STUDY ON MUNICIPAL SOLID WASTE MANAGEMENT IN MALAYSIA : CASE STUDY IN KUCHING, MIRI AND SIBU

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STUDY ON MUNICIPAL SOLID WASTE MANAGEMENT IN MALAYSIA : CASE STUDY IN KUCHING, MIRI AND SIBU

by

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledge.

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TABLES OF CONTENTS

CHAPTER 4 - RESULT AND DISCUSSIONS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

ABC	-	Action Plan for a Beautiful and Clean Malaysia
APO	-	Asian Productivity Organization
ASTM	-	American Society of Testing and Materials
CAP	-	Consumers Association of Penang
CCL	-	Compacted Clay Liner
CMU	-	Community Mobilization Unit
DBKU	-	Dewan Bandaraya Kuching Utara
EPU	-	Economic Planning Unit
EMS	-	Environmental Monitoring Systems
FOD	-	First Order Decay
GCL	-	Geosynthetic Clay Liner
GHG	-	Green House Gases
GM	-	Geomembrane
IGES	-	Institute for Global Environment Strategies
IPCC	-	Intergovenmenatal Panel on Climate Change
ISWMS	-	Integrated Solid Waste Management System
KIWMP	-	Kuching Integrated Waste Management Park
KMC	-	Kathmandu Metropolitan City
LAs	-	Local Authorities
LFG	-	Landfill Gases
MBKS	-	Majlis Bandaraya Kuching Selatan
MCC	-	Miri City Council
MHLG	-	Ministry of Housing and Local Government

MIGHT	-	Malaysia Industry-Government Group for High Technology
MOH	-	Ministry of Health
MPP	-	Majlis Perbandaran Padawan
MRF	-	Material Recovery Facility
MSW	-	Municipal Solid Waste
NREB	-	Natural Resource and Environment Board
PCM	-	Public Cleansing & Maintenance
RM	-	Ringgit Malaysia
RORO	-	Rolled-on/rolled-off
S.P	-	Standard Deviation
SMC	-	Sibu Municipal Council
SWDS	-	Solid Waste Disposal Sites
SPSS	-	Statistic Package for Social Sciences
SWB	-	Spiral Waste Bin
WHO	-	World Health Organization
WTE	-	Waste to Energy

KAJIAN PENGURUSAN SISA PEPEJAL PERBANDARAN DI MALAYSIA : KAJIAN KES DI KUCHING, MIRI DAN SIBU

ABSTRAK

Berjuta-juta tan sisa pepejal dijana setiap tahun. Malaysia telah membelanjakan banyak wang, masa dan ruang untuk perkhidmatan pengurusan sisa ini. Program kitar semula kurang mencapai sasaran yang diharapkan. Kajian ini telah dijalankan di Bandar Kuching, Sibu dan Miri untuk mengetahui sikap penduduk, kesesuaian sistem kutipan, masalah dan kesesuaian program kitar semula yang pernah dilaksanakan sehingga kini. Pengurusan sisa pepejal di tiga bandar utama tersebut ditentukan. Soal selidik digunakan untuk mengetahui sikap dan percepsi orang ramai terhadap kitar semula. Kesan taruh penutup terhadap gas rumah kaca juga ditentukan di tiga tapak pelupusan di kawasan kajian. Pengelasan tanah di tapak pelupusan dianalisis mengikut Standard American Society of Testing and Materials (ASTM). Daripada data kitar semula, sisa pepejal utama yang dihasilkan adalah sisa makanan, ini diikuti oleh suratkhabar lama, kertas, plastik, kaca dan botol serta tin aluminium. Kadar lembapan dan nilai tenaga juga ditentukan kerana ia mempengaruhi opsyen pelupusan. Kajian mendapati Sibu mempunyai kadar lembapan sisa yang paling tinggi. Purata kadar penjanaan sisa pepejal seorang dalam kawasan kajian adalah 0.85 kg seorang sehari. Kajian masa pergerakan kutipan mendapati berat purata sampah yang dikutip adalah 323 kg/pekerja/masa kutipan mewakili keberkesanan 65% daripada jumlah masa kutipan. Hasil kajian mendapati bahawa kecekapan sistem kutipan yang sedia ada di Sarawak adalah memuaskan. Tanah di Sibu mempunyai index plastik yang paling tinggi. Gas Kesan Rumah Kaca ditentukan menggunakan *Clean Development*

