.3 Waste Management Practices

There are a number of alternatives available for technology and practices throughout the waste management cycle from reduction, collection, and transportation to final disposal. To manage solid waste effectively and efficiently depends on several factors such as financial support, social norms, policy priority, and so on. From the typical waste management hierarchy, waste reduction is the most preferred practice. However, not all communities and countries have similar supporting settings and potentials to achieve the same waste reduction target. System performance is affected by different practices in waste management. Table 2.6 presents a comparison of waste management practices in different countries based on income level. It shows that higher income countries tend to be more advanced in managing waste by following the concept of the circular economy which involves recirculating waste to resource.

The source reduction practice in high-income countries has achieved a higher level of progress in organizing educational programs to raise 3R awareness for consumers and in redesigning products and processes for producers to help minimize wastage. Whereas in low-income countries the practice of source reduction has shown much less movement. However, the rate of waste generation in low-income countries is relatively lower than that in high-income countries.

Table 2.6 Comparison of solid waste management practices by income level

Activity	Low income	Middle income	High income
Source reduction	No organized programs, but reuse and low per capita waste generation rates are common	Some discussion of source reduction, but rarely incorporated into an organized program	Organized education programs emphasize the three 'R's'—reduce, reuse, and recycle. More producer responsibility and focus on product design
Collection	Sporadic and inefficient. Service is limited to high visibility areas, the wealthy, and businesses willing to pay. High fraction of inerts and compostables impact collection. Overall collection below 50%	Improved service and increased collection from residential areas. Larger vehicle fleet and more mechanization. Collection rate varies between 50 and 80%. Transfer stations are slowly incorporated into the SWM system	Collection rate greater than 90%. Compactor trucks and highly mechanized vehicles and transfer stations are common. Aging collection workers often a consideration in system design

(continued)

Table 2.6 (continued)

Activity	Low income	Middle income	High income
Recycling	Although most recycling is through the informal sector and waste picking, recycling rates tend to be high both for local markets and for international markets and imports of materials for recycling, including hazardous goods such as e-waste. Recycling markets are unregulated and include a number of 'middlemen'. Large price fluctuations	Informal sector still involved; some high technology sorting and processing facilities. Recycling rates are still relatively high. Materials are often imported for recycling. Recycling markets are somewhat more regulated. Material prices fluctuate considerably	Recyclable material collection services and high technology sorting and processing facilities are common and regulated. Increasing attention towards long-term markets. Overall recycling rates higher than low and middle income. Informal recycling still exists (e.g. aluminum can collection.) Extended product responsibility common
Composition	Rarely undertaken formally even though the waste stream has a high percentage of organic material. Markets for, and awareness of, compost lacking	Large composting plants are often unsuccessful due to contamination and operating costs (little waste separation); some small-scale composting projects at the community/neighborhood level are more sustainable. Composting eligible for CDM	Becoming more popular at both backyard and large-scale facilities. Waste stream has a smaller portion of compostables than low- and middle-income countries. More source segregation makes composting easier. Anaerobic digestion increasing in popularity. Odor control critical
Incineration	Not common, and generally not successful because of high capital, technical, and operation costs, high moisture content in the waste, and high percentage of inerts	Some incinerators are used, but experiencing financial and operational difficulties. Air pollution control equipment is not advanced and often by-passed. Little or no stack emissions monitoring. Governments include incineration as a possible waste disposal option but costs prohibitive	Prevalent in areas with high land costs and low availability of land (e.g., islands). Most incinerators have some form of environmental controls and some type of energy recovery system. Governments regulate and monitor emissions. About three (or more) times the cost of landfilling per tonne

(continued)

Table 2.6 (continued)

Activity	Low income	Middle income	High income
Landfill/ dumping	Low-technology sites usually open dumping of wastes. High polluting to nearby aquifers, water bodies, settlements. Often receive medical waste. Waste regularly burned. Significant health impacts on local residents and workers	Some controlled and sanitary landfills with some environmental controls. Open dumping is still common. CDM projects for landfill gas are more common	Sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems. Often problematic to open new landfills due to concerns of neighboring residents. Post closure use of sites increasingly important, e.g. golf courses and parks
Cost	Collection costs represent 80 to 90% of the municipal solid waste management budget. Waste fees are regulated by some local governments, but the fee collection system is inefficient. Only a small proportion of budget is allocated toward disposal	Collection costs represent 50–80% of the municipal solid waste management budget. Waste fees are regulated by some local and national governments, more innovation in fee collection, e.g. included in electricity or water bills. Expenditures on more mechanized collection fleets and disposal are higher than in low-income countries	Collection costs can represent less than 10% of the budget. Large budget allocations to intermediate waste treatment facilities. Up front community participation reduces costs and increases options available to waste planners (e.g., recycling and composting)

Source Adapted from *What a Waste* (2012)

Waste collection involves the collection of solid waste from the point of production (residential, industrial, commercial, institutional) to the point of treatment or disposal. MSW is collected in several ways (see Table 2.7). According to the data analysis report by Hoornweg and Bhada-Tata (2012), regions where there are low-income countries tend to have low collection rates. The average waste collection rates are directly related to income levels. Low-income countries (i.e., African regions) have low collection rates of around 41%, while high-income countries (i.e., OECD countries) have higher collection rates averaging 98%.

Recycling practices in high-income countries is more advanced in using technology to help sorting and processing recycle materials. The recycling rate in high-income countries is higher than that in low-income countries. Most of the recycling operators in low-income countries are from the informal sector. The waste-recycling process is not properly handled nor well operated which potentially

Table 2.7 Different methods of waste collection

Method of collection	Details
House to house	Waste collectors visit each individual house to collect garbage. The user generally pays a fee for this service
Community bins	Users bring their garbage to community bins that are placed at fixed points in a neighborhood or locality. MSW is picked up by the municipality, or its designate, according to a set schedule
Curbside pickup	Users leave their garbage directly outside their homes according to a garbage pickup schedule set by the local authority (secondary house-to-house collectors not typical)
Self-delivered	Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators (or the municipality)
Contracted or delegated service	Businesses hire firms (or municipality with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private operators and may designate collection areas to encourage collection efficiencies

Source Adapted from *What a Waste* (2012)

can increase adverse impacts on community and environmental health. The greater the environmental awareness, the more marked the recovery and recycling policies applied. Some countries, such as Japan, have prioritized the recycling of industrial waste ahead of municipal waste.

Composting/anaerobic digestion can help reduce the amount of waste sent to landfill. If waste separation at source is done effectively, by-products from composting (e.g., methane recovery) can be very advantageous. In low-income countries, although there is waste with high organic composition, the practice of composting is rarely carried out. Whereas the practice of composting/anaerobic digestion in high-income countries is carried out more widely.

Incineration in low-income countries is inefficient due to the limited waste separation capacity at source. The high moisture content in MSW affects the performance of incineration that converts waste to energy. Moreover, the cost of waste management using incinerators is greater than landfilling. Therefore, incinerators are commonly implemented in high-income countries where land areas are limited and the cost of land is high. Incinerators aimed at energy recovery are commonly found in high-income countries. Generally, the choice of incineration corresponds to high urban population densities and a relative shortage of space, such as is the case in Japan.

Landfilling is a popular waste treatment method in low-income/developing countries. Open dumping or uncontrolled landfill sites are commonly found in low-income countries. Whereas high-income countries have at their disposal controlled landfills using cutting-edge techniques to recover biogas and convert waste to energy. This is because priority has been given to a clear energy and environmental policy and stringent regulation is enforced.

From Waste to Resource: World Waste Survey (2009) indicated that the poorer a country, the less it possesses effective waste policies and the higher the proportion of waste landfilled with a very high percentage placed in open dumping sites. The greater the size of a country, the greater the attraction of using space for controlled landfill sites such as Australia. In Japan, three quarters of all waste treatment involves incinerators. Growth in material recovery (composting and recycling) is very strong (over 50%) not only in Northern Europe, but also in South Korea and Singapore.

Description: Condition at an open dumping site. Photo by: Chanathip Pharino

2.4 Formal and Informal MSW Recycling

Improving the efficiency of MSW separation and recycling has become one of the approaches to enhance the co-benefits from waste management systems (i.e., reducing MSW landfilling) and energy in the production of raw materials and so on. Since the MSW generation rate is on the increase while the availability of land for landfilling and management resources (i.e., governmental budgets for MSW collection and disposal) are limited. Many countries, such as Japan, South Korea, and the U.S.A., tackle the challenges through mandating waste separation and charging a relatively higher fee for landfilling MSW as a deterrence against landfilling mixed or unsorted waste. Nauclér and Enkvist (2009) reported that MSW recycling is a cost-effective measure for solving the MSW crisis and can also reduce greenhouse gas emissions concurrently. Nevertheless, 3R programs are still not widely successful for social structure/culture reasons, such as the lack of appropriate education on the management of MSW and the lack of incentives from utilizing the 3R approach. In general, global recycling and the policy for source reduction programs around the world can be summarized as in Table 2.8. Table 2.8 shows the recycling rate of Thailand is low compared with most high-income nations. Most countries with good recycling records often set targeted recycling rates. Thailand has yet to establish a mandatory targeted rate for recycling.

Recycling in developing countries tends to be practiced on a community or on a for-profit basis. The typical model of for-profit recycling involves informal waste workers, both in terms of ragpickers at landfills and itinerant recyclable buyers, diverting a portion of recyclable MSW from being sent to landfills. There are many settlements where informal waste workers perform multiple roles in servicing MSW collection processes, such as hauling waste from households, scavenging waste, and eventually discarding rejected waste to dumpsites, resulting in high diversion rates

Table 2.8 Recycling statutes and policies toward MSW reduction in various countries

Countries	Statutory required	Target recycling rates	Current rates	Source
Wales, U.K.	Yes	52	56	BBC (2015)
European Union	Yes	50	39	European Environment Agency (2013)
Virginia, U.S.A.	Yes	25	41.2	Virginia Department of Environmental Quality (2014)
Thailand	No	30	18.4	PCD (2015)
Vancouver, CA	Yes	70	60	Nagel (2014)
Singapore	Yes	70	60	National Environment Agency (2015)

Table 2.9 Estimated costs for MSW disposal (in USD)

	Low-income countries	Lower middle-income countries	Upper middle-income countries	High-income countries
Collection	20–50	30–75	40–90	85–250
Sanitary landfill	10–30	15–40	25–65	40–100
Open dumping	2–8	3–10	N/A	N/A
Composting	5–30	10–40	20–75	35–90
Waste-to-energy incineration	N/A	40–100	60–150	70–200
Anaerobic digestion	N/A	20–80	50–100	65–150

Source Adapted from Hoornweg and Bhada-Tata (2012) of recyclables compared with those of urban settlements that do not allow informal recycling (Gunsilius et al. 2011).

For non-scavenging informal waste workers, itinerant recyclable buyers function as service providers for curbside recycling where households sell or donate recyclables to itinerant recyclable buyers. Itinerant recyclable buyers then gather those recyclables and resell them to recyclable buying centers, which is the equivalent of a drop-off recycling center in a formal recycling system. Nevertheless, the strong advantage of itinerant recyclable buyers and recyclable center buying is that they are self-funded, and the cost of running them is not a burden on the government or taxpayers, which is in contrast to the official curbside or drop-off recycling that may incur great costs to the public (Kinnaman and Fullerton 2000). The research by Challcharoenwattana and Pharino (2016) employed an analytic hierarchical process (AHP) to nominate the best informal recycling modes. Itinerant recyclable buying is recommended for all urban settlements as an effective, informal MSW collection activity.

2.5 Waste Management Cost

In terms of MSW disposal, landfilling remains the most popular choice with waste management authorities in developing countries (Agamuthu 2013). Table 2.9 shows the cost of open dumping and landfilling tending to be at the lower range compared with other waste disposal methods (i.e., waste-to-energy or anaerobic digestion). Low-income countries continue to spend most of their SWM budgets on waste collection, with only a fraction going toward disposal. This is the opposite in high-income countries where the main expenditure is on disposal.

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Chapter 3
Municipal Waste Management in Thailand

This chapter presents an overview of municipal waste management in Thailand, including the rate of waste generation, waste management policies, and management structures in Thailand. 3R implementation in MSWM, community-based waste management, and some recommendations for future system improvements are explained and discussed. The content in this chapter and the following chapters is based on the work of the author investigating how to promote sustainable municipal waste management in different areas in Thailand.

3.1 Waste Management Situation

Municipal and hazardous waste problems in Thailand have become more severe because of the lack of effective integrated management systems. In many local municipalities, there is little space for waste disposal and final treatment as a result of public protests about landfill or incineration projects near the community. In many cases, waste is managed by open dumping or open burning. The improper treatment of waste affects public and ecological health as a result of bad smells, leachate contamination to ground water or surface water, landfill burning, air pollution, and so on. Moreover, the lack of awareness of local citizens about managing municipal and hazardous waste has become a major concern. As a result, waste reduction, reuse, and recycling in Thailand leaves much to be desired. For example, in 2014 only 30% of waste generated were treated properly and recycled. The remaining untreated waste accumulates yearly and has become a major challenge for all stakeholders to resolve. Several ongoing problems about waste management in Thailand include:

C. Pharino, *Challenges for Sustainable Solid Waste Management*,
SpringerBriefs on Case Studies of Sustainable Development,
DOI 10.1007/978-981-10-4631-5_3

Description: Municipal wastes full over collection bin in residential area in Bangkok. Photo by: Methawee Thammakasorn

- Accumulating amounts of waste that are not properly handled and treated
- Lack of public cooperation in waste separation and waste reduction
- Lack of proper waste management facilities due to the NIMBY effect
- Lack of infrastructure, tools, and equipment to collect and treat waste properly from a wide range of different sources

- Lack of regulation to enforce effective waste management such as waste separation and waste management fees
- Waste collection fees do not include the true cost of waste management throughout the lifecycle of the waste management system
- Lack of policy consistency and limited budgets from local municipalities on waste management
- Lack of an holistic and integrative approach between many government agencies in policy, reduction, action plan, and budget plan.

On August 26, 2014 the Thai government approved the Roadmap for Municipal and Hazardous Waste Management. The Ministry of Natural Resources and Environment set up the Master Plan on Waste Management (2016–2021). The main principles of the plan comprise the 3R principles, which involve the reduction of waste at sources, reuse, and recycle of wastes as resources (PCD 2016). During the past 10 years in Thailand, efforts have been made to change public perceptions about waste—instead of being a burden, assets can be reused and recycled. Waste is a potential resource that can be a source of additional income and help reduce the cost of production to promote sustainable waste management. Waste that is properly separated, reused, recycled, and finally treated will prevent or at least reduce the social and environmental impact. The government supports public-private partnerships for waste management investment. The Master Plan will be the main strategy to implement and effectively manage the waste problem in Thailand.

Description: 3Rs station in condominium in Bangkok. Photo by: Methawee Thammakasorn

3.2 Waste Generation

Thailand, like many other developing countries, also faces problems of rising MSW generation. In 2015 the amounts of generated waste in Thailand were around 26.19 million tons. The trend in waste generation is increasing each year. The waste generation rate increased from 1.04 kg/capita/day in 2010 to 1.11 kg/capita/day in 2014 (see Table 3.1). The trend continues to grow according to a report by the Thailand Pollution Control Department (PCD). There is some variation in the rate of waste generation in different types of urban areas. Daily MSW generation rates were found to be 0.91 kg per capita in the smallest towns (classified by Thailand's Department of Local Administration where population size is lower than 5000) to 1.89 kg per capita in fully urbanized towns (categorized by Thailand's Department of Local Administration where population size is higher than 50,000) (Challchareonwattana and Pharino 2016). In tourist areas, waste generation is approximately 0.46 kg/capita/day for tourists who do not stay overnight and 1–2.5 kg/capita/day for those who do. In national parks the waste generation rate is around 1–2.5 kg/capita/day during the high season and 0.5–0.8 kg/capita/day during the low season. The makeup of waste depends on the types of tourist attraction and season (PCD 2016).

The two main factors affecting the rate of waste generation are (1) increasing population and (2) changing consumer behavior. There are significant increases of packaging waste in the waste stream. Bangkok (the capital) is the province that has the highest waste generation in Thailand of around 10,870 tons/day in 2014. Currently, there are 2490 waste disposal and management facilities. There are 466 landfills that can properly treat waste of around 7.88 million tons (30.1% of total waste), as shown in Table 3.2 (ThaiPublica 2014). About 4.82 million tons of waste (18.4%) are reused and recycled. Unfortunately, there are 18 waste treatment facilities that have not been able to start operation after construction mainly due to strong public protests. Many landfills often face strong opposition from stakeholders.

The current MSWM system does not provide any incentives for MSW separation and recycling for local people in Thailand. The majority of towns and cities in Thailand still employ unsound disposal methods in their approach to waste management (i.e., open dumping or open burning). The main reason is clearly the benefits of having relatively lower cost/expense for polluters compared with other more advanced MSWM methods (Hoornweg and Bhada-Tata 2012). However, recent policy and the Power Development Plan 2015 (PDP 2015) from the Ministry of Energy have set a target of promoting the production of renewable energy from waste to be 500 MW in 2036. The current installed capacity of electricity generation from waste is 66 MW (not including power from biogas and steam).

Thailand is categorized as a middle-income country. Thailand's MSW characteristics are classified as food waste (40–60% of MSW found at the landfill) while plastic, paper, glass, and metal predominate in the group of non-food waste (PCD 2004). However, the rate of material recovery from MSW, excluding composting or biogas generation, in Thailand is still low (PCD 2015). Thailand's recycling rate in 2014 was only 18.4% (PCD 2016) while that of the U.K. was 44.2% (Department for Environment Food & Rural Affairs, 2014) and that of the U.S.A. was 34.3% as reported by the U.S. Environmental Protection Agency (USEPA 2013).

Municipal solid waste management is a major concern in Thailand. The composition of waste in Thailand consists of kitchen waste or organic waste (51%), plastic and foam (22%), paper (13%), and glass (3%). Waste composition varies depending on many factors i.e population density, urbanization and income level. Different provinces in Thailand show slightly different waste composition (See Fig. 3.1). Organic waste is a major GHG source in the waste management sector. The Thai PCD reported that the predominant waste disposal practice in Thailand is open dumping (about 64%), landfill (35%), and incineration (1%). The illegal disposal of waste is widespread in Thailand as a result of the high cost of proper waste disposal.

The MSW crisis in Thailand means is now urgent to increase the efficiency of waste management by every possible approach to deal with this ongoing problem. The recycle rate in Thailand is rather low. Integrated waste management (including reduce, reuse, and recycle) has proven to be the solution of choice. Local communities could become key to improving waste management activity in their own communities. Incentives to help reduce MSW in local communities are crucial. Local efforts to manage municipal solid waste have been implemented using a number of approaches. A widely implemented 3R campaign to increase the recycling of MSW is via waste banks. Waste banks have been set up to promote the participation of sorting and recycling wastes at the community level. Waste/garbage banks are organized in many forms (e.g., school garbage banks or SGBs and community garbage banks or CGBs). In Thailand, garbage banks have been established in many areas; however, 3R campaigns have yet to be taken up by most communities. In 2001, there were approximately 500 garbage banks in 30 provinces. Thailand has yet to fulfill its potential in developing garbage banks and improve the efficiency of waste recycling.

Table 3.1 Statistics of waste management in Thailand during 2008–2014

Year	Amount of waste generation (Mton/year)	Waste generation rate (kg/cap/day)	Waste management					
			Final treatment proper improper				Utilization	
			Mtons/year	%	Mtons/year	%	Mtons/year	%
2008	23.93	1.03	5.69	23.8	14.79	61.8	3.45	14.4
2009	24.11	1.04	5.97	24.8	14.28	59.2	3.86	16.0
2010	24.22	1.04	5.77	23.8	14.55	60.1	3.90	16.1
2011	25.35	1.08	5.64	22.2	15.61	61.6	4.10	16.2
2012	24.73	1.05	5.83	23.6	13.62	55.1	5.28	21.4
2013	26.77	1.15	7.42	27.7	14.20	53.0	5.15	19.2
2014	26.19	1.11	7.88	30.1	13.49	51.4	4.82	18.4

Source PCD (2016)

Table 3.2 Statistics of MSWM methods in Thailand

MSWM methods	Details	Numbers of sites
Compliance with Thailand's MSWM standards	Sanitary/engineered landfill	73
	Controlled dump	367
	Incinerator with appropriate pollution control equipment	10
	Waste-to-energy system	1
	Mechanical-biological treatment	3
	Integrated solid waste management	12
	Subtotal	466
Non-compliance with Thailand's MSWM standards	Controlled dump	24
	Open dump	1955
	Incinerator with not-up-to-standard pollution control	45
	Total	2490

Source Adapted from ThaiPublica (2014)

An approach to encourage citizens to sort household waste at source, before disposal, is the challenge facing all stakeholders. Proper waste management would not only solve the waste crisis but would also initiate social activity toward the formation of a local carbon society (LCS). GHG emissions in Thailand in 2003 were energy sector 56.1%, agriculture sector 24.1%, waste sector 7.8%, land use and forestry sector 6.6%, and industrial sector 5.4%. The waste sector is the third largest source of GHG emissions. Therefore, the avoidance of GHG emissions as a result of improved waste management should also be considered a priority. GHG emissions from the waste management sector mainly come from the decomposition of organic waste in landfills and energy used in collection and transportation of waste. If waste is recycled, the energy used for extraction, transportation, and production of the new materials will be reduced and natural resources will be conserved for future uses as well.

Supplements paid to citizens from selling waste are the main incentives to recycle and reduce waste at source. Although, the waste bank system could help reduce environmental impacts, such as GHGs, heavy metals, and other pollutants, through the recycle lifecycle, the degree of impact reduction has neither been assessed nor explained widely to local people. The current study recognizes the importance of developing an environmental impact evaluation and accounting system that takes recycle waste into account. To acknowledge their efforts about total avoided impacts derived from whole community actions will help a government recognizing potential benefits to more promote waste banking system to other communities.

3.3 Situation of MSW in Bangkok (Thailand)

Bangkok is the capital of Thailand. The city has a financial and residential center, covers an administrative area of 1568.74 km^2, and comprises 50 districts. Bangkok is home to, 2,753,972 households and about 5,696,409 people, excluding the non-registered population (BMA 2014). The Department of Environment (DOE) of the Bangkok Metropolitan Administration (BMA) is responsible for MSWM together with the Environment and Sanitation Section of each district office. Bangkok's MSW collection has grown steadily, the volume of waste saw the greatest rate of increase between 1987 and 1990 (an average of 9.3%/year), but the rate fell back to 6–6.5% between 1991 and 2000. MSW began to rise again in 2011, reaching an average of 8943 tons/day. In 2012 the amount increased to 9747 tons/day as a result of floods at the end of 2011 and 9940 tons/day in 2014 (BMA 2015a, b).

MSW is collected by the BMA from receptacles in front of houses, buildings, or designated locations on specific dates and times. MSW is transported to three transfer stations located in Bangkok (On-Nuch, Nong-Khaem, and Sai-Mai). Some MSW is disposed of by composting using organic fertilization technology (1200 tons/day or 12% of all MSW at the On-Nuch center), and the rest from all three centres disposed of by sanitary landfill (approximately 8700 tons/day) (BMA 2014). The On-Nuch transfer station is responsible for MSW from the 16 districts of Bangkok while the Nong-Khaem and Sai-Mai transfer station cover 22 and 12 districts, respectively. Capacity at the On-Nuch transfer station is the largest: 1200 tons/day is treated by composting and 2700 tons/day goes to landfill at Chachoengsao province. The capacity of the Nong-Khaem transfer station is 3600 tons/day. Waste-to-energy technology (incineration) treats 500 tons/day while 3100 tons/day goes to landfill in Nakhornpathom province. The capacity of the Sai-Mai transfer station is the lowest, with 2400 tons/day going to landfill in Nakhornpathom province (see Fig. 3.2).

