MUNICIPAL SOLID WASTE CHARACTERISTICS AND MANAGEMENT IN PHUNTSHOLING CITY, BHUTAN

NORBU

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (INDUSTRIAL ECOLOGY AND ENVIRONMENT) FACULTY OF GRADUATE STUDIES MAHIDOL UNIVERSITY 2008

Thesis
Entitled

MUNICIPAL SOLID WASTE CHARACTERISTICS AND MANAGEMENT IN PHUNTSHOLING CITY, BHUTAN

.....
Mr. Norbu
Candidate

.....
Assist. Prof. Sittipong Dilokwanich
Ph.D.
Major-Advisor

.....
Assist. Prof. Patompong Saguanwong
M.A., M.B.A.
Co-Advisor

.....
Assoc. Prof. Usanee Uyasatian
M.Eng.
Co-Advisor

.....
Prof. Banchong Mahaisavariya
M.D.
Dean
Faculty of Graduate Studies

.....
Lect. Kitikorn Charmondusit
Ph.D.
Chair
Master of Science Programme in Industrial Ecology and Environment
Faculty of Environment and Resource Studies

Thesis
Entitled

MUNICIPAL SOLID WASTE CHARACTERISTICS AND MANAGEMENT IN PHUNTSHOLING CITY, BHUTAN

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Industrial Ecology and Environment)
on
May 15, 2008

.....
Mr. Norbu
Candidate

.....
Assoc. Prof. Soparatana Jarusombat
Ph.D.
Chair

.....
Assist Prof. Sittipong Dilokwanich
Ph.D.
Member

.....
Assist. Prof. Patompong Saguanwong
M.A., M.B.A.
Member

.....
Assoc. Prof. Usanee Uyasatian
M.Eng.
Member

.....
Prof. Banchong Mahaisavariya
M.D.
Dean
Faculty of Graduate Studies
Mahidol University

.....
Assist Prof. Sittipong Dilokwanich
Ph.D.
Dean
Faculty of Environment and Resource Studies
Mahidol University

ACKNOWLEDGEMENT

It is my great pleasure to present this thesis entitled, “Municipal Solid Waste Characteristics and Management in Phuntsholing City, Bhutan”, which I undertook as a part of academic curricula in partial fulfillment of the requirement for the degree of Masters of Science in Industrial Ecology and Environment.

Directly or indirectly, there are many people who had contributed for completion of this research and my study in Thailand. To them I acknowledge with profound gratitude the patronage they extended to me, without them my study would have not been a success. I am highly indebted to my major advisor Assist. Prof. Sittipong Dilokwanich for sparing his valuable time, continuous guidance and motivating me despite his time constraints and equally my co-advisors Assoc. Prof. Usanee Uyasatian and Assist. Prof. Pathompong Saguanwong for their continuous support. I also thank my external thesis committee member Assoc. Prof. Soparatana Jarusombat for her valuable comments and constructive suggestions for my thesis. My special thank to Lect. Achara Ussawarujikulchai for providing me with resourceful documents oriented to my research and all professors and lecturers of Faculty of Environment and Resource Studies for sharing their knowledge.

I would like to thank Thailand International Development Cooperation Agency (TICA) for giving me scholarship for studying in Thailand. I am specially grateful and thankful to Bhutan Chamber of Commerce and Industry and the selection committee members of Mahidol University for selecting me as candidate and my company, Bhutan Carbide and Chemicals Ltd for nominating me and granting me the study leave. A special mention about Ms. Nun, Ms. Knitt and Ms. Goi about their support they extended to me throughout my study period.

I also thank the existing and previous staff of international program office at Faculty of Environment and Resource Studies for their support. I feel pleasure to thank my cohort 4 friends; Mr. AD from Vietnam, Mr. Sushil from Nepal, Mr. Anurat from Thailand, Ms. Jib from Thailand who had always been cooperative and helpful to me and to my batch mates in ENRM and new cohort students for being part and memorable stay in Mahidol University.

My sincere thanks go to Phuntsholing City Corporation authorities and people of the city for sparing their invaluable time for discussion, participation and providing me with their fruitful feed back and required data for my research.

Finally, I am greatly indebted to my late parents, brothers, relatives and friends at home, wife Tshering Wangmo and daughter Ngawang Choden for the patience, love, concern, support and the inspirations for my study and towards attainment of my endeavors.

Norbu

MUNICIPAL SOLID WASTE CHARACTERISTICS AND MANAGEMENT IN PHUNSHOLING CITY, BHUTAN

NORBU 4937449 ENIE/M

M.Sc. (INDUSTRIAL ECOLOGY AND ENVIRONMENT)

THESIS ADVISORS: SITTIPONG DILOKWANICH, Ph.D. (HUMAN GEOGRAPHY); USANEE UYASATIAN, M.Eng. (SANITARY ENGINEERING); PATOMPONG SAGUANWONG, M.A., M.B.A.

ABSTRACT

Municipal solid waste management is an emerging concern in major cities of Bhutan, especially Phuntsholing city. Despite lack of reliable data on both the waste composition and quantity, no research studies are conducted to identify problems and alternatives to improve the current management system. Therefore, the study objectives are: 1) to determine solid waste composition and generation rate; 2) to investigate current solid waste management system in Phuntsholing City; and 3) to propose alternatives for its improvement.

The study methodology involved both qualitative and quantitative methods. Waste samples were selected from various collection depots and analyzed for composition and generation rate. Investigation was carried out through interviews with municipal authorities and local residents, existing document reviews and field observations, to obtain information pertaining to the current management system.

It was found that the organic fraction of waste composition was about 71% of the total. The average waste generation rate was estimated to be 0.40 kg/capita.day and the haul density was 298.11kg/m^3. Further results revealed that the current management system is technically inefficient. Financial constraints, lack of policy and planning and weak social collaborations worsened the management problem. Therefore, recommendations are suggested to improve the current situation.

KEYWORDS: MUNICIPAL SOLID WASTE/ WASTE GENERATION/ WASTE COMPOSITION/ WASTE MANAGEMEN/ BHUTAN.

100 pp.

CONTENTS

CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviations	Meaning
ADB	Asian Development Bank
APO	Asian Productivity Organization
CHPC	Chukka Hydro Power Corporation
ENPHO	Environment and Public Health Organization
LWTR	Leather, Wood, Textiles and Rubber
METAP	Mediterranean Environmental Technical Assistance Program
MOC	Ministry of Communication
MoWHS	Ministry of Works and Housing Settlement
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MTI	Ministry of Trade and Industry
NECs	National Environment Commission Secretariat
Nu.	Ngultrum (Bhutan National Currency)
PCC	Phuntsholing City Corporation
PHCB	Population and Housing Census of Bhutan
PWD	Public Works Department
RGoB	Royal Government of Bhutan
RICB	Royal Insurance Corporation of Bhutan
RSPN	Royal Society for Protection of Nature
TCC	Thimphu City Corporation
USD	United States Dollar
USPS	Urban Sector Programme Support
WHO	World Health Organization
%	Percent

CHAPTER 1
INTRODUCTION

1.1 Background and justifications

The problem of municipal solid waste management is a universal issue. It is a man-made disaster and it depends upon systematic measures taken to deal with them. It is the people's greed that enforces temptation to consume resources more than necessary and it is the people's ignorance of the responsibility to manage individual wastes, ultimately creating waste disasters to make the society vulnerable. The waste quantity increases proportionately to population, economic growth and rapid urbanization of the nation (Talyan, Dahiya and Sreekrishnan, 2007; Ojeda-Benitez, Armijo de Vega and Ramirez-Barreto, 2003). It is obvious that with changes in economic status, the individuals change in their resources consumption pattern, thus changing the composition and quantity of the waste imposing greater challenge to the waste management (Viniegra, Cortes and Cuevas, 2001).

Basically, waste storage, collection and transportation, treatment and recovery and its disposal are the important technical aspects of waste management system that are well practiced in developed countries through well established and regulated programs (Al-Khathib et al, 2007). Besides the technical aspects, financial, policy and planning, and social aspects are inherently important issues of management system (Schubeler, Wehrle and Cristen, 1996: Online; Sharholy et al, 2006). While most of the developed countries have put these management concepts into best practice through well organization and planning, developing countries are often encountered with ineffective management system. Generally, inadequate technologies, poor financing, lack of policy and planning and workable legislation, regulation and implementation plans are common causes for ineffective management systems (Vidanarachi, Yuen and Pilapitiya, 2006; Al-Khathib et al, 2007).

In order to adopt an effective management practices, the availability of information on waste composition and quantity are cornerstone to understand its potential for waste recovery and successful management planning (Gidarakos, Havas and Ntzamalis, 2006; Ojeda-Benitez, Armijo de Vega and Ramirez-Barreto, 2003; Magrinho, Didelet and Semiao, 2006; Jin, Wang and Ran, 2006; Chang and Davila, 2007; Abu Qdais, 2006; Amponsah and Salhi, 2004). The waste components such as glass, paper, plastics and metals are recyclable materials while organic components can be composted (Sharholy et al, 2006). However, to move from existing condition to more sustainable waste management, there is critical need to review the existing conditions and identify its associated problems as an initial step to come out with suitable alternative solutions (Al-Khathib et al, 2007; Tinmaz and Demir, 2006; Vidanarachi, Yuen and Pilaptiya, 2006; Pasang, Moore and Sittorus, 2006).

Like any other developing countries, Bhutan is also not spared by problem of municipal solid waste (MSW) generation and management. Especially it is an emerging concern for two cities of Thimphu (Capital city) and Phuntsholing that exhibit complexity of issues concerning high population growth and waste generation (NEC, 2000). Its limited land size and rugged topographical condition further compounds the problem of solid waste management for its disposal. Municipal city corporations are responsible body to manage the solid waste generated within the cities. In Phuntsholing city, the area of the study, Phuntsholing City Corporation (PCC) takes initiative to manage waste whereby waste are collected and transported to newly constructed landfill site. The current solid waste management system is ineffective whereby waste littering prevails in every nook and corner of the city (Kuensel, 2006: Online). Despite its concern to improve existing situation, there is few reliable data on neither waste composition nor waste quantity, which is prerequisite for overall waste management planning. Furthermore, few studies had been conducted to investigate the existing solid waste management system that tries to identify its problems and potential for its improvement.

Therefore, this study aims to determine MSW characteristics and investigate current management system to identify problems and alternatives for its improvement.

1.2 Objectives of the study

The study had fulfilled the following objectives

1. Determine the MSW generation and its composition.
2. Investigate the current MSW management system.
3. Propose alternatives to improve the current MSW management system.

1.3 Research questions

This study answered following questions

1. What are the MSW generation and composition?
2. How is the situation of current MSW management system?
3. What are the alternatives to improve the current management system?

1.4 Conceptual framework

In any communities including Phuntsholing city, wastes are being generated daily from every activity. It becomes main responsibility of the government, especially the local government to curb its problem. Primarily, waste management includes technical, financial, policy and planning, and social collaboration; however, no management systems are ideal and are no exception to existing problems. As such, existing management system needs to be investigated and their problems and alternatives must be identified for effective management system. Basically, information about waste characteristics such as waste generation and waste composition are essential to design and overall planning of waste management system. Therefore, the existing data must be updated in order to analyze together with different conditions in technical management, financial, policy and planning and social collaboration for recommended management planning (Figure 1). As a result, the main guiding principles for MSW management development is to achieve various goals, which include protection of human health, promote environmental quality, and support economic productivity of the city.