Mechanism Project Design Document Form (CDM-PDD) versi 03.1. Didapati Gas Kesan Rumah Kaca di Kuching adalah 14,114 ton pada tahun pertama manakala di Sibu dan Miri adalah masing-masing 5,383 dan 5,379 ton. Kelakuan pengasingan di punca dan sikap kitar semula dikaji berdasarkan beberapa parameter sikap penduduk. Keputusan menunjukkan sikap penduduk merupakan faktor signifikan dalam mempengaruhi pengasingan sisa di punca. Ini menunjukkan bahawa perubahan sikap penduduk adalah penting dalam memperbaiki perkhidmatan pengurusan sisa pepejal perbandaran.

STUDY ON MUNICIPAL SOLID WASTE MANAGEMENT IN MALAYSIA : CASE STUDY IN KUCHING, MIRI AND SIBU

ABSTRACT

Several million tonnes of solid wastes are generated each year. Malaysia allocates a lot of money, time and space for the waste management services. However, the recycling programmes has remained unsuccessfull in achieving the set targets. This study was carried out in Kuching, Sibu and Miri municipalities to evaluate the communities attitude, suitability of collection services and identifying the problems and effectiveness of waste management practices and recycling programmes implemented to date. The waste management practices in three towns were determined. Surveys via questionnaires were used to determine the public awareness and public perception on recycling. Landfill capping effects on greenhouses gases emissions were also studied from three landfills in the areas under study. Standard soil classification was done, in accordance to the American Society of Testing and Materials (ASTM). The results deduced from the data on waste recycling and composition, indicated that the composition of solid waste was dominated by food waste. This was followed by old newspapers, mixed papers, plastics, bottles/ glass and aluminium cans. The moisture content and energy value of waste was also determined as it influences the disposal option. It was noticed that Sibu had the highest moisture content. Average solid waste generation rate per individual in Sarawak was 0.85 kg/person/day. The collection time motion study showed that the average weight of solid waste collected for the three towns was 323 kg/worker/collection hour with an efficiency of 65% of the total collection time. With this finding, it can be concluded that the efficiency of the collection system in Sarawak was quite satisfactory. The soil in Sibu had the highest plastic index (PI). The baseline emission of green house gases (GHG) was determined using the Clean Development Mechanism Project Design Document Form (CDM-PDD) version 03.1. The GHG in Kuching was 14,114 tonnes in first year while for Sibu and Miri it was 5,383 and 5,379 tonnes, respectively. Source separation and recycling behaviour was analysed with several parameter related to public attitudes. According to the results, the public attitude was found to be a significant factor in influencing source separation behaviour. This implies that changing public attitude is an important factor towards improving municipal solid waste management services.

CHAPTER ONE

INTRODUCTION

1.1 Background

Solid waste and its disposal have rapidly moved to the forefront of public attention in the last two decades. Waste is any unwanted material that does not have any apparent, obvious or significant economic or beneficial value to humans. Generally, solid waste comprises non-hazardous industrial, commercial and domestic refuse including household organic trash, street sweepings, hospital and institutional garbage, and construction wastes (Zerbock, 2003). It is could be originated from various sources including houses, factories, shops, streets, and other institutions where the government or other municipal authorities are in charge of the collection and disposal (UNDP, 2008).

Solid waste management could be described as the best practice that considers many aspects such as environmental consideration and public attitudes involved with controlling the generation, storage, collection, transfer and transport, processing and disposal of solid waste (Tchobanoglous *et al.*, 2002). On the other hand, integrated solid waste management is based on the selection and application of suitable techniques, technologies and management programs in order to achieve specific waste management objectives and goals (Tchobanoglous *et al.*, 2002). Thus, an integrated solid waste management is where some significant activities in solid waste management are combined together.

Increased solid waste generation primarily arises due to rapid urbanization and is one of the major global issues that directly lead to human health hazard. According to the Asian Productivity Organization (APO), the waste generation in Asia has reached to 1 million tonne per day in 2007. Industrial countries account for a disproportionately high share of the world's waste relative to their share of world population, while developing countries account for a disproportionately high share of the world's waste relative to their share of world income. Furthermore, municipal solid waste in developing countries is sometimes more harmful to human and ecological health than it is in industrial countries because of poor processing and disposal practices.