3.4 Waste Management Policies in Thailand

The structure of the waste management system in Thailand can be divided into three different levels according to the responsible authority (see Table 3.3). (1) Central government including agencies in the Ministry of Natural Resource and Environment, such as the Pollution Control Department (PCD), Department of Environmental Quality Promotion (DEQP), Office of Natural Resources and Environmental Policy and Planning (ONEP), the Ministry of Interior's Department of Local Administration (DOLA), and the Ministry of Public Health's Public Health Department, establish policies, guidelines, programs, regulations, and standards for waste management and enforcement of these regulations. (2) Regional government acts as the intermediary between central and local government for adopting and implementing policies and guidelines from central government to local government. (3) Local government is directly responsible for handling and managing waste

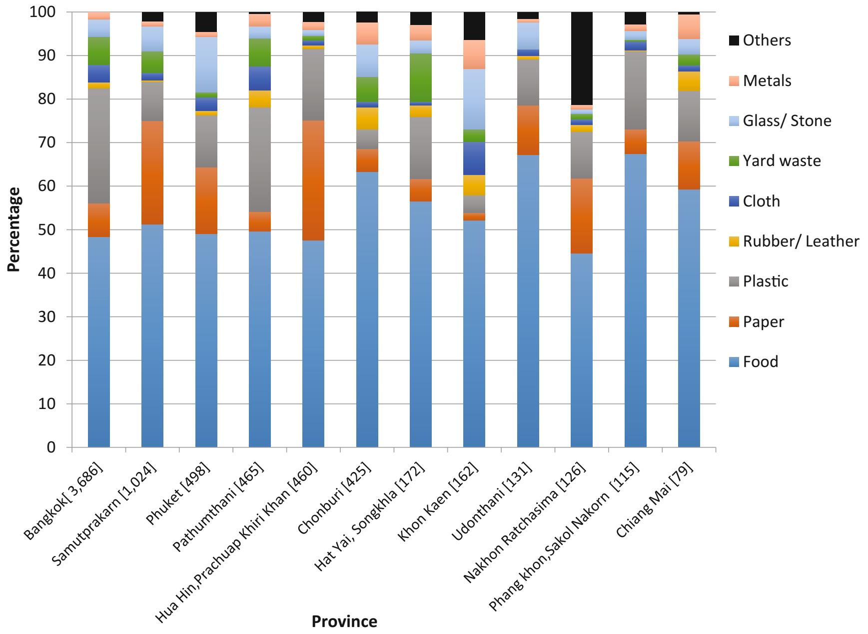

Fig. 3.1 MSW composition from selected provinces of Thailand [population density]. *Source* AIT (2004), BMA (2012), Puangsiri and Pharino (2010), Srivisitphan (2004)

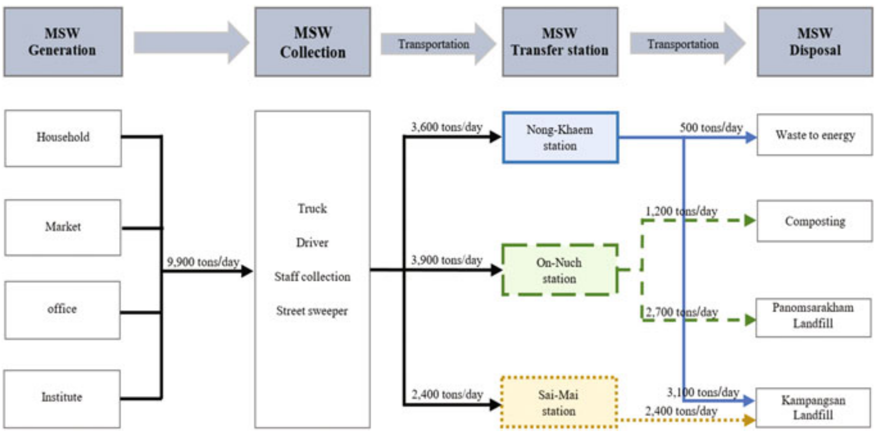

Fig. 3.2 The service system of municipal solid waste management (*MSWM*) of the Bangkok Metropolitan Administration (BMA 2014)

Table 3.3 Waste management authority and its responsibility in Thailand

Authority	Responsibility
Central government • Pollution Control Department (PCD) • Department of Environmental Quality Promotion (DEQP) • Office of Natural Resources and Environmental Policy and Planning (ONEP) • Department of Local Administration (DOLA) • Public Health Department	• Provide recommendations on the technical preparation of MSW management policy • Develop guidance/guidelines and processes for MSW management • Promote and disseminate information pertaining to MSW management • Prepare policies and prospective plans • Administer the Environmental Fund • Administer the finance of local government organization • Provide support for the preparation of local development plans • Issue ministerial regulations to stipulate service charges
Regional government • Provincial offices of the Ministry of Natural Resources and Environment	• Coordinate related work between central and local government
Local government • Local/District Municipality • Sub-district Administrative Organizations (SAOs) • Provincial Administrative Organizations (PAOs) • Special Administrative Areas (i.e., Bangkok and Pattaya)	• Handle and manage waste in their own area

within its own area. Therefore, local government plays a major role in bringing about efficiencies in waste management. However, policy coordination from government at all levels is key to better performance in MSWM.

As far as law and regulation related to waste management in Thailand is concerned, Public Health Act B.E. 2535 (A.D. 1992) is the basic regulation for waste control and management in Thailand (Mullikamal 2000). The act requires each local administration to manage its own waste by developing and issuing ordinances and regulations for collection, transportation, and disposal of waste. In addition, there are other regulations and local provision of laws for municipal solid waste management (Jiaranaikhajorn 2008) including:

The Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (A.D. 1992) empowers the local administration with the responsibility to set up a central disposal facility for public service and/or license private contractors for provision of a waste management service in the area. Moreover, this act allows for the provision of environmental funds to disburse grants or loans for investment and operation in their central facility.

The Public Health Act B.E. 2535 (A.D. 1992) provides the local government with the authority and duty to manage waste and/or to set regulations for waste management in the local area.

The Public Cleansing Act B.E. 2535 (A.D. 1992) states the requirements for public cleansing if any area is contaminated; it also covers the prohibition of litter.

Municipality Act B.E. 2496 (A.D. 1953) provides each municipality with the duty to clean up its area of responsibility and dispose of waste in its own area.

Although central government provides some budgets and/or loans for waste disposal facilities, budgets for a waste management service are mostly the responsibility of each local government. Many local areas lack sufficient investment for an effective waste management system. Historically, the lack of sufficient budgets for waste management is a main barrier to solving the ongoing problem in the waste management system (PCD 2004).

In 2014 the Thai government issued an MSW management roadmap (PCD 2014). It discourages landfilling without prior treatment and places much emphasis on waste separation and recycling as integrated parts of solid waste management. The installation of large numbers of incinerators using waste-to-energy technology are set in the roadmap.

Moreover, the government has issued a new law to raise the ceiling for MSW collection fees from 40 to 150 THB per month (Maintenance of Public Sanitary and Order Act B.E. 2560 2017). The new law also enables the local government to collect MSW disposal fees, previously covered by the local government's budget and not directly from the waste generator. The new regulation applies the polluter pays principle as the approach to financing new integrated waste management projects to meet targets already set in the new roadmap. Big challenges lie ahead in implementing this new law such as the willingness to pay (WTP) of local citizens, the fee collection system, the transparency of waste budget management, monitoring and enforcement.

3.5 Waste Management in Thailand

An estimation for MSWM costs in Thailand is presented in Table 3.4. Fees for solid waste collection contribute most to the cost of MSWM. Low construction costs and low operation costs of landfilling and open dumping continue to make the approach a popular management option. Whereas the high costs of operation and maintenance make incineration the less preferred option at the moment. Investment and operating costs for more modern MSW management are often higher when they are compared with the landfilling method.

Table 3.4 MSW cost estimation

Technology	MSW collection fee (USD per ton)	Treatment and disposal cost (USD per ton)	Total cost (USD per ton)
Sanitary landfill	24.38	9.00	33.38
Incinerator	24.38	31.32	55.69
Refuse-derived fuel (RDF) system	24.38	4.90	29.28
Integrated MSW management	24.38	14.34	38.72

Source Adapted from Department of Local Administration (2015). Exchange rate 1 USD = 34.87 THB (Bank of Thailand 29/07/2016)

Description: Wastes in Open Dumping Site in Thailand. Photo by: Nuchcha Phonphoton

Description: Separated Waste for Recycling, Community Waste Management in Thailand. Photo by: Amornchai Challcharoenwattana

Description: Wastes compression machine to reduce volume easing transportation. Photo by: Amornchai Challcharoenwattana

Description: Tractor is working in the waste transfer station in Bangkok. Photo by: Chanathip Pharino

Description: Municipal wastes are wrapped with plastic at transfer station before transporting to landfill. Photo: Chanathip Pharino

Description: Municipal workers separate wastes at transfer station. Photo by: Chanathip Pharino

Under the Thailand Public Health Act B.E. 2535 (1992) (TPHA), the responsibility to collect and dispose of MSW is delegated to Local Administrative Organizations (LAOs) such as municipal governments. However, the TPHA only authorizes LAOs to charge MSW collection fees from waste generators. Treatment and disposal costs are not mentioned in the TPHA as they are supposed to be covered by the Enhancement and Conservation of the National Environmental Quality Act B.E. 2535 (1992). Consequently, most LAOs, who are the main implementers, use the fees to handle both collection and disposal expenses. MSWM costs per resident have risen substantially as a result of urbanization increases brought about by complicated collection routes and higher waste generation amounts. Table 3.5 shows that collected MSWM fees cover only approximately 10–36% of the annual cost of MSWM in sampled small municipalities and less than 10% in sampled larger municipalities. The lack of sufficient finance for MSWM has become a major concern in finding a sustainable solution. There is a need for a more effective approach such as the polluter pays approach and stakeholder participation.

3Rs of Waste Management

Waste reduction, reuse, and recycling (3R) seems to be the management hierarchy of choice in all countries. The reduction of waste generation requires not only citizen actions but also incentives from private and government sectors in an effort to bring about behavioral change. Moreover, the recycling rate of Thailand is relatively low compared with most high-income nations. Most countries with good recycling records have often set targeted recycling rates. Focused as it is on setting recycling goals, Thailand has not established a mandatory targeted rate for recycling. In 2016 the Thai government had set up a master plan for municipal waste management that emphasized the 3Rs as the key principle. There is no specific mandatory act to enforce the recycling of waste. It will be necessary in the near future for the Thai government to set up such a regulatory framework as a management instrument to increase the effectiveness of the 3R principle on waste management. Additionally, at-source separation helps a material recovery facility (MRF) to achieve better recovery.

Recycling activities in developing countries tend to be practiced at the community or for-profit level. The typical model of for-profit recycling is that informal waste workers (IWWs), both in terms of ragpickers at landfills and itinerant recyclable buyers (IRBs), divert some of the recyclable MSW from being sent to landfills. In many settlements, IWWs performed multiple roles in servicing MSW collection processes, such as hauling waste from households, scavenging it, and eventually discarding it to dumpsites, resulting in high diversion rates of recyclables compared with those of urban settlements that do not allow informal recycling (Gunsilius et al. 2011).

For non-scavenging IWWs, IRBs function as service providers for curbside recycling where households sell or donate recyclables to them. IRBs then gather

Table 3.5 MSWM expense from municipal budget in selected municipalities in Thailand

Parameters	Peri-urban (Thumbon municipality)		Urbanized municipality (Muang municipality)		Most urbanized municipalities (Nakorn municipality)	
	Thumbon Lamthough Municipality, Nakorn Rajsrima	Thumbon Krui Buri Municipality, Prachub Khirikhan	Muang Nong Pre Municipality, Chonburi	Muang Municipality, Prachub Khirikhan	Nakorn Nakorn Rajsrima, Nakorn Rajsrima	Nakorn Chieng Rai, Chieng Rai
Registered populations	5950	9830	61,198	17,901	136,153	69,612
% MSW's related expense from overall expenses	0.57	3.48	13.88	10.41	9.78	14.54
% fee covered in MSWM expense	36.36	10.47	11.48	3.47	0.05	6.37
Expense for MSWM per head (USD)	0.91	5.69	18.06	26.16	23.23	27.17

Source Adapted from Challcharoenwattana (2015) those recyclables and resell them to recyclable buying centers, which is the equivalent of a drop-off recycling center in a formal recycling system. Nevertheless, the great advantage of IRBs and recyclable center buying (RCB) is that they are self-funded, and the cost of running them is not a burden on the government or taxpayers, which is in contrast with the official curbside or drop-off recycling that may incur great costs to the public (Kinnaman and Fullerton 2000).

In Thailand, recycling actions mostly rely on scavenging activity to recover recyclables. This practice is inadequate because high potential recyclables may be contaminated by wet waste, which degrades their quality and can eventually be deemed unsuitable for recycling, or by household hazardous waste (i.e., motor oil) (Gunsilius et al. 2011). Recovery by ragpickers and scavengers has been found to account for approximately 4–12% of generated MSW (Challcharoenwattana and Pharino 2015; Ojeda-Benitez et al. 2002; Wilson et al. 2001). Itinerant recycling collection tended to outperform other modes of informal recycling collection in various towns in Thailand. The WTP analysis for a recycling service in different urban settlements in Thailand revealed that the mean monthly WTP rose with urbanization in the least urbanized areas ($\sim$0.73 USD), urbanized areas ($\sim$1.96 USD), and the most urbanized areas ($\sim$1.65 USD). Common factors that influenced WTP were (a) higher level education and (b) the habit of separating recyclables. However, other socioeconomic and recycling behavior factors affected WTP in each settlement differently (Challcharoenwattana and Pharino 2016).

3.6 Thailand Environmental Quality Management Plan (2012–2016)

The Thailand Environmental Quality Management Plan (2012–2016) puts forward strategies to promote the good environmental quality of Thai citizens. Guidelines in the plan aim to increase the efficiency and roles of all stakeholders to help manage environmental quality and natural resources. Strategies related to municipal waste management that the government will implement include:

1. Support local municipalities to manage municipal, infectious, and hazardous waste. The government will allocate budgets for local municipalities to apply appropriate waste management approaches that are suitable for local problems and local capabilities. The private sector is encouraged to partner in providing services and solutions for waste management.
2. Develop an economy-based management instrument to increase incentives for waste reduction at source such as emission taxes, waste charges, and deposit-refund systems.
3. Improve the municipal hazardous waste management system, especially by setting up a system to manage waste from electrical and electronic equipment (WEEE) such as lamps and batteries.

4. Create incentives for large, medium, and small-sized investors to implement environmental technology for pollution prevention rather than pollution treatment which can lead to zero waste/emission or the implementation of clean technology to increase the efficiency of investment in terms of tax exemptions, soft loans, investment privileges, and so on.
5. Promote technology transfer from foreign investors/manufacturers to increase producer responsibility for waste management.
6. Develop a capacity-building campaign for local municipality staff in environmental management, especially when it comes to infectious waste management.

3.7 Recommendations for MSWM in the Future

The lessons learned from Challcharoenwattana and Pharino (2015, 2016) about promoting the recycling system for municipal waste management in Thailand can be applied to other countries with similar socioeconomic backgrounds. The recommended approaches include:

I. Establish appropriate MSW service fees for MSWM system improvement

The option of raising MSWM fees to cover the cost is acceptable from the WTP study for increasing the efficiency of a recycling system. Unit-based pricing remains the most appropriate pathway for MSW reduction. Respondents for all study sites are willing to pay for the implementation of an MSW recycling system. The mean WTP from all three study sites were still lower than the true cost of MSWM via landfilling.

II. Using price incentives to promote recycling

Recycling that has a financial return, when compared with recycling that does not, provides support for changing from a flat rate MSWM fee to a pay-as-you-throw system. Respondents reacted well to a change in price. Incentives and pricing of MSWM should be tailored to suit the local context and not be a one-size-fits-all scheme as is currently implemented in Thailand and other countries.

III. Promoting informal waste collection

IRBs are a good choice for collecting recyclables compared with other recycling collection activities. A curbside recycling service can help divert more recyclables in terms of unit weight of recyclables per member when compared with other drop-off collection programs in Thailand. The incorporation of IRBs into MSW service would be beneficial for MSW recycling and would help increase the cost-effectiveness of recycling waste collection.

IV. Empowering community-based recycling

Examples of public-private partnerships can be found in CBM activities, such as waste banks. Landfill or open dumping may have relatively lower initial investment costs, but in the long run these methods can incur expensive operating costs and produce significant adverse impacts on the environment, particularly climate change. Raising public awareness, elaborating the benefits of reducing MSW, and creating incentives for comprehensive waste management for citizens nationwide are essential to creating a sustainable waste management system.

V. Develop a tailored MSW servicing program

A roadmap to promote recycling should start by conducting a public survey in the town of interest before implementing a recycling program because local people may already engage in some form of informal recycling activity. The local government may need to provide incentives to those participating in the informal recycling system by allocating funds that otherwise would have been used for landfilling those recyclables. Establishing a public-private partnership program, especially a community-based one, may provide additional incentives, both in terms of economies of scale (Callan and Thomas 2001; Zen and Siwar 2015) and in terms of moral support and peer pressure (Sekerka and Stimel 2014; Sexton and Sexton 2014). For Thailand, however, the synergy between local activists and local government is likely to help promote recycling activities, both in the formal and informal recycling sectors.

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Chapter 4
Community-Based Waste Management in Thailand

Case Study: Phang Khon, Sakon Nakhon Province

This chapter focuses on the community-based management (CBM) approach to waste. The CMB concept is explained in detail. Since waste banks are widely implemented in Thailand, the chapter looks at their design and performance. A case study on CBM in Phang Khon, Sakon Nakhon province (Thailand) is the focus of the chapter. The research presented in this chapter was conducted by the author and fellow researchers. Key factors in successfully implementing CBM and lessons learned from the case study are presented. There are key features in the case study that might be beneficial for other communities to adapt and apply to fit local settings in each community.

4.1 Community-Based MSWM

Community-based management (CBM) is a bottom-up approach to solve problems where members of the community function as core operators. CBM can resolve waste management issues effectively with less burden on the taxpayer than the traditional waste management model (Cunningham et al. 1995; Liddle et al. 2014; McKenzie-Mohr 2000). Employing CBM as a tool for resource management is found in other fields such as water resource management (Dewan et al. 2015; Margerum and Robinson 2015), forest management (Cagalanan 2015; Sharma et al. 2015), and community services (Farmer et al. 2001; Wallerstein and Duran 2006).

Regarding solid waste management, CBM is employed for both regular MSW services and specific waste services. Regular MSW services involve CBM members collecting refuse from households, as well as sorting and managing waste (Afroz et al. 2009; Wilson et al. 2006). Specific waste services focus on certain types of waste; they only accept recyclable waste or organic waste for composting/biogas generation. In addition to promoting better resource reutilization, associated

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benefits of CBM in MSW are also reported such as increased incomes for CBM members due to better economies of scale and reduced health risks from random scavenging (Medina 2008). An example can be found in the city of Surabaya (Indonesia) where organic waste is successfully managed using a community composting system (Afroz et al. 2010; Kurniawan et al. 2013). Other examples include the recycling program practiced by the waste picking service of the Zabbaleen group in Cairo (Egypt) or CBM projects in Lusaka (Scheinberg et al. 2011; Wilson et al. 2006).

In Thailand, CBM favors waste banks for municipal waste. Local communities set up a common location as the place for recycling. Program operators act as intermediaries to sell sorted recyclables at greater net revenues. Such activity is often part of a collaboration between waste generators and other stakeholders who agree to host recyclables at their sites (often schools or community centers). The success of waste banks in Thailand varies depending on the social structure and political situation in local communities (Mongkolnchaiarunya 2005; Suttibak and Nitivattananon 2008).

Examples of CBM in Thailand can be found in Mongkolnchaiarunya (2005) who reported the "recyclable wastes for eggs" recycling project introduced in the municipality of Yala. The project was initially able to attract a large volume of recyclable waste, but the rate significantly dropped during the 13-month reporting period. Nevertheless, the decrease was viewed as usual since people often store waste before putting it out for collection at which time the volume of waste returns to a normal MSW generation rate. The author also observed an increasing percentage of people collecting MSW collection fees from 37.7% in 1999 to 58.6% in 2001. BMA (2013) reported that its community-based MSW management program helped to reduce MSW generation of 12 participating communities by 40% compared with collected MSW in 2010. The Bangkok Metropolitan Administration's special showcase, the Tawee-Saph Tawee-Boon Recycling Project, which is a waste bank program, used a drop-off system to collect recyclable materials and credit participants' accounts after waste dealers payed for the lot. During its 3-year program, the system has amassed 2197 members and is able to divert 130 tons of recyclable materials from landfills. Other styles of community-based MSWM are provided in Table 4.1.

4.2 Waste Banks in Thailand

Waste banks have been implemented in many countries such as Vietnam, Indonesia, and Thailand. Initially, waste banks are usually set up in schools for student recycling such as the Bogor Nature School in Indonesia (Sufa 2010) and Ban Bakan School in Thailand (Siangyen 2009). Now, waste banks are either in the form of school waste banks or community waste banks. In Thailand, school waste banks are implemented more than community garbage banks (CGBs) (World Bank

Table 4.1 The performance of community-based MSWM

Activity	Incentive	Reutilization metric
Regular MSW collection and disposal service		
Enugu (Nigeria) (Nzeadibe 2009)	Cash revenue higher than minimum wage	Potential earnings of USD 3.91–5.47 per day
Guiyang (China) (Xu et al. 2015)	Monetary incentive for MSW separation	87.3% of MSW is separated
Nungankkan (India) (Colon and Fawcett 2006)	De facto rights to provide service	6.5% of generated MSW is sold
Jubilee Hills (India) (Colon and Fawcett 2006)	De facto rights to provide service	25% of generated MSW, one half as compost, and one half as recyclables
Waste bank operations		
Rayong municipality (Thailand) (Rayong City Municipality 2013)	Community recognition and cash return	17.33 kg/member
Yala municipality (Thailand) (Mongkolnchaiarunya 2005)	Bartering between unused recyclables and eggs	15.71 kg/member
Average 10 community-based programs in Thailand (Suttibak and Nitivattananon 2008)	Community recognition and cash return	18.6 kg/member
Average 100 school-based programs in Thailand (Suttibak and Nitivattananon 2008)	Community recognition and cash return	32.13 kg/member

Source Adapted from Challcharoenwattana (2015)

2003; Suttibak and Nitivattananon 2008). Many developing countries face the same situation as Thailand. Waste banks in Indonesia, for example, are not widely implemented (Terre de hommes Italia 2010).

The recycling campaign in local communities in Thailand has led to waste banks being set up only in some communities in Thailand. Waste/garbage banks are places/organization where members take their recyclable materials in exchange for money, then the bank records the value of the waste sold and deposits the income from selling it into the member's account. The Wongpanich Company set up garbage banks in Thailand, and in so doing helped poor children and students in Pitsanulok City who collected the recyclable waste to sell to the store, then deposited the money from selling waste into their bank accounts. Hence, if there were garbage banks in schools, it would be more convenient for students (TEI 2011). In 1999, the first garbage bank project was set up at Panpi Temple Municipality School, Amphur Muang, Pitsanulok to encourage students and citizens to sort, recycle their waste, and take it to sell (TEI 2011).

Because of the success of school garbage banks (SGBs) the concept was expanded to other communities. The waste banking system in Thailand is set up in the form of SGBs and/or CGBs. In Thailand, there are about 500 SGBs set up in 30 provinces (TEI 2011). Each garbage bank reduces the total amount of waste that would otherwise be disposed of into landfill at the rate of approximately 3–5 tons/month. Total waste has decreased by approximately 18,000–30,000 tons/year. Hence, waste banks have the potential to reduce the national budget spent on waste management by many millions of baht (TEI 2011). The financial benefit is an incentive for other communities in Thailand to adopt waste management systems. Moreover, garbage banks are symbolic of environmental conservation activity in which the community plays a major role in voluntary care of the environment. Nevertheless, in many areas of Thailand the garbage bank system is in its infancy. Continuation, improvement, and expansion of the concept to other communities in Thailand is very important.