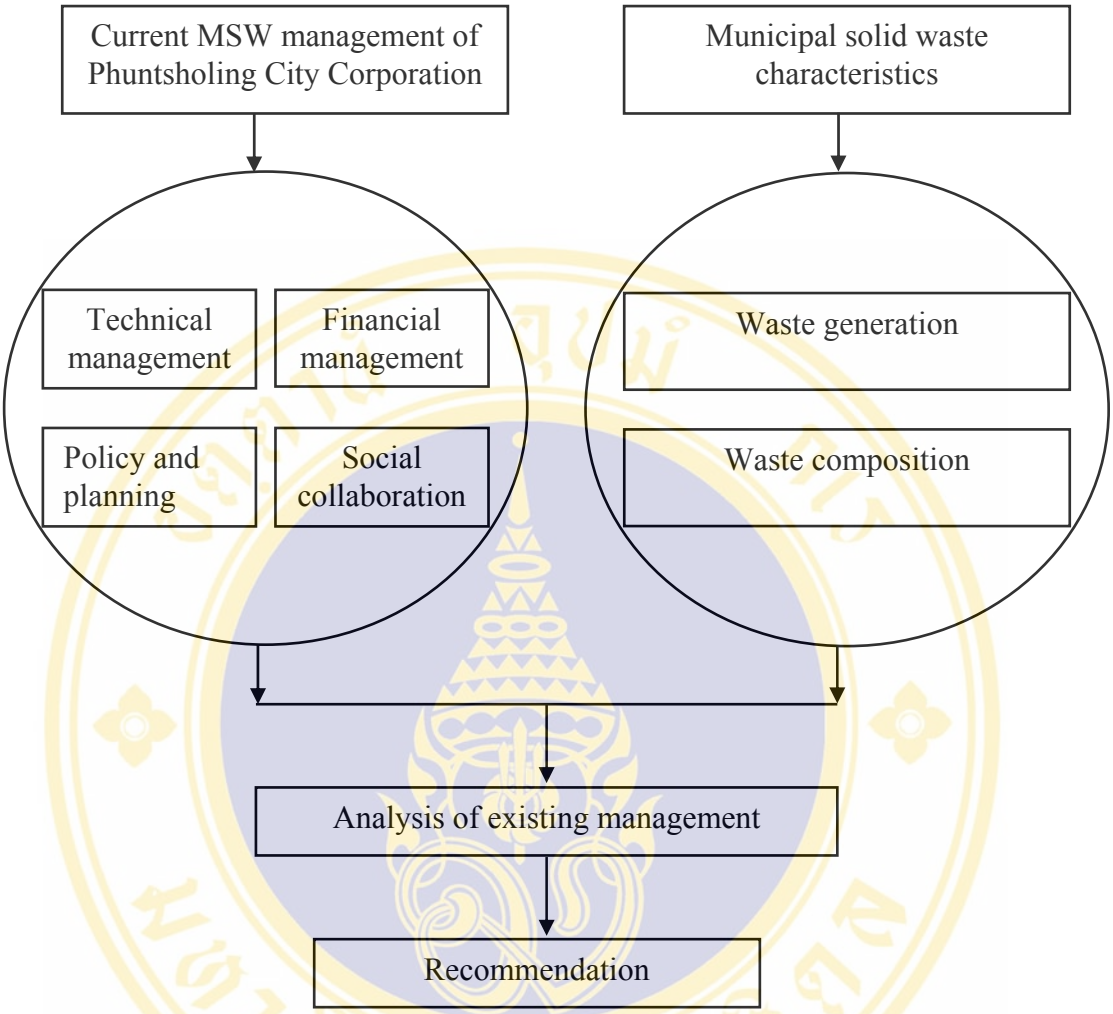

Figure 1 Conceptual framework

1.5 Scope of the study

The scope of this study covered waste generation and its composition, procedures and facilities of handling, planning and management system including technical, financial, policy and planning and social aspects of the management conceptualizing that municipal solid waste as the solid waste generated within the territorial limits of municipality service, which is independent of the source of generation.

Solid waste generation and composition

In this study, municipal solid waste generation is the estimated quantity of waste generation in kg/capita.day. Waste composition is the estimated physical composition, constituting mean wet-weight fraction of individual components of waste. Both genetaion and its composition were based on actual amount of waste collected and not on classification by source of generation.

Municipal solid waste management system

It encompassed technical, financial, policy and planning and social aspects of the management. Technical aspects covered waste storage, collection and transport, treatment and recovery, and final disposal. Financial aspects looked at capital investment, operation and maintenance cost, cost reduction and control mechanisms. Policy and planning aspects included reviewing the existing policy pertaining to solid waste management and implementation plans of the municipal city corporation. Social aspects comprised the social survey interview for the residents of the city following the process of MSW management, covering waste storage, collection and transportation, waste separation at house, fee collection and performance of the current management system.

Target groups for the study

Phuntsholing City Corporation was solely responsible for solid waste management in the city. The main target group comprised municipal city corporation authorities responsible for solid waste management. It included head of waste management, Dasho Thrompon (mayor), deputy managing director, the engineers responsible for solid waste management division (Civil & Works), site engineers, drivers, and waste workers. Also, residents of the city as responsible for MSW generators, social survey encompassed 338 household heads which was 10 % of the total population.

Study area

The study was conducted in Phuntsholing city located to extreme south of the country. The total land area of city is 22 km^2, which included 2 km^2 urban and 20 km^2 rural areas (PCC, 2005). It had a population of 22,500 people comprising 3,379 households. The study covered three areas/zones namely area 1, main town, area 2, Royal Insurance Corporation of Bhutan (RICB), and area 3, Chukha Hydro Power Corporation (CHPC), the urban areas which was within the territorial limits of current waste management service. The study was conducted for duration of one month in November 2007.

1.6 Expected outcomes

This study provides following contributions:

1. Provide baseline data on MSW generation and its composition to provide an understanding of waste recovery potential.
2. Provide information about the current situations of MSW management system and identify problems.
3. Provide alternatives for improving current MSW management system.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The urban environment deterioration is inherent with all countries and especially the issue of solid waste problem had posed a universal issue. Obviously, rapid economic and urban population growth had led to change in consumption pattern, thereby changing its quality and quantity of waste. In Bhutan, Thimphu and Phuntsholing had emerging concern regards to solid waste problem. While information regarding waste characteristics is important for overall management planning, availability of such data are very limited. While municipalities are directly responsible for managing local waste, existing managing systems had always remained unaccessed and problems unidentified.

This chapter reviews the literatures which are relevant to the present study. First it reviews the literatures pertaining to solid waste characteristics, highlighting the standard methods used for conducting waste generation and composition analysis. Further in the subsequent sub-sections, it reviews the various concepts of municipal solid waste (MSW) management system which includes technical, financial, policy and planning and social aspects of the solid waste management.

2.2 Municipal solid waste generation and composition

2.2.1 Solid waste generation

Waste refers to all kinds of refuse that are thrown away after the consumption or production. The terminology municipal solid waste, urban solid waste, residential solid waste and domestic solid waste are often used in ambiguous manner in most of the studies but actual with the same meaning. MSW is defined in several ways. Some

studies define as materials collected by the municipality or authorized organization. In general, MSW is defined as refuse from residential, institutions, and in general all solid waste generated by the activities of the community (Buenrostro, Bocco and Cram, 2001). Most researchers reveal that in most of the developing countries, due to availability of limited resource in MSW management sector, maximizing the cost effectiveness in using resource has to be one of the priority tasks for waste management practitioners. However, to achieve such objective, strategic planning is crucial, and the information on waste generation including generation rate and density is very essential. Basically, the use of data on waste generation rate and density finds importance in determining the size of waste storage, vehicle requirements, equipments, etc. Therefore, it is important to obtain the basic information about waste generation (WHO, 1996: Online; Amponsah and Salhi, 2004; Kumar, 2005: Online; Gidarakos, Havas, and Ntzamalis, 2006; Chang and Davila, 2007).

However, information on waste generation in some countries is unavailable. When information is available, the validity of collected data sometimes remained unevaluated due to limited surveys. Some researchers looked for different choices to gain reliable data. For example, while information pertaining to waste generation can be obtained either based on waste generation by source or on actual amount of waste collection, waste generation study by source are acute due to technical knowledge, financial restrictions and time (Buenrostro, Bocco and Cram, 2001). Therefore, most of the studies for waste generation are based on actual amount of waste collection that portrays the waste generations. In this method, it involves quantifying the actual waste collected by the municipalities or other waste collection organizations for its disposal. Load count analysis is one mostly adopted method to quantify actual waste generation. It involves counting numbers of vehicles collecting the waste and taking note of its weight directly for certain period of time and computing total weight of waste. On the other hand, if direct weighment is not possible, it requires computing the waste volume using the typical specific weights and obtaining total weight. Finally, the unit wastes generation and generation rate considering the population covered by the municipality service can be computed (Tchobanoglous, Thiensen and Vigil, 1993).

2.2.2 Solid waste composition

When municipal solid wastes are discharged into the containers without any separation, the result is a complex composition thereby making the management more difficult. The solid waste management options include source reduction, curbside recycling, material recovery, waste-to-energy, landfilling and composting. However, the information on solid waste composition is crucial to understand the potential for waste recovery and for overall planning of waste management system (Ojeda-Benitez, Armijo de Vega and Ramirez-Barreto, 2003; Amponsah and Salhi, 2004, Magrinho, Didelet and Semiao, 2006; Chang and Davila, 2007; Sha Ato et al, 2007).

For instance, if organic materials make up the bulk of local solid waste stream, composting facilities would be favored while on the other, high fraction of plastics or papers could indicate recycling or incineration as good options due to its high heating value (Chang and Davila, 2007; Burley, 2007). Most of the studies (APO, 2007: Online; Vishvanathan and Trankler, 2007: Online) reveal that developing countries have similar trend of waste composition. Mostly, biodegradable portion dominates the bulk of solid waste and especially biodegradable portion consisting of food and yard wastes, which portrays composting as most appropriate technology for waste reduction.

Several studies are being conducted on waste composition analysis. It reveals that most of the researches (Cascadia Consulting Group, Inc., 1999; 2004; 2006: Online; Gidarakos, Havas and Cram, 2006; Chang and Davila, 2007) employ waste sampling by obtaining sample size, sorting and weighment and then analyzing its mean composition.

2.3 Municipal solid waste management

Solid waste management is defined as the discipline associated with the control of generation, storage, collection and transport, processing or recovery and treatment and disposal of solid waste in a way that is in accordance with best

principles of public health, economics, engineering conservation, aesthetic, other environmental considerations and taking public response into account (APO, 2007: Online). Therefore, in order to achieve sustainable and effective waste management system, it is important to consider financial, policy and planning and social aspects of the management system besides technical management (Schubeler, Wehrle and Cristen, 1996: Online; WHO, 1996: Online; Vidanarachi, Yuen and Pilapitiya, 2006; Al-Khathib et al, 2007; Hui et al, 2006).

It obvious that in the absence of any mentioned aspect, it would constrain the overall performance of management system. Therefore, the existing solid waste management system must be reviewed and investigated to identify their problems and provide suitable alternatives for their improvement (AI-Khathib et al, 2007; Tinmaz and Demir, 2006; Vidanarachi, Yuen and Pilapitiya, 2006; Pasang, Moore and Sittorus, 2006; Rathi, 2006)

2.3.1 Technical management

Technical aspects of solid waste management include waste storage, waste collection, transfer and transport, waste treatment and recovery and waste disposal. The details of technical aspects are explained in following sub-sections:

Waste storage system

In general, the main purpose of providing on-site storage system is primarily for temporarily storing the generated waste before collection for its final disposal. This measure is to prevent creation of unaesthetic and unhygienic condition from generated waste by avoiding open dumping. Further, it is meant to facilitate easiness for waste collection (Tchobanoglous, Thiensen and Vigil, 1993).

Waste storage comprises provision of household and communal waste containers by the municipality to store individual waste before collection. This activity is associated with containment of solid in large receptacles used as central

collection points (Schubeler, Wehrle and Cristen, 1996: Online). Common types of waste storage include receptacles such as plastic containers, plastic bags, dumpsters, roll-off containers, etc. In fact, in some countries, the house owners requires to buy special bags so that cost of disposal is distributed towards individuals who produce more and in some, the owners requires to buy special bags and pay for the disposal on a per-bag basis (Mihelcic and Hutzler, 1999).

For the on-site storage, there should be the provision of adequate number of waste storage facilities and capacity to handle total generated waste with their proper locations and distribution of storage bin through proper planning. In order to achieve the mentioned concerns, the availability of reliable information about its existing waste characteristics is inherently important (Gidarakos, Havas and Ntzamalis 2006; Ojeda-Benitez, Armijo de Vega and Ramirez-Barreto, 2003; Magrinho, Didelet and Semiao, 2006; Jin, Wang and Ran, 2006; Chang and Davila, 2007; Abu Qdais, 2006). Therefore, selection and provision of appropriate waste storage facilities should be based on area-specific data on prevailing condition of the waste characteristic such as waste generation rate, density, etc., in order to lower the cost and to reach efficient operation and maintenance. Remarkably, design and procurement must be made in close attention to requirement of preventive maintenance, repair and availability of spare parts (Schubeler, Wehrle and Cristen, 1996: Online; WHO, 1996: Online).

Waste collection and transportation system

Collection of waste involves gathering of solid waste and recyclable materials and transporting to disposal site directly or either to transfer station or to processing facility. It includes temporary storage and transfer stations, vehicles and equipment's for waste transfer, and the procedures for operating and maintaining these facilities and equipment. Basically transfer stations facilitate central points for waste scavenging and waste separation activities (Schubeler, Wehrle and Cristen, 1996: Online). In fact, their design and use must match the characteristic of the local collection systems and the availability of suitable and environmentally safe transfer

station place. In general, transfer station is necessary when the disposal site is more than 10-15 km away from generation (WHO, 1996: Online; Sharholy et al, 2007).

In collection and transportation, decision about types of service, frequency of collection, types of collection vehicles, crew size, utilization of vehicles and collection route design are important aspects. In terms of types of service, curbside pick up is most widely used service in most of the countries instead of door-to-door service to minimize time of collection. Frequency of collection depends upon the amount of generation rate; however 2-3 times per week is most commonly practiced. As daily collection requires more vehicles and workers, it is less efficient therefore, it is better to provide a reliable and regular collection service with lower frequency than unreliable one with higher frequency (WHO, 1996: Online). The selection of collection vehicle must be based on existing condition of the area and also considering easiness to maintenance and availability of spare parts. Collection vehicle such as compactor truck is considered to increase the mass of collection and typical crew size is usually 1-3 crews. The efficient crews and waste workers would enhance the waste collection and transportation effectiveness. As such, provision of basic economic and social securities to workers would improve their efficiency. In terms of collection route, while there are no fixed rule but following certain criteria such as pick up of waste in crowed areas before traffic, pedestrian congestion is at peak and collection points that generate a large a large volume of daily waste should be serviced earlier in the day (Mihelcic and Hutzler, 1999). Further, the use of properly planned collection and transportation route for vehicle is important for proper utilization of vehicle, manpower, saving of fuel and reduction of time (Schubeler, Wehrle and Cristen, 1996: Online; WHO, 1996: Online; Vishvanathan and Trankler, 2007: Online; Alam et al, 2007).