The issues of solid waste management have reached at a critical level especially in highly urbanized areas where ineffective or irresponsible disposal can pollute the environment and pose a health risk to the public (Gutberlet, 2008). Although the actual figures on global solid waste are not available due to the lack of proper data collection, with approximately 6% annual increase in global waste generation, the total solid waste generation is expected to reach about 585 million tonnes in 2010 (Agamuthu *et al.*, 2009). Malaysia, according to 2009 estimation has a population of 28.3 million where more than half of the populations are living in urban area (Jabatan Perangkaan Malaysia, 2009). According to the Consumers Association of Penang (CAP), 45% of the total solid waste discarded annually, consists of food waste which is worth RM 27 to RM 360 million. In 2005 alone, from the 7.34 million tonnes of solid waste generated, 3.30 million tonnes originated from food waste (Audrey, 2009).

The total volume of municipal waste generated in Malaysia is 31,000 metric tonnes/day and annual increase of 3% has been forecasted. (Agamuthu *et al*., 2009).

The issue of poor solid waste management (SWM) has become a challenge for governments in developing Asia and Africa (Calo & Parise, 2009).

1.2 Problem Statement

Municipal Solid Waste (MSW) can be divided into recyclable and non recyclable materials. Poor processing and disposal practices have serious adverse effects on the quality of air, water, and land. For this reason, MSW in developing countries is sometimes more harmful to human and ecological health than it is in industrial countries (Kreith, 1994). In 2006, about 7.34 million tonnes of solid wastes were generated in Malaysia (Siraj, 2006). Based on the research conducted by Kathirvale *et al.* (2004), the generation of MSW in Malaysia was about 0.5–0.8 kg/person/day in 2003. However, according to a recent research carried out for Kuala Lumpur, the amount has reached 1.62 kg/person/day and it is expected to increase up to 2.23 kg/person/day in 2024 (Agamuthu *et al*., 2009). Effectiveness of any recycling activities is mainly dependant on the participation of public. However, in Sarawak, this aspect has not been adequately addressed.

The concept of waste to energy (WTE) is important to be considered before ultimate disposal of the final inert materials. Hence, this research was carried out in order to evaluate the amount of energy that could be recovered if the MSW generated was to be incinerated. This data could be considered as primary data for Sarawak in deciding a suitable technology for this purpose.

Treatment and disposal of municipal, industrial and other solid wastes produces significant amounts of methane (CH_4). In addition to CH_4, solid waste disposal sites (SWDS) also produce biogenic carbon dioxide (CO_2) and non-methane volatile organic compounds (NMVOCs) as well as smaller amounts of nitrous oxide (N_2O), nitrogen oxides (NOx) and carbon monoxide (CO). CH_4 produced at SWDS contributes approximately 3 to 4 percent to the annual global anthropogenic greenhouse gas emissions (IPCC, 2001).

Kyoto Protocol contains market mechanisms which enable industrialized countries to invest in greenhouse gas (GHG) emission reduction projects on the territory of other countries, either industrialized or developing. Project co-operation between industrialized and developing countries takes place under the clean development mechanism (CDM). CDM projects typically result in a transfer of GHG abatement technologies to developing countries in exchange for the GHG emission reduction credits.

Sarawak is the largest state of Malaysia with an estimated population of 2.5 million (Jabatan Perangkaan Malaysia Negeri Sarawak, 2009). Population growth, rising standards of living, increasing urbanization and industrialization all have contributed to increased solid waste generation in Sarawak, especially in the fast growing urban areas such as Kuching, Sibu and Miri. The annual population growth in Sarawak is 2.5% with the highest in Kuching (3.4%) and the lowest in Sibu (2.0%) (Jabatan Perangkaan Malaysia Negeri Sarawak, 2009).

Waste management in these towns still requests continuous attention. Present practices of waste management in three of the biggest towns in Sarawak (Kuching, Sibu and Miri) were examined in this research and the results were compared. The study looked at the areas for improvements, in particular related to recycling and effective collection services. Waste composition and quantification was also studied, together with the determination of moisture content which influences the energy content. The influence of recycling on the energy of waste was also determined. As all of the wastes are currently landfilled, effective capping material was also studied with associated total green house emission estimation using an established model.