4.3 Lessons Learned from Sakon Nakhon Province (Thailand)

Given the MSW crisis Thailand is facing, it is important to try every possible approach to increase the efficiency of waste management to deal with the ongoing problem. Integrated waste management (including reduce, reuse, and recycle) has proven to be the recommended solution. Municipal solid waste (MSW) is actually a local environmental, economic, and social problem, which could effectively be managed by local people. Therefore, incentives to help reduce MSW in local communities are crucial. However, local initiatives to eliminate solid waste in local communities are still insufficient.

Local efforts to manage MSW have resulted in waste banks being set up to promote participation in sorting and recycling at the community level. Waste/garbage banks are organized in various forms such as SGBs and CGBs. In Thailand, garbage banks have been established in many areas; however, campaigns promoting these do not cover all communities. Suttibak and Nitivattananon (2008) claimed that SGBs and CGBs are beneficial for material recycling and recovery. But lack of incentives to participate in the 3R campaign setting as community center needs to be solved to increase municipal waste management efficiency. Once garbage banks and the 3R principle are widely implemented, this will certainly bring significant benefits to local communities and help improve MSW situations in Thailand in a sustainable way; hence, finding a means of encouraging citizens to sort household waste at source before disposal is a major challenge facing the government.

Description: Community biogas from organic waste management in Pangkone, Sakonnakorn, Thailand. Photo by: Chanathip Pharino

Description: Compost from organic waste management in Phang Khon, Sakol Nakorn, Thailand. Photo by: Chanathip Pharino

The local government in Phang Khon Municipal District in Sakon Nakhon province aims to encourage its citizens to participate in a local waste management campaign. Therefore, a waste-banking system has been set up in the community which requires local people to open waste accounts so that they can deposit incomes from selling recyclable wastes to the community center. As banking continuously operates and records recycling waste activity in the accounts, data are readily available for evaluating the efficiency and effects from recycling waste activity as a consequence of the waste-banking system.

In Sakon Nakhon province there are 11 municipal districts participating in the municipal waste reduction campaign including Srijumpa, Nongsarpang, Banmai, Joaputhongdang, Poachai, Poangan, Nongsim, Banthung, Talard, London, and Namuang. The total population of the communities is approximately 3555 persons. Average waste generation of the community is approximately 127.2 tons/month.

In support of the 3R campaign the local government has set up a waste-banking system using the community center as the waste deposit and selling site. To participate in the scheme, citizens have to open accounts to be able to deposit their income from selling recyclable waste. The purpose of the system is to create incentives for citizens to manage their own MSW and change their consumption-disposal behavior.

Local government officials and volunteers in the community operate the waste-banking system in Phang Khon district. Recyclable waste is collected separately by regular municipal waste collection. As a result of the limited capacity of officials to collect recyclable waste from the entire area every day, the frequency of recyclable waste collection in each district rotates on average every 2 weeks. Municipal officials collect recyclable waste from community drop-off points, and then directly transport and sell them to the recycling company at the market price. Citizens benefit from the convenience and better sale price (as a result of large volumes). Based on the amount and types of waste sold, income balances are credited to each citizen's waste account.

To register for the system, citizens in the community must continuously sell their recyclable waste for at least 6 months. If members do not continuously sell their waste for 6 months, their membership expires and all benefits provided by the bank system will be cancelled. During the first 6 months of membership, members cannot withdraw their money. Incentives of the bank system go beyond revenues from selling their recyclable waste, they also guarantee welfare if a member dies by providing financial support for the funeral of 5000 baht/person.

Based on the case study results, the ratio between waste recycling and total waste generation by weight from high to low is glass 1.75%, paper 1.44%, plastic 0.51%, ferrous 0.33%, and aluminum 0.03%. Glass recycling has the highest recycle efficiency (82.59%). This is probably because glass is highly consumed and easy to sort and collect for recycling. Ferrous recycling (2.12 tons) ranks second for recycling efficiency (46.21%). In addition to the supplement incomes citizens receive from selling waste, the system helps reduce environmental impacts such as GHGs, heavy metals, and other pollutants, through the recycle lifecycle.

Based on my research study (Puangsiri and Pharino 2010), Sakon Nakhon province (Thailand) was chosen to investigate the local government mechanism of setting up a waste-banking system to increase MSW efficiency and alter citizens' consumption-disposal behavior. Several lessons can be learned from the study including (1) financial incentives via the waste-banking system help change local people's waste disposal actions; (2) the system creates awareness and a new culture in which people feel more responsible for their own trash; and (3) being able to measure negative impacts helps educate citizens to recognize the values of energy saving and the environmental impacts from their actions. Local-scale waste management should be given higher priority so that awareness of the importance of increased SWM effectiveness is made clear to the community as a whole.

4.4 Key Factors for Case Study Success

The study found the key factors for program success included (1) financial incentives the system provides for members; (2) the awareness and willingness of local officials to initiate and operate the system; (3) increased public education in properly sorting and disposing of waste; and (4) provided adequate support (facility and service) to make it easy for members to recycle their waste.

As soon as the local government in Sakon Nakhon recognized the benefits of proper waste management, it set up the waste-banking system to systematically improve the public recycling system. The bank concept helps educate citizens about waste management and provides advantages from recycling waste via waste-banking accounts.

Moreover, the local officials operating the system continuously service members by picking up their waste from the local waste-recycling center every 2 weeks. The main objective is to provide convenience and to incentivize customers to recycle waste.

The government has come up with several incentives to increase the rate of participation. Financial incentives are (1) incomes for members who recycle their waste and (2) provision of financial support to members in the event of death to the tune of 5000 baht/member. The benefits have successfully stimulated public participation to become members of the system.

Moreover, to increase public awareness, participation rate, and waste separation efficiency, the local government regularly educates people and asks neighbors to help each other to properly sort their waste.

Dedicated government planning and implementation of the system as well as public willingness to participate have proved to be significant elements for improvement of waste management in the local community, as shown by the case study of the Phang Khon Municipal District in Sakon Nakhon province.

4.5 Incentives from CBM Programs

The Phang Khon waste bank in Sakon Nakhon province put in place several waste management programs such as “Wastes to Saving for Ensuring the Future” (*Kayah Sasom Ngern Thong Kum Krong Ana Kote* in Thai) and “Hazardous Wastes Exchange for Eco-Points” (*Kayah Pis Laak Taam* in Thai). The study collected waste data from waste accounts (Figs. 4.1 and 4.2). Waste information recorded in the bank system served as a good database for evaluating reduction of the environmental impact compared with the business-as-usual scenario (no recycling).

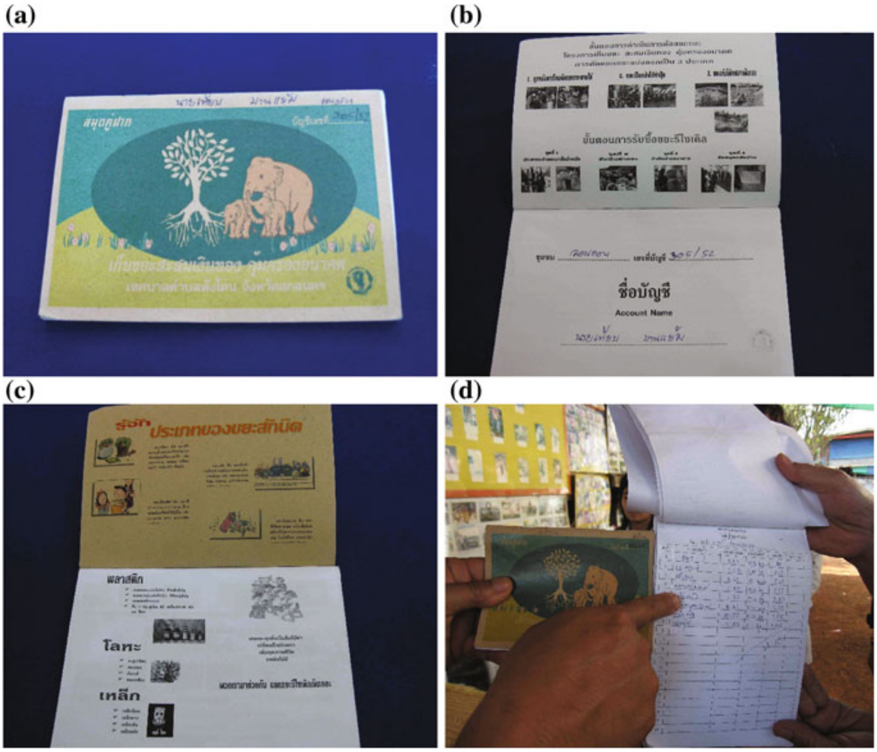

Fig. 4.1 A ledger showing a waste bank account in Phang Khon district. **a** First page of the waste bank ledger. **b** The ledger provides details and name of the member, and the process of operation. **c** The ledger provides details about the waste recycled. **d** Worksheet recording the types and weight of waste and the income earned

Fig. 4.2 A building in a village in Phang Khon province used as a community waste bank

Description: Community campaign to promote reduce, reuse, recycle in Phang Khon, Sakol Nakorn, Thailand. Photo by: Amornchai Challcharoenwattana

Based on the study to evaluate the co-benefits from better MSWM via CBM by Challareonwatta and Pharino (2015) in Phang Khon, the results confirm that CBM activities have been proven to provide the co-benefits of a reduction in the financial burden for administration and operation by minimization of landfill for MSW and the generation of income from sales of recyclables from CBM members. Moreover, CBM can also pride itself on the co-benefits of reducing GHGs from recycling and stopping waste from going to landfills. The results show that baseline carbon intensity (CI) of GHG emissions was 0.47 tons of CO_2e per ton of collected MSW which is lower than the CIs from other towns of similar size such as 0.67 tons of CO_2e per ton of collected MSW in Muang Klang municipality (Menikpura et al. 2013a, b) or 0.73 tons of CO_2e per ton of collected waste in Nonthaburi landfill (Menikpura et al. 2012).

The environmental impacts avoided can be estimated from the fact that recycling waste (mainly glass, paper, plastic, ferrous, aluminum) can be recycled for reuse and save the exploitation of raw materials and in so doing reduce upstream environmental impacts in extraction, transportation, and production. Organic waste reutilization programs (e.g., composts and residuals from biogas generation) are highly applicable to agriculture-based societies and periurban/rural settlements as most MSW is organic based. A more advanced model of MSW recycling may be more suitable (i.e., refuse-derived fuel produced by a mixture of plastic, garden, and paper waste, or large-scale anaerobic digestion system for food and organic waste).

Description: Community campaign to promote reduce, reuse, recycle in Phang Khon, Sakol Nakorn, Thailand. Photo by: Amornchai Challcharoenwattana

Description: Community campaign to promote reduce, reuse, recycle in Phang Khon, Sakol Nakorn, Thailand. Photo by: Amornchai Challcharoenwattana

The case study suggests that MSW reduction through CBM can potentially be extended and implemented in up to around 50% of residential communities in Thailand. Because the local government in Phang Khon recognizes the benefits of proper waste management, it set up the waste-banking system to systematically improve the public recycling system. The bank concept helps educate citizens about waste management and alter their behavior in caring for the local environment. The local government regularly educates people and asks neighbors to help each other sort their waste. Moreover, local officials operating the system have continuously provided members with a service by picking up their waste from the drop-off local waste recycling center every 2 weeks. The main objective is to provide convenience and make it easier for customers to recycle waste. In addition to income from selling the waste, the waste bank provides welfare to support members when they die to the tune of 5000 baht/member. They need to keep their membership up for at least 6 consecutive months to qualify for the benefits. The case study shows that benefits successfully stimulate public participation in the system. Dedicated government planning in implementing the system and public willingness to participate have proved to be significant elements of the success of community waste banks.

Description: Municipal workers separated wastes after collection in Phang Khon, Sakol Nakorn, Thailand. Photo by: Amornchai Challcharoenwattana

Description: Municipal workers weight recycle wastes in waste bank campaign in Phang Khon, Sakol Nakorn, Thailand. Photo by: Amornchai Challcharoenwattana

In conclusion, the incentives from participating in waste banks could convert local communities into sustainable communities. Sustainable development can be viewed from three aspects: environmental, social, and economic. From the environmental aspect, community waste banks help reduce waste dumped into landfills and minimize associated environmental impacts. From the social aspect, communities could reduce the numbers of people looking for and picking up recyclable waste from curbsides and/or bins. From the economic aspect, waste banks provide benefits to communities in the form of financial support, which participating members enjoy. The amount earned depends on their efforts and the market values of recycling materials. The waste-banking system needs to be promoted in an effort to get it implemented more widely. This will certainly help increase public benefits and the effectiveness of MSW management and become a pathway toward a low-carbon community.

The system merits promotion and wider implementation because it clearly verifies and acknowledges local efforts in recycling waste and in so doing avoid negative environmental impacts on the whole community. The association of climate co-benefits and the ability to save public funds through MSW reutilization is clear. This will help increase public benefits and the effectiveness of MSW management.

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Chapter 5
Household Hazardous Waste Management in Thailand

This chapter presents details of household hazardous waste (HHW) situations, generation, and characteristics. How these types of waste are managed in Thailand and the impact of such management are also presented. A case study on HHW management in Bangkok based on the author's own research is provided and discussed. Policy recommendations to better improve HHW management are explained. The content is based in part on the author's research.

5.1 Household Hazardous Waste

Definition

Hazardous waste and HHW can be defined as "Household hazardous waste (HHW) is hazardous waste generated by communities and households, but does not include industrial hazardous waste and infectious waste." In Thailand, the Pollution Control Department defines HHW as any household products containing hazardous substances. "Hazardous substances" under the Hazardous Substance Act, B.E. 2535, are defined as flammable materials, oxidizers and peroxide substances, toxics, substances causing diseases, radioactive materials, genetically modified products, corrosives, irritants, and other materials that might cause danger to individuals, animals, plants, property, and the environment. The U.S. Environmental Protection Agency (USEPA) also has given the HHW definition as leftover household products that contain corrosive, toxic, ignitable, or reactive ingredients (EPA 2013).

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Hazardous waste can be described as follows:

Property	Detail
Ignitability	Ignitable waste, such as waste oils and solvents, can create fires under certain conditions
Corrosive	Corrosive waste, such as battery acid, are acids or bases (pH less than or equal to 2, or greater than or equal to 12.5) that are capable of corroding metal containers, such as storage tanks, drums, and barrels
Reactivity	Reactive waste, such as lithium-sulfur batteries and explosives, are unstable under "normal" conditions. They can cause explosions, toxic fumes, gases, or vapors when heated, compressed, or mixed with water
Toxicity	Toxic waste is harmful or fatal when ingested or absorbed (e.g., containing mercury, lead, etc.)

Households and businesses such as shops, hotels, dry cleaners, gas stations, etc. are the main sources of HHW. Common items considered major sources of HHW can be listed as follows:

Category	Products
Household cleaning products	Aerosols, air fresheners, bleach, ammonia, drain cleaners, oven cleaners, aluminum cleaner, spot remover, dyes, furniture polish, rug cleaners, wood preservatives
Automotive products	Lead-acid batteries, antifreeze, automatic transmission fluid, brake fluid, fuel additives, gasoline
Paints and solvents	Acetone, wood preservatives, varnishes and lacquers, paints, paint and varnish removers, paint thinner
Pesticides	Insecticides, herbicides, rodenticides, fungicides, germicides, insect repellents
Medicine	Food supplements
Other products	Pool chemicals, ammunition, dry cell and disk batteries, toy airplane glue, photographic chemicals, septic tank cleaners, some glues and adhesives

5.2 Household Hazardous Waste Generation

HHW is mainly generated in residential and commercial areas such as households, shops, hotels, gas stations, and schools. According to the Thailand State of Pollution Report in 2011, 719,500 tons of HHW was generated that year. Waste from electrical and electronic equipment (WEEE) accounted for approximately 52% (374,140 tons) while HHW such as batteries, light bulbs, and chemical containers accounted for approximately 48% (345,360 tons). The waste generation rate was 1971 tons/day or 0.03 kg/capita/day. Figure 5.1 shows that in Thailand industrial hazardous waste, HHW, and infectious waste generation increased every year between 2007 and 2011.

Table 5.1 shows the HHW generation rate in different countries. The rate varies greatly in these countries. In Thailand and Vietnam, the HHW generation rate was similar. Many factors may have influenced the rate including consumption behavior, economic activities, and scope of data collection.

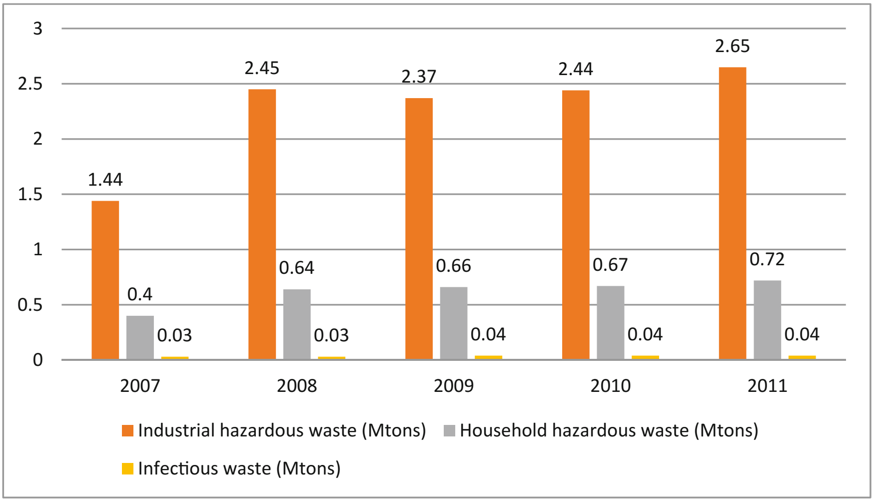

Fig. 5.1 Hazardous waste generation in Thailand between 2007 and 2011 (PCD 2011)

Table 5.1 HHW generation in different countries

Country	HHW generation	References
India	5 g/capita/day (110 Mtons/year)	Lakshmikantha and Lakshminarasimaiah (2007)
Vietnam	0.554 g/capita/day	Thanh et al. (2010)
EU-27	202 kg/capita/year (4.05 Mtons/year)	Eisted and Christensen (2011), Kahhata and Williams (2012)
Thailand	0.72 Mtons/year	Pollution Control Department (2011)

In Bangkok (the capital city of Thailand), 0.89 million tons per year of hazardous waste was generated. Approximately 69.6% (0.62 million tons) was industrial hazardous waste, 29.21% (0.26 million tons) was HHW, and 1.78% (0.016 million tons) was infectious waste.

While the percentage of industrial hazardous waste was very high, regulatory requirements for proper treatment of industrial wastes were also in place and enforced stringently. The situation of industrial hazardous waste, therefore, was not as serious as that of HHW since the HHW lacked proper collection and treatment processes and procedures.

5.3 HHW Impact and Treatment

There are a number of impacts caused by HHW as a result of the various possible toxic substances it contains. Table 5.2 presents the major toxic substances and health impact of each substance. Without proper management of HHW, hazardous substances may contaminate the environment and can pose serious health risks to the general public in the nearby area. For example, if fluorescent lamps are mixed together with general waste, they may get broken during transportation. The mercury contained inside the lamps may directly be exposed to workers. This can cause skin irritation, hyperplasia, inflammatory bleeding, abdominal pain, and severe diarrhea.

Description: Household Hazardous Waste Collection Station in Condominium in Bangkok. Photo by: Methawee Thammakasorn

Table 5.2 Impact of HHW substances on health

Material	Major hazardous substance	Health impact
Light bulbs	Mercury	Skin irritation, hyperplasia, inflammation, severe diarrhea, bleeding, abdominal pain
Batteries	Lead	Headache, tiredness, anemia, abdominal pain, muscle aches, amnesia, shaking, loss of consciousness
Chemical containers (depending on type of chemical) such as insecticides and paint	Mercury, lead, manganese	Similar to batteries but also emotional and mental difficulties, hallucination, cramps, confusion, encephalitis
WEEE	Lead	Damages nervous system, endocrine system, blood, kidneys, and brain development of children
	Mercury	Damages brain and medulla resulting in loss of self-control
	Chlorine	Carcinogen
	Cadmium	Acute effect on respiratory system
	Bromine	Carcinogen
Others such as cosmetics, cleaning products, self-care products	Specific to type of substance	Skin irritant allergies

Source Pollution Control Department (2011)

There are a number of HHW treatment technologies available. Each has different advantages and disadvantages. Five management approaches that are commonly used with HHW are recycling, alternative fuel, treatment, incineration, and secured landfill (as summarized in Table 5.3). Examples of common HHW disposal methods for specific waste streams are presented in Table 5.4.

Table 5.3 Household hazardous waste disposal approaches

Management approach	Description
1. Recycle	There are different forms of HHW recycling. A particular product is refined and returned to original use such as motor oil and latex paint. Another form of recycling involves breaking down the product and reconstituting the usable part such as light bulbs and electronic waste. HHW items that are commonly recycled include latex paint, propane cylinders, rechargeable batteries, mercury, antifreeze, motor oil, and oil filters
2. Alternative fuel	Fuel blending or alternative fuel management is the process of combining high BTU-value materials, such as oil-based paint, solvents, and gasoline to use as an energy source alternative to fuel cement kilns
3. Treatment	Treatment is widely available for corrosive and oxidizing waste. There are a number of specific treatment methods available such as chemical oxidation and reduction, neutralization, metal precipitation, flocculation, filtration, and carbon adsorption. HHW items commonly sent for treatment include cleaners and pool chemicals
4. Destructive incineration	HHW heats to extremely high temperatures (1800–2200 °F, sometimes more). The process converts solid and liquid waste into gases. A by-product of this method is hazardous ash. Ash residue is treated to meet regulatory specifications and then sent to a hazardous waste landfill. HHW items commonly incinerated include pesticides and organic peroxides
5. Secured landfill	Hazardous waste landfills are required to meet stringent federal and state standards regarding their location, design, construction, operation, and final closure. The advantage of landfills over other methods is low cost. HHW items commonly sent to landfill including alkaline batteries and asbestos

Table 5.4 Examples of common disposal methods

Waste	Disposal Management Method				
	Recycle	Alternative fuel	Treatment	Incineration	Secured landfill
Aerosols	x			x	x
Propane cylinders	x			x	x
Fire extinguishers	x			x	x
Flammable liquids		x		x	x
Oil-based paint		x	x	x	x
Flammable solids		x	x	x	x
Air reactive			x	x	x
Water reactive				x	x
Oxidizing acid				x	x
Oxidizing alkaline				x	x
Organic peroxide			x	x	x

(continued)

Table 5.4 (continued)

Waste	Disposal Management Method				
	Recycle	Alternative fuel	Treatment	Incineration	Secured landfill
Corrosive acidic				x	x
Corrosive alkaline				x	x
Mercury	x			x	
Asbestos				x	x
PCB ballasts	x			x	x
PCB contaminating materials	x			x	x
Antifreeze	x			x	x
Car batteries	x				x
Fluorescent light tubes	x			x	x
Latex paint	x			x	x
Motor oil	x			x	x
Oil filters	x			x	x
Electronic waste	x			x	x
Sharps	x			x	x
Household batteries	x			x	x

Source Adapted from Cabaniss (2008)

5.4 Case Study: Household Hazardous Waste Management in Bangkok

5.4.1 Background

This case study is based on research carried out by Sueb and Pharino (2014). The study investigated HHW generation rates and the behavior of residents regarding HHW management in Bangkok. The research included questionnaires together with face-to-face interview of residents living in 12 districts throughout Bangkok.