Collection and transportation can be organized by either individual owners/groups, service provided by public authority, private collection service on contractual or combination of both. Most of the waste management practitioners reveal that service provided by public and private is a better practice in view of environment and health and even costs if indirect costs are taken into account.

Collection and transportation is the most expensive unit operation of solid waste management which make up 70-80% of the municipal budget and its improvement and cost savings will generate financial resources necessary for final disposal (WHO, 1996: Online; Nair, 1993: Online).

Waste treatment and recovery

Primarily, the main purpose of waste treatment and recovery process is to reduce the volume and mass of solid waste for disposal and to recover conversion products and energy. Basically this involves recovery of separated materials, separation and processing of solid waste components, and transformation of solid waste. Separation of waste can be achieved through manual sorting, screens, shredding, and magnetic separation. Materials transformation can be achieved by chemical transformation through combustion for waste to energy or through biological process such as composting (Tchobanoglous, Thiensen and Vigil, 1993).

Generally the waste components such as mainly metals, glass, and plastics are common recyclable materials besides other recyclables rubber, wood, textiles, etc (Schubeler, Wehrle and Cristen, 1996: Online; Sharholy et al, 2007). As such, recyclable materials can be recovered through recycling and reuse. This activity is economically useful and equally increases the life of landfill site through waste volume reduction. It can be achieved through informal waste scavengers. As there might be formal public sector workers recruited for waste scavenging activity, it is necessary to specify rights and recovery conditions of both formal and informal workers. The public sector may lease waste recovery rights to formal private sectors or else public sector itself become involved in waste recovery for recycling and reuse. WHO (1996: Online) provides useful keys to successful recycling as mentioned below:

1. Develop a system that connects the generation of recyclables to collection, transportation, intermediate processing such as crushing, sorting, etc. and shipment to recipient facilities.

2. Devise the means in each of the above components, and estimate costs.

3. Develop a cost recover-cum-economic incentive method such as import/sales tax on canned/bottled drinks, deposit-refund system, tax incentive or direct financial aid for privates involved in recycling.

4. Organize public information and campaign activities to encourage people's participation in recycling.

Composting is another promising area for the recovery of organic materials. However, the success of establishing composting plant would largely depend upon the availability of the market. Therefore, decisions for composting plant must be market oriented and based on economic and financial analysis. While large scale sector composting plants are seldom financially viable, however, small-scale, decentralized composting plants are feasible options. As such, community based composting may be promoted. Obviously, the location of facility at the vicinity to market such as near farm may provide some advantage. In any case, the concern authorities needs to promote waste storage facilities and information campaigns on waste separation as success of composting demands waste separation at source (Schubeler, Wehrle and Cristen, 1996: Online).

The other options for minimizing organic waste are home composting or gardening. There are some success stories of home composting through some projects such as " Honiara Sup Sup Garden" project in Honiara, Solomon Island or/and Family Nutrition Improvement project in Micronesia and WHO (1996: Online) provides useful keys to successful home composting as mentioned below:

1. Organize community group
2. Use grass-root communication
3. Make the operation simple with use of local resources

Waste disposal

Proper disposal of MSW is a necessity to minimize the environmental health impacts and degradation of land resources. In most developing countries, studies reveal that solid wastes are disposed of by transporting and in open dumps, which are

environmentally unsafe. Some common options of waste disposal are composting, incineration and land filling. While, disposal options such as composting and incineration methods serves as intermediate disposal methods to minimize waste volume, there is always a large quantity of waste remaining for disposal in an environmentally sound manner. As such, waste disposal to land fill is often inevitable and integral part of waste management (Vishvanathan and Trankler, 2007: Online).

Initially, the primary concern of waste disposal on the land as landfill is finding the suitable location and site. In most cases, while there is problem of finding suitable land site due to the limited land size, it is further constrained by limitation of sitting criteria requirement. Therefore, local government authorities responsible for MSW management should ensure the availability of appropriate waste disposal sites. While the technology for landfill is fairly simple, it involve complex organic process, therefore in order to ensure their efficient operation and to limit disturbances and environmental pollution, landfills need to be carefully sited, correctly designed and well operated that is in accordance to with locational and sitting criteria of the national and international standard (WHO, 1996: Online; Schubeler, Wehrle and Cristen, 1996: Online).

In fact, methods of landfilling exists in various categories such as open dump or open landfill, semi-controlled or operated landfill and sanitary landfill among which sanitary landfill is an engineered system which is the best option taking into account the likely environmental impacts by solid waste with regards to air, water and soil. However, due to operational constraints, there is fear of air pollution from open burning and landfill gas generation and also contamination of surface and ground water through uncontrolled release of leachate. Therefore, particular attention must be given to ground water, soil, and air through the control of leachate and gases. It must be operated with daily soil cover, leachate control and treatment, gas control, proper liner system and ground water monitoring system (Tchobanoglous, Thiensen and Vigil, 1993; Agdag, 2008; Hui et al, 2006).

2.3.2 Financial Management

The financial aspects of the waste management comprise capital investment cost, operation and maintenance costs, and cost reduction and control measures.

Capital investment

Capital investments are costs that are incurred in the planning and construction phase including the equipment costs processing and handling of waste (Rhyner et al, 1995). These investments can be realized in the analysis of a project on a yearly basis as fixed costs by annualizing the costs in either depreciation or amortization (Criner, Allen, and Schatzer, 2001). The main options available to local governments for financing capital investment in the solid waste sector are local budget resources, loans from financial intermediaries and special loans or grants from the central government (Schubeler, Whrle and Cristen, 1996: Online; METAP, 2000: Online).

In some countries, municipal bonds may be a workable source of financing. In the recent years, private sector financing has also attracted growing interest for capital investment as an alternatinative option. Doubtlessly, in spite of all the available options, it is mainly the central government which is the central source of funding for major infrastructure investment in solid waste management (METAP, 2000: Online). However, for the planning of investment programs, it is indeed the full responsibility of the concerned local government authorities that must subsequently operate and maintain the acquired facilities and equipments being procured. Adequate financial analysis procedures are required at local government level at the planning phase so as to ensure suitability of the investment decisions (Schubeler, Wehrle and Cristen, 1996: Online).

Operating and maintenance costs

These costs are associated with the daily operation of a facility (Rhyner et al., 1995). In general, the operation and maintenance cost is most expensive and

concerning to on-going waste management. Therefore, careful attention is required for operation and maintenance financing (APO, 2007: Online; Vishvanathan and Trankler, 2007: Online). While foreign aid and support from nongovernmental organizations can help finance waste management, they cannot be relied upon as long-term funding source. Thus, to ensure long-term financial sustainability, measures to generate revenues such as imposing user charges for solid waste management service becomes part and parcel to on-going management (WHO, 1996: Online; ENPHO, 2007: Online). Further, Schubeler, Wehrle and Cristen (1996: Online) emphasized that financial operations through user charge is preferable to encourage the responsiveness of the supplying agencies to user needs to ensure that collected funds are actually used for waste management. As such, its collection efficiency may be increased by adding solid waste utility charges, such as the water bill. The important issue is the question of implementing a user charge scheme in the areas where such practice is never adopted before without creating any socio-political problems. However, the above mentioned problems can be avoided by establishing affordability and willingness-to-pay level for waste management service in areas where such schemes are to be introduced and the most worldwide applied user charge level is a monthly user charge of less than 1% of the family monthly income (WHO, 1996: Online).

Besides user charge as applicable source of generating the revenue, other available options can be in the form of local taxes and inter-governmental transfers (World Bank, 1999: Online). The local tax such as property tax is worldwide applied and their collection is directly the responsibility of the municipality. As far as possible, user charges should be based on the actual costs of solid waste management, and related, and the volume of collection service actually provided. Variable fees could be applied to meet the demand for waste services by providing added incentive for waste minimization for large waste generators. Obviously, the revenue so generated may be only sufficient to cover partial financing of operation and maintenance (METAP, 2000: Online). However, once the concept of payment for service is accepted by users, the level of charges can be increased gradually after providing visual improvement for the service provided initially to meet the operation

and maintenance cost and eventually the full service cost including capital cost, thus achieving a sustainable solid waste management system (WHO, 1996: Online). Moreover, in order to achieve equity of waste service, large scale waste generators should pay full cost of disposal services based on the "polluters pay principle" (Schubeler, Wehrle and Cristen, 1996: Online; METAP, 2000: Online).

However, in practice, the collection of waste service is quite poor in most of the local municipalities. Eventually, if the service provided to the localities is perceived to be unsatisfactory, it is likely that locals would be reluctant to pay for the service. Doubtlessly, this poor payment system would ultimately result to further worsen the service quality (Schubeler, Wehrle and Cristen, 1996: Online). Thus, this calls for improved fee collection means. It can normally be achieved by clubbing waste collection charges with other bills such as water supply or electricity, making progressive such that large users pay higher rate per volume of collected waste than small users. There must be link between waste revenues to the actual volume of provided service and it may be appropriate to adopt weight or volume based charge for large single point waste producers such as commercial and industrial sectors (World Bank, 1999: Online; Arntzen and Fidzani, 2000: Online).

Quite often, in many cities, solid waste service revenues flow into general municipal accounts. This bureaucratic accounting procedure tends to be absorbed by overall expenditures instead of being used for intended purpose of solid waste management and making more dependency on central government (ENPHO, 2007: Online). These results to getting less share of the amount collected for waste management. Further, danger of misuse of funds is greater when locally generated revenues are transferred to the central government before being applied to local municipality. This often results to provide linkage between revenues and the actual levels of service provision, which ultimately creates discouragement to improve local municipality service for the local municipalities. Thus, in order to ensure the collected revenues are actually used for solid waste management, this demands autonomy of the concerned body and as such, municipality must be authorized for solid waste management agencies to have own planning and implementation, collection of

charges, imposing standards, imposing penalties for non-compliance and other related (WHO, 1996: Online; Schubeler, Wehrle and Cristen 1996: Online).

Further, besides the above mentioned option of generating revenues for solid waste management, other means would be to capitalize on composting and generate revenue through sale of compost to be used as soil conditioner for agricultural purpose (Vishvanathan and Trankler, 2007: Online). Obviously, the success of compost is likely to depend on market for the compost. Thus, decision about introducing composting plant must be market-oriented and based on economic and financial analysis. While large scale composting plant are seldom financially viable, a small scale decentralized composting could be practical and its nearby location to market for compost such as farms and horticulture may also bring advantage for its sale (Schubeler, Wehrle and Cristen, 1996: Online).

Cost reduction and control measures

The existence of a sustainable waste management system depends very much on its financial viability and it is often a difficult challenge to waste management practitioners. Thus, to ensure the long-term economic sustainability of management systems, investments in system development should be in accordance to the level of resources which the society can make available for waste management. It is common problem that high rate of urbanization increases the service demand which far out-strips the increase in funding provided. While potential for increasing revenue from waste management is usually limited, the most effective way to ensure financial sustainability is eventually “to do more with less”, which calls for cost reduction (WHO, 1996: Online; Schubeler, Wehrle and Cristen, 1996: Online; ENPHO, 2007: Online).

In fact, there are options to significantly reduce the operational costs of MSW management services. As such, minimizing the waste generation of waste or reducing the waste load at source is one straight way to reduce the variable cost component (i.e., operation and maintenance cost) of the waste management (METAP, 2000:

Online; EI-Hamouz, 2007). While the potential for waste reduction in low-income residential areas might be quite limited, however, local residents' participation in local solid waste management would reduce public waste collection costs. This step would involve recruitment of informal waste collection workers or hiring of small scale private enterprise for waste scavenging and recovery. Thus, this informal waste scavenging and waste recovery would contribute to cost savings through waste volume reduction that needs to be transferred and disposed and at the same time reduce waste collection cost (Schubeler, Wehrle and Cristen, 1996: Online).

At the outset, the success of cost reduction would certainly indicate a better utilization of available manpower and equipment, improved maintenance of equipment, use of relevant technologies, etc. Therefore, accessibility to information on actual cost of MSW management service and other important relevant performance standards are vital to both central and local concerned authorities to understand the cost reduction potential of the service. Further, information about the cost data of collection and dissemination, efficiency indicators, performance standards, etc may provide the waste mangers attention on particular areas that would require improvement for the existing service (Schubeler, Wehrle and Cristen, 1996: Online; ENPHO, 2007: Online).

2.3.3 Policy and planning

The problem of solid waste is a universal issue and is an emerging concern for both developed and developing countries to solve out the problem. In most of the developed countries, they have well established legislation, regulations and action plans however, in developing countries there is usually lack of organization and planning in waste management due to insufficient information about regulations (Tiymaz, and Demir, 2006). Besides technical and financial constraints, indeed it is generally the lack of appropriate policy and legislation that are common cause for ineffective waste management system. In some cases, while policies are framed, it remains broad and there are wide policy gaps and difficulties in upgrading the existing policies due to lack of education, poverty and in some cases customs that do not fit to

modern world (Vidanarachi, Yuen and Pilaptiya, 2006). Therefore, at the outset it is very essential to have comprehensive policies and implementation plans at the national or central level to provide clear guidelines in working procedures for the municipalities (WHO, 1996: Online). As such, policies and implementation plans should encompass clear goals and priorities, roles and jurisdictions, and legal and regulatory framework.