1.3 Research Objectives

This study focuses on the solid waste management practices from three different towns in Sarawak, Kuching (representing a city council with privatization concept- Trienekan), Sibu (representing municipal council managed by Local Government) and Miri (representing a city council managed by local government). The specified objectives are:

1. To compare the quantity and composition of wastes produced.
2. To gauge the level of recycling activities and to establish main recycling data.
3. To determine the effectiveness of the collection system using time motion method.
4. To determine the potential of energy recovery from the landfill after the recycling process.

1.4 Scope and Limitations of Study

The main constraints faced during this research were related to the individual interviews and studying the composition of recyclable materials. 60 samples were selected randomly from the study area in Kuching, Miri and Sibu. The samples were interviewed and analysed correctly. Thus although the results obtained were insufficient but it did cover a wide range of community.

The recycling activities included the door to door sampling collections and sampling from Mambong landfill, Sibuti landfill and Kemunyang landfill, and the greenhouse gases estimation at these three landfill.

1.5 Organization of the Thesis

Chapter 1 commences with some basic knowledge on solid waste followed by a brief overview of the solid waste problems in Malaysia. Issues of concern, which served as input for this research, are also elaborated upon. The research objectives and scope are also outlined.

Chapter 2 provides literature review, elaborates on the definition of solid waste collection effectiveness and its management in Malaysia and abroad. The chapter also explicates on the household attitude towards recycling and factors affect recycling. The importance of recycling in waste management and recycling method are mentioned. Subsequently, a literature review on various published works on the recycling of solid wastes and its benefits is provided.

Chapter 3 details methodology and procedures employed in this research are described. Descriptions of the questionnaire survey and interviews used as well as other primary data generation techniques used in the research are further elaborated.

Chapter 4 presents the results of the data analysis and its interpretations. The present practices of the case study area and perception and satisfactory level of the respondents are discussed. It also describes the generation and composition of primary waste data on moisture content and time motion study. Further, calculation on energy content and landfill capping are also summarized.

Chapter 5 present important concluding remarks and recommends some of the possible approaches in improving the waste management practices.

CHAPTER TWO

AN OVERVIEW OF SOLID WASTE MANAGEMENT AND WASTE RECYCLING IN MALAYSIA

2.1 Introduction

In line with the country's vision 2020, Malaysia has developed very rapidly towards industrialisation and urbanisation with significant economic and population growth over the recent years. The rapid economic growth has lifted the standard of living for the whole nation tremendously. The spending capability is increasing with increasing development in the country. It has adversely brought about increase in generation of solid waste in the country. The situation has worsened, as the population increased with time but the wastes generated were not properly managed. The term solid waste as used in this text is all-inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial and mineral wastes (Tchobanoglous *et al*., 1992).

There are three main municipal solid waste sources, which consist of construction and demolition, commercial and light industry, and household such as domestic waste.

2.2 Amount of Solid Waste Generated

In 1995 urban Bangladesh generated 0.49 kg/person/day waste which was estimated to increase to 0.6 kg by 2025 (Ray, 2008). Study by Osman *et al.* (2009) showed the nation's average solid waste generation in Turkey was 0.8–0.9 kg/person/day. In 2003, the average amount of MSW produced in Malaysia was 0.5-0.8 kg/capita/day. The generation rate per capita in Malaysia varied from 0.38 to 2.03 kg/capita/day and the national average was estimated to be 0.87 kg/capita/day (Hanssan *et al*., 2009). However, in major cities such as Kuala Lumpur and Petaling Jaya, it was as high as 1.7 kg/capita/day (Latifah *et al.*, 2009). Urban areas tend to produce larger amount of wastes. In other words, it reflects that people living in well-developed cities produce more waste compared to those in less developed ones.