The average rate of HHW generation in Bangkok from residential sources is approximately 1.033 ± 0.82 kg/capita/year or 2.9 ± 2.2 g/capita/day. Table 5.5 summarizes information about MSW and HHW in Bangkok. In Vietnam, the estimated rate of HHW generation was 0.554 g/capita/year (Thanh et al. 2010). A similar study carried out in India found that the HHW generation rate was 5 g/capita/year (Lakshmikantha and Lakshminarasimaiah 2007). There is a wide range in the generation rate in different countries. This variation may be caused by differences in lifestyles, consumption patterns, and generation patterns (Otoniel et al. 2007, 2008).

The Wang-Thonglang district in Bangkok showed the lowest HHW generation rate, while the Prawet district had the highest HHW generation rate. These two

Table 5.5 Information on HHW and MSW in Bangkok

Bangkok (2013)	Data	Unit	Reference
Registered population	5,975,386	Persons	Office of Register, Ministry of Interior (2013)
Nonregistered population	3,100,000	Persons	Office of Register, Ministry of Interior (2013)
Generation rate of HHW by residents	1.033	kg/capita/year	Sueb (2014)
Total amount of HHW from residents	9375	Tons	Sueb (2014)
Total amount of MSW	3,636,594	Tons	Pollution Control Department (2011)
Percentage HHW compared with total MSW	0.26	%	Sueb (2014)

districts have similar population densities ranging from 5000 to 6500 per square kilometer which indicates that population density does not appear to have a significant influence on the generation rate.

The percentage of HHW from the residential sector accounted for 0.26% of the total municipal solid waste stream in Bangkok (not including electronic waste). By contrast, Otoniel et al. (2007) reported the HHW generation rate in central Mexico was approximately 1.03% of MSW. In the U.K., Slack et al. (2009) reported that the HHW generation rate was approximately 0–1.0% of MSW. In terms of percentage of HHW composition by weight in Bangkok, self-care products, light bulbs, and chemical containers were the top three constituents of HHW found in the waste stream (Sueb and Pharino 2014) (see Fig. 5.2; Table 5.6). In comparison with the HHW percentage composition in central Mexico, the main HHW constituents

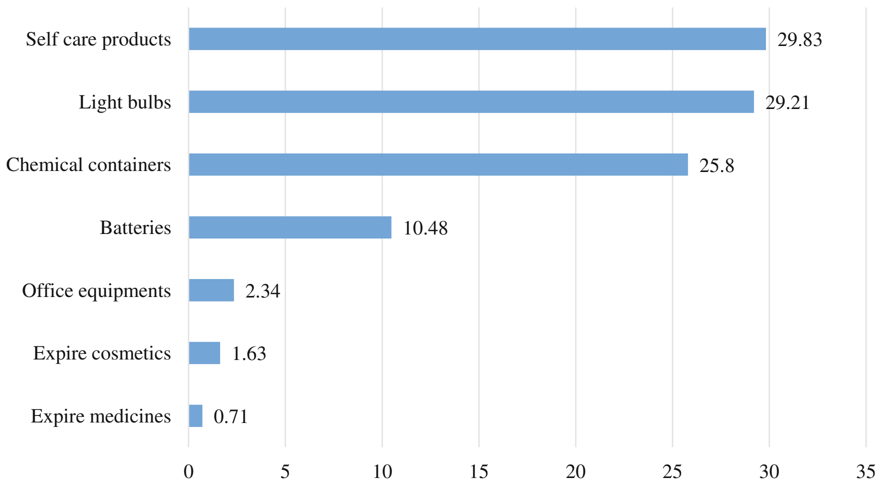

Fig. 5.2 Types and percentages of HHW from residential sources in Bangkok (2013)

Table 5.6 Amount of HHW in Bangkok 2013

HHW	Percentage (%)	Total amount (ton)
Self-care products	29.83	2796.53
Light bulbs	29.21	2738.40
Chemical containers	25.8	2418.72
Batteries	10.48	982.49
Office supplies	2.34	219.37
Expired cosmetics	1.63	152.81
Expired medicines	0.71	66.56
Total	100	9374.88

Source Sueb and Pharino (2014)

were cleaning products (39%), self-care products (27.3%), and insecticides (14.4%) (Otoniel et al. 2007).

Comparative analyses of the characteristics of HHW in two Mexican regions were carried out (northern and central). In the northern region (Mexicali city), HHW comprised 3.7% of municipal solid waste; the largest constituents in this fraction were home care products (29.2%), cleaning products (19.5%), and batteries and electronic equipment (15.7%). In the central region, HHW comprised 1.03% of municipal solid waste; the main constituents in this fraction were cleaning products (39%), self-care products (27.3%), and insecticides (14.4%) (Otoniel et al. 2007). Self-care products and e-waste have similar percentages between the case study in Thailand and that in Mexico. As already mentioned, many factors underlie the HHW consumption pattern including levels of income, lifestyle and behavior, and urbanization.

In Bangkok, self-care products were found by the case study to make up the highest proportion. This is because most families buy self-care products almost every month. Light bulbs (second highest proportion), by contrast, are normally changed once or twice a year. Chemical containers (third highest proportion), also had a very high consumption rate. Other constituents included expired cosmetics, expired medicines, and office equipment. When reviewing data from other countries, we found that cleaning products and self-care products shared the highest proportion in HHW both in Thailand and other countries. The increasing amounts of HHW in MSW raises serious concerns and highlights the need to set up an effective management plan.

5.4.2 *Current Practice on HHW Management in Bangkok*

Currently, there is no specific regulation that directly addresses HHW management in Thailand. There are, however, some initiatives that have begun to be implemented for HHW management such as a program to take back expired medicines and the setting up of HHW banks. Practices related to HHW management were

Table 5.7 HHW management scheme in Bangkok (Thailand)

Approach	Details
Raising awareness	There are many campaigns aimed at raising awareness in the local community as outlined on posters and in brochures. All aim to inform residents about household hazardous waste and its impact
Separation	The local government set up drop-off centers for hazardous waste in the community. The pilot district was Lat Krabang district
Collection	Hazardous waste is collected from drop-off centers on the 1st and 15th of every month
Storage	Hazardous waste is stored in each district (hazardous waste storage building) until the target amount is reached and then transported to the transfer station
Transportation	Transportation is only done by permitted agencies
Recycling	At the moment, only light bulbs and some electronic waste are recycled. Two important companies are actively involved in waste recycling: Toshiba and Wongpanit Group
Treatment or disposal	Current technology is used for household hazardous waste treatment and results in stabilization and solidification by private companies. Solidified HHW is then sent to a secure landfill

started in 2007 by the Pollution Control Department and the Bangkok Metropolitan Administration (BMA) (see Table 5.7). The program, however, has made little progress as a result of lack of continuity and support. These management programs are not continuous since there is no specific regulation or organization to support them. HHW management practice and efficiency in Thailand need more serious efforts focusing on the development of suitable policies and programs to achieve a long-term solution.

As for the BMA, it operates an HHW management service that includes HHW drop-off centers for handling HHW such as batteries, fluorescent lamps, oil, paint, drain cleaners, cosmetics, motor oil, pesticides, and cleaning chemicals. The BMA recently started a campaign to encourage people to separate HHW. On the 1st and 15th of every month, refuse collectors collect and transfer HHW to transfer stations in Nong Kham, Saimai, and On Nut. Waste is then stored at the sites until a contracted private company authorized by the Department of Industrial Works transports the waste to a final proper disposal site or handles the wastes using appropriate methods. Currently, the BMA has contracted Akkhie Prakarn PLC to incinerate HHW.

A BMA report on their operational experience in HHW management indicates that the amount of HHW collected was substantially less than expected. In 2011 the amount of HHW collected was expected to be 249 tons/day; however, the actual amount of HHW collected was only 1 ton/day. The main reason is there is no HHW segregation from other waste and no specific program for HHW management. The report also listed containers as the most common type of HHW waste (71%), followed by fluorescent lamps (24%), and batteries (5%) (BMA 2012).

In 2013 the BMA reported that more than 90% of HHW was still not separated and was disposed of together with municipal solid waste to landfill. Only a small percentage of HHW was sent for incineration and recycling. HHW discarded together with municipal solid waste is typically separated in a hazardous chamber inside a waste collection truck. Since there are limited numbers of specific HHW collection trucks for each BMA district, regular municipal waste collection trucks have been used for HHW collection as well. HHW, then, must be separated during the collection phase. HHW that was segregated from MSW is stored at HHW storage areas in each district until the amount of HHW stored meets the BMA's target. HHW will then be sent to Akkhie Prakarn PLC for incineration. HHW that is not separated from municipal waste is transported for final disposal into a landfill.

5.5 Suggestion for Future Management Improvement

Efficiency in HHW management depends on several fundamental factors (Manomaivibool and Vassanadumrongdee 2012). Important factors particularly for a developing country may be classified as follows: (1) financial (e.g., budget, access to financing), (2) human resources (e.g., professional competency, provisions for training of personnel), and (3) relevant political issues. Recommendations to help promote HHW management in Bangkok and all over Thailand based on author's research include the following:

I. ***Improving waste segregation behavior and collection***

There is a need to increase the efficiency of the separation and collection system especially as waste segregation at the source/household level is not widely implemented in Thailand. Only a small amount of HHW is sorted during the collection process. Furthermore, only three main types of HHW—chemical containers, light bulbs, and batteries—are segregated from municipal solid waste. This is because those three types can be separated relatively easily. Therefore, greater effort in HHW separation is sorely needed. There is also no segregation process for HHW at transfer stations before it is sent to landfill. A separate collection schedule for HHW may be required to achieve an increase in proper HHW treatment. Another issue is how to store HHW at each collection location. While each district has temporary HHW storage areas, these are in some cases open areas. It is very important to develop a proper and permanent HHW storage building/facility that can support the forecast amount of HHW. Suggestions include:

i. ***Establish environmental education programs in school***

The research shows that more than 90% of people have general knowledge about HHW but their level of awareness leaves much to be desired. Therefore, increased awareness about proper waste management in public education should be key. Children should be educated to increase awareness as early as possible to instill environmentally conscious behavior. Education can be accomplished both formally and informally. The formal approach involves the establishment of environmentally educational programs in schools, as well as publicity campaigns. Programs and campaigns should focus on benefits from proper waste management, while emphasizing the high costs associated with inadequate public cooperation on waste management. Raising awareness is more effective when children are at early stages of development.

ii. ***Provide an HHW drop-off center in the community***

The questionnaire indicated that 40.3% of respondents would carry out HHW segregation were a proper drop-off center available in the community. The BMA is currently promoting a campaign to set up drop-off locations in communities. This campaign, however, is still quite limited in the number of drop-off locations. In the future, drop-off centers should be set up in all major communities in Bangkok. The location of HHW drop-off centers should be properly studied to ensure that they are suitably located. They should be near the center of the community, where everyone can conveniently drop their HHW waste off as well as providing easy access for refuse collectors to collect HHW for later disposal. Increasing the number of drop-off centers will help improve the amount of HHW collected and, therefore, will allow more HHW to be treated properly. Another consideration on drop-off centers is the need to locate them in a safe area with proper drop-off bins. At the minimum, drop-off areas should have two chambers, one for recyclable waste and another for nonrecyclable HHW such as chemical containers. For schools, universities, and commercial organizations separate bins for HHW collection should be promoted.

II. **Household hazardous waste collection**

i. ***Training program for HHW collectors***

HHW can have adverse impacts on the environment and can be a health risk to people in nearby areas or workers who handle such waste. HHW collectors need to be properly trained before working with hazardous waste. Each district should have training and education programs covering the processes and procedures for handling HHW, requirements for proper protective equipment, information on various types of HHW, and risks and accidents caused from inappropriate handling of waste. Attending regular training programs can help improve the efficiency and safety of HHW collectors.

ii. ***Increase the frequency of HHW collection***

Currently, the BMA carries out HHW collections twice a month on the 1st and 15th of every month. Findings from the research suggest that HHW collection times should increase from twice a month to once a week. This will have a direct impact on separation behavior. HHW collection trucks should be designed to suit the relatively small volume of HHW to improve efficiency and allow for more frequent pick-up of waste.

iii. ***Household hazardous waste storage buildings***

HHW storage buildings should be established in all three transfer stations of Bangkok—Nong Khaem, Saimai, and On Nut—to ensure that waste is properly secured and stored. Establishing appropriate areas for storage of HHW after collection is important to protect and prevent them from leakage and contamination into the environment.

III. **Policy for household hazardous waste management system improvement**
   i. ***Imposing waste treatment fees***

Regulation of HHW management and its enforcement are essential to improve the HHW management system as well as that of other waste. According to our survey on attitudes to willingness to pay, 78.8% of respondents said they would pay more for a better HHW management system. However, there are many factors in system design that need to be considered to ensure that practices are widely accepted by the general public.

ii. ***Promote take-back policies for producers***

Producer take-back policies are necessary to enhance the efficiency of lifecycle management of products. Each producer should be accountable for waste that comes from their products after they reach end of life. In addition, promoting green products can be effective in reducing the amount of waste that needs to be disposed of or recycled. This option, however, needs careful review as green products may incur higher costs to production and, thus, may disincentivize the general public from supporting them.

The continuity and commitment of local government are key to HHW management. The BMA has carried out many campaigns to promote HHW management in Bangkok such as HHW banks, HHW drop-off centers, and green schools since 1992. The campaigns received a lot of favorable feedback. However, the lack of continuation in practice by local communities and governments has meant the program has made little progress. This issue needs to be addressed and improved to achieve long-term benefits.

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Chapter 6
Infectious Waste Management in Thailand

Public health facilities and healthcare businesses are growing in tandem with increases in population and demand. Consequently, the amount of waste from operating a health service is increasing as well. As the amount of infectious waste has been steadily increasing, it is essential to establish an appropriate and efficient collection and treatment system to handle such waste. Infectious waste management in Thailand, however, still faces many challenges. When inappropriately managed, this may become a serious public health threat causing outbreaks of diseases that adversely impact human health and the environment. Waste generated by the public health service sector requires specific types of treatment to prevent environmental and health impacts from all stages of the waste management lifecycle. This chapter looks in depth at the infectious wastesituation and management including a case study undertaken by the author conducted in Bangkok City (Thailand).

6.1 Definition and Types of Infectious Waste

The World Health Organization defined the meaning and categories of infectious waste as "Infectious waste is suspected to contain pathogens (e.g., bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause diseases in susceptible hosts" (WHO 1999). "These categories include:

1. Cultures and stocks of infectious agents from laboratory work
2. Waste from surgeries and autopsies on patients with infectious diseases (e.g., tissues and materials or equipment that have been in contact with blood or other body fluids)
3. Waste from infected patients in isolation wards (e.g., excreta and dressings from infected or surgical wounds and clothes heavily soiled with human blood or other body fluids)

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4. Waste that has been in contact with infected patients undergoing hemodialysis (e.g., dialysis equipment such as tubing and filters, disposable towels, gowns, aprons, gloves, and laboratory coats)
5. Infected animals from laboratories
6. Any other instruments or materials that have been in contact with infected persons or animals".

In Japan, infectious waste is defined as "the waste materials generated in medical institutions as a result of medical care or research which contain pathogens that have the potential to transmit infectious diseases" (Miyazaki et al. 2007). In Ethiopia, infectious waste is any waste generated from health and health-related facilities that is capable of producing infectious diseases. According to Alemayehu et al. (2005), "Infectious waste can be generated from various points of activities including;

1. Cultures and stocks of infectious agents and associated biological, including, specimens cultures, cultures and stocks of infectious agent, waste from production of biological and discarded live and attenuated.
2. Laboratory wastes that were, or are likely to have been, in contact with infectious agents that may present a substantial threat to public health if improperly managed.
3. Pathological wastes, including, human and animal tissues, organs, and body parts, and body fluid and excreta that are contaminated with or are likely to be contaminated with infectious agents, removed or obtained during surgery or autopsy or to diagnostic evaluation, provided that, with regard to pathological wastes from animals, the animals have or likely to have been exposed to a zoonotic or infectious agents.
4. Waste materials from the rooms of humans, or the enclosures of animals, that have been isolated because of diagnosed communicable diseases that are likely to transmit infectious agent. Also included are waste materials from rooms of patients who have been placed on blood and body fluids.
5. Human and animal specimens and blood products that are being disposed of, provided that with regard to blood specimens and blood products from animals, the animals were or are likely to have been exposed to a zoonotic or infectious agent.
6. Patients care waste such as bandages or disposable gowns that are lightly spoiled with blood or other body fluids, unless such wastes are spoiled to the extent that the generator of the waste determines that they should be managed as infectious wastes.
7. Sharp used in the treatment, diagnosis, or inoculation of human beings or animals or that have, or are likely to have, come in contact with infectious agents in medical, research, or individual laboratories, including, without limitation, hypodermic needles and syringes, scalpel blades, and glass articles that have been broken. Such wastes hereinafter referred to as "sharp infectious waste" or sharps.

8. Contaminated carcasses, body parts, and bedding of animals that were intentionally exposed to infectious agents from zoonotic or human diseases during research, production of biological, or testing of pharmaceuticals, and carcasses and bedding of animals otherwise infected by zoonotic or infectious agents that may represents a substantial threat to public health if improperly managed.
9. Any other waste materials generated in the diagnosis, treatment and immunization of human beings or animals, in research pertaining these, or in the production or testing of biological.
10. Any other waste materials the generator designates an infectious waste."

In Thailand, the Regulation of Ministry of Public Health (MOPH) B.E. 2545 defined the meaning and types of infectious waste as follows:

"Infectious waste is any waste that contains pathogens (e.g., bacteria, viruses, parasites, or fungi) in sufficient concentration and quantity to cause diseases in susceptible hosts. The term of infectious waste includes as follows:

1. Body parts or carcasses of humans and animals generated from surgery, autopsies, and researches.
2. Sharps such as needles, blades, syringes, vials, glass wares, slides, and cover slides.
3. Discarded materials contaminated with blood, blood components, and body fluids from humans or animals, or discarded live and attenuated vaccines, such as cotton, other cloths and syringes.
4. Wastes from wards as specified by the Ministry of Public Health."

Infectious waste is produced during treatment, diagnosis, immunization of humans and/or animals at healthcare facilities, veterinary clinics, health research centers, medical laboratories, clinics, polyclinics, government and private hospitals, educational institutions, Red Cross centers, detention centers, medical units, medical institutes, biotechnology units, home healthcare, medical manufacturing, and others (Huang and Lin 2008; Thanakom 2013).

6.2 Situation of Infectious Waste Management

Currently, the number of public health facilities such as hospitals, health centers, clinics, polyclinics, and others belonging to both government and private sectors have been increasing in Thai society domestically and internationally. Based on international statistics, during 2003–2005 the number of small clinics in Taiwan increased from 18,183 to 18,877 (Huang and Lin 2008) while the number of hospitals in Greece in 2006 was 317 with 53,701 beds excluding military hospitals (Monni 2012; Karagiannidis et al. 2010). Regarding the amount of infectious waste generated, infectious industrial waste accounted for about 19–22% of total medical waste in Taiwan during 2003–2005. The amount of infectious waste was around 19,350 tons in 2004 (Huang and Lin 2008). In Greece, more than 14,000 tons of infectious hospital waste was produced yearly (Karagiannidis et al. 2010). In Jordan, the average generation rates of total medical waste in hospitals in 2004 were estimated to be 6.10 kg/patient/day (3.49 kg/bed/day) for public hospitals, 5.62 kg/patient/day (3.14 kg/bed/day) for maternity hospitals, and 4.02 kg/patient/day (1.88 kg/bed/day) for private hospitals, respectively. As for medical laboratories, waste generation rates were in the range 0.053–0.065 kg/test-day for governmental laboratories and 0.034–0.102 kg/test-day for private laboratories (Bdour et al. 2007).

In Thailand the total number of public health facilities was more than 37,000 and bed availability was around 140,000 in 2012 (PCD 2013). The total average number of public health facilities in Bangkok in 2012 were 2352 in 2012 and bed availability was 28,143 beds (Thanakom 2013). Public health facilities are major sources of infectious waste. In 2012 the amount of infectious waste in Thailand was approximately 42,000 tons/year, of which around 28,000 tons/year were generated by governmental health facilities, and around 14,000 tons/year were generated by those of the private sector (Than Online 2013). In Bangkok the total average amount of infectious waste generated by public health facilities in 2012 was approximately 814 tons/month or 10,190 tons/year (Thanakom 2013). The amount of infectious waste in Bangkok accounted for 24.26% of total infectious waste in Thailand.

Several technologies for infectious waste treatment, consisting of mechanical, thermal, chemical, and irradiation processes, are used in many countries. Incinerators are thermal processes that are widely used to treat infectious waste generated at public health facilities because they yield very high disinfection efficiency and significantly reduce the weight and volume of waste (80–90%) (MSEA 2013). On the other hand, there are limitations in that incineration causes air pollution problems that cannot be effectively controlled (Panyaping and Okwumabua 2006). Incineration is a threat to human health and the environment primarily as a result of heavy metals found in bottom ashes leaching into surface and ground water (Gidarakos et al. 2009).

6.3 Infectious Waste Treatment Technologies

There are several technologies for infectious waste treatment based on mechanical, thermal, chemical, and irradiation processes. Autoclaves and incinerators are the most frequently used of these technologies for the treatment and disposal of infectious waste (Panyaping and Okwumabua 2006; MSEA 2013).

Type	Detail
Mechanical process	Changes the physical form of waste to facilitate waste handling. It consists of compaction and shredding. Compaction involves compressing the waste into containers to reduce its volume. Shredding is used to break waste into smaller pieces
Thermal process	Uses heat at low temperature (150 °C) and high temperature (600–5500 °C) to decontaminate infectious waste. Thermal processes include autoclaving and incineration. Incineration uses high-temperature (800–1050 °C) combustion under controlled conditions to convert waste containing infectious and pathogenic materials to inert material residues and gases. It results in significant volume and weight reduction, and it sterilizes the waste. Autoclaving is a steam sterilization technique that uses steam to directly disinfect waste. Steam under pressure is used to obtain a temperature of at least 121 °C
Chemical process	Uses chemicals (e.g., ozone [gas], chlorine, formaldehyde, ethylene oxide [gas], propylene oxide [gas], and peracetic acid) for disinfection. The effectiveness of each chemical agent depends on temperature, pH, and the presence of compounds that can interfere with disinfection
Irradiation process	Uses ultraviolet or ionizing radiation for irradiating and sterilizing infectious waste. This method includes microwave irradiation. Microwave irradiation is designed to use frequencies in the electromagnetic radiation spectrum between 300 and 300,000 MHz to inactivate microbial organisms

Infectious waste management in public hospitals can be broken down into four methods (Hansakul 2009) as summarized below.

Management method	Details
Onsite hospitals	Some hospitals treat infectious waste using their own incinerators
Local administrative organization	Some hospitals and public health facilities that have no incinerators transport infectious waste to incinerators of the Local Administrative Organization
Other hospitals	Some hospitals and public health facilities that have no incinerators transport their infectious waste to incinerators of other hospitals
Private sector disposal service	Some hospitals and some public health facilities use the private sector for collection, transportation, treatment, and disposal of their infectious waste

6.4 Processes of Infectious Waste Management

A notification of the Ministry of Public Health determining the site and container characteristics for infectious waste was promulgated in the *Royal Government Gazette* in volume 122, special section 52 (IV) on July 14, 2005. It also determined the site characteristics for storage of infectious waste containers within hospitals.

Description: Condition municipal waste management site. Photo by: Amornchai Challcharoenwattana

Regulations on managing solid waste and sewage from buildings, places, and public health facilities can be found in B.E. 2545. They were listed under section 49 of the Bangkok Administration Act, B.E. 2528, along with articles 7 and 14 of the Bangkok Commandment, B.E. 2544, on collection, transfer, treatment, and disposal of garbage or solid waste.