While formulation of clear cut goals remain important, priorities and trade-offs between alternative goals and objectives are inherent under extensive waste management demands and limited resources. Furthermore, it is important to clearly define the roles, jurisdiction, legal responsibilities and rights of the concerned agencies and other organizations to avoid misunderstandings, controversies for the concerned agencies which would lead to inaction and ineffectiveness of the solid waste management. Legal and regulatory framework which is detailed in the form of by laws, ordinance and regulations regarding solid waste management is the instrumental basis for implementing the strategic policy and plans. It also includes corresponding inspection and enforcement responsibilities and procedures at both central and local levels. Generally, regulations should be few in number, transparent, unambiguous, which is easily understandable and equitable (Schubeler, Wehrle and Cristen, 1996: Online; ENPHO, 2007: Online).

WHO (1996: Online) pointed out that administration is one of indictors of waste management. Generally, administering body is responsible for making policies, implementation plans and public relations. Therefore, an efficient organization and administration structure with appropriate legal framework is basis to support an effective solid waste management. In Bhutan, National Environment Commission Secretariat, Royal Society for Protection of Nature, Ministry of Trade and Industry, Ministry of Works and Human Settlement are responsible for policy and planning at the central level for waste management. Some of the existing rules, regulations, guidelines and policy documents relating to waste management includes Water and Sanitation Rules 1995 (PWD and MOC, 1995), Bhutan Municipal Act 1999 (MOC, 1999), Environment Assessment Act 2000 by NECs, Environmental Codes for

Practice for Hazardous Waste Management 2002 (NEC, 2002), National Environment Strategy, " The Middle Path", (NEC, 1999), Ban on Use and Sale of Plastic Bags and Wrappers by Ministry of Trade and Industry, 1999, Action Plan for Thimphu 1992 (TCC and NEC, 1992), etc. Amongst these documents, the most comprehensive document oriented to MSW management are Water and Sanitation Rules 1995, Bhutan Municipal Act 1994 and Ban on Use and Sale of Plastics (see the details of policy review of Bhutan pertaining to waste management in appendix IV).

However, most of the documents related to policies, plans, guidelines, rules and regulation related to waste management are broad and there are wide gaps between policy and implementations. For instance, there is ban on use of plastic bags and wrappers, but there is no mention about its alternatives for use of plastics. Action plan for Thimphu 1992 provides autonomy of municipality in terms of financial and administration but till date it had not been implemented. Further, such policies and plans are not available at municipality or local government level which obviously would constrain the waste management system due to lack of clear working procedures.

2.3.4 Social management

People in the societies clearly generate solid wastes through their daily production and consumption. A solid waste management system that ignores social aspects is prone to be a failure and ineffective. For this reason, it is necessary to understand waste generation, disposal patterns and public participation especially in planning and implementation apart from knowing about technical or financial aspects in waste management research and decision making (Joos et al, 1999).

Basically, people directly or indirectly generate waste. Direct generation includes use of product and its subsequent discard by individuals and indirect generations through discard of wastes created in manufacturing, marketing, sales, and any other processes associated with production and distribution of materials (Tammemagi, 1999). It is obvious that individuals change their consumption pattern

with economic status, thus resulting to change in their waste generation pattern. Moreover, waste generation is attributed to many reasons, such as their attitudes towards waste, patterns of material use, their handling pattern, interest in waste reduction and minimization. Besides, it entrails the effectiveness of waste collection services that influence waste generation and their disposal pattern (Bernstein et al, 2004: Online).

Obviously, in the absence of waste disposal options, individuals are likely to easily dispose their waste at the lowest cost such as open dumping. Therefore, it is necessity to provide waste disposal options for individuals to improve waste handling pattern with improvements in waste collection service. Waste disposal option includes storing waste in individual waste bins and disposing it to public storage containers or waste collection vehicles. Other options are waste separation and sale recyclable materials to recycling facilities. Degradable materials such as food and yard wastes can be home composted. Waste disposal patterns are influenced by those of their neighbors. Thus, their participation for use of solid waste service is crucial for improving waste handling practices (Schubeler, Wehrle and Cristen, 1996: Online; Bernstein et al, 2004: Online; Raji, Wakhare, and Deshpande, 2001).

Solid waste management is an essential public service that benefits all urban residents in terms of public health and environment protection. Therefore, no vulnerable social groups can be excluded from the service benefits and improvements. In fact, an efficient waste management cannot ignore incorporation of social aspects such as public participation and there are clear evidences whereby the management service is prone to fail and be ineffective due to lack of public participation[1]. Therefore, their participation in solid waste management is central to planning and implementation, design and operations of the management system to strengthen working capacity of the municipality (Saundra, 1994: Online).

[1] For instance, inadequate public participation has resulted to cancellation of municipal solid waste management project in Antalya, Turkey (Bernstein et al, 2004: Online).

Public participation refers the extent to which stakeholders can influence development by contributing to the project design, influencing public choices, and holding public institutions accountable for the goods and services they are bound to provide. It is a process that involves participation of beneficiaries in service design and implementation as well as participation in the opportunities created by the service and also managing expectations and providing timely feedback and follow-up of participants. Therefore, while waste management services may be provided by the municipal authorities, the public cooperation and their active participation is very essential for effective solid waste management in various areas. Once the public comprehend and acknowledge the main constraints and the challenges in the management system, public participation should be noticed in the form of proper storage of household waste, waste separation at source, placement of household containers and effective use of public waste service facilities, willingness to pay adequate fees and charges for the service, voluntary involvement in solid waste campaigns, following rules and regulations concerning waste disposal, and voicing any environmental unethical behavior on the part of public or government (Bernstein et al, 2004: Online; Vishvanathan and Trankler, 2007: Online). There are good examples of such public participation in Sri Lanka[2] and China[3]. Further, participation by whole community for solid waste service is essential to bring about changes in waste management with regards to source separation, recovery of reusable and recyclables and storage of their waste prior to collection. For instance, one vivid example of successful venture is the "Garbage for Eggs", Project in Klong slum area of Bangkok[4].

[2] In Sri Lanka, 1,280 families in Moratuwa area are encouraged to separate their waste at household by NGO and it has enabled NGOs to establish small scale composting plant and biogas generation, paper recycling, and sharing information within the network for benefit of the community as funded by Community Environmental Initiative Facility pilot project and the NGOs hopes to extend the system to about 8,000 families to make project a successful example (Vishvanathan and Trankler, 2007: Online).

[3] The involvement of Women Federation in China had encouraged its members especially mothers who took out their children for cleaning the litters and encouraged them to plant greenery every month (Vishvanathan and Trankler, 2007: Online).

[4] Eggs were provided by Environmental Conservation Group in exchange for recyclable materials like glass and plastic bottles, paper/boxes, plastic bags collected and deposited and initiated by group of 25 residents of 70 Rai Community in 1997 after serious flooding of slum area. It took 8 months for removal of garbage from sewers and canals. The sale proceeds of the materials were further used to exchange eggs for the next batch such that the project became self-sustaining and similar projects were extended to other 23 communities in Bangkok (Vishvanathan and Trankler, 2007: Online).

Thus, public or community as a whole as a waste generators, they must be aware of hazards posed by ineffective management of solid waste. Therefore, concerned authorities are required to play important role in bringing about awareness to create sense of ownership among individuals and thus developing keen interest for shouldering responsibilities. Unless public are involved throughout the waste management programs by implementing agencies, awareness cannot be achieved. Thus, while public participation is important for effective management system which in turn demands high awareness programs, therefore, it is very important to provide such awareness programs to improve their participation and ultimately to attain sustainable management system (Schubeler, Wehrle and Cristen, 1996: Online).

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter describes the methodology of the study on municipal solid waste characterization and management in Phuntsholing City. Primarily, various literatures were reviewed relevant to present study to support data collection, analysis and compilation. It involved in both qualitative and quantitative methods. Both primary and secondary data were collected. The secondary data on current MSW service were provided by relevant reports and documents, while the primary data consisted of information on waste generation, composition and public's opinions regarding existing solid waste management system, covering technical, financial, policy and planning, and social aspects of the management.

3.2 Municipal solid waste sampling and analysis

3.2.1 Solid waste generation

This study was conducted in Phuntsholing city in November 2007. In order to obtain solid waste generation, the actual weight of waste collected from the three areas for disposal during one week period (29th October to 4th November, 2007) was recorded. The study assumed that all the actual amount of waste generated was collected for disposal. The per capita waste generation was then computed taking into account of population, provided by PCC, using equation (1).

$$\text{Waste generation rate, kg/capita.day} = \frac{\text{Total waste generated, kg/week}}{\text{Total population} * 7 \text{ days}} \quad (1)$$

Haul density

As information on haul density is important for selection of type of waste collection vehicle, haul density of the MSW was computed on weight-volume analysis. Initially, the capacity of each vehicle was recorded as provided by PCC. Based on the markings on vehicle body, the volume of waste collected was recorded and consecutively, the weight of waste collected by each vehicle was also recorded for duration of one week. Haul density was then calculated using the equation (2).

$$\text{Density, kg/m}^3 = \text{Weight, kg / Volume, m}^3 \quad (2)$$

3.2.2 Solid waste composition

Municipal solid waste in this study included all solid waste generated by the residents and commercials in the city, which was collected by Phuntsholing City Corporation. Waste sampling and analysis was carried out as per method described in Cascadia Consulting Group (1999; 2004; 2006: Online). Primarily it involved two steps: waste sampling and analysis.

Waste sampling

Waste sampling was done at several designated collection spots within the city and at the landfill site. There were three waste collection areas and three waste collection vehicle employed to collect waste from respective areas. Therefore, one designated waste collection spot from respective areas (3 sample loads) and one vehicle load from three areas (3 sample loads) were selected as waste sample loads. Thus, a total of six sample loads was selected.

To obtain waste samples from the designated spots, initially whole weight of the waste was weighed to make at least 100-135 kg. Whole sample load was taken as waste sample. After obtaining the required weight, the waste components were sorted

into its prescribed components (Table 3.1). Each waste component were then weighed and recorded.

Table 3.1 Waste components of municipal solid waste

Types of waste	Components
Putrecibles	Food waste (vegetables, meat scrap, egg shell, dairy products) and yard waste (leaves and grass, pruning and trimmings, branch and stems, crop residues, manures and others).
Paper	Newspaper, office paper, ledgers, magazines, books, cardboard.
Plastics	Plastic containers, bags, HDPE, PETE, other composites
LWTR	Leather, wood, textiles, rubber, threads, yarns, fabrics, cloths, etc.
Ferrous metals	Tins, steel cans, iron rods and all other ferrous metals
Non-Ferrous	Aluminum foils, aluminum cans and all other non-ferrous metals
Glass	Clear bottles, colored bottles, composite glass and others glasses
Inert	Stones, rocks, soils/fines, ash and others
Miscellaneous	Others that do not fit to any of the mentioned categories

Source: Gidarakos, Havas and Ntzamalis, 2006

For the selected waste collection vehicle as waste sample load, one vehicle from three existing waste collection areas was selected and weighed at the weighbridge to obtain the total weight of the waste. The waste was unloaded at the landfill site, and mixed manually. From the known weight, waste sample load was divided into cells each making at least 100-135 kg and one cell was selected as the representative waste sample. It was then manually sorted into the prescribed waste components (Table 3.1), weighed and recorded.

Waste composition analysis

The mean waste composition (wet-weight basis) estimate was calculated using equation (3) with the help of software Micro Office Excel 2003. It was derived by summing each component's weight across all of the selected samples and dividing by

the sum of the total weight for the entire sample. The ratio of the component weight was converted to percentage by multiplying with 100.

$$R_j = \sum C_{ij} / \sum W_i \quad (3)$$

Where,

R_j is ratio of component weight to the total weight of the entire sample

i = 1 to n, where n is the number of selected samples

j = 1 to m, where m is the number of components

C = the weight of particular component

W = sum of all components weight

3.3 Municipal solid waste management in Phuntsholing city

The existing MSW management system was investigated covering technical, financial, policy and planning, and social aspects of the management system. It mainly involved obtaining information through existing documents and record reviews, consultations and interviews with concerned authorities of PCC mainly the MSW section and administrative section. Field investigation and records, interviews with waste workers and public was also conducted. The details of the method and types of data collected with regards to various aspects of management are detailed in following sub-sections:

3.3.1 Technical management

To acquire information regarding technical management, initially, the prescribed questionnaire guide was provided to officer in charge of MSW, mainly engineers. The existing documents and records were also reviewed and to obtain in-depth information, they were personally interviewed. Field observation and interviews with waste workers, drivers and supervisors were also conducted to investigate the existing condition of service provided by PCC. This investigation acquired the

information regarding waste storage facilities, waste collection and transportation, waste treatment and waste recovery practices and final waste disposal methods.