Two major states, Kuala Lumpur and Selangor generated significantly larger amount of wastes, recorded as 2,325 and 1,900 tonnes/day, respectively. Smaller states with comparable populations such as Kedah and Perak produced lesser amounts of waste which were 885 and 906 tonnes/day, respectively. However, according to Latifah *et al.* (2009), with a population growth of 2.4% per annum, the MSW generation has also increased by 2%. The figures indicate that the waste generated has direct relation with the increase in total population as well as improved standards of living and changing lifestyle of people. Due to the rapidly changing lifestyle, waste productions are always expected to increase tremendously. The current lifestyle has accelerated the production of waste through the consumer products which generates higher demands for extra packaging. Inevitably, most of the urban areas will experience large increase in terms of solid wastes produced. This is mainly due to the increment in new housing developments, industrial as well as commercial activities. In 2003, about 2500 tonnes of municipal solid waste was collected every day in Kuala Lumpur and dumped at Taman Beringin Landfill (Kathirvale *et al.,* 2003). There are 301 disposal sites throughout Malaysia including 41 closed facilities. Table 2.1 shows the total landfill in Malaysia.

Table 2.1: Total landfill in Malaysia January 2011

States	Landfill	Closed landfill	Total
Johor	14	23	37
Kedah	9	6	15
Kelantan	13	6	19
Melaka	2	5	7
Negeri Sembilan	7	11	18
Pahang	16	16	32
Perak	17	12	29
Perlis	1	1	2
Pulau Pinang	2	1	3
Sabah	19	2	21
Sarawak	49	14	63
Selangor	8	14	22
Terengganu	8	12	20
Kuala Lumpur	0	7	7
Labuan	1	0	1
Total	**166**	**130**	**296**

Source: Jabatan Pengurusan Sisa Pepejal Negara (2011).

In Peninsular Malaysia, MSW generation exceeds 19 000 tonnes per day where roughly 75% of this is collected and disposed of in 130 landfills and dumps while about 20% is burned or dumped into rivers or at illegal sites, and only 5% is recycled (Agamuthu *et al.,* 2009). However not all solid waste generated is being collected. In Peninsular Malaysia, it was estimated that only 75% of solid waste generated was being collected by concessionaires, local authorities and their contractors (UNDP, 2008). Table 2.2 below shows the estimated amount of solid waste generated in Peninsular Malaysia

Table 2.3 shows the generation of municipal solid waste in major urban areas in Peninsular Malaysia. From Table 2.3, it is evident that the increment in the amount of solid waste is notable especially in big cities such as Kuala Lumpur, Melaka and Klang.

Table 2.2: Solid Waste Generated by States in Peninsular Malaysia 2007

States	SW Generation (Tonnes/day)
Johor	2,499
Kedah	1,728
Kelantan	1,350
Negeri Sembilan	672
Pahang	988
Perak	1,249
Perlis	1,993
Pulau Pinang	225
Selangor	1,419
Terengganu	3,689
Kuala Lumpur	1,152
Total	**3,289**

Source: Agamuthu, 2007

Table 2.3: Generation of Municipal Solid Waste in Major Urban Areas in Peninsular Malaysia (1980 – 2006)

Urban center	Solid waste generated (tonnes/day)			
	1980	**1990**	**2002**	**2006[a]**
Kuala Lumpur	310.5	586.8	2754	3100
Johor Bharu (Johor)	99.6	174.8	215	242
Ipoh (Perak)	82.7	162.2	208	234
Georgetown (P.Pinang)	83.0	137.2	221	249
Klang (Selangor)	65.0	122.8	478	538
Kuala Terengganu (Terengganu)	61.8	121.0	137	154
Kota Bharu (Kelantan)	56.5	102.9	129.5	146
Kuantan (Pahang)	45.2	85.3	174	196
Seremban (N. Sembilan)	45.1	85.2	165	186
Melaka	29.1	46.8	562	632

[a] **Estimated figures**

Source: Modified from Agamuthu *et al.* (2009)

2.2.1 Solid Waste Composition in Malaysia

Table 2.4 shows the solid waste composition in Kuala Lumpur.

Table 2.4: Kuala Lumpur's Solid Waste Composition (1975-2005)

Composition of waste	1975	1980	1985	1990	1995	2000	2005
Organic	63.7	54.4	48.3	40.8	61.76	68.67	44.8
Paper	7.0	8.0	23.6	30.0	12.16	6.43	16.0
Plastic	2.5	0.4	9.4	9.8	5.27	11.45	15.0
Glass	2.5	0.4	4.0	3.0	5.27	1.41	3.0
Metals	6.4	2.2	5.9	4.6	6.89	2.71	3.3
Textile	1.3	2.2	NA	2.5	2.84	1.50	2.8
Wood	6.5	1.8	NA	3.2	0.00	0.70	6.7
Others	0.9	0.3	8.8	6.1	5.81	7.13	8.4

Source: [a]Agamuthu *et al.* (2009)

Meanwhile, Table 2.5 shows the waste composition in Malaysia from 1980 to 2005. The highest percentage of MSW consisted of organic waste, approximately 45%, followed by paper and plastics at 16% and 15% respectively (Agamuthu and Masaru, 2010). In 1985, the paper and plastic generation might be high because of the introduction of Malaysian Food Regulations (1985), which enforced the usage of safe and suitable packaging material.