Description: Infectious wastes about to put in the incinerator for final disposal. Photo by: Chanathip Pharino

Description: Infectious wastes about to put in the incinerator for final disposal. Photo by: Tech Sukprasert

In Thailand, there are four stages of infectious waste disposal in public hospitals. The Ministry of Public Health determined the processes of infectious waste management as (i) segregation and collection, (ii) storage, (iii) transportation, and (iv) treatment and disposal.

I. ***Segregation and collection***

Infectious waste must be segregated and collected where it is generated in well-specified containers for infectious waste storage.

(a) Containers must be visibly labeled as "Infectious Waste" and given a biohazard symbol. Red boxes and drums must be made of strong materials that are resistant to perforation or the erosion of chemical solutions to prevent fluid leakages. Red bags must be opaque as well as resistant to chemicals, laceration, leakages, and loading capacity.
(b) All types of infectious waste excluding sharps must be packed in red bags, but must not exceed two thirds of the total volume.
(c) Sharps must be packed in red boxes or drums, but must not exceed three quarters of the total volume.

II. ***Storage***

After segregating and collecting infectious waste, the next step is to transfer it to gathering or storage areas to wait transfer for further disposal. Workers must undergo training programs and take exams in the prevention and inhibition of outbreaks of harmful diseases caused by infectious waste; they must also wear personal protective equipment such as thick rubber gloves, aprons, masks, and boots throughout the operation.

The transfer of infectious waste must be operated daily as specified by law using infectious waste-containing trolleys and following specific routes to transfer infectious waste to gathering or storage areas. During the transfer of infectious waste, infectious waste-containing vehicles must not stop or pause anywhere. Infectious waste containers must not be thrown or dragged. Should infectious waste or containers be dropped during transfer, workers must not pick them up bare handed, but must use pliers or thick rubber gloves instead.

Carts or trolleys used for transferring infectious waste must be made of materials that are easy to clean and can be cleaned with water. They must have opaque floors and walls. When infectious waste containers are put into carts or trolleys, their lids must be tightly closed to prevent spillage. They must be visibly labeled with "Only for the Transfer of Infectious Waste."

Storage areas must have enough loading capacity, smooth floors and walls; they must also be free of moisture, rails, or sewers connected to wastewater treatment systems. They must facilitate the transfer of infectious waste and be easy to clean. They must be visibly labeled with "Gathering or Storage Area for Infectious Waste Only."

III. ***Transportation***

This is the transportation of infectious waste from gathering or storage areas to disposal facilities by infectious waste-containing vehicles which have a controlled temperature of not more than 10 °C. Drivers and workers must undergo training programs and take exams in the prevention and inhibition of outbreaks of harmful diseases caused by infectious waste.

IV. ***Treatment and disposal***

Incinerators and autoclaves are the most common technologies used for the treatment and disposal of infectious waste. Within 30 days of collection and transportation, infectious waste has to be disposed of. Monitoring and operating reports should be submitted monthly to the local government. After disposal of infectious waste by these technologies, there needs to be an examination to see whether infectious waste successfully eliminated pathogens as specified in biological standards and regulations.

6.5 Impacts of Infectious Waste

For serious viral infections such as HIV/AIDS and hepatitis B and C, healthcare workers are at risk of infection through injuries from contaminated sharps (largely hypodermic needles). Needle stick injuries are caused by uncapped hypodermic needles disposed into containers. Certain infections are spread through other media and may lead to significant risk to the general public and to patients. For example, uncontrolled discharges of sewage from field hospitals treating cholera patients have been strongly implicated in cholera epidemics in some countries. In developing countries, many cases of infections from a wide variety of pathogens are suspected that have resulted from exposure to improperly managed infectious waste.

Most infections that may not be present in the patient at the time of admission to a health facility develop during the course of the stay in the health facility. Healthy people can naturally be infected through infectious waste. Feces contain about 1013 bacteria per gram, and the number of microorganisms on the skin varies between 100 and 10,000 per cm^2. Many species of microorganisms live on mucous membranes where they form a normal flora. Microorganisms that can penetrate the skin or the mucous membrane barrier reach subcutaneous tissue, muscles, bones, and body cavities (e.g., peritoneal cavity, pleural cavity, and bladder), which are normally sterile (i.e., contain no detectable organisms). If a reaction to this contamination develops with symptoms, there is an infection (Alemayehu et al. 2005).

6.6 Case Study: Infectious Waste Generation and Management in Bangkok

6.6.1 Infectious Waste Management in Bangkok

The generation rate of infectious waste depends on several factors such as the size of public health facilities, occupancy rate of hospital beds, infectious waste segregation program, location of the facility, type of public health facility, and type of services provided. During 2001–2012, generation rates of infectious waste increased from 11.37 to 27.13 tons/day (Thanakom 2013). Krungthep Thanakom Co. Ltd. is one of the main service providers for collection, transfer, treatment, and disposal of infectious waste generated by public health facilities in Bangkok. Public health facilities using the services of Krungthep Thanakom had increased from 535 to 2329 (Thanakom 2013). During 2006–2010, infectious waste had been steadily increasing until more clinics started using the services of Krungthep Thanakom. However, more than 50% of clinics (1381 clinics and polyclinics) did not use the services of

Krungthep Thanakom. This meant that significant amounts of infectious waste were still disposed of along with general waste. This is a serious issue and has the potential to cause outbreaks of diseases with impacts on human health and the environment.

Based on information in June 2000 regarding the amount of infectious waste generated in Bangkok, the rate of infectious waste of 75 hospitals was 0.31 kg/bed/day. The average amount of infectious waste of 148 health centers and 248 clinics and polyclinics was 1.10 and 1.51 kg/place/day, respectively. In May 2012 the total number of public health facilities using Krungthep Thanakom was 2329, and the average amount of infectious waste was 814 tons/month (Thanakom 2013). This showed that the trend in infectious waste continues to increase.

Sukprasert and Pharino (2013) studied the mass flow analysis of infectious waste management in Bangkok to gain a better understanding of the origins and flow paths of infectious waste (in terms of type and quantity) and the current status of management. The main findings can be summarized as follows (Fig. 6.1):

The total average number of public health facilities was 2409 and hospital beds 28,141 in 2013. The infectious waste generation rate from public health facilities ranged from 21.23 to 11,062.03 kg/month/place with a weighted average of 5541.58 kg/month/place. The two main contributors are government and private hospitals which generate higher amounts of infectious waste than other public health facilities in Bangkok.

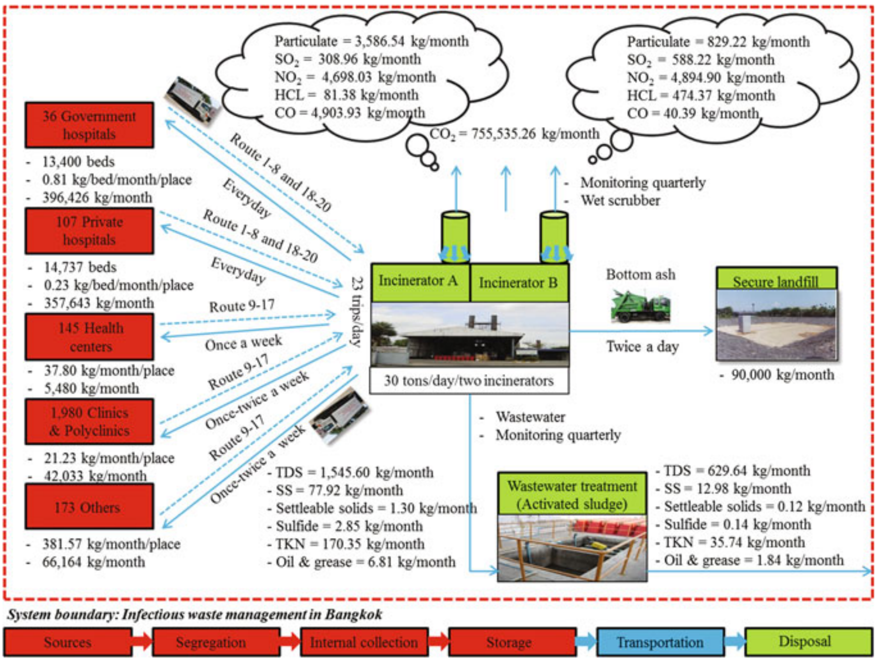

Fig. 6.1 Mass flow analysis of infectious waste quantities and forms in kg/month in Bangkok 2013. *Source* Sukprasert and Pharino (2013)

The total average number of trips of the 18 special vehicles used for the collection and transfer of 871,325 kg/month of infectious waste from sources to the disposal company was 687 trips/month in 2013. Pre-establishment of 20 routes for the collection and transfer of infectious waste generated by public health facilities to the disposal company was a very necessary step to reduce if not prevent the risk of spread of infectious diseases, pathogens, and bacteria from infectious waste-containing vehicles. These routes can help the disposal company determine the exact distance and time for infectious waste collection and transfer.

The two waste incinerator units in Bangkok in 2013 could handle 29.04 tons/day of infectious waste, but the amount of infectious waste was steadily increasing. Therefore, the BMA is planning install more infectious waste incinerators to cope with this problem. Of all the infectious waste incinerated by the two incinerators, 89.43% of it transformed into air pollutants (87.29% for CO_2 and 2.14% for other air pollutants), 10.33% for bottom ashes, and 0.24% for wastewater components. Therefore, air pollutants were the main impact on the environment. The wastewater treatment plant (an activated sludge system) could remove 61.02% of total wastewater components. Bottom ashes from infectious waste incineration were buried at a secure landfill.

The total costs for handling 871,325 kg/month of infectious waste were 6,883,468 baht/month (approximately 7900 baht/ton). As a result of the high cost of waste management, this may be the reason for the illegal dumping of infectious waste.

6.6.2 *Infectious Waste Management Systems Within Hospitals*

Sukprasert and Pharino (2013) undertook a case study into the situation of infectious waste management in hospitals in Bangkok. The results are as follows.

For infectious sharp collection most hospitals use special and general rigid plastic containers which are strong and resistant to laceration and perforation by infectious sharp objects. These containers are intended to help prevent or at least reduce accidents to workers from infectious sharp accidents when collecting and transferring infectious sharps and waste for treatment and disposal.

Most hospitals had very low or in some cases no infectious sharp accidents because workers wear prevention equipment and strictly follow the rules and regulations of the Ministry of Public Health for collecting and transferring infectious sharps and waste. In addition, hospitals used containers for infectious sharp collection that are strong and resistant to perforation by infectious sharps.

The research survey 65 hospitals in Bangkok found that no hospital reported accidents to workers from infectious diseases. These results indicated that all hospital workers wore prevention equipment and strictly followed the rules and regulations of the Ministry of Public Health for collecting and transferring infectious sharps and waste to prevent or at least reduce infectious diseases. As for infectious sharp accidents to workers, the survey indicates that all hospitals provide immediate health checkups and vaccines for treatment of infectious diseases. Most hospitals run a program in which workers undergo annual health checkups. Most hospitals are very conscious of the health of their workers.

Hospitals get medical personnel and workers to undergo training programs on infectious waste management. The frequency of training programs run by most hospitals ranged from once to four times per year. The frequency of training programs in some hospitals was as high as 12 times per year. Some hospitals provided incentives in the form of compensation and welfare to motivate their staff to improve infectious waste management.

Most hospitals paid attention to each step of infectious waste management from the source of infectious waste generation to collection and transfer, storage, treatment, and disposal by setting up training programs. By doing so the efficiency of infectious waste management within public and private hospitals helps prevent or at least reduce accidents and damage from infectious sharps and waste during operations. However, some hospitals have failed to set up training programs on appropriate infectious waste management. Workers, without proper training, are at higher risk of inappropriately handling infectious waste. This can lead to increased risk of exposure and more cases of infectious sharp accidents and infectious diseases.

Guidelines on the allocation and separation of bins for collecting each type of waste are important to preventing or at least reducing general waste mixed with infectious waste. Doing so helps public and private hospitals reduce the amount of general waste mixed with infectious waste sent to disposal companies. However, some hospitals still face problems regarding general waste mixed with infectious waste. This increases the amount of infectious waste sent to disposal companies and causes increases in costs for collection, transfer, treatment, and disposal.

6.6.3 Recommendations for Infectious Waste Management Improvement

The case study on current practices of infectious waste management in Bangkok recommended many potential strategies to improve infectious waste management in Bangkok. These recommendations include:

I. ***Segregation and collection***

- Hospitals should provide enough effective containers for collecting infectious sharps.
- Workers from waste collection and disposal companies should be well trained on how to handle waste-containing bags properly to minimize the risk of leakage and contamination.

- Workers of both disposal companies and hospitals should wear preventative equipment during waste operations to reduce and prevent infectious sharp accidents and diseases.
- Workers should wash their hands thoroughly after finishing operations.
- Disposal companies should collect and transfer infectious waste generated by hospitals on specific dates and at predetermined times agreed between the companies and hospitals. The frequency of collecting and transferring infectious waste should be appropriately determined according to the amount of infectious waste generated by each hospital.

II. ***Storage***

- Temporary infectious waste storage areas within hospitals should be properly identified (i.e., away from other functional areas) such as general waste storage or community areas.
- Temporary infectious waste storage areas within hospitals should follow regulated standards and be strictly controlled.
- Temporary infectious waste storage areas within hospitals should be cleaned immediately after infectious waste is collected and transferred for disposal.

III. ***Training and education***

- Training and education programs on infectious waste management for all personnel within hospitals should be conducted for both existing and new staff.
- Hospitals should have guidelines and methods of infectious waste management available for staff.
- Information regarding the segregation of waste into specific bins within hospitals should be made aware to patients and visitors to reduce the potential mixing of infectious waste with general waste.
- Training and education programs regarding preventative equipment and appropriate methods for infectious waste management for personnel of disposal companies should be conducted regularly.

IV. ***Public awareness***

- Disposal companies and hospitals should increase the awareness of their personnel regarding the use of protective equipment while they work.
- The BMA should encourage safe practices on infectious waste management through various means such as organizing contests and awards for departments that achieve outstanding infectious waste management and in so doing the awareness of management in each hospital.

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Chapter 7
Electronic Waste Management in Thailand

This chapter presents an overview of e-waste generation and management strategies and systems not only in Thailand but worldwide. E-waste generation types and management policies in Thailand are explained in detail. Current management practices and impacts from e-waste management in Thailand are also discussed. Suggestions for future improvement of e-waste management are presented. Case studies based on the author's own research on the main types of electronic waste including mobile phones, computers, and televisions, are provided and discussed in detail in the Chap. 8.

7.1 E-waste Management Worldwide

The situation of e-waste management in Thailand is similar to that in many developing countries. Waste from electrical and electronic equipment (WEEE) is a priority in waste management because of the major challenges in growing quantities of waste and the complexity of WEEE, which affect treatment and recovery technology. There has been an increase in the number of environmental policies as well as legislation focusing on the principles of extended producer responsibility (EPR). The policy instruments that lie under the EPR umbrella include different types of product fees and taxes, such as recycling fees, product take-back mandates, virgin material taxes, and combinations of these instruments. Nnorom and Osibjoan (2008) summarized the policy used for EPR implementation and possible approaches and examples.

C. Pharino, *Challenges for Sustainable Solid Waste Management*,
SpringerBriefs on Case Studies of Sustainable Development,
DOI 10.1007/978-981-10-4631-5_7

Instruments	Example
Administrative	Collection and/or take-back of discarded products, reuse and recycling targets, setting emission limits, recovery obligations, product standards, technical standards
Economic	Material/product taxes, subsidies, advance disposal fee systems, deposit-refund systems, upstream combined tax/subsidies
Informative	Environmental reports, environmental labeling, information provision to recyclers about the structure and substances used in products, consultation with authorities about the collection network

Type of EPR approach	Example
Product take-back programs	Mandatory take-back
	Voluntary or negotiated take-back programs
Regulatory approaches	Minimum product standards
	Prohibition of certain hazardous materials or products
	Disposal bans, mandated recycling
Voluntary industry practices	Voluntary codes of products
	Public/private partnerships
	Leasing and servicing, labeling
Economic instrument	Deposit-refund schemes
	Advance recycling fees, fees on disposal
	Material taxes/subsidies

Sources Adapted from Nnorom and Osibjoan (2008)

The European Union has instituted policies such as Waste Electrical Electronic Equipment (WEEE) (Directive 2002/96/EC) and the Restriction of Hazardous Substances (RoHS) (Directive 2002/96/EC), aimed at improving the environmental performance of electronic products. While many countries in Europe and Asia (Japan, Taiwan, etc.) are putting in place take-back laws that require the manufacturer to take back used products at their end of life (EoL). The WEEE Directive aims to shift e-waste management from incineration and landfill to environmentally sound recycling and reuse, in order to preserve resources and energy. The financing for recycling and responsibility for organizing collection of WEEE has to be taken over by the producers of electrical and electronic equipment (EEE). Nnorom and Osibjoan (2008) emphasized key points in the WEEE Directive as the following: (1) the design and production of EEE should facilitate dismantling and recycling; (2) WEEE should be collected separately from other waste, and the collection should be free of charge; (3) best available recovery, recycling, and treatment techniques should be used to protect human health and the environment; (4) producers are responsible for financing the management and take-back of WEEE; (5) information should be provided to users and to treatment facilities.

Switzerland was the first country in the world to develop and implement a well-organized and formal e-waste management system for collection, transportation, recycling, treatment, and disposal of e-waste. The legal and operational framework of the system is based on the EPR model and places the physical and financial responsibilities for environmentally sound handling, recycling, and disposal of e-waste on the manufacturer/producer and exporter of these products. The system is financed by an advance recycling fee (ARF) collected from the purchaser of the new electronic appliance. The end consumer pays the recycling fee, which is equivalent to the difference between the total system cost and the total recovered value from the e-waste. Switzerland has established and implemented a formal e-waste management system and has recycled 11 kg/capita of WEEE against the target of 4 kg/capita set by the EU (Wath et al. 2010).

Developing recycling industries and applying EPR in developing countries may be difficult because of the following factors: (1) it is difficult to collect EoL equipment from rural communities; (2) recycling is undertaken by the informal sector so collecting used e-waste is difficult; (3) establishing where the responsibility lies for used products that have been modified or repaired or even smuggled lies with importers or producers; and (4) there are products that have been brought in as private imports and it is difficult to identify ownership (Kojima 2005). Developing countries lack the appropriate technology for e-waste management. The reasons behind ineffective e-waste management in developing countries includes: (1) unwillingness of consumers to pay for the disposal of e-waste or handout their EoL products; (2) lack of awareness among collectors, consumers, and recyclers of the potential hazards of e-waste; (3) lack of funds and investment to finance recycling improvements; (4) lack of appropriate management and infrastructure for recycling of e-waste; (5) lack effective take-back programs for EoL electronic devices; (6) lack of legislation to handle e-waste and ineffective implementation of existing regulations on the transboundary of e-waste (Nnorom and Osibjoan 2008).

Mobile phone waste is a type of e-waste that impacts every country in the world. For example, in Korea an average of 14.5 million mobile phones were retired annually over the period of analysis (2000–2007). Most EoL mobile phones end up being stored at home waiting for disposal. The methods and infrastructure for recycling remain to be well established. More active collection activities and systems for EoL are still needed including the establishment of more collection points where consumers can drop off EoL mobile phones. Producers, consumers, and local government need to promote collection and recycling schemes. For effective management of mobile phone waste, there has to be put in place a well-coordinated network for collection. The quantity collected will however determine the EoL approach to be adopted. Economics and environmental performance will have to be considered in choosing combinations of the management option (Jang and Kim 2010).

Osibanjo and Nnorom (2008) studied how to reduce the impacts of EoL mobile phones in developing countries from mobile phone usage and manufacturing. They made recommendations for relevant stakeholders. For manufacturers the researchers recommend (1) redesigning mobile phones to reuse components, this is important for recycling; (2) encouraging product life extension through training labor in the repair and remanufacture of mobile phones; (3) implementing EPR (voluntary) and taking responsibility for management of their EoL products. For governments in developing countries the researchers recommend (1) introducing

EPR mandating producers to be stimulated in the EoL management of products, this requires legislation dealing with e-waste management; (2) encouraging the introduction of formal recycling for e-waste, the technology necessary for the recovery of materials from EoL mobile phones, and ban the disposal of e-waste along with municipal waste; (3) promoting e-waste management (e.g., exchange of knowledge on e-waste management, discuss strategies toward promoting management options for e-waste); (4) adopting strategies to prevent the dumping of mobile phone waste. For effective management of e-waste, there has to be in place a well-coordinated network for the collection of EoL mobile phones. Environmental performance and economics will have to be considered when choosing management options. In developing countries the introduction of mandated producer responsibility is necessary.

Lim and Schoenung (2010a, b, c) suggested that government, corporate, and consumer responsibilities are required for effective mobile phone waste management. For example, (1) government should be responsible for implementation and establishment of a waste management system, educating the population on environmental responsibility, and coordinating all stakeholders; (2) there should be corporate responsibility in which manufacturers develop environmentally responsible mobile phones and take-back EoL electronic devices to increase recycling; and (3) there should be consumer responsibility in which consumers prevent excessive consumption of resources and the toxicity potential associated with mobile phones and return EoL mobile phones to a take-back system that is linked with treatment and recycling facilities. Figure 7.1 shows the triple bottom line for effective mobile phone waste management put forward by Lim and Schoenung (2010a, b, c).

7.2 Toxic Materials and Precious Metals inside E-waste

Chemical elements in e-waste commonly contain over than 1000 substances. Many of them are harmful and create serious pollution (Grossman 2006). Table 7.1 gives a list of toxic substances that are known to have acute or chronic effects in living things. Improper management practices such as open dumping or primitive recycling can cause substances to leach out and be transported with soil, water, and air and become available to living organisms (Pirzada and Pirzada 2006).

7.3 Situation of E-wastes in Thailand

Technological innovation and a plethora of electronic equipment have rapidly been introduced in consumer markets in recent decades. Moreover, the lifestyle and behavior of consumers has changed accordingly as a result of professional necessity and social function. Increasing amounts of unused or out-of-date electronic

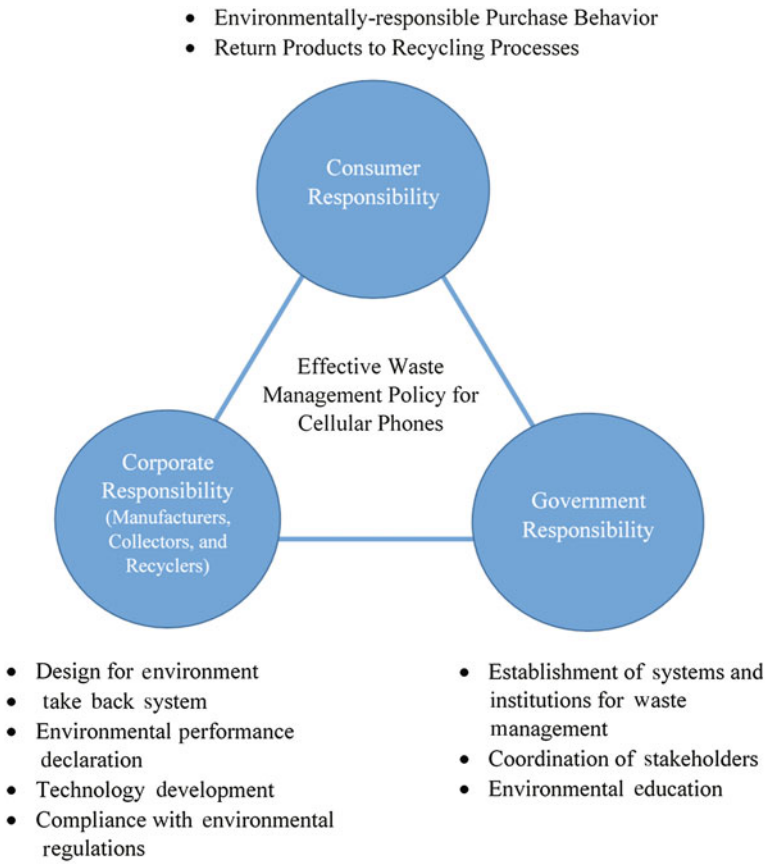

Fig. 7.1 *Triple bottom line* for effective mobile phone waste management. *Source* Adapted from Lim and Schoenung (2010a, b, c)

Table 7.1 Toxic Substances in E-waste

Material	Toxicity
Arsenic	Skin diseases, lung cancer, decreased nerve conduction
Barium	Brain swelling, muscle weakness, damage to heart, liver, and spleen
Beryllium	Lung cancer, skin disease
BFRs	Severe hormonal disorders
CFCs	Skin cancer, deleterious to ozone layer
Chromium (VI)	Irritating to eyes, skin, and mucous membranes, DNA damage
Dioxins	Impairment of the immune system
Lead	Vomiting, diarrhea, convulsions, coma, even death
Mercury	Brain and liver damage if ingested or inhaled
PVC	Respiratory problems
Selenium	Hair loss, nail brittleness, and neurological abnormalities

Source Pirzada and Pirzada (2006)

equipment are becoming a major problem for modern society. Developing countries such as Malaysia, Vietnam, and Thailand face difficulties, as a consequence of the actual amount of waste entering from abroad, assessing the environmental impact of the importation of electronic waste, as well as recycling or getting rid of it properly. U.S. data indicate that more than 80% of e-waste is exported to developing countries for disposal or recycling (USEPA 2008a, b).