3.3.2 Financial management

To investigate financial management system, it was mainly carried out through reviewing of the existing documents. It also comprised personal interviews with the concerned authorities of MSW management department. Information related to investment cost, operation and maintenance cost, cost reduction and control measures of the existing management system were obtained. Local residents were interviewed through cross-checking of bills such as property taxes, water bills and electricity bills.

3.3.3 Policy and planning management

In terms of Policy and planning, it mainly involved interviews with the administrative section, MSW division heads and existing document reviews. Researcher had reviewed the existing policy and plans, acts and regulations oriented towards MSW management. Further, information about PCC's implementation plans for waste management and their administration organization were also obtained.

3.3.4 Social management

The case studies revealed that as residents of any communities as the generator of wastes, understanding their perception about current management situation are important. As per the concept of solid waste management, social aspects of the management include waste generation, their waste disposal pattern and public participation. As such, many researchers (Sharholy et al, 2006; Vidanarachchi, Yuen and Pilapitiya, 2006) had conducted social survey mainly following the process of MSW management. Therefore, social survey was conducted through questionnaire as method to obtain qualitative data that will be quantified to descriptive.

Study site, sampling and sample size

Social survey was conducted in Phuntsholing city, covering mainly three areas of the city, including only the urban populations that have access to PCC's solid waste management service. As per the survey, total population of the city was about 22,500 people with 3,379 households.

Random sampling method has been used in selecting the sample. While sample size is likely to vary with total population, Neuman (2003), Isreal (1992) and Cochran (1963) suggest that for a study population under 1000, the required sample size of 30% is suggested for more accuracy, for more population 10,000, sample size is about 10% and for population over 150,000, the sample size can be 1%. Therefore, total sample size of 338 households representing 10% of total population households was selected.

Questionnaire

The questionnaire (Appendix III: Table 1) in general was designed to obtain information regarding waste storage and disposal practices by individuals, waste separation at source, collection and transportation service, fee collection, and overall performance of current waste management service.

Data compilation, analysis and interpretation

The results of data obtained from investigation with regards to current management system with covering technical, financial, policy and planning, and social aspects have been compiled and analyzed using software package Micro Excel 2003. It involved both quantative and qualitative method and is interpreted in descriptive manner. Social survey respondent's analysis is presented in appendix III: Table 2.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

The aim of this chapter is to describe the findings of the study regarding municipal solid waste (MSW) characterization and management in Phuntsholing city, Bhutan. Firstly, it discusses the results of MSW generation rate and composition in the city. Secondly, it discusses the results of investigation of current municipal solid waste management (MSWM) system. This covers the discussion of the findings with regards to technical, financial and policy and planning, and social aspects of the solid waste management. The results of this study are presented and discussed in the following sub-sections:

4.2 Municipal solid waste generation and composition

4.2.1 Solid waste generation

Municipal solid waste generation rate for the whole city was computed on actual amount of waste collected by collection vehicle for duration of one week in the November 2007.The total amount of MSW collected in one week was 62,770 kg and the urban population covered by the MSW management service was 22,500 people (PCC, 2007). Therefore, waste generation rate per capita is 0.40 kg/capita.day (Table 4.1). Obviously, the waste generation rate in the city has increased from 0.31 kg/capita.day in 2000 (NEC, 2000) to 0.40 kg/capita.day in 2007 indicating an increase rate of 3.8% per year. As such, waste generation per day was estimated to be 8,967 kg, which indicated that waste generation per year is about 3,273,006 kg. Ingeneral, the waste generation is considered to increase with population growth and

rapid urbanization (Sharholy et al, 2006). The country as a whole, the population growth rate is 1.3% and the estimated urban population growth rate is between 7-10% per annum due to rural-urban migration (PHCB, 2005: Online). This portrays that the waste generation will be more pronounced especially due to urban population growth. At present, besides the capital city, Thimphu, Phuntsholing is one among the most urban city showing highest population growth and the largest generator of MSW (NEC, 2000). The waste generation in Phuntsholing city in 2007 is presented in Table 4.1(Details in appendix I: Table 1).

Table 4.1 Waste generation by areas in Phuntsholing city in 2007

Areas	Waste generation (kg/day)	Waste generation (kg/week)	Waste generation (kg/year)	Total population*	Waste generation rate (kg/capita.day)
No.1	4,341.43	30,390.00	1,584,621.95	-	-
No.2	2,695.71	18,870.00	9,83,934.15	-	-
No.3	1,930.00	13,510.00	7,04,450.00	-	-
Total	8,967.14	62,770.00	3,273,006.10	22,500	0.40

Source: Survey in November 2007

Note: * Data provided by Phuntsholing City Corporation

Actually, the quantity of waste collected is different from the quantity generated from the source. Therefore, in this study, it was assumed that the waste generated from all sources is equal to waste collected by the vehicle for disposal. This assumption was reasonable to certain extent because there were no waste separation at source, which would have lead to diversion of recyclable waste to recycling facilities.

In practice, there was waste diversion due to waste collection by the waste scavengers from the waste storage areas. Obviously, most of the waste at the backyards always remained uncollected and there was existence of open burning both at source of generation and collection spots. These activities revealed that the actual waste generation was clearly higher than actual volume collected for disposal.

Doubtlessly, the actual amount of waste generation in the city was higher than the present estimation.

In order to collect the waste, there were mainly three areas covering an area no.1, which is the main town area, area no.2 Royal Insurance Corporation of Bhutan (RICB) area, and area no.3, Chukka Hydro Power Corporation (CHPC) area (PCC, 2007). The waste generation by areas revealed that the area no.1 had highest with 4,341 kg/day, followed by area no.2 with 2,696 kg/day and then area no. 3 with 1,930 kg/day (Table 4.1). The per capita waste generation rate estimation by areas was not possible, as there was only total number of population in all areas/zones

As information on waste density along with waste generation finds importance in provision of waste storage and waste collection systems, haul density of the MSW was estimated. It was computed on weight-volume analysis of waste collected by the vehicle in the city (Details in appendix I: Tables 1 and 2). It was estimated in an average of 298.11 kg/m^3 (Table 4.2).

Table 4.2 Haul density of solid waste by areas and type of vehicle in Phuntsholing city in 2007

Areas	Vehicle type	Average volume of waste (m^3 /trip)	Number of vehicle trips (trip)	Total volume of waste (m^3)	Total weight of waste (kg)	Haul density (kg/ m^3)
No.1	Open truck No.1	5.92	13	76.96	30,390.00	394.88
No.2	Compactor truck No.1	6.23	13	80.99	18,870.00	232.99
No.3	Compactor truck No.2	3.90	13	50.70	13,510.00	266.46
Total	-	16.05	39	208.65	62,770.00	894.33
Average	-	5.35	13	69.55	20,923.33	298.11

Source: Survey in November 2007

The haul density by areas revealed the highest in area no.1 with 394.88 kg/m^3, followed by area no.3 with 266.46 kg/m^3 and lowest in area no.2 with 232.99 kg/m^3. The higher density for area no.1 was authentic as construction works were under progress and the mix of construction and demolition waste was observed in the collected waste. Normally, haul density of compacted waste collected by compactor truck are higher than un-compacted waste collected by open trucks but in contrary, it showed that density for waste collected by compactor trucks were lower than open trucks. Further, its density was lower than typical specific density of the compacted waste of 296.65 kg/m^3 (Tchobanoglous, Thiensen and Vigil, 1993). Obviously, the higher density of waste collected by open truck was reasonable because it was collecting construction and demolition waste mixed with MSW from area no.1. On the other, the damage of compaction system can possibly occur so that haul density for compactor truck can be lower. However, as waste generation varies with seasons and accordingly its density (Nair, 1993: Online), therefore further study on waste generation and density following seasonal variations is necessary.

4.2.2 Solid waste composition

Municipal solid waste composition was determined in November 2007. The results of the MSW composition by wet-weight analysis were mainly organic materials (Table 4.3) (Details in appendix II: Table 1).

As a whole in the city, total waste generation in 2007 was estimated to 327, 3006 kg. The total organic fraction of the waste composition made up the largest 70.93% (2,321,543 kg) of the total, which mainly constituted putrecibles 31.04% followed by paper 20.35%, plastics 10.84% and leather, wood, textiles and rubber (LWTR) 8.70%. The total inorganic materials comprised 23.95% (783,885 kg/year), which constituted glass 10.74%, ferrous metal 2.34%, non-ferrous metal 2.45%, and inert (stones, ash, soil, construction and demolition waste) 8.42%, while other miscellaneous materials constituted 5.12% (167,578 kg/year). The total percentage of materials such as paper, plastic, ferrous metal, non-ferrous metals and glass comprised 46.72 % (1,529,149 kg/year) of the total MSW generated in the city.

Table 4.3 Municipal solid waste composition in Phuntsholing city in 2007

Type of waste	Waste quantity		Compostable waste		Recyclable waste	
	(kg/year)	(%)	(kg/year)	(%)	(kg/year)	(%)
Organic						
Putrecibles	1,015,941.09	31.04	1,015,941.10	31.04	-	-
Paper	666,056.74	20.35	-	-	666,056.74	20.35
Plastics	354,793.86	10.84	-	-	354,793.86	10.84
LWTR*	284,751.53	8.70	-	-	-	-
Inorganic						
Ferrous metal	76,588.34	2.34	-	-	76,588.34	2.34
Non-ferrous	80,188.65	2.45	-	-	80,188.65	2.45
Glass	351,520.86	10.74	-	-	351,520.86	10.74
Inert**	275,587.11	8.42	-	-	-	-
*Misc.***	167,577.91	5.12	-	-	-	-
Total	3,273,006.10	100.00	1,015,941.10	31.04	1,529,148.45	46.72

Source: Survey in November 2007

Note: * Leather, Wood, Textile and Rubber

**Stones, ash, soils, construction and demolition waste.

***Nappies, sanitary napkins, other materials that do not fit into any of the mentioned categories.

In general, all kinds of waste components were the generation from residents, commercials, institutions, public services, hospitals, construction and demolition, street sweeping and industries. Analyzing the types of waste and its components in the city, the putrecible waste was mainly food scraps and yard waste. The paper components constituted newspapers, packaging materials, magazines, office papers and cardboards. Plastic components were in forms of packaging materials, bags, bottles and other miscellaneous plastics, while LWTR constituted mainly textiles, rubber, and leather and wood. Both ferrous and non-ferrous were in the forms of top and end cuts (scraps) and cans. In glass components, there were glass bottles and other broken glasses. Inert consisted mainly in forms of stones and gravels while other were sanitation waste such as napkins, diapers, etc.

The MSW composition of the city in 2007, the organic component of putrecible waste constituting mainly food and yard waste with 31.04 % which indicates 1,015,941 kg/year of waste can be recovered through composting. While, the most commonly recyclable materials namely ferrous metal, non-ferrous metal, paper, plastic and glasses, constituted 46.72% of the total waste, which indicates 1,529,149 kg/year of waste can be recovered through recycling. As a whole, considerably high percentage (77.76%) of total waste, which indicates 2,545,090 kg/year of the waste generated in the city, can be recovered through composting and recycling while the rest had to be managed through disposal in landfill.

4.3 Municipal solid waste management system in Phuntsholing city

It looked at technical, financial, policy and planning and social aspects of waste management which is detailed as follows under each sub-section:

4.3.1 Technical management

Technical management system covered investigation with regards to waste storage, waste collection and transportation, waste treatment and recovery and final waste disposal systems as presented in Figure 4.

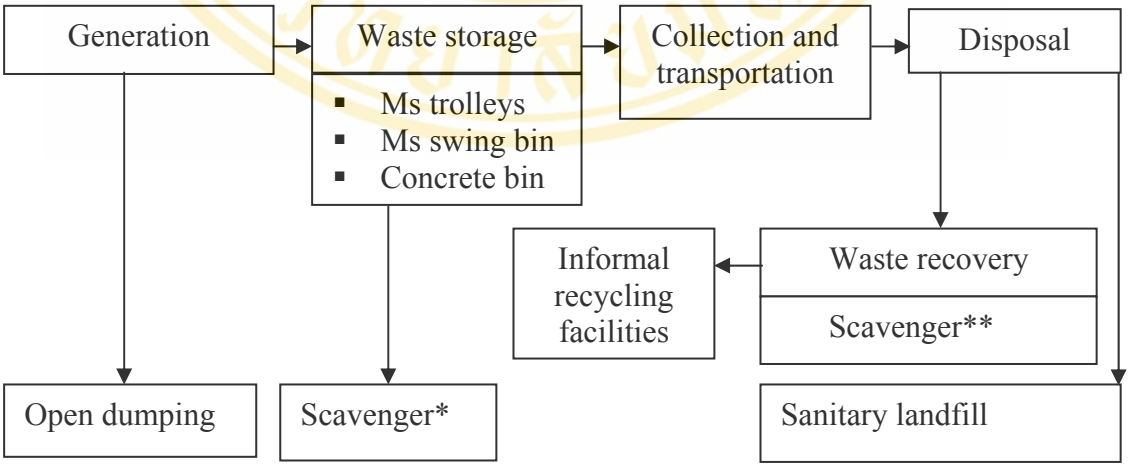

Figure 4.1 Municipal solid waste management in Phuntsholing city in 2007

Source: Survey in November 2007

Note: * Informal waste scavenger not assigned by PCC

** Informal waste scavenger assigned by PCC

Waste storage

The waste generated from residential, commercial, industries, construction and demolition, institutions, public services, hospitals, food and yard wastes and street sweeping were stored in waste storage facilities provided by Phuntsholing city Corporation (PCC). The type of waste storage is all commingled or mixed waste. The facilities were mainly of three types, which consisted metallic sheet trolley bins, metallic sheet swing bins and masonry concrete bins excluding open storage, which were placed at designated spots as shown in Figure.4.2.