During the economic downturn, the plastic and paper production reduced, causing reduction in plastic and paper waste. However, during 2000, the amount of plastic and paper increased again due to the introduction of hygienic types of plastic-and-paper-based packaging material thus decreasing the amount of organic waste (Agamuthu *et al*., 2009).

Table 2.6 shows the MSW Generated area by the High, Medium and Low Socio-economic area in Petaling Jaya, Malaysia.

Table 2.5: Waste Composition (% of Wet Weight) in Malaysia from 1975 to 2005

Waste Composition	1980	1985	1990	1995	2000	2005
Organic	54.4	48.3	48.4	45.7	43.2	44.8
Paper	8.0	23.6	8.9	9.0	23.7	16.0
Plastic	0.4	9.4	3.0	3.9	11.2	15.0
Glass	0.4	4.0	3.0	3.9	3.2	3.0
Metal	2.2	5.9	4.6	5.1	4.2	3.3
Textiles	2.2	NA	NA	2.1	1.5	2.8
Wood	1.8	NA	NA	NA	0.7	6.7
Others	0.3	8.8	32.1	4.3	12.3	8.4

NA, not available

Source: Modified from Agamuthu *et al.* (2009)

Table 2.6: MSW Generated area by the High, Medium and Low Socio-Economic area in Petaling Jaya

Composition (%)	Socio-economic status		
	High	**Middle**	**Low**
Paper products	19.75	15.73	13.04
Plastic and Rubber	21.05	18.61	13.01
Glass and ceramics	14.99	9.42	7.57
Food waste	24.13	29.77	31.86
Metals	8.80	12.75	9.15
Textiles	1.57	3.87	3.08
Garden waste	5.50	6.95	15.56
Total	**100.0**	**100.0**	**100.0**

Source: Agamuthu, 2001

Figure 2.1 shows the average waste composition in Malaysia for the year 2005 was within the Ninth Malaysia Plan, as reported by the JPSPN (http://www.kpkt.gov.my/jpspn/main.php?Content=sections&SectionID=55. Date accessed; 28 April 2010).

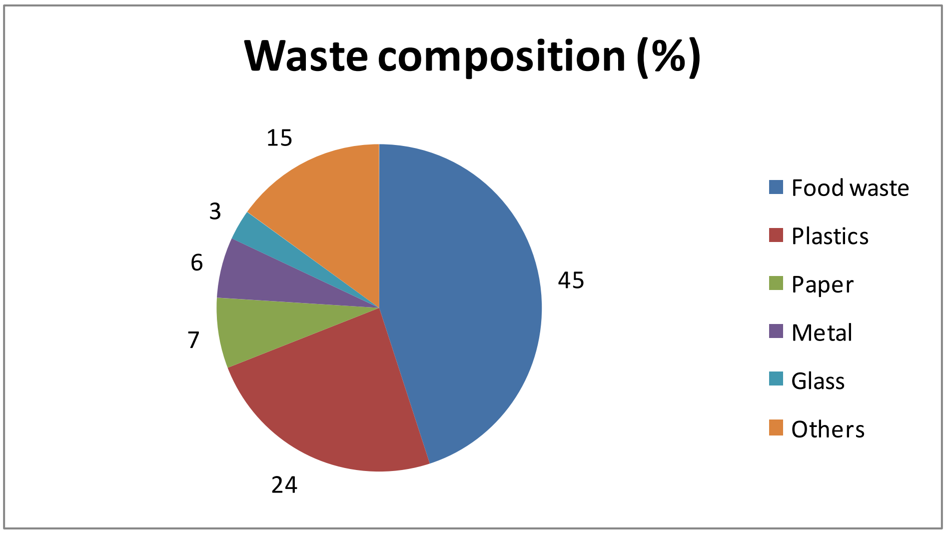

Figure 2.1: Average Waste Composition in Malaysia for Year 2005, Within the Ninth Malaysia Plan as reported by JPSPN, 2009