It is quite a challenge to estimate and collect accurate numbers on EoL electronic products based on types and lifetimes of electronic devices as well as on consumer behavior, which can vary widely. However, many governmental agencies are trying to determine the quantity and quality of e-waste discarded into the environment. The Pollution Control Department (PCD) of Thailand reported that the consumption of electronic devices in the country during 2007–2010 kept rising each year (see Table 7.2). Table 7.3 presents occupied units and product lifespans of major types of electronic devices including TVs, mobile phones, personal computers, digital cameras, refrigerators, and air-conditioning units. The average lifetime of electronic devices is between 3 and 6 years. Moreover, the amount and rate of e-waste generation in Thailand keeps rising every year (see Table 7.4). Mobile phones rank the highest among all electronic devices in numbers of consumption units, units per household, and amount of waste generated. In terms of units, discarded mobile phones were forecast to increase from around 8.52 million units in 2012 to 10.91 million units in 2016 (PCD 2012).

The Pollution Control Department (PCD 2012) surveyed the behavior of households in managing the EoL of electronic devices in the country and found that the preferred approach of the population was (1) sell to recycle shops (51.24%), (2) keep at home (21.32%), (3) discard with municipal solid waste (15.6%), and (4) donate (i.e., give them to friends and family) (7.84%) (see Fig. 7.2). The majority of people look for financial incentives to recycle. However, most e-waste that could be recycled still remains outside collection systems (Table 7.5).

Table 7.2 Domestic consumption of electronic devices in Thailand (PCD 2012)

Product (1000 units)	2007	2008	2009	2010
TV (CRT, LCD, plasma)	3106	2840	2500	2655
Digital camera	9369	9863	10,382	10,928
Media player	3429	3610	3800	4000
Printer	1724	1814	1910	2010
Mobile phone	47,760	54,130	56,836	59,678
PC	2726	2870	3021	3180
A/C	1568	1650	1737	1829
Refrigerator	1474	1552	1634	1720
Fluorescent lamp	101,362	105,609	117,954	122,598
Battery	416,770	424,575	432,380	440,186
Total	589,288	608,513	632,154	648,784

Table 7.3 Product ownership and average lifespan of electronic devices in Thailand (PCD 2012)

Product	Occupied unit with product (%)	Unit per household	% Brand new	% Second hand	Average use period (years)
TV (CRT)	85.52	1.45	98.98	1.02	6.90
TV (LCD/plasma)	29.7	0.39	100	–	3.80
Refrigerator	94.55	1.29	98.27	1.73	6.87
Mobile phone	92.98	2.25	99.67	0.33	3.09
DVD player	60.02	0.7	99.47	0.53	3.78
PC/notebook	56.81	0.78	98.57	1.43	3.65
Digital camera	42.45	1.52	99.76	0.24	3.13
Air-conditioning unit	41.34	0.58	99.15	0.85	5.20
Printer	14.48	0.18	100	0	3.05

Table 7.4 E-waste generation forecast in Thailand (1000 units) (PCD 2012)

Product	2012	2013	2014	2015	2016
TV	2377	2483	2587	2689	2790
Digital camera	724	785	875	983	1059
Media player	3253	3380	3476	3537	3571
Printer	1495	1507	1520	1532	1542
Mobile phone	8524	9146	9750	10,337	10,907
PC	1789	1999	2210	2421	2630
A/C	696	717	740	766	796
Refrigerator	822	872	922	972	1023

7.4 E-waste Management Strategy in Thailand

The challenges facing e-waste management in Thailand as analyzed by the PCD before setting up the WEEE strategic plan phase I (2007–2011) included:

(1) no plans to link the government, the private sector, and the public sector to manage e-waste in the country over the long term;

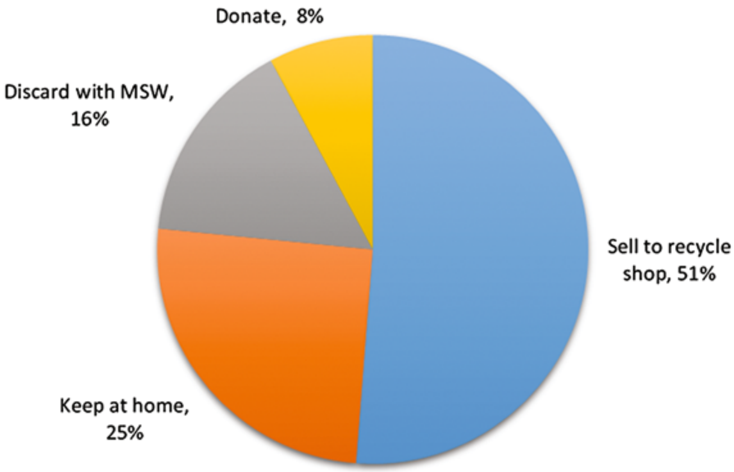

Fig. 7.2 Household e-waste management in Thailand (percentage) (PCD 2012)

Table 7.5 Consumer behavior on e-waste management after end of life (percentage) (PCD 2012)

Type of E-waste	Discard with MSW	Sell to Recycle Shop	Donate	Keep at Home
TV (CRT/LCD/plasma)	8.7	62.6	7.24	21.42
Digital camera	22.44	40.24	4.63	32.69
Video camera	10.26	25.64	15.38	48.72
DVD player	21.39	54.19	6.6	17.83
Printer	17.52	52.55	8.76	21.17
Home phone	36.6	38.99	4.51	19.89
Mobile phone	12.39	50.18	5.77	31.66
PC/Notebook	7.77	61.81	6.8	23.95
Air-conditioning unit	9.01	66.74	6.47	17.78
Refrigerator	8.82	65.21	7.53	18.43

(2) limitations in the rules and guidelines for e-waste management such as law and enforcement for separation;
(3) no charges/fees that reflect the true cost of e-waste management for managing e-waste effectively;
(4) campaigns aimed at the public and operators at all levels in e-waste management remain fragmented and discontinued from source, collection, to final treatment;
(5) the government and private sector lack the incentive to invest in e-waste management (PCD 2012).

In Thailand, the separation, collection, and storage of e-waste are still not efficient. EoL electronic device management poses a number of problem that need to be addressed urgently such as the lack of capital to build and operate the system, shortage of personnel and expertise, finding a place to set up a management center, and putting in place the appropriate treatment technology.

Description: A local shop for electronic waste resale in Bangkok. Photo by: Witthawin Sangprasert

Description: Informal sector e-waste separation in Suea Yai community in Bangkok. Photo by: Witthawin Sangprasert

Description: Informal sector e-waste separation in local community in Bangkok. Photo by: Tatthap Veeratat

The Pollution Control Department set up the WEEE Strategic Plan Phase I. It was implemented during 2007–2011 to solve the electronic waste problem in the country. The plan comprised five main strategies. **Strategy 1**, which involves technology development and best available practice, has the objectives of developing technology and finding the most appropriate way to handle e-waste. The production of EEE must also be environmentally friendly. **Strategy 2**, which involves capacity building and empowerment, has the objectives of enhancing the learning process and getting all sectors to participate in managing the problem of e-waste. **Strategy 3**, which involves law enforcement and development, has the objective of enhancing the efficiency of law enforcement and legal systems that facilitate the management of e-waste. **Strategy 4**, which involves the financial and investment system, has the objective of using financial measures to promote investment to support the production of EEE in an environmentally friendly way as well as managing e-waste. **Strategy 5**, which involves the management scheme and organization development, has the objectives of setting up a management system for e-waste in an efficient and comprehensive way as well as establishing environmental responsibility (PCD 2012).

A number of projects have been implemented in the Strategic Plan Phase I including:

1. Promoting the ecodesign of electric and electronic products
2. Development of a national electric and electronic products standards-testing laboratory
3. Setting and priority lists of electric and electronic products according to the plan
4. Pilot project on recycling fluorescent lamps
5. Setting standards for electric and electronic products
6. Capacity building of relevant agencies on import and export control on electric and electronic products, WEEE
7. Setting a code of practice for electronic waste separation
8. Campaign to raise awareness about the impacts from electronic waste and promoting recycle and reuse
9. Promoting the consumption of ecofriendly electric and electronic products
10. Development of a database on electric and electronic products.

Despite implementation of the WEEE Strategic Plan Phase I, e-waste management problems still remained. The government set up the WEEE Strategic Plan Phase II (2012–2016) to tackle additional challenges in e-waste management including (1) citizens' lack of awareness of hazardous substances in e-waste, (2) no separate collection system (truck and storage) at local municipalities, (3) low interest in private investment in separation and recycling businesses, (4) improper separation and recycling of e-waste by the informal sector, and (5) no regulation and enforcement system for e-waste from electronic and repair shops.

Thailand's WEEE Strategic Plan Phase II (2012–2016) comprised five strategies. **Strategy 1**, which involves strengthening import and export control, has the objective of setting up a system to restrict the import of low-quality electronic and electric products from overseas and prevent illegal import and export of e-waste. **Strategy 2** has the objective of promoting the production and consumption of ecofriendly electronic and electric products. The government aims to increase the percentage of ecofriendly electronic and electric products it procures by up to 20% between 2012 and 2016. **Strategy 3** has the objective of developing a database system of WEEE information. **Strategy 4** has the objective of improving the separation, collection, and transportation of WEEE. The government set up a mechanism to effectively collect WEEE and send to a formal recycling factory for at least 10 types of e-waste including (1) fluorescent lamps, (2) dry batteries, (3) refrigerators, (4) TVs, (5) air-conditioning units, (6) digital cameras/video recorders, (7) DVD and CD players, (8) printers and faxes, (9) phones, and (10) PCs. **Strategy 5** has the objective of increasing the capacity building of waste separation and recycling factories throughout the lifecycle.

7.5 Situation in E-waste Recycling in Thailand

Some waste collection and recycling in Thailand is still carried out by private waste dealers. Thailand's Pollution Control Department reported in 2003 that there were more than 3000 waste dealers. They act as middlemen in recycling processes by selling metal and plastic scrap to recycling companies; however, their activities fall short of being ideal when it comes to environmental protection and material conservation because of the lack of proper waste stream management. Thailand has registered two types of waste processor factories to deal with WEEE recycling including factory type-105 which is authorized to separate or landfill waste according to order by the Ministry of Industry and factory type-106 which is authorized to recycle residuals from industrial process or industrial waste (EEI, 2007). Although investments and technology are less required in collection and dismantling, mechanical preprocessing and metallurgical metals require some investment. By contrast, recycling might not be worth investment in Thailand because such a small amount of material exists to reach the breakeven point. Therefore, many companies in Thailand prefer to ship their scrap for further metallurgic processes abroad (Manomaivibool et al. 2009). Moreover, Manomaivibool et al. (2009) reported that several investors have expressed interest in WEEE recycling in Thailand, but they are waiting for the Thai government's WEEE policies to show a clearer direction; the government does say, however, that it will support investment in recycling by enhancing resources within the recycling program.

7.6 Urban Mining and Recycling of E-waste

Urban mining can be defined as actions and technologies that recover resources from residues produced by municipal, industrial, and agricultural waste in terms of secondary raw materials and energy. Krook et al. (2011) argued that urban mining has primarily dealt with the potential of long-term strategies for managing such ore because of increasing recycling rates of annual discards. Valuable materials in e-waste, which typically provide the incentive for recycling, include base metals such as copper and precious metals such as gold or palladium (Wäger et al. 2011). Mobile phone waste contains precious metals such as gold, silver, and copper.

Table 7.6 Precious metals recovered per ton of mobile phone waste (Baba et al. 2010)

Recovered metal	Weight (g/ton)
Gold	280
Palladium	137.1
Copper	140
Aluminum	145.1
Silver	450

If these metals are collected and undergo a proper recycling process, environmental impacts can be minimized and energy can be saved from resource extraction. Baba et al. (2010) pointed out that up to 280 g/ton of gold can be extracted from mobile phone waste. The composition of other precious metals in mobile phone waste is shown in Table 7.6 (Baba et al. 2010). Therefore, mobile phone waste is an important source for urban mining since the precious metal extracted is several-fold higher than that from a natural mine.

The recycling of mobile phone waste is very attractive because mobile phones are small in size and printed wiring boards (PWBs) contain a high content of precious metals such as gold, palladium, and silver. So, successful recycling of mobile phones hinges on efficient technologies and whether valuable metals can be recovered economically from PWBs. Figure 7.3 shows the methods of recycling developed in South Korea. One (process I) involves shredding of PWB waste and sending to a copper smelter. Another (process II) comprises shredding, incineration, melting into copper alloy (containing precious metals), and refining processes including leaching, separation, and recovery. Both processes have been employed for the recovery of valuable metals (Lee et al. 2007).

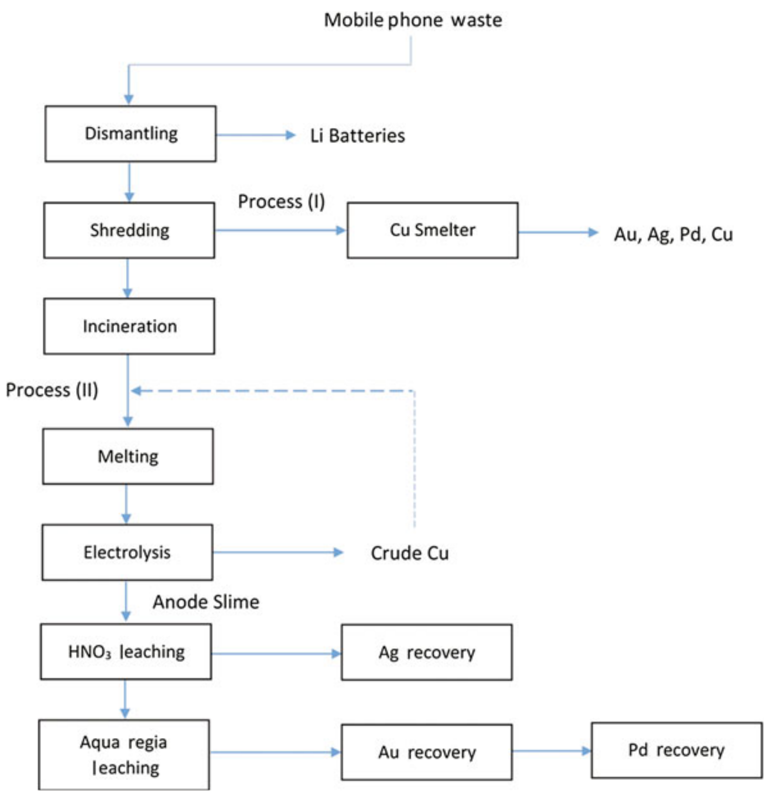

Fig. 7.3 Flowchart for the recycling of metal from mobile phone waste. *Source* Lee et al. (2007)

Table 7.7 Metal content of E-waste and recovery rates (*Source* Bigum et al. 2012)

Metal	Metal content of high-grade E-waste		Recovered (%)		
	Value	Unit	Pre treatment	Recovery process	Overall
Palladium	7	g/ton	26	98	25
Gold	22	g/ton	26	98	25
Silver	313	g/ton	12	97	12
Nickel	3	kg/ton	100	90	90
Aluminum	33	kg/ton	86	79	68
Copper	44	kg/ton	60	95	57
Iron	204	kg/ton	96	100	96

Table 7.8 Benefits of using scrap iron and steel instead of virgin materials (Cui and Forssberg 2003)

Benefits	Percentage
Savings in energy	74
Savings in virgin materials	90
Reduction in air pollution	86
Reduction in water use	40
Reduction in water pollution	76
Reduction in mining waste	97
Reduction in consumer waste	105

Table 7.9 Recycled materials energy savings over virgin materials (Cui and Forssberg 2003)

Materials	Energy savings (%)
Aluminum	95
Copper	85
Iron and steel	74
Lead	65
Zinc	60
Paper	64
Plastics	>80

Recycling is emerging as a potential solution to reducing waste and slowing down the depletion of natural resources as a consequence of mass production for today's socially networked society (Kim et al. 2009). A recent lifecycle assessment (LCA) study by Bigum et al. (2012) reported on the metal content of high-grade e-waste and the recovery rates for pretreatment, the recovery process, and overall (see Table 7.7). The functional unit of the study is the recovery of gold, iron, nickel, aluminum, copper, palladium, and silver from 1 ton of high-grade e-waste (assessments are attributable to average data for energy substitution). The environmental costs of pretreating e-waste and recovering metals are less than the cost of producing similar amounts of metals from virgin ore. When recycling e-waste, it

Table 7.10 Environmental impact assessment of recovery of metal per ton high-grade WEEE (Bigum et al. 2012)

Impacts	Mass (person equivalents, PE)	Economics (person equivalents, PE)
Environmental impact categories		
Acidification	−0.25	−0.27
Ecotoxicity in soil	-1.13×10^{-3}	-1.10×10^{-3}
Ecotoxicity in water (chronic)	−7.83	−4.41
Global warming (100 years)	−0.25	−0.38
Human toxicity via air	−0.98	−1.00
Human toxicity via soil	−0.26	−0.50
Human toxicity via water	−0.48	−0.25
Nutrient enrichment	−0.05	−0.07
Photochemical ozone formation	−0.02	−0.04
Stratospheric ozone depletion	-1.01×10^{-4}	-2.16×10^{-3}
Resource consumption		
Aluminum	−5.07	−5.07
Brown coal (lignite)	−0.41	−2.18
Copper	−11.0	−11.0
Crude oil	−0.21	−0.49
Gold	−14.6	−14.6
Hard coal	−0.62	−0.91
Iron	−3.93	−3.94
Lead	-2.50×10^{-4}	-5.21×10^{-3}
Manganese	−1.44	−1.44
Natural gas	−0.18	−0.43
Nickel	−12.3	−12.3
Palladium	−63.0	−63.0
Silver	−11.7	−11.7
Uranium	−0.20	−0.03
Zinc	−0.04	−0.01

is important to be aware of the need for a cost-effective and environmentally friendly recycling system. The process of recycling e-waste involves disassembly and mechanical/physical processing, which is based on the characteristics of e-waste (i.e., screening, magnetic, eddy current, electrostatic, etc.).

The recycling of e-waste is important for the recovery of valuable materials, savings in energy, conserving virgin materials, and reducing waste. The U.S. Environmental Protection Agency (EPA) has identified major benefits when using scrap iron and steel instead of virgin materials (see Table 7.8). Using recycled materials in place of virgin materials results in significant energy savings (see Table 7.9) (Cui and Forssberg 2003).

The results from LCA of the recovery of metals per ton of high-grade WEEE are shown in Table 7.10. This table allocates the environmental loads, benefits, and economics from mass flows. Environmental impacts show negative person equivalent values, which means that the environmental costs for recovery of metals are less than the cost of producing metals from virgin minerals. Therefore, pretreatment and recovery of metals from WEEE is significant to reducing resource consumption and environmental impacts (Bigum et al. 2012).

7.7 Impact from End-of-Life E-waste Management

7.7.1 *Dumping Desktop PCs into Landfill*

Dumping desktop PCs into sanitary landfills can contribute a range of potentially hazardous substances. EPA standards classify CRT glass in computers as hazardous waste. TCLP (toxicity characteristic leaching procedure) tests have shown that circuit boards and CRT glass exceed EPA limits for lead leachability (Williams et al. 2008). Moreover, a lot of research has found leaching. For example, Musson et al. (2006) found that lead concentrations of 13 different types of electronic devices, including CPUs, CRTs, and laptops, also exceeded Federal TCLP limits for classification as hazardous waste. Jang and Townsend (2003) collected a representative sample from 11 Florida landfills and measured leaching properties using the TCLP approach. They concluded that PWBs and CRTs have the potential to leach lead at average concentrations of 2.23 and 4.06 mg/L, respectively.

Besides leaching, heavy metals can escape from a landfill into the environment by advection through landfill gas. Heavy metals may also be released from landfills by solid-state diffusion, or to a lesser extent by diffusive flux (Williams et al. 2008). Nevertheless, the concentrations of heavy metals in landfill leachate and landfill gas are only part of the overall question about the effectiveness of sanitary landfill management to prevent such toxic materials from escaping.

7.7.2 *Informal Recycling*

So-called “backyard recycling processes” are widespread in China, India, and Pakistan. For example, Guiyu (China) is infamous for being an informal electronics recycle center contaminated by heavy metals, making the water undrinkable and producing dioxin ash. This resulted in workers and 80% of children in the city suffering from lead poisoning (Huo et al. 2007; Pirzada and Pirzada 2006). In addition, the level of polybrominated diphenyl ethers (PBDEs) or polybrominated biphenyls (PBBs) as flame retardants at one e-waste combustion site in the city was more than 16,000 times the control level, which ended up affecting the blood levels of many villagers (Williams et al. 2008). Particularly high toxicity levels were found at the schoolyard and the food market. Risk assessment predicted that Pb and Cu originating from circuit board recycling likely posed a serious health risks to Guiyu's workers and local residents. The levels of Pb and Cu in road dust were 330 and 106, and 371 and 155 times higher, respectively, than non e-waste sites located 8 and 30 km away (Leung et al. 2008). However, long-term health studies of e-waste workers have yet to be conducted.

Informal recycling proliferates more in developing countries because there are fewer restrictions. Many developing countries are targeted for e-waste dumping; estimates point to around 50–80% of such waste coming from developed countries (Basel Action Network 2002). As for the situation in Thailand, there is evidence if e-waste being imported from Singapore, Japan, and the U.S.A. and being dumped in areas around Klong Toey port (Lundgren 2012).

7.8 Policies for End-of-Life Management: International Scheme

Many countries around the world have set up policies to control e-waste. WEEE is a totally different type of waste. Traditional waste management cannot be applied to e-waste because of the latter's characteristic of containing highly toxic substances which pose a danger to both health and the environment. Table 7.11 shows example regulations in various countries.

At the international level, the central framework for controlling international movements of hazardous substances is the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (the Convention). This regulation is mainly related to trade measures and non-trade measures. It presents four main aims related to the waste hierarchy of prevention, reduction, recovery, and final disposal. This regulation requires prior notification between signatories when trading hazardous waste. Many categories of e-waste are classified as hazardous waste and thus are targeted for prior notification (Lundgren 2012).

Then there is the Rotterdam Convention which deals with the responsibility between exporting and importing countries to protect human health and the environment, and provides exchange information about potentially harmful chemicals that could be exported and imported (Widmer et al. 2005).