(a) Trolley bin (b) Swing bin (c) Concrete bin

Figure 4.2 Three different types of waste storage bins provided by PCC

Source: Survey in 2007

The official data revealed that all trolley bins had the same capacity of 1.38 m^3; swing bins had capacity of 0.55 m^3 and concrete bins varied in their capacities with average capacity of 4.26 m^3. The details of the storage facilities as provided by PCC are shown in Table 4.4.

It indicated that trolley bins is mostly distributed, which is 44.04% of the total followed by swing bins 41.67% and the least distribution is concrete bins 14.29%. As per the information obtained from the municipal authority, the distribution of existing types of waste storage facility is attributed to various reasons. The distribution of heavy metallic sheet trolley bins was meant for security of the containers from loosing it. Furthermore, since it is bulky and cannot be moved easily, it was meant to keep the containers in designated collection spots intact in position. The second dominant distribution of waste storage was swing bins. The distribution of this type of bins was

attributed to convenience to unload the waste during waste collection. The least distribution was concrete bins. It was meant to receive large volume of waste in the city. Another prevailing waste storage was open areas for residents who had no access to waste storage facility. In general, it is found that maintenance conditions of all types of bins were poorly maintained. The existing condition of each type of bins is explained as follows.

Table 4.4 Waste storage bins and its capacity in Phuntsholing city in 2007

Type of waste storage bins	Capacity of bins (m^3/bin)	Numbers of bins	Total capacity of bins (m^3)	% of bins
Ms trolley bins	1.38	74	102.12	44.04
Ms swing bins	0.55	70	38.50	41.67
Masonry concrete bins	4.26*	24	298.20	14.29
Total	-	168	438.82	100.00

Source: PCC, 2007

Note: *Average capacity (Ranges from 4.00 - 4.52 m^3)

Metallic sheet swing bins

Swing bins were placed on the stand that can swing at the pivot making convenient for waste collection. The workers can unload the waste by pouring it down. It had lid at the top to cover the stored waste. However, due to poor maintenance conditions, these bins were not in proper position. Most of them were tilted. When the waste was full, there were lot of overflows and the lid remained all times opened thereby making easy access to flies, insects and rodents, etc. It made the waste collection spots aesthetically unsound and unhygienic thereby creating Not In My Backyard situations who reside near to the collection spots. However, it is easier to maintain, convenient to use, more hygienic and cost cheaper compared to trolley bins and concrete bins. The prevailing conditions of the swing bins are as shown in Figure 4.3.

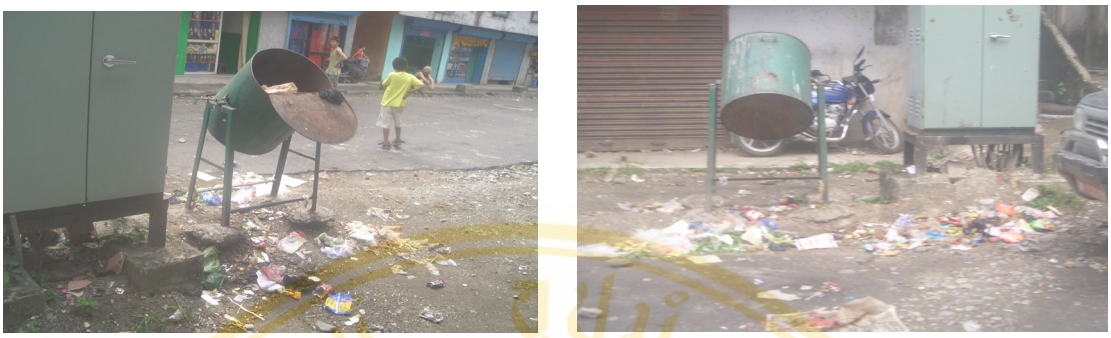

Figure 4.3 Existing conditions of swing bins in Phuntsholing city in 2007

Source: Survey in November 2007

Masonry concrete bins

Another kind of waste storage was the concrete bin at various locations fixed in one place with varied capacities (Figure 4.4). It did not have any cover at the top. It was kept wide open at all times. Most of them were found damaged which indicated poor maintenance condition. Due to its open nature, there existed lots of overflows and scattering of waste due to wind and access to animals at the site. It is not suitable to use during rainy season. There also existed open burnings at these waste storage facility sites. Open burning is considered an unhygienic practice, which will pollute the air. The use of concrete bins as waste storage facility is not appropriate. Initially, it requires high cost for construction and since it is fixed in one place, it has no flexibility to change its position other than to dismantle it whenever there is set up of new infrastructures.

Figure 4.4 Existing conditions of concrete bins in Phuntsholing city in 2007

Source: Survey in November 2007

Metallic sheet trolley bin

Another kind of waste storage was the trolley bins which weighed about 180 kg. It had the wheels at the bottom for easy movement of the bin from one spot to another. It had no lids or covers at the top and it remained opened at all times. Due to its open condition, lots of waste was found scattered nearby. Most of the bins were found tilted and its wheels damaged which indicated its poor maintenance conditions. The difficulties of maintenance were foreseen due to its heavy weight, which cannot be easily taken to workshops. Obviously, it was not suitable during rainy seasons due to its open nature. Further, the overflows and drainage of this water made its surrounding dirty thus creating aesthetically unsound and unhygienic. Also, availability of such containers for replacement of the damaged one was apparently expensive and has to be imported from overseas (Figure 4.5).

Figure 4.5 Existing conditions of trolley bins in Phuntsholing city in 2007

Source: Survey in November 2007

Open storage and illegal dumping

Besides the three types of waste storage bins, there were the open waste storage areas in open space beside the roads. These areas were designated by PCC for storing the individuals waste and it was mainly in the areas where there is no direct access to waste storage bins. Other kind of waste disposal by individual was illegal open disposal practices which revealed the lack of individual responsibility and social awareness. The individuals simply dispose of their waste in and around their residential premises and in the open space which remained always uncollected. Both

practices of waste storage in open designated areas and illegal disposal of individual waste were found to be aesthetically unsound and unhygienic (Figure 4.6).

Figure 4.6 Existing condition of open dumping of waste in Phuntsholing city in 2007
Source: Survey in November 2007

In principle, the main purpose of provision of on-site waste storage facilities is primarily for public concern, aesthetic consideration and to facilitate easiness for waste collection (WHO,1996: Online), however, as mentioned, the prevailing condition of distribution and use of existing facilities provided by current management system do not intend to serve any of this purpose.

With regards to capacity of the various types of bins (Table 4.4), currently distributed 24 numbers of concrete bin with an average capacity of 4.26 m^3/bin had the highest capacity to store 298.20 m^3 of waste. The next was the 1.38 m^3/trolley bin whereby, the distributed 74 numbers had the capacity to store 102.12 m^3 of waste. The least was the swing bins whereby 70 numbers of 0.55 m^3/bin had capacity to store 38.50 m^3. Therefore, as a whole, it revealed that the existing distributed bins had the capacity to store 438.82 m^3 of waste generated in the city.

In general, provision of waste storage facilities must be based on its area specific data such as waste generation, composition, volume, density of waste, volume of containers, etc (Schebuler, Wehrle and Cristen, 1996: Online; Tchobanoglous, Thiensen and Vigil, 1993). As per the present study on waste generation, total volume of waste generated in the city in one week period accounts to 208.65 m^3 (Table 4.2).

Therefore, estimated total volume of generated waste in the city is 29.81 m^3 per day while the existing total volume of containers provided to the city is 438.82 m^3 (Table 4.4). Thus, this indicated that the total waste storing capacity of the containers provided to the city is in excess to total volume waste being generated. This portrays that provision of storage bins in the city is not appropriate. It also clearly reveals current MSW management system did not take into account of the current existing situation of the city's waste generation while providing waste storage facilities.

While the provision of waste storage capacity facilities is in excess to the current waste generation, field investigation found the existence of designated open waste storage areas and illegal open dumping of individuals waste in and around the city, which made surrounding dirty and at the same time, it is an unhygienic practice. This situation portrayed that waste storing capacity of the bins provided by current MSW management system is insufficient to handle the current total waste generated in the city. Thus, it indicated that the distribution of waste storage bin is improper.

Waste separation at source and waste storage in segregated form are practiced in many countries. Waste separations into organic, recyclable and other non-recyclable materials are commonly practiced. However, the introduction of waste recovery and source separation must be done in incremental manner beginning with pilot scale to assess and encourage the householder to participate. In the study area, there is no separation of waste at source, nor the provision of waste storage facilities for segregated waste. All kinds of waste generated are stored in one common container provided by PCC. There are hardly any measures taken towards introduction of waste recovery and waste separation in the city.

Thus, with regards to waste storage facilities in the city, the present study found that current management system had failed to consider the information on current existing waste generation for provision of required capacity of storage facilities. This has led to provision of improper distribution of storage facilities with weak purpose of public concern, aesthetic consideration and easiness of waste collection.

Waste collection and transportation

In the city, waste collection and transportation included transferring the stored waste in individual waste bin to the nearest collection containers or directly loads to the collection vehicle by individuals during arrival of waste collection vehicle provided by Phuntsholing city corporation (PCC). It also included the street sweepings. For the main road and streets, there is provision of street sweepers that cleans it on daily basis and collects the accumulated waste to the collection spots.

There consisted the use of stationary container system, manually loaded vehicle and waste loading by waste crews from collection spots to the waste collection vehicle that transport it to the disposal site. In order to collect the waste, there were mainly three areas: area no. 1 (main town), area no. 2 (CHPC colony area) and area no. 3 (RICB colony area). In respective areas, the stationary containers mainly consisted of trolleys bins, swing bins and concrete bins placed in designated collection spots. From the designated collection spots, the collection crews manually loaded the wastes to the vehicle using basket containers and were directly transported to disposal site without waste transfer stations. As per the official report, the waste collection service had 100% service coverage of the urban areas of the city with daily waste collection frequency of two trips per day (morning and noon).

There were total of five waste collection vehicles, which comprised three compactor trucks and two flat-bed open trucks. For daily collection of waste, three vehicles were engaged on daily basis making two trips per day which included two compactor and one flat-bed open truck. Other two vehicles, one compactor truck and one flat-bed open truck were kept as standby collection vehicles but during the study period, both the standby collection vehicles were under maintenance. The open truck was used for collection of waste from area no. 1 and other two trucks from area no. 2 and 3.

Along with the waste collection vehicles, there were 17 collection crews who were engaged for daily waste collection. There were also three drivers for three

respective vehicles and two numbers of supervisors for daily waste collection supervision and one vehicle maintenance personal. All the collection workers were paid on daily wages system except the drivers, supervisors and vehicle maintenance personal, who were regularized. The details of the human resource and vehicle for collection and transportation of MSW in the city are shown in Tables 4.5 and 4.6.

Table 4.5 Human resource for waste collection in Phuntsholing city in 2007

Duty	Numbers	Status
Supervisors	2	Regular
Drivers	3	Regular
Collection crews	17	Daily wage
Street sweeper	7	Daily wage
vehicle maintenance	1	Regular
Others	3	Regular
Total	33	-

Source: PCC, 2007

Table 4.6 Types of vehicle, frequency, capacity and capacity utilization of waste collection vehicle in Phuntsholing city in 2007

Vehicle	Frequency (trips/d)*	Capacity of vehicle (m^3/trip)*	Total collection capacity (m^3/d)	Average volume of waste collected (m^3/trip)	Total volume of waste collected (m^3/d)	Utilization of vehicle capacity (%)
Compactor truck no.1	2	9.00	18.00	6.23	12.46	69.22
Compactor truck no.2	2	5.10	10.20	3.90	7.80	76.47
Open truck no.1	2	6.00	12.00	5.92	11.88	99.00
Total	6	-	40.20	-	32.14	-

Source: Survey in November 2007

Note: * Information provided by PCC

Generally, concerning waste collection and transportation, decision about types of service, frequency of collection, types of collection vehicle, crew size and collection route design are important aspects to be considered (Schebuler, Wehrle and Cristen, 1996: Online).

In terms of types of waste collection and transportation service, PCC had adopted curbside pick up or stationary container service system. However, along with curbside waste pick up, there was also door-to-door waste collection service whereby individuals directly load to collection vehicle from their own dust bins. In fact, waste collection service comprised the mixed of two services. While much time was required for collecting waste from fixed stationary container system, additional time was required in waiting for the individuals to dispose their waste from their dust bins. Due to default in timings of vehicle arrival, most often residents who practice direct loading were prone to adopt other easy disposal options such as open dumping in open spaces. Therefore, direct loading or door-to-door collection service was not effective. Indeed, curbside waste pick up was more practical and effective if there was provision of appropriate waste collection bins such as collection bins that can be easily lifted for waste loading instead of using heavy built, fixed collection bins.