2.3 Waste Management

2.3.1 Waste Storage

Waste handling method generally differs in every country and region and more formal and well developed system is often found in the developed countries (Ngoc and Schnitzer, 2009). Formal here means the professional approach that follow the solid waste management hierarchy in handling the wastes. The improper handling of MSW will lead to contamination of water, soil and has major impact on public health (Batool and Ch, 2009). Generally, after waste generation at its source, the wastes are stored before being collected and transported to the disposal site. Each urban domestic household is provided with three types of bins by the municipalities; one recyclables, another for general waste and the third for garden materials. To encourage recycling behaviour among public, larger recycling bins compared to general waste bins are provided by the Australia municipalities. Due to these actions the recycling rate in

Australia according to a survey in 2003 was reported to increase, with 99% of households reported to be recycling or reusing some of their waste (Saeed *et al.*, 2009).

As another example, according to a study carried out by Audrey (2009), through interviews conducted on solid waste management organization in Kathmandu Metropolitan City (KMC), Nepal, two types of waste storage existed in the city; commingled and segregated waste storage. The commingled waste means original or mixed wastes. The most common practice form was commingled waste storage, whereby 84% of the households stored waste in commingled form and the rest separated the organic waste from the other wastes. Recently, 1001 storage bin called ‘community bin’ has been provided at an economical rate by a separated unit known as Community Mobilization Unit (CMU) serving for KMC for domestic waste storage. This bin was designed to be perfect for a family size of 5–7 people where it has dual function of both storage and composting. The 1001 perforated hexagonal plastic bin has attracted public attention because it has 3 months storage capacity besides the promotion by the KMC to charge reasonable amount for the composted waste. On the other hand, fewer problems at the transfer station occurred due to the application of the bin. In Sarawak, waste was collected from the movable waste bins and the recyclable wastes were directly delivered to recycling bins provided by the municipalities.

Generally, the type of waste container depends on the main activity of the area. For a residential house, usually a waste bin or a wheelie is used to collect waste direct from the house. Meanwhile, for low and medium size apartments, communal bins are provided and either the tenants themselves transfer their waste into the communal bins or use the service of the building maintenance personnel. For example, in Malaysia spiral waste bin (SWB) is located at apartments and condominiums where high quantities of wastes are generated. SWB enables a higher capacity of storage as it has the ability to compress the waste (Tinmaz, 2002). This will provide a more hygienic and efficient system but the implementation cost is high. Some of these system applications in Malaysia are at KLIA, Complex, Kastam Kelana Jaya and Kompleks Maju Junction (Solid Waste Management and Public Cleansing Corporation, 2010). Meanwhile, in the industrial and wet market the local authorities or private companies usually provide rolled-on/rolled-off (RORO) bin; a 12 m^3 bin that can be rolled on and off the trailer.

For the waste separated at source in Malaysia practices, mainly three types of collection system are being applied; curbside collection using conventional and specially designed vehicles, incidental curbside collection by charitable organization and the residents themselves deliver the separated waste to drop-off and buyback centers (Tinmaz, 2002). Thus, residents use their own containers where they are required to separate the waste at source. The container could be of any type such as boxes and drums. However, there are also recycling bins located at some of the residential areas and also at many other public places to promote recycling awareness among the public.

2.4 Waste Collection and Transportation

2.4.1 Introduction

In the field of solid waste management, the management of collected waste is the most complex and difficult issue in the urban environment because solid waste and recyclables are generally everywhere; houses, building, industrial sites, road side and even vacant spaces (Fadil, 1990). The collection process mainly includes both the gathering/collection of solid wastes and recyclable materials to the location such as the landfill, transfer station or materials-processing facility to empty the collection vehicle. Approximately 50 to 70% of the total amount required for solid waste management (collection, transport, processing, recycling, and disposal) is spent on the collection activity (Tchobanoglous *et al.,* 2002).