The Waste Electrical and Electronic Equipment (WEEE) directive is the well-known regulation that mandates electronics be taken back or recycled in the 27 countries of the European Union. Europe is leading the way in framing and implementing policies to manage WEEE.

Table 7.11 WEEE regulation in some developed countries

Country	Legislation	Responsibility	In force since
Switzerland	Ordinance on the Return, Taking back and Disposal of Electrical and Electronic Equipment (ORDEE)	Manufacturer/importer	July 1998
Denmark	Statutory Order from the Ministry of Environment and Energy No. 1067	Local government	December 1999
Netherlands	Disposal of White and Brown Goods Decree	Manufacturer/importer	January 1999
Norway	Regulations Regarding Scrapped Electrical and Electronic Products	Manufacturer/importer	July 1999
Belgium	Environmental policy agreements on the take-back obligation for waste from electrical and electronic equipment	Manufacturer/importer	March 2001
Japan	Specified Home Appliances Recycling Law (SHAR)	Manufacturer/importer	April 2001
Sweden	The Producer Responsibility for Electrical and Electronic Products Ordinance (SFS 2000:208)	Manufacturer/importer	July 2001
Germany	Act Governing the Sale, Return and Environmentally Sound Disposal of Electrical and Electronic Equipment (ElektroG Act)	Manufacturer/importer	March 2005

Source Adapted from Khetriwal et al. (2009)

The RoHS directive was set up to control the materials used in the manufacture of all electronic products sold in the European Community (EC 2006). It has been in force since 2003. It also provides a means of checking how effective the various regulations are at protecting human health, as well as ensuring proper recovery and disposal of e-waste.

In contrast to OECD countries, electronic waste is not given priority when it comes to management policy in some countries such as those in South Asia, Latin America, or the Pacific. While there are no laws regarding e-waste, there are several regulations detailing the implementation of trade laws that control the import of used appliances (Arora 2008). The difficulties of e-waste management stem mainly from lack of awareness in end-users, improper collection methods, collection along with bulky waste, scant waste disposal facilities, stockpiling at households, open dump landfilling, the absence of an organized market, and insufficient data/statistics for policy setting (Arora 2008).

7.9 Policies and Relevant Regulations of E-waste Management in Thailand

Even today Thailand has no specific legal framework for controlling WEEE disposal. Waste disposal is controlled by two acts. First, with the aim of providing a waste disposal service to its citizens, the Public Health Act, B.E. 2535 (A.D. 1992) was passed by the Thai government to allow local governments to issue regulations and make levies for service collection and the disposal of municipal solid waste. Second, the Factory Act, B.E. 2535 (A.D. 1992) was passed to classify and regulate industrial activities, recovery, treatment, and disposal of wastes by establishing sorting plants and landfill operators (Vassanadumrongdee and Manomivibool 2011). For example, an industrial WEEE waste manifest system for the transportation of industrial waste to various localities should be managed under the regulations and requirements of this act.

Thai policy still mandates nothing from the producer such as payment for waste disposal, the setting up of specific take-back programs, or effective procedures for recovery, reuse, and recycle. However, Thailand has already drafted the National Integrated WEEE Management Strategy Phase II: 2012–2016 which proposes synchronizing various ministries for effective management. Unfortunately, the draft documents are still under consideration.

Economic incentives will be provided by the Act on Economic Instruments for Environmental Management, which is currently being drafted by the Ministry of Finance (MOF) in coordination with the a royal decree as a subordinate law from the Ministry of Natural Resources and Environment (MONRE). The principle of this framework is to apply fiscal instruments such as performance bonds, tradable permits, and environmental subsidies to motivate organizations to bring about environmental outcomes (PCD 2010).

7.10 Appropriate Ways of Managing the End of Life of WEEE

Extending the lifespan by upstream management is an approach that is seen as usual in Thailand. This aims to reduce much of the waste by extending the lifespan of EEE and by so doing dispose less of it to the environment. Moreover, extending the lifespan of aging EEE can lead to energy saving and reduced energy expenditure relative to choosing a new one (Williams et al. 2008). There are many ways of applying this scheme including:

Repairing or upgrading: This approach involves replacing the same by a new component so that the PC functions with at least the same or higher performance. CPU microprocessor, memory, and hard disk drive are typical areas where performance and lifespan can be improved. However, some PC equipment (e.g., motherboards) cannot be repaired as a result of incompatibility with new technology architecture. Nevertheless, upgrading might cost more than the price of a new machine (Williams and Sasaki 2003). Overall, Thailand is fortunate in having many shops selling/installing PC equipment staffed by highly skilled technicians.

Reselling or donation: This approach extends the life of EEE by giving it a second lifespan. Such an approach is convenient in Thailand because there is a lot of support in Bangkok and other provinces in the form of second-hand internet shops. Despite the popularity of reselling, donation (selling computers at zero prices) still goes on. Donation often involves giving used PC equipment to schools, nonprofits, and charities. This approach allows people with no accessibility to main databases to access websites and other online areas (Williams and Sasaki 2003).

Leasing: This approach involves reducing the impact of WEEE on the environment and increasing cost-efficiency for some sectors. Basically, this works by consumers leasing the services of leasing providers for products instead of buying the actual product. Thus, the equipment remains the property of the vendor, which consumers have to return when the contract runs out.

Donation is often preferred by private companies and households for humanitarian reasons. The Wat Suan Kaew Foundation (SKF) and the Mirror Foundation happily receive donations of durable used products, which are repaired for reuse again.

7.11 Recommendation for Managing E-waste in Thailand

I. ***Extending lifespan and promoting recycling***

The government should create a policy aimed at extending usage lifespan approaches such as reuse, donate, resell, and take-back. In the private sector, manufacturers and e-appliance companies should undertake campaigns aimed at prolonging the lifespans of products such as donation schemes.

Recycling can be promoted by: (1) increasing the collection of e-waste in local communities by providing donation boxes or bins to collect end-of-life mobile phones and other types of e-waste; (2) support advanced research and development for appropriate technology to recover resources from e-waste.

II. ***Providing incentives for better management***

People wanting to improve e-waste management should be given incentives like (1) receiving discount prices when buying new mobile phones if they bring their old ones to the shop for recycling, (2) offering benefits or refunding money when they bring end-of-life mobile phones to e-waste collection centers.

III. ***Establishing appropriate e-waste collection centers or schemes***

The government should set up an e-waste collecting framework via new regulations and policies. This should lead to a mechanism for public and private sector participation in supporting waste-collecting schemes set up by the government. Waste collection centers or schemes not only have to come up with an e-waste collection system, but also provide a facility, safety operating plan, and financial plan for operation.

IV. ***Developing laws and regulations for e-waste management***

Laws and regulations should be developed to bring informal recycling up to quality control standards. There should be a national framework to pave the way toward a proper recycling scheme. Furthermore, financial and technological support needs to be given to gradually change the current situation into a proper recycling scheme.

V. ***Public education and raising awareness on e-waste management***

Education will help increase the awareness of people to recycle e-waste properly. This strategy has to be implemented concurrently by government, private sector, public sector, and academic sector all together. The government and private sector should set up a campaign and database on the appropriate approach to disposal of e-waste and the harm caused by improper recycling. Educating the public about hazardous substances and precious metals in e-waste and how to sort e-waste properly from municipal waste for recycling purposes is of utmost importance.

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Chapter 8
E-waste Management in Thailand (Case Studies)

This chapter presents three case studies on electronic waste management including one on mobile phone waste management, one on PC waste management, and one on TV waste management. All case studies were conducted in Thailand by the author's research team. The chapter presents the current situation of each type of waste and how they are managed. Recommendations about how to improve the performance of each type of e-waste management are presented in each section.

8.1 Case Study on Mobile Phone Waste Management

Mobile phone waste is becoming a major problem for many countries in the world including Thailand. Used mobile phones in Thailand are typically resold domestically or exported to neighboring countries such as Myanmar, Laos, Vietnam, Cambodia, and Bangladesh (DOWA 2007). End-of-Life (EoL) mobile phones are exported to China as sources for spare parts. Also, used mobile phones still have economic values because they contain precious metals such as gold, silver, and copper. This could potentially be used as incentives or benefits to consumers who can collect used mobile phones and take them to proper processing facilities.

Hazardous substances and precious metals contained in phones can be viewed as both threats and opportunities for waste management and resource recovery. While mobile phone waste contains some precious metals such as gold, silver, and copper, it can pose serious health and environmental risks. If these metals are collected and sent through proper recycling processes, environmental impacts can be minimized and energy can be saved by not having to extract new resources to replace the recyclable metals.

For example, the amount of gold extracted from a typical primary gold mine is approximately 5 g per ton of soil. A study by Polák and Drápalová (2012), concerning extraction of precious metals from mobile phone waste, found that gold can

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Table 8.1 Materials in mobile phones produced between 2001 and 2005

Materials	Mass (mg per unit) in 2001	Mass (mg per unit) in 2005
Silver	244	150
Aluminum	2914	8166
Gold	38	18
Beryllium	3	2
Bismuth	31	1
Bromine	941	427
Chromium	345	1046
Copper	14,235	9996
Iron	8039	8399
Glass	10,594	7501
Nickel	1124	3276
Lead	301	10
Palladium	15	1
Antimony	84	3
Tin	689	911
Zinc	641	655

Source Polák and Drápalová (2012)

be extracted at up to 300–350 g/ton of mobile phone waste. Table 8.1 presents the composition of metals in mobile phones produced between 2001 and 2005. Mobile phone waste, therefore, is an important source for urban mining which can extract precious metals at a rate several-fold higher than that of a natural mine.

The printed wiring board (PWB) is an important part of a mobile phone. It should be recycled because it contains various valuable metals such as copper, iron, tin, nickel, lead, aluminum, gold, and silver. The high percentage of precious metals in PWBs makes them more interesting for recycling (Kasper et al. 2011). Metals present in the PWB account for approximately 52% while the remaining 48% is made up of plastics and other materials.

8.1.1 Environmental Impact of Mobile Phones Waste

Lead and cadmium are among the hazardous substances found in mobile phones that may cause environmental impacts. Many of these hazardous substances can persist in the environment, accumulate in the food chain, and pose a serious risk to the environment and human health should they contaminate the ecosystem. Note that newer models of mobile phones are more eco-efficient than older ones. However, this is not the result of a reduction in usage of hazardous materials, but rather down to significant advances in miniaturization of devices which accordingly weigh less and are smaller in size.

According to an analysis of materials in mobile phone waste by Wu et al. (2008), the authors reported that, although mobile phones differ in model and production year, the types of toxic substances and their relative ratio do not change. In addition, the rates at which new models of mobile phones are introduced is on the increase as a result of innovation, therefore the overall usage of toxic substances in mobile phones is expected to increase substantially. Osibanjo and Nnorom (2008) assessed the environmental impact of mobile phone waste and mobile phone accessory waste. They reported that printed wiring boards (PWBs) and liquid crystal displays (LCDs) are the components that have the greatest environmental impact in the life of mobile phones, accounting for approximately 98% (59 and 39%, respectively) of waste.

Description: LCD computer screen separation. Photo by: Tatthap Veeratat

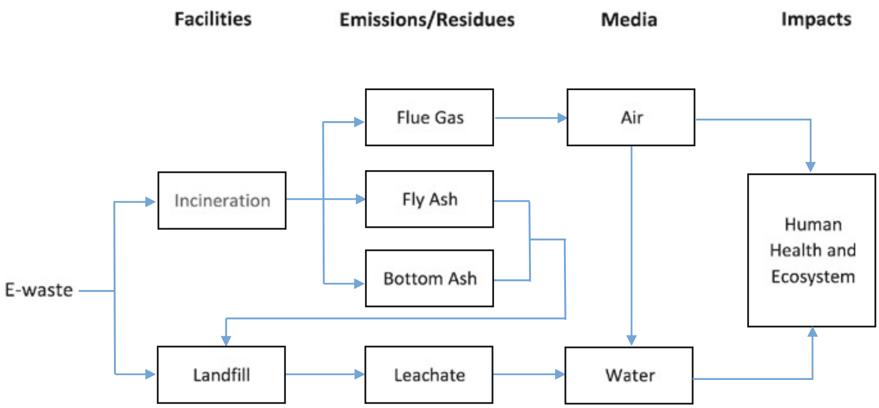


Fig. 8.1 Pathway and impact model for heavy metals in e-waste. *Source* Adapted from Lim and Schoenung (2010)

Many research findings report the health risks and negative health outcomes from exposure to e-waste (e.g., Song and Li 2015). A study by Lim and Schoenung (2010) evaluating ecotoxicity potentials found that those from mobile phone waste are mainly from copper and mercury. Cancer potentials from mobile phone waste are mainly from lead and arsenic. Toxic substances from mobile phones can get into air and water via e-waste; an impact model from heavy metals in e-waste is shown in Fig. 8.1. Many toxic substances can persist in the environment by bio-accumulating through the food chain. Heavy metals in e-waste treated in incineration facilities are distributed into flue gas, fly ash, and bottom ash. The heavy metals in fly and bottom ashes are typically landfilled for final disposal. These ultimately leak into the water table creating serious environmental and health risks.

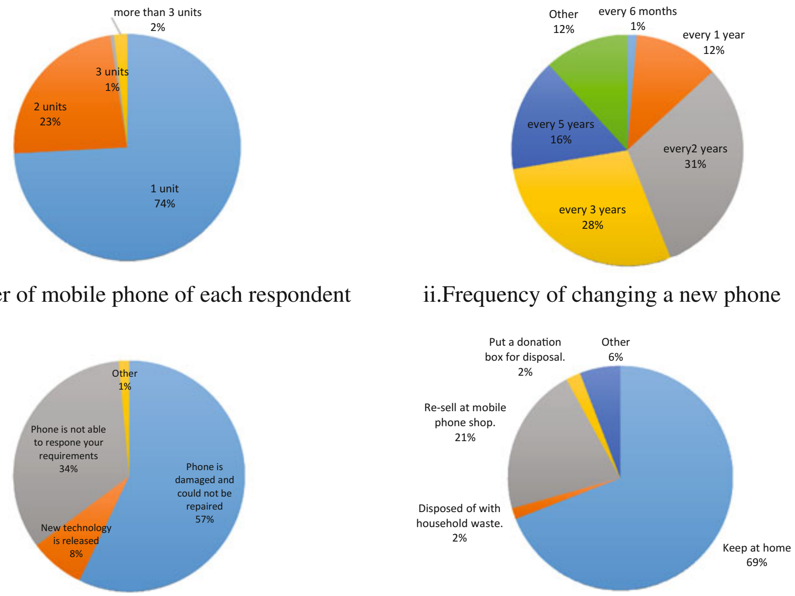
The toxic substances in mobile phones may not be an immediate danger at the end of life (EoL) if they are appropriately treated or managed. If their disposal is not properly treated, it can lead to release of toxic substances. A major problem of mobile phone waste in most developing countries is the way in which it is incinerated or disposed of along with domestic waste. This is due to lack of appropriate treatment systems and take-back of waste. So the disposal of mobile phone waste needs to be managed to minimize toxic substances that will be released into the environment and impact human health (Osibanjo and Nnorom 2008).

8.1.2 Mobile Phone Waste Management Preferences in Thailand

Most mobile phone waste comes from regular phones as smartphones are still not significantly discarded as waste. Factors that increase the amount of mobile phone waste include: (1) The competitive mobile phone market in which manufacturers are trying to increase sales volumes in the consumer market by lowering prices, making mobiles more affordable to people at various economic levels; (2) reducing the rate of mobile phone service charges and adopting marketing strategies such as free SIM card deals, motivating consumers to own more than one mobile unit; and (3) technological innovation speeds up the rates at which new models of mobile phones are introduced. This creates indirect incentives for consumers to change mobile phones more often than is really necessary (TCIJ 2013).

A major problem with managing EoL mobile phones in Thailand is the lack of an efficient collection system for mobile phone waste. Only few EoL mobile phones were sent to formal management systems because the country lacks a proper management system for e-waste. Most EoL mobile phones end up in an informal management/recycling system.

Recent research carried out by Sangprasert and Pharino (2012) had the objective of understanding the general public's opinions on mobile phone waste management. Questionnaires were conducted to see how people regard the mobile phone waste situation with the objective of understanding the problem and finding potential solutions to mobile phone waste in Thailand. The total number of respondents in two surveys were 377 (207 from a hard-copy survey and 170 from an online survey). As shown in Fig. 8.2, most respondents own one mobile phone



i.Number of mobile phone of each respondent

ii.Frequency of changing a new phone

iii.Reason to change a new phone

iv.Management of EoL Mobile Phone

Fig. 8.2 Thai citizen behavior on mobile phone waste management. *Source* Sangprasert and Pharino (2012)

(74%) while some have two (23%). The frequency with which mobile phones are renewed is every 2 years (31%) and every 3 years (28%). The main reason to change mobile phone or buy a new phone is because the old phone was damaged and could not be repaired. Discarded phones are mainly kept at home (69%) followed by taking them for resale at mobile phone shops (21%).

Thai people usually keep discarded phones at home maybe with the intention to giving them to family or friends but also because people are unaware of the environmental impacts of hazardous substances from mobile phone waste. If waste management is ineffective, hazardous substances can potentially contaminate the environment.

The case study also focused on what motivated the public to recycle mobile phone waste. As shown in Fig. 8.3, motivating the general public toward mobile phone recycling can be brought about by (1) monetary or financial benefits from recycling (27%), (2) increasing the awareness of risks and benefits from mobile phone waste (25%), (3) setting up laws and regulations to mandate recycling of e-waste (22%), (4) convenience of drop-off locations (16%), and (5) increasing public awareness of the environmental value of recycling (10%).

A major problem with all waste management systems is how to set up a system that works. The case study investigated public preferences for an e-waste collection system. Participants were asked which mobile phone collection system they preferred the most. The results indicated that the participants preferred to bring mobile phone waste to drop-off centers for recycling. Figure 8.4 shows the preferred drop-off locations: (1) convenience stores (27%), (2) department stores (21%), (3) home pick-up (19%), (4) mobile phone shop/repair shop (16%), (5) public transport stations (5%), and (6) government agencies (5%).

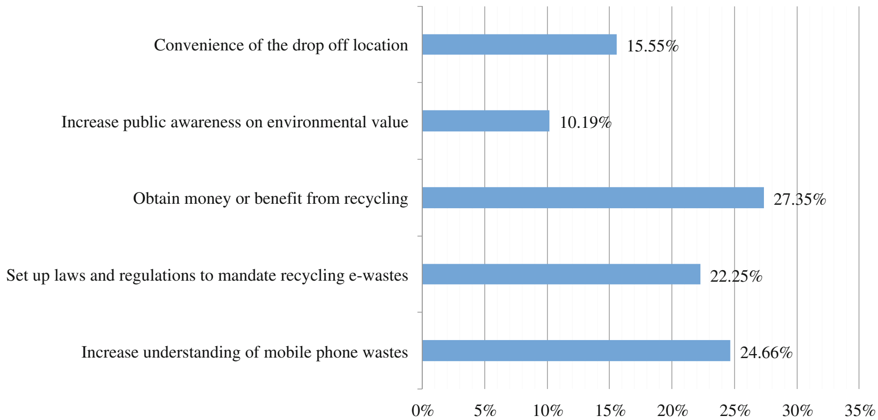


Fig. 8.3 Preferred motivation/options for recycling mobile phone waste. *Source* Sangprasert and Pharino (2012)

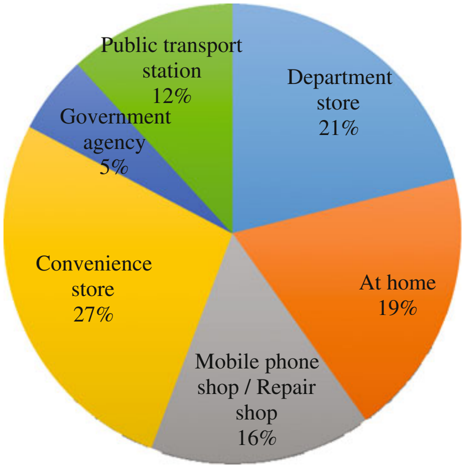


Fig. 8.4 Preferred locations for mobile phone waste drop-off/collection for recycling. *Source* Sangprasert and Pharino (2012)

It is clear from the survey that participants prefer to bring mobile phone waste for recycling to a convenience store or a department store. This is because most people are familiar with these places and because they tend to open every day. Nevertheless, most Thai people still keep EoL mobile phones at home. An at-home collection service would help eliminate the amount of time and transportation costs required to bring mobile phones to a recycle center/location. A disadvantage is the high collection cost since only relatively few can be collected in an area when compared with a drop-off scheme at convenience stores or department stores. The investment required to implement a home collection service would also be very high because of transportation costs. Based on the case study, it is recommended that the best option is to use convenience stores or department stores as drop-off locations for mobile phone waste for further recycling.

The public policy aspects participants are most interested in regarding the management of mobile phone waste include: (1) provide a discount on the purchase of a new mobile phone in return for an EoL mobile phone (69%), (2) implementing and enforcing laws and regulations (10%), (3) integrating recycling fees into the cost of new products (8%), (4) donating to government agencies for recycling (7%), and (5) paying for mobile phone waste management when they are disposed of (6%) (Fig. 8.5). It is clear that most participants prefer financial incentives through discounts when purchasing a new mobile phone in return for the old model (69%). The reasons for this are this policy offers tangible financial incentives/benefits and is easy to understand and follow (once rules are set up). There are, however, several concerning issues with this policy, especially on how to set up a financial system to provide refunds to recyclers. The rules and rates of compensation are difficult to set since each model of mobile phone uses different technology and has a different price.

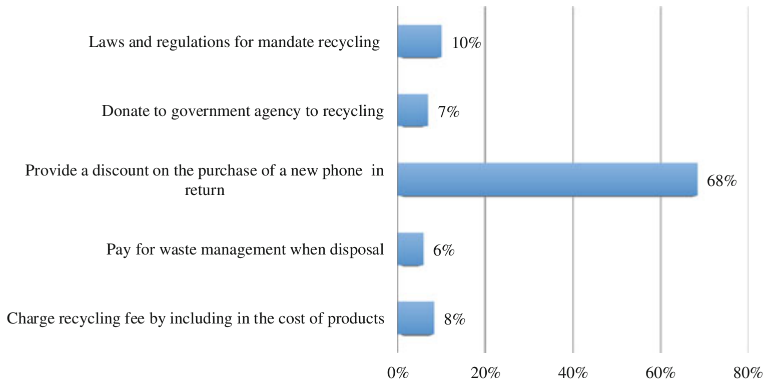


Fig. 8.5 Policy to manage mobile phone waste that respondents preferred the most. *Source* Sangprasert and Pharino (2012)

Example 8.1 Public participation in the recycling of mobile phone waste in Thailand

In 2011, Nokia, TES-AMM (Singapore), and the Center of Excellence for Environmental and Hazardous Waste Management (Chulalongkorn University) worked together to promote and raise consumer awareness regarding mobile phone recycling. They started a take-back campaign called "Chula Loves the Earth 2011." The objectives of this campaign included: (1) raising the awareness of students and the public about the importance of mobile phone recycling, (2) taking back used mobile phones, old mobile phones for recycling, and (3) raising funds for the Chaipattana Foundation. This campaign was initiated under the Pollution Control Department's WEEE CAN DO to celebrate His Majesty the King's 84th Birthday. For each person who joins the campaign by returning their unused phones, Nokia donates $2 for every phone returned to the Chaipattana Foundation. This campaign continues to operate within Chulalongkorn University and communities and schools in the neighborhood. Every month, drop-off mobile phones and accessories are collected from all specified recycling bins.