Currently waste collection frequency was two times per day. Even with this frequency, current waste collection system had failed to maintain good aesthetic condition and hygienic condition in the city. About 80% of residents complained about flies, insects and rodents, 77% about bad odor due to waste degradation from waste collection spots, and 51% about waste remained uncollected (Appendix III: Tables 1 and 2). It clearly revealed the inefficiency of waste collection frequency. Due to more frequent waste collection service, it had resulted to high fuel consumption. The study draws conclusion that involvement of more frequent collection was due to under capacity utilization of waste collection vehicle's capacity.

Pertaining to the existing waste collection capacity and utilization of vehicle, current management system had provided two compactor trucks with a capacity of 9.00 and 5.10 m^3 and one flat-bed open truck of 6.00 m^3 for waste collection on daily

basis with frequency of twice per day. Therefore, in ideal case, the provided waste collection vehicle with two trips per day had total waste collection capacity of 40.20 m^3/day. However in practice, current waste collected from compactor trucks were only 12.46 and 7.80 m^3/day, while flat-bed open truck had 11.88 m^3/day on average. Thus, total volume of waste collected was 32.14 m^3/day, which is 79% of the total vehicle capacity (Table 4.6).A breakdown by type of vehicle reveals that current management system had better capacity utilization of open truck 99% compared to compactor trucks, which had 69 to 76 % in terms of waste collection. It portrayed that use of open truck is more appropriate in the city. Thus, improving the capacity utilization of the existing vehicle and selection of appropriate collection vehicle would reduce the demand for more frequent collection frequency. Obviously, vehicle capacity utilization can be improved through development of work monitoring system. It can be done through use of standard data forms to collect relevant information over a period of time which would form the baseline data for their performance analysis and pin-point its shortcomings.

Basically, selection of vehicle types must be based on area specific data such as prevailing condition of waste and considering operation and maintenance requirement. Since the current management system are encountered with lack of necessary maintenance support, thereby operation of compactor trucks revealed to be ineffective and costly.

In fact, good performance of waste workers would contribute to enhanced waste collection system. Currently, the waste collection system involved high number of labors, whereby the normal crew size varied from 4-6 crews per truck (PCC, 2007). Obviously, intensive requirement of waste workers was attributed to use of highly inappropriate fixed type of waste collection bins such as concrete bins and trolley bins. Most of the waste workers were untrained and not regular workers (Table 4.5). As such, it was encountered with irregularities and shortages in their duties which resulted to default the daily waste collection schedules. Recruitment of national waste workers in the city was very acute due to common notion of the citizens that waste workers job is low profile job. All the waste workers were from overseas and their

commitment to service was low and their performance foreseen poor. All the workers worked on daily wage systems which do not provide any economic incentives. Moreover, while they worked under the extreme hazardous conditions which are detrimental to their health, there was no provision of safety equipments and clothing for safe working conditions. Therefore, provision of the above mentioned constraints may alleviate the waste workers performance and ultimately enhance waste collection system.

While present study had limited information regarding waste collection route and routing, it was found that mainly the lack of good network of road in the city had constraint proper route design. The existing small and mainly unpaved road condition had led to much fuel consumption and time. Further, many households did not have convenient access to roads and in addition they had to ensure timely arrival of collection vehicle for their waste disposal especially those who use direct loading. As such, due to default in timing, they were likely to other easy disposal options such as open dumping in open spaces. Therefore, direct waste collection by existing large collection vehicle through scheduled routing was not very effective. In fact, provision of smaller waste collection vehicle according to the existing road condition may prove to be effective to collect waste especially from areas where there are no convenient accesses or/and small roads.

Waste treatment and recovery

In the city, there is no waste treatment or recovery facilities established by neither the City Corporation, nor private companies. However, there exist some informal recycling facilities within the city that accepted major recyclable items such as metals, glass, plastics, rubber and papers. While transfer stations serves to be center for waste scavenging and waste recovery, there is no involvement in transfer station. Most of the waste recovery was done at the disposal site. The average quantity of waste recovered in 2006 is shown in Table 4.7.

Table 4.7 Recovered items from disposal site in 2006

Items	Quantity (kg/year)	Rate (Nu/kg)	Total amount	
			(Nu/year)	(USD*/year)
Plastics	3,600	0.50	18,000	464.51
Papers	1,440	10.00	14,400	464.52
Glass	1,800	6.00	10,800	278.71
Rubber	24,000	1.00	24,000	619.36
Total	30,840	-	67,200	1,827.10

Source: PCC, 2007

Note: There was no available data of metal

1USD* = Nu. 38.75 (November 2007)

It revealed that, the main wastes recovered are papers, glass, plastic and rubber. A total average 30,840 kg of waste were recovered in 2006. The waste recovery practice involved the recruitment of informal waste scavengers at the disposal site. The individual was allowed to segregate the waste they wanted. They were not paid by the PCC but were assigned by the PCC. Whatever, they have recovered were allowed to be taken by them and the returns from this recovered items were own by the individual without any financial benefit to PCC.

In actual, the waste which is recoverable from the waste stream is presented in Table 4.8. Putrecibles (food and yard wastes) waste constituted about 31.04 % (1,015,941 kg), which are highly degradable and it can be composted and used as soil conditioner. Further, total commonly recyclable materials including paper, plastic, metals and glass constituted 46.72 % that can be recovered. Field survey also revealed that rubber items had its economic value (Table 4.7) and the visual observation depicted rubber items were major fraction in LWTR components, which would increase the percentage of recoverable items in the waste stream. Thus, more than 77.76 % (2,545,089.54 kg) of the total waste generated were recoverable. However, currently only about 30,840.00 kg of total waste was recovered in 2006. Therefore, it is important to improve waste recovery through composting and recycling as an alternative to increase the life of existing landfill site.

Table 4.8 Percentage and quantity of recoverable waste through recycling and composting in Phuntsholing city in 2007

Materials	Composition (%)	Recoverable waste items (kg/year)
Paper	20.35	666,056.74
Plastics	10.84	354,793.86
Ferrous metals	2.34	76,588.34
Non-ferrous metals	2.45	80,188.65
Glass	10.74	351,520.86
Putrecible (food and yard wastes)	31.04	1,015,941.09
Total	77.76	2,545,089.54

Source: Survey in November 2007

Note: Total waste generation in 2007 was 3,273,006.10 kg

However, the case studies from other cities of the different countries reveal that the success of waste recovery through recycle and composting depends much upon the efforts taken towards waste separation. While waste separation at source by individuals remains to be the top priority but as it is evident from other practitioners that it demands high social awareness regarding waste management and it is a long term process. Since, in Phuntsholing, currently there is no practice of waste separation at source and moreover, due to recent set up of waste management, it is very likely that the issues regarding waste management is new to the residents of the city and obviously their awareness is poor. Therefore, introduction of waste separation at source would likely to be long term goal. The most common practice is to separate waste at waste storage points through provision of different containers for recyclable waste, food and yard wastes, and other non-recyclable waste. Therefore, PCC could initially start with pilot scale such as in institutions, commercial, big housing complexes and then extend to residential level.

Currently, waste recovery for reuse and recycling were done by waste scavengers or waste pickers at the landfill site. These practices of waste recovery at final disposal site were found to be inappropriate for various reasons. Primarily, when

recyclable waste were collected and transported mixed with food and yard waste, obviously recyclable materials especially paper components were easily degraded, other reusable components such as glass bottles were damaged and other recyclables contaminated. Thus, it had resulted to reduce the quantity of waste to be recovered and at the same time degrade the quality of recovered materials. Further, it also did not intend to reduce the burden of waste collection and transportation through waste volume reduction because waste recovery was carried out at final disposal site. Therefore, measures should be taken to shift the waste recovery practices to be carried out at source or at waste collection points. The waste scavengers can then be organized into waste recycling worker at the waste collection points, and recovered items can be sold to the existing informal waste recycling facilities within the city.

Although home composting by individuals can be adopted, still requirement of composting plant was very crucial due to its highest share in the waste stream and it was the major component destined for landfill. As in Thimphu, capital city, Thimphu City Corporation (TCC) has already established composting plant along with provision of separation unit and it is intended to reduce the amount of waste destined for landfill and at the same time generate revenue for TCC through sale of compost. As such PCC may also establish composting plant which would increase the life of existing landfill and at the same time generate revenue.

Waste disposal

Waste collected from Phuntsholing city was disposed at Toribari, newly constructed disposal site situated at 9 km away from the city. It is a sanitary landfill site with surface water diversion system, single liner, and leachate collection system with soil cover. The waste disposal to this site was started recently in March 2005. It was constructed with an expected life span of 10 years. It has total land area of 1.512 hectares (PCC, 2007).

The daily operation of the waste disposal comprised hydraulic automatic unloading of the collected waste from the vehicle to the disposal site. Unloaded waste

was spread out with bulldozer. Two informal waste scavengers were assigned by PCC to separate the recyclable items, which were mainly metals, plastics, glass and papers. The dry waste was open burnt, followed with or without compaction using the compactor (roller) to reduce the volume of waste. There was a single layer of liner provided for final cover and final soil cover at the top. There was also provision of bottom liner. Around the disposal site, there was drainage constructed for surface water diversion. There was also leachate collection system through perforated HDPE piping system and leachate was stored in concrete built storage facility. The total waste disposed in 2007 is presented in Table 4.9.

Table 4.9 MSW disposed in Phuntsholing city in 2007

Particulars	Quantity of waste (kg/year)	Quantity of waste (%)
Total waste recovered[1]	30,840.00	0.94
Total waste disposal	3,242,167.14	99.06
Total waste generation[2]	3,273,006.10	100.00

Source: 1. PCC, 2007
2. Survey in November 2007

Note: Waste recovered in 2006 is assumed to be equal to waste recovered in 2007

Sanitary landfill is considered to be an engineered facility for MSW disposal, which has to be designed and operated to minimize public health and environmental impacts. However, the most concerning issues regarding its operation is the fear of contamination of ground water or surface water streams through uncontrolled release of leachate (Tchobanoglous, Thiensen and Vigil, 1993; WHO, 1996: Online). At the present disposal site, there was inadequate quality control of liner system, which is likely that there is release of leachates into the ground water. Moreover, provision of small inadequate leachate collection systems, the absence of leachate treatment system and ground water monitoring system revealed the fear of contamination of ground water and nearby streams, which is of high health risk for downstream water users. The complaints about sensible negative effects by the downstream users portrayed the condition of nearby streams and ground water due to release of leachate from the landfill site. Provision of perfect liner system, leachate collection and treatment

system such as aerobic or anaerobic treatment would be difficult for the existing small scale landfill site. However, action must be taken to minimize leachate production. The measures such as re-circulation and evaporation of generated leachate were found to be a suitable method to reduce leachate production at the existing site due to its location in tropical zone. Further, the capacity of the leachate collection system needs to be enlarged so as to overcome the overflows of generated leachate and to curb contamination of nearby stream.

Another concerning issue is the air pollution from open burning of the waste at disposal site. Open burning is often adopted as a means to reduce the volume of waste to disposal site to extend its life span. However, open burning as means for waste reduction is considered as inappropriate method as it releases toxins and carcinogens especially from plastic materials. The present practice of open burning of waste at the disposal site as daily operation for waste reduction were prone to pollute air and have direct or indirect public health risk. However, the best option to reduce waste volume and extend life of existing disposal site would be to improve waste recovery through recycling and composting.

Currently, besides the small amount of waste being recovered by the waste scavengers from the disposal site as mentioned, rests of the waste were all disposed of to the disposal site. The MSW disposed in Phuntsholing city in 2007 is presented in Table 4.9. It revealed that total waste generated is 3,273,006 kg. However, only 30,840 kg of waste was recovered and rest 3,242,167 kg of waste was all disposed of to the landfill site which indicated that the current waste disposal was 99%. Obviously, at this current waste generation and its disposal, it is evidently putting much pressure on existing landfill site life span and also demand for new disposal site which is practically difficult to find the appropriate site. Therefore, urgent steps must be taken to reduce the amount of waste disposed to the landfill site. Eventually, it can be reduced through adoption of improved waste recovery practices. Thus, current waste management needs to put much effort for waste recovery through recycling and composting for all the reasons mentioned above.

4.3.2 Financial management

The financial aspects of MSW management covered investment cost, operation and maintenance cost, cost reduction and control mechanisms. It is detailed as follows.

Capital investment cost

In 2005, Phuntsholing City Corporation had invested a total capital investment of 372,000 USD for MSW management in procuring the equipment and other facilities (Table 4.10). More than half (54%) of the total investment was made towards acquiring landfill site. Other major investment was for procurement of landfill heavy equipment (22%) and waste collection truck (16%). Other investment was made towards procurement of inspection vehicle such as scooter, waste storage bins and others. The main source of financing capital investment for MSW management for municipality was from the central government and funding aids from DANIDA and Urban Sector Program Support (USPS).

Table 4.10 Total capital investment for MSW management in Phuntsholing city in 2005

Investment	Costs	
	(USD)	(%)
Waste collection truck	60,000	16.12
Landfill heavy equipment	80,000	21.51
Inspection vehicle	3,000	0.81
Waste bins	19,000	5.11
Landfill	200,000	53.76
Others	10,000	2.69
Total Investment	372,000	100.00

Source: PCC, 2007

Operation and maintenance costs

The current MSW management system is encountered with very high expenses towards operation and maintenance, which was about 122,900 USD in 2006 (Table 4.11).