In Malaysia, MSW management is under the local authority's responsibility. However, they are facing a number of problems especially concerning the collection and transportation of wastes where 50% of the local authority's operating budget is for MSWM and while 50% of this is resorted for waste collection (Latifah *et al.*, 2009). Thus, a little improvement in the collection operation can significantly affect the overall system cost as a large part of the total cost is associated with the collection operation. Furthermore, poor collection would affect public confidence on the service. Most complaints received by local authorities in Malaysia are related to inefficient collection services provided.

The waste receptacles should be designed and utilized for optimum collection efficiency. Physical process of waste collection is highly variable throughout the region in terms of both frequency and method. Industrial and commercial waste collection practices will usually be different from residential waste collection. Front curbside and backland collection of wastes are the most widely practical methods of collection in Malaysia. The central point of collection is practical in areas not fully accessible to collection vehicles. There are various ways of arranging the pick-up of refuse from premises and transferring it to the collection vehicles. There are two variables related to collection, which are needed to be optimized:

i) Maximum utilization of vehicle capacity since collection vehicles are expensive,

ii) Maximum utilization of collection workers, who constitute the majority of workers in most solid waste departments.

In areas where labour is abundant, it is reasonable to assign several workers to each collection vehicle to maximize utilization of equipment. On the other hand, in areas where labour is scarce and expensive, labour saving measures such as the use of one-man vehicles necessitate more investment in equipment. Table 2.7 shows the solid waste collection system and their description in German.

Table 2.7: Solid Waste Collection Systems and Their Description in German

System	Outline	Public Participation	Equipment
House to House	100% house to house	Place refuse into individual household container at entrance.	Ideally rear end loader refuse truck
Kerb Side	Direct access by rear end loading refuse vehicles	Place refuse into kerb side container. Container is ideally with lid.	Rear loading/side loading refuse truck
Communal	Central bulk container	Place refuse into bulk container	Rear end loader
Special Collection	This for extremely bulky or heavy waste. Transfer of refuse by mechanical handle aid.	To call department for this special services	Tipper equipment with tailgate lift.

Source: Krieger (1986)

2.4.2 System of Collection and Transportation

Solid waste collection may be classified from several viewpoints such as the mode of operation, the equipment used and the type of waste collected. Collection systems have been classified according to the following categories (Tchobanoglous *et al*., 2002).

i) Hauled container system – a system in which the container used for the storage of waste are hauled to the disposal sites, emptied and returned to either the original location or some other location.

ii) Stationary container system – a system in which the containers used for the storage of waste remain at the point of generation except for occasional short trip to the collection vehicles. In the Malaysian context, the stationary container system is commonly used. This is because the stationary container system can be used for all types and quantities of waste.

Table 2.8: **Solid Waste Collection Operation System**

Operation sequence	System description
i) Hauled container system (conventional mode)	Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to their original location
ii) Hauled container system (exchange container mode)	Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to a different location in the exchange mode of operation. The exchange mode works best when the containers are of a similar size. In the exchange mode, the driver must given the collection route with an empty container of the vehicles to be deposited at the first collection site.
iii) Stationary container system	Containers used for the storage of wastes remain at the point of generation, except when they are moved to the curb or other location to be emptied. The collection vehicle id driven from pickup location to pick up location until it is loaded fully.

Source: Tchobanoglous *et al*., 2002

2.4.3 Collection Routes

Once equipment and labour requirements have been determined, collection routes must be laid out so that both the collectors and equipments are used effectively. In general, the layout of collection routes involves a series of trials. There is no universal set of rules that can be applied to all situations. Thus, collection vehicle routing remains a heuristic (common sense) process. The collection route is important in Sarawak as some of the areas are hilly areas.

Some heuristic guidelines that should be taken into consideration when laying out routes are as follows (Shuster and Schur, 1974):

i) Existing policies and regulations related to such items as the point of collection and frequency of collection must be identified.
ii) Existing systems, such as crew size and vehicle types, must be coordinated.
iii) Wherever possible, routes should be laid out so that they begin and end near arterial streets, using topographical and physical barriers as route boundaries.
iv) In hilly areas, routes should start at the top of the grade and proceed downhill as the vehicle becomes loaded.
v) Routes should be laid out so that the last container to be collected on the route is located nearest to the disposal site.
vi) Wastes generated at traffic-congested locations should be collected as early in the day as possible.
vii) Sources at which extremely large quantities of wastes are generated should be serviced during the first part of the day.