For more information: https://www.facebook.com/ChulaLovestheEarth/

8.1.3 Recommendations for Future Improvement in How to Manage Mobile Phone Waste

The following part of the questionnaire focuses on participants' opinions and suggestions on how to improve the management of mobile phone waste in the future. The results can be categorized into four main groups of suggestions including: (1) financial incentives; (2) laws and regulations; (3) practicality, such as providing convenient locations for people to bring mobile phone waste for recycling; and (4) social elements.

I. ***Financial incentives***

There are two main issues with respect to financial incentives including: (1) benefits, such as providing discount rates when old mobile phones are returned at the time of buying a new phone, or providing a discount for utility expenses such as water or electricity bills; and (2) tax, implementing a taxation scheme that is included in the cost of new products.

Based on the survey results, financial incentives would motivate people to return old mobile phones to a recycling system. Regarding a taxation scheme for new products, it may be easier and more straightforward for consumers if the government collected taxes from manufacturers or suppliers rather than from consumers. Taxes from manufacturers and suppliers could be used to set up a fund to support a mobile phone recycling program. Suitable financial instruments can help change the behavior of the general public and help solve the problem of mobile phone waste effectively.

II. ***Laws and regulations***

With respect to laws and regulations, there were two suggestions for the government to focus on including: (1) disposers should be charged when discarding mobile phone waste mixed with household waste; and (2) the government should stringently enforce laws on the management of mobile phone waste and at the same time put in place an easy-to-follow process for mobile phone waste collection.

Laws and regulations are vital to promoting or hindering the development of a successful mobile phone waste recycling program. The European Union, for example, has set a clear directive on waste electrical and electronic equipment (WEEE) to manage the electronic waste problem. By contrast, there are currently no laws and regulations on the management of electronic waste in Thailand. Hence, management is inefficient and collaboration among the government, private, and public sectors in Thailand on mobile phone waste management is poor.

III. ***Practicality: location for drop-off mobile phone waste***

Results from the survey indicated that participants want more collection stations/locations and want to be informed regarding any that exist in their neighborhood. The major problem concerning the collection of mobile phone waste in Thailand is the lack of a proper system to collect it.

IV. ***Social issues***

Social issues include: (1) general knowledge concerning mobile phone waste should be promoted to get the general public to participate in recycling programs. They should be made aware that mobile phone waste contains precious metals and hazardous substances. The treatment, recycling, and problems related to mobile phone waste should be key topics taught in schools. Government should support research and technology with a view to making electronics products more environmentally friendly. They should set up an organization to oversee plans and collaborate with manufacturers/distributors of mobile phone to help minimize the waste problem. (2) Awareness about environmental sustainability is a very important subject. Companies in the mobile phone sector in the country should aim to protect the environment and return benefits to society at the same time as pursuing their own goals. Manufacturers need to enhance their social responsibility by designing ecofriendly products and helping with the waste management of their products.

8.2 Case Study on Computer Waste Management

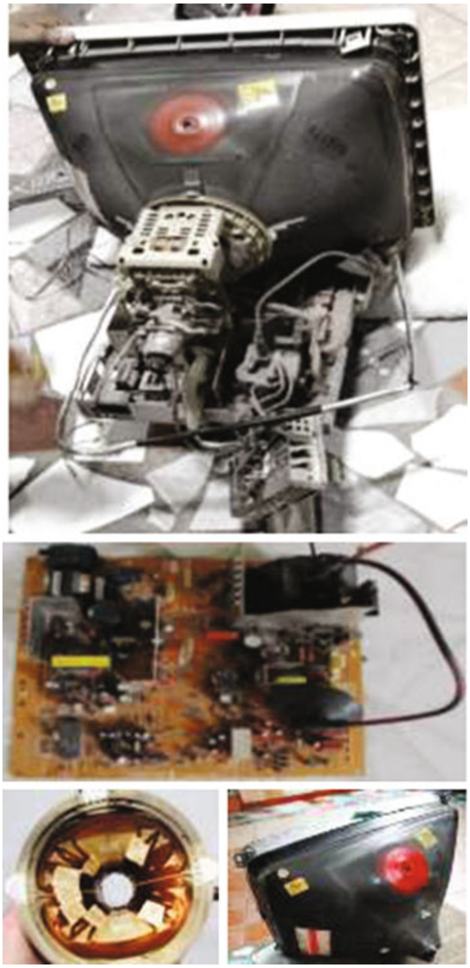
8.2.1 The Computer Waste Situation

Computers have become common household items in recent decades in Thailand, despite it being a developing country. Desktop PC consumption typically increases with economic growth. However, the numbers of computers increase faster in countries that are more economically advanced than in less developed countries (Robinson 2009). Increased computer usage in Thailand came about as a result of the National IT Policy Framework (2001–2010) which outlined the governmental goals of developing a knowledge-based economy and society by integrating information technology.

Nowadays, computers are essential for productivity in almost every industrial sector, a significant driving factor distinguishing today from past decades. In Thailand the number of PC users rapidly grew in recent decades, reaching 19.1 million in 2010. The typical lifespan of a PC is approximately 4–6 years but may be as low as 2 years (Culver 2005). The critical factors here are rapid changes in computer technology which make older computers obsolete as a result of incompatibility and inability to support newer technology or platforms. Computer manufacturers have also been able to cut the production cost of computers significantly in recent decades, consequently making new computers more affordable. A combination of these factors drives people to replace their computers and increasingly discard many before their expected end of life.

Computers are discarded for a number of reasons including: the operating system used to run the computer is incompatible with the new model or requirements; insufficient memory, speed, or size limitation to support new platforms or software; and the existing hardware cannot support or is incompatible with newer and more advanced hardware requirements such as new connectivity standards (USB 3.0, Thunderbolt, etc.) (Technology Recycling 2003).

The hazardous substances in desktop PC waste are mainly embedded in printed wiring boards and plastics materials. These substance include tin, lead, polychlorinated biphenyls, mercury, and brominated flame retardants (Deng et al. 2007; Liu et al. 2008; Qu et al. 2007). CRT computer screens contain a large amount of toxic substances such as phosphor and lead oxide. It has been estimated that CRT glass comprises 70% lead oxide (Socolof et al. 2005). Heavy metals, dyes, and other coatings are found in LCD assemblies and even on film sets. Blacklight lamps and fluorescent lamps are well-known toxic sources because they contain mercury.

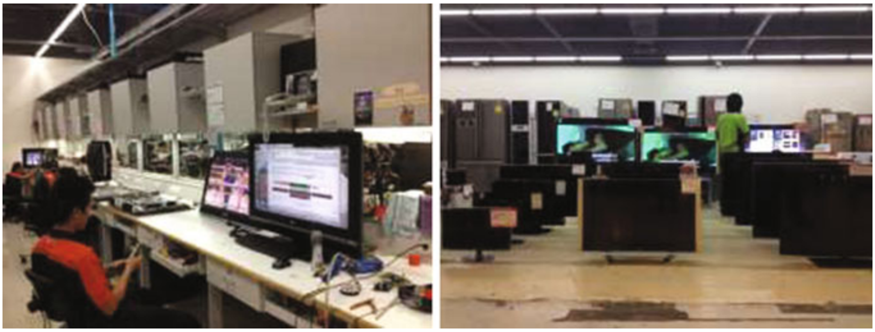


Description: CRT computer screen separation. Photo by: Tatthap Veeratat

Description: Massive discarded old model television. Photo by: Jakwida Choowongsirikul

Description: Massive discarded old model television. Photo by: Jakwida Choowongsirikul

Description: Old model TV at informal recycling shop. Photo by: Jakwida Choowongsirikul



Description: Electronics shops (sell and repair). Photo by: Jakwida Choowongsirikul

Description: Dissembled mobile phone (mobile phone case, electronic circuit, battery). Photo by: Witthawin Sangprasert

Description: Dissembled personal computer. Photo by: Tatthap Veeratat

Inappropriate handling, operation, and safety approaches could pose serious risks to the ecosystem and health via leakage of heavy metals and other hazardous elements. This has been known to happen during recovery of copper wire by burning the outer plastic wire, the recovery of precious metal from printed wired boards using an acid cyanide bath without proper safety procedures, disposal of CRT leaded glass, and LCD backlight residues without an appropriate prevention mechanism. These problems have become critical in many developing countries where 80% of total e-waste (including desktop PCs) has been managed by backyard activities without proper operating and safety protocols (Lundgren 2012).

8.2.2 Public Perception of Computer Waste Management in Thailand

As part of the case study, Veeratat and Pharino (2013) conducted a survey regarding desktop PC equipment and how such equipment is managed when discarded. The results indicated that 58.08% of all participants own PC equipment. Of the participants who own old desktop PCs, 90% have old CRT computer screens and 63% have LCD computer screens.

As shown later in the chapter (Fig. 8.8) on how discarded PC equipment is managed in practice, the three main options participants choose are: (1) keeping at home (52% of desktop PCs, 48.67% of CRT monitors, and 52.97% of LCD computer screens, respectively); (2) giving or donating to others (19% of desktop PCs, 21.67% of CRT monitors, and 19.46% of LCD computer screens, respectively); and finally (3) selling to tricycler waste buyers (so-called *Sa-leang* in Thai) (12% of desktop PCs, 14.07% of CRT monitors, and 10% of LCD computer screens, respectively).

Further data make clear why participants discard desktop computers (see Fig. 8.6). Almost 32% of participants discarded their old equipment because they bought a newer model or equipment. This is the main reason participants discard old computer equipment. Hence, people tend to discard computers earlier than expected and before the physical lifespan. Breakdown of computer equipment was the second most significant portion (30.75%). This is mainly because it is often uneconomical to repair broken devices.

The survey also showed that almost three fourths of participants (74.05%) already knew there were precious metals in computers. The majority of participants who responded indicated that they already knew there were toxic substances in discarded computers (78%). Only 21.36% did not know this. However, 64.87% of total respondents were aware of the benefits of proper recycling including the likely recovery of a large amount of primary resources, which can help reduce environmental, human health, and ecosystem impacts.

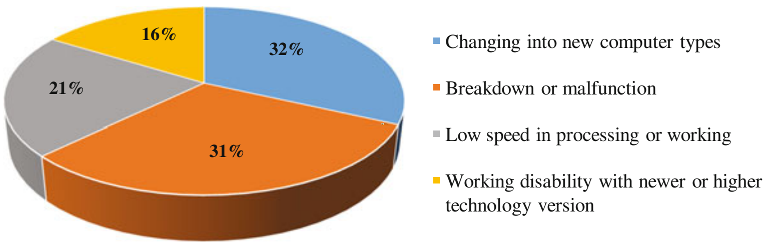


Fig. 8.6 The most relevant reasons for discarding desktop PCs

8.2.3 Approach for Collecting Discarded Desktop PCs

An appropriate management approach is a prerequisite to a good collection system in which most waste is gathered under a proper management scheme. The approach should be easy to understand and widely acceptable by the people to be effective. The survey wanted to understand which approach to operating a discarded PC collection system was most favored by participants. Participants had to prioritize choices using a preference-rating method to rank the most preferred approach from: (i) paying a waste management fee when buying a PC, (ii) reselling PC waste as a product to a responsible sector, and (iii) paying a waste management fee when buying a new PC.

Figure 8.7 shows how the three options fared in the survey. It was found that 53.52% of participants selected “reselling PC waste as a product to the responsible sector” as their favorite option, approximately 46.77% favored “Abiding by statutory regulations for e-waste management” as the second favorite option, and about 67.24% selected “Paying a waste management fee when buying a PC” as the least preferred option.

Reselling PC waste as a product to a collection center was the favorite option. This was understandable because people could get money back from discarding their PCs. This approach was familiar to participants as it was similar to selling discarded devices to tricycler waste buyers. Abiding by statutory regulations for e-waste management was the option that participants accepted as important in the control of PC waste. However, it might be considered too stringent a way and would need to be adopted gradually in Thai culture. Paying a waste management fee when buying a new model was the least preferred option. This option is directly related to willingness to pay for waste management which very much depends on people awareness and culture.

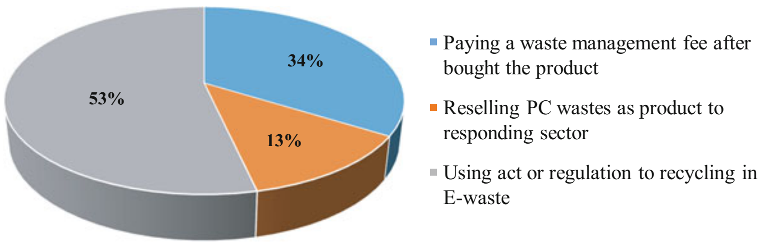


Fig. 8.7 Favorite approaches to end-of-life PC waste management

Monetary considerations in the form of price discounts were found to be effective ways of getting people to participate in recycling programs. The administrative body managing PC waste collection should offer monetary incentives or special privileges to people who return discarded equipment to the collection system. However, the feasibility of and appropriate rates for returning PC waste to the collection system have yet to be worked out. In addition, setting up collection centers for PC waste also needs to be addressed. These centers should be located conveniently for effective implementation.

The survey also compared collection system options based on participants' preferences (Fig. 8.8). The results show that the majority of participants chose "collection from home." This finding is consistent with previous research done by the Pollution Control Department (2010). Since people's lifestyles differ the collection system should be flexible and offer several options to maximize the collection rate.

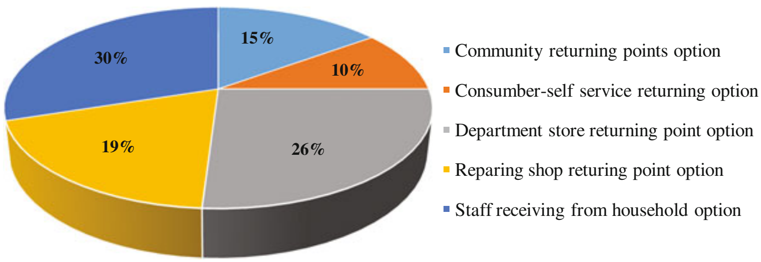


Fig. 8.8 Favorite options for returning discarded desktop PCs to a waste collection system

Based on the case study, the favorite policy option was reselling PC waste as a product to a collection center. Since most people considered their old and unused PCs as having some value, it will be difficult to apply other policies or regulations that do not provide tangible benefits. By instituting a policy encouraging reselling of PC waste to a collection center a good level of participation from the general public can be expected.

The favorite options related to recycling of PC waste were financial. However, there were other motivations such as awareness regarding environmental sustainability, other environmental benefits, and convenience of the system for returning unused or old devices.

As far as collection system management is concerned, it is necessary to set up a central administrative body to operate overall activities and budgets as well as to collaborate with all stakeholders. This role can be played most effectively by a responsible governmental organization, while other stakeholders in various social segments should participate in this framework so that an effective operating mechanism is developed.

8.2.4 Recommendations for Future Improvement of PC Waste Management

There needs to be strong collaboration between relevant stakeholders such as governmental or nongovernmental sectors, formal or informal, profit or nonprofit, and the public sector to have an effective PC waste management system. Based on the analysis from the case study, recommended strategies are presented to motivate proper desktop PC waste management in Thailand as follows:

Strategy I. Increase people awareness and participation in desktop PC waste management

This strategy is most effectively implemented by a government administrative body in conjunction with the private sector, public sector, and academic sector. The government and private sector should focus on setting up a campaign and database concerning appropriate approaches to the disposal of PC waste, hazards from improper recycling, and provide useful knowledge to the general public.

Strategy II. Extend lifespan by using proper upstream management

This strategy focuses on the development of policies and implementation plans to establish people confidence in the collection system. A government administrative body needs to set up a policy supporting all "state-of-the-art approaches" such as reusing, donating, reselling, and taking back. With respect to the private sector, computer manufacturers and resellers should focus on building their strategy or facilitating plans to induce clients to extend computer lifespans. This can be in the form of a long-term unified connectivity standard that allows old obsolete pieces of hardware to be replaced rather than replacing entire PCs. Furthermore, the private sector needs to conduct the extended lifespan concept as an organization policy.

Strategy III. Promote creation of an appropriate desktop PC waste collection center/scheme

Promoting an appropriate waste collection center/scheme can be done by various means including: (a) developing policies and implementation plans to establish people confidence in the collection system; (b) establishing a suitable site and processes of the collection system; and (c) developing effective safety plans for the operation.

The government sector has an important role to play in setting up an overall collecting framework by developing relevant laws, regulations, measurements, and policies. Their role also includes encouragement and support of the private sector to participate in the development of an effective collection system/scheme.

Strategy IV. Gradually change an improper recycling scheme into a proper one

Possible frameworks to bring this about include: (a) development of policies and implementation plans to establish a formal recycling scheme; (b) encouraging informal recyclers to adopt a formal recycling framework and, thus, become formal recyclers; (c) design the structure of recycling facilities and maintenance plans in such a way that is easy to effectively adopt and implement.

8.3 Case Study: Television Waste Management in Thailand

8.3.1 Current Situation of TV Waste Management

Hazardous materials released from discarded TVs are major concerns when the waste stream is disposed of in open dumps, landfilled, or in incinerators (The Basel Action Network 2002). This waste can contaminate the environment and adversely affect human health. The Organization of Economic Cooperation and Development (OECD) countries established the WEEE regulation for generated waste and outlined means by which it can be prevented. On the other hand, WEEE can be regarded as a resource of valuable metals. These valuable metals include copper, aluminum, and gold. When such resources are not recovered, raw materials have to be extracted and processed to make new equipment, resulting in significant loss of resources and environmental damage necessitated by mining, manufacturing, transport, and energy use.

In Thailand, TVs started to become household mainstays in the 2000s and the trend has continued to grow faster in recent years. TVs were transformed from monochrome to color and have undergone significant competition in the industry which resulted in the development of more advanced and better quality systems. The competition between manufacturers has brought down the price of TVs substantially while increasing use of advanced technology has allowed TVs to be multifunctional devices, making TVs common household devices. Nevertheless, awareness of the management of TV waste is still very low among the general population.

Choowongsirikul and Pharino (2013, 2014) undertook a face-to-face questionnaire to gauge public opinion on TV waste management. With respect to the current situation of digital TV in Thailand, about 60% of participants who live in Bangkok were aware of the change in transmission method from analog to digital in Thailand. About 74% of participants decided to use their existing TVs with add-on set-top boxes to be able to receive digital signals. The remaining considered buying new TV models capable of directly receiving digital signals.

The survey looked at the type of TV equipment held by people and the way in which they managed discarded TV equipment. It was found that 54% of all participants had CRT TVs, 29.96% had old LCD TV screens, and 16.34% had LED TV screens. The three main options practiced by most participants regarding EoL management for TVs (Fig. 8.9) included: (1) keeping at home (33.57% for CRT TVs, 39.83% for LCDs, and 38.36% for LED TV screens, respectively); (2) giving or donating to others (19.86% for CRT TVs, 22.94% for LCDs, and 21.92% for LED TV screens, respectively); and (3) selling to tricycler waste buyers (so-called *Sa-leang* in Thai) (29.79% for CRT TVs, 19.05% for LCDs, and 18.49% for LED TV screens, respectively) (Figs. 8.10 and 8.11).

Just under half (49.22%) of participants indicated that they discard old TVs because they are defective. There is also a trend in which participants consider replacing their old TVs with new models because the continuing decline in price makes newer models more affordable (23.54%). And, finally, low efficiency and incompatibility with newer technology are the third and last factor driving participants to consider acquiring new TVs.

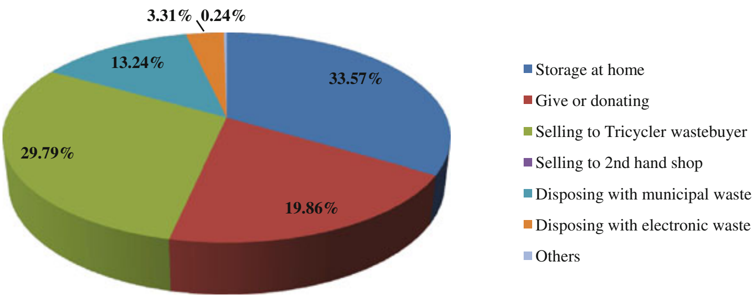


Fig. 8.9 Current management approach to discarded CRT TVs

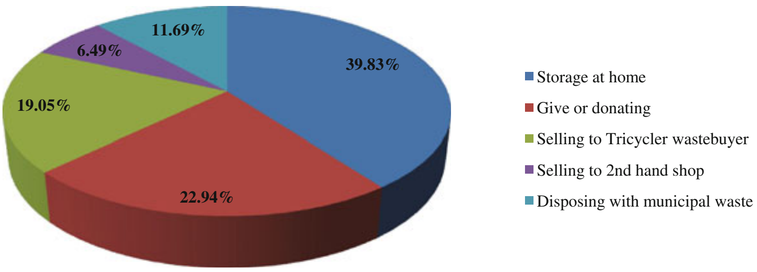


Fig. 8.10 Current management approach to discarded LCD TVs

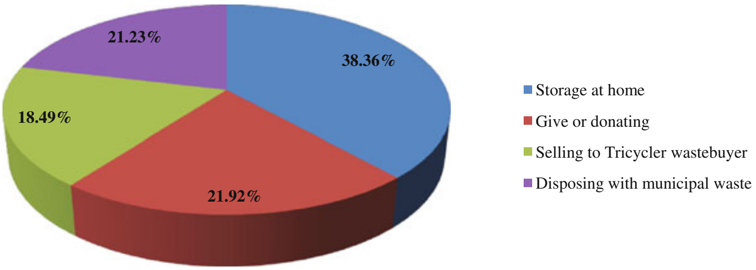


Fig. 8.11 Current management approach to discarded LED TVs

8.3.2 Approaches to End-of-Life TV Waste Collection

The results of the case study show that using acts or regulations to control recycling was the favorite option for proper management when returning TV waste. Despite its stringent requirements controlling the return of TVs to collection centers, such regulations set out effective and easy-to-understand rules for people to follow, which may be in keeping with Thai culture. Enforcing waste management fees when buying new models was the second most favorite option. This method directly relates to willingness to pay for waste management which very much depends on people's awareness level and culture. The last option selected by participants was collecting an environmental tax for e-waste management. This option, which imposes tax on everyone, may be difficult to implement in Thailand, at least for the foreseeable future.

8.3.3 Recommended Policies for TV Waste Management

A management plan for a TV collection system should be set up in such a way that it is acceptable to the public. The case study showed that people would abide by acts or regulations to enforce the recycling of TV waste; in fact, it was the favorite option.

Based on the survey of incentives to stimulate collection of TV waste, the participants preferred monetary incentives such as returning fees, discount coupons, and other privileges when returning old TVs or unused devices. Other motivations such as a convenient system for returning old devices and tax credits when returning TV waste to a collection system also had merit.

Regarding TV collection system management, it is necessary to set up a central administrative body to oversee overall activities and budgets as well as to promote collaboration among stakeholders in the system. The operation of collection systems could be efficiently done by the private sector, while other stakeholders in various social segments should assist to achieve an effective operating mechanism. The case study found that participants preferred a collection scheme that is convenient for them to return old items such as household collection.

Three strategies are recommended for enhancing the practicality and effectiveness of a TV waste management system in Thailand. These strategies can be described as follows:

Strategy I. Build people awareness on participation in TV waste management

This strategy is most effectively implemented through collaboration between relevant government administrative bodies and the private sector. Government in tandem with the private sector should set up campaigns and a unified database on the disposal of e-waste and hazards as a result of improper recycling with an aim to providing people with useful knowledge and acting as a guideline for general good practice.

Strategy I. Increasing the effectiveness of management and collection of used electronics

Strategies for increasing effectiveness include extended producer responsibility (EPR) for electronic waste management, establishment of suitable sites and collection system services, and the development of safety plans for operation.

Strategy III. Appropriate incentives to promote electronic waste collection

A national framework comprising laws and regulations is necessary to set up a proper recycling scheme. Financial incentives appealed the most to participants. Other incentives include creating a convenient TV waste pick-up system and tax credits.

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