Table 4.11 Overall operations and maintenance cost for MSW management in Phuntsholing city in 2006

Particulars	Cost	
	(USD)	(%)
Maintenance	36,500	43.71
Operation	30,000	35.93
Rent sites and buildings	15,000	17.96
Operational sites and building	2,000	2.40
Total operation and maintenance	*83,500*	*67.94*
Salaries	*39,400*	*32.06*
Total	122,900	100.00

Source: PCC, 2007

About 83,500 USD was spent mainly in operation and maintenance, which is about 68% of the total recurrent cost and rest 32% were spent for salaries. A breakdown of the operation and maintenance cost shows that, the expenses were made towards operation and maintenance of vehicle, equipments, and for renting sites and buildings. Most of the expenses on operation and maintenance cost were incurred towards waste collection and transportation. The operation and maintenance cost for waste collection and transportation of Phuntsholing city in 2006 is presented in Table 4.12.

It revealed that a total of about 81,217 USD were spent for overall waste collection and transportation service in the form of operation and maintenance of vehicle, and salaries. The majority of the expenses for waste collection were towards operation and maintenance of vehicle that is about 73% (58,949 USD) of its total expenses, and rest 27 % (22,267 USD) were for salaries. A breakdown of the expenses

for operation and maintenance of vehicle revealed that the expenses for compactor truck were higher than open truck.

Table 4.12 Operation and maintenance cost for waste collection and transportation of Phuntsholing city in 2006

Particulars	Operation and maintenance cost		
	(Nu/year)	(USD*/year)	(%)
Refuse compactor no.1	799,819.20	20,640.50	35.01
Refuse compactor no.2	769,281.60	19,852.43	33.68
Open truck no.1	715,183.20	18,456.34	31.31
Total	*2,284,284.00*	*58,949.26*	*72.58*
Salaries	*862,860.00*	*22,267.40*	*27.42*
Total	3,147,144.00	81,216.66	100.00

Source: PCC, 2007

Note: 1USD* = Nu. 38.75 (November 2007)

As the mentioned above, the overall expenses on operation and maintenance cost accounted to 122,900 USD out of which about 81,217 USD were attributed to waste collection and transportation. Therefore, as a whole almost 66% of expenses were incurred towards waste collection services. This revealed that the expenditures towards waste disposal are lower than collection and transportation. With assumption that solid waste collected in 2006 is equal to 2007, as a whole, the cost for operation and maintenance cost is about 37.55 USD/ton (0.40 USD/kg) of waste and cost for operation and maintenance for waste collection and transportation is about 24.81 USD/ton (0.03 USD/kg) of waste.

In the city, there are no direct user charges levied on households for waste collection or disposal or/and MSW service as a whole. While present study had limited information regarding exact figures of the tax collection rate, the residents were liable to common local taxes such as property tax. Thus, apart from the support from central government, the cost of operation of MSW management was covered by this general local tax collection. However, while municipality authority is responsible

for local tax collection, all the locally collected fees and generated revenues are transferred to the central government before being distributed to the local level. Thus, the misallocation of funds for waste management was clearly visible with current management system. Further, this kind of accounting procedures did not intend to provide any incentive for local authorities to improve the existing services. Therefore, while responsibility is being given, there was also necessity for local government's authority. As such, autonomy of local government in financial aspects was crucial as a resolution to mentioned problem.

Although, financial constraints for capital expenditures were met with support from central government and financial aids from donor agencies, there was crucial need for funding the recurrent expenditures such as for operation and maintenance. The concerned authorities of the municipality stressed that some kind of fund injection is necessary for current operation of waste management service and for improving existing service. Waste collection levy such as levying users' charges was suggestible option. The main concern is the question to implement a user charge scheme in areas where such services charges have never been imposed before without creating socio-political problems. The practitioner of user charges reveals that such problems can be avoided by establishing the affordability and willingness to pay for the management services in areas where user charges are to be imposed. Interestingly, the municipality had great opportunity to introduce the above mentioned charge. The survey exposed the fact that majority of the residents (88%) had willingness-to-pay for waste collection and disposal if the city is cleaner or has a better environment. Only 12% were not willing to pay as their main concern being the rate the authorities may impose (Appendix III; Tables 1 and 2). This called for consideration of resident's income for their affordability and rate to be charged. The level of user charge rate should be less than 1% of family monthly income which is applied worldwide (WHO, 1996: Online). Therefore, further study should be conducted looking at income level and establish the affordability and willingness-to-pay level and introduce such scheme to meet recurrent cost and for further improvement of current service.

Other available option to generate revenue is through sale of composting. As evident from waste composition study (Table 4.3), putrecible waste constituted highest fraction (31%) of the total waste. As such, there is an opportunity to capitalize on composting to generate additional revenue. While large scale composting plant may not be financially viable, but introducing small scale community based composting plant would be feasible option.

Cost reduction and control measures

As the earlier mentioned, the waste collection and transportation service was most expensive operation. It constituted about 66% of the overall operation and maintenance expenses. Thus, it was imperative for current waste management authorities to devote close attention to this area and look for ways and means of improvement and cost savings or/and cost reduction. This savings can then be used to provide funds for improvement in other areas of solid waste management such as for final disposal without increasing the overall solid waste management budget.

Obviously, the first priority option and straight way to reduce the variable cost component such as expenses on wages, fuel, maintenance, and other miscellaneous is waste volume reduction at source. This might be achieved through local resident's participation in local solid waste management. Basically, it would involve hiring of informal waste scavengers (Schubeler, Wehrle and Cristen, 1996: Online) or waste sorter. As such, they would not only help in cost reduction of collection cost, but also contribute to cost savings by reducing the volume of waste that needs to be transported and disposed to the landfill site. However, in the city, cost reduction through waste volume reduction at source was very limited. In fact, PCC had assigned few waste scavengers for waste recovery at the landfill site, and the quantity of waste recovered and their financial implication is presented in Table 4.7 under waste treatment and recovery section.

A total quantity of 30,840 kg of recyclable waste was recovered in 2006. Further, it also revealed high financial implication of more than 1,827 USD per year

through waste recovery. However, currently all the waste recovery through informal waste scavenging were done at the final disposal site. As such, the means of cost reduction at source and/or cost savings through waste volume reduction for transportation was very limited. Further, as all kinds of waste being recovered and the financial benefits obtained from recovered items were taken by waste scavenging individuals. Therefore, there were no direct financial benefits from waste recovery to current waste management system. However, the volume recovered with associated value indicated potential of waste that can be reduced at source for cost reduction and/or cost savings by reducing the volume of waste which needs to be transported and disposed in landfill site.

As per the present study on waste composition, it entrails high cost reduction and financial implication from waste scavenging as presented in Table 4.13.

Table 4.13 Cost reduction and cost saving potential of MSW in Phuntsholing city in 2007

Materials	Composition	Recoverable waste	Rate	Total amount	
	(%)	(kg/year)	(Nu/kg)	(Nu/year)	(USD/year)
Putrecible	31.04	1,015,941.09	NA	NA	NA
Paper	20.35	666,056.74	10.00	6,660,567.41	171,974.37
Plastics	10.84	354,793.86	0.50	177,396.93	4,580.35
Ferrous metals	2.34	76,588.34	NA	NA	NA
Non-ferrous	2.45	80,188.65	NA	NA	NA
Glass	10.74	351,520.86	6.00	2,109,125.13	54,457.14
Total	77.76	2,545,089.54	16.50	8,947,089.47	231,011.86

Source: Survey in November 2007

Note: Total waste generation is 3, 273, 06.10 kg in 2007 in Phuntsholing city

* Average rate provided by Phuntsholing City Corporation

1 USD = Nu. 38.75 (November 2007)

In an ideal case, out of total waste generation of 3,273,006 kg, about 2,545,090 kg of waste can be recovered through reuse and recycling of recyclables and

composting of putrecible waste. This indicates it has high cost reduction potential through waste reduction of about 78% of the waste generated through waste recovery. Moreover, there is also high financial implication of more than 231,002 USD per year through sale of recyclable materials alone. The shown financial implication is only for paper, plastics and glass which are exclusive of financial implication from ferrous and non-ferrous metals. Furthermore, textiles and wood (Ojeda-Benitez, Armijo de Vega and Ramirez-Barreto, 2003) and rubber (Table 4.7) are also recyclables which has financial implications. In real practice, some components of recyclables of paper, plastic, glasses, etc may not be recycled or have high financial values due to its degraded quality. Therefore, in general assuming that at least 30% of the waste components are highly recyclable with same rate, the financial implication is about 69,300 USD per year. As such, the financial implications are still high from waste recovery.

As evident from the above mentioned, as a whole, there is high potential for cost reduction through waste quantity reduction. Quite obviously, cost reduction implies a better utilization of available resources, introduction of appropriate methods and elimination of improper procedures. Currently, while waste recoveries are being practiced with involvement of informal waste scavengers, the methods of waste scavenging at disposal was not appropriate. It is because, since waste recoveries were being done at disposal site, it did not intend to reduce the volume of waste that needs to be transported and disposed off. As such, cost reduction for waste collection was very limited. Therefore, there was need to shift the waste scavenging at waste storage points instead of disposal sites to reduce the waste collection cost through waste volume reduction which needs to be transported and disposed to final disposal site.

4.3.3 Reflection of local residents in Phuntsholing city

Opinions of local residents in Phuntsholing city are prime indicator reflecting Phuntsholing City Corporation (PCC)'s service in municipal solid waste management. Before focusing local responses in this matter, PCC's working direction and style are discussed under the framework of concerned policies and implementation plans.

Policies and implementation plans

In the national level, National Environment Commission Secretariat (NECs), Ministry of Trade and Industry (MTI), Royal Society for Protection of Nature (RSPN) are major responsible agencies which create solid waste management policies and their implementation plans for all city corporations to work at municipal level. However, such policies and plans do not provide practical mechanisms for public officials to work efficiently and for local residents to participate in solid waste management properly.[1] In 2005, although the central government, DANIDA, and USPS provided financial supports to PCC in order to have a landfill site, compactor trucks, and other essential equipments, the PCC had not created specific policies and implementation plans for municipal solid waste management of the city.

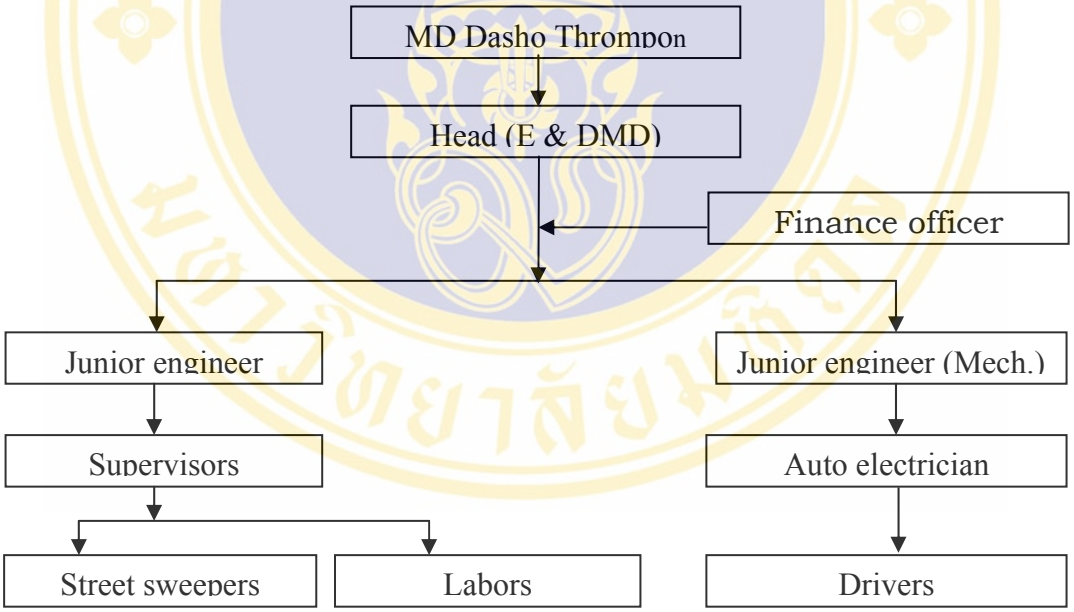

Figure 4.7 Organization chart of Phuntsholing City Corporation in 2007

Source: PCC, 2007

[1] For example, regulation on ban of plastic has failed to provide other materials to replace plastic use. Plastic in forms of drinking bottles, goods wrappings, and food containers have been noticed in public waste bins and at disposal site.

Without such policies and plans, PCC had no clear direction in working procedure. Moreover, when we focus on the existing administration body of PCC as shown in Figure 4.7, there are main sections of engineering and finance. Planning and monitoring sections, for instances, have not been established in its administration structure. As mentioned in earlier sections, the design of waste bins were poor and their distribution in the city were improper. Clearly, municipal solid waste management in Phuntsholing city had not employed any baseline data of waste generation and composition as well as behavior of local people in production and consumption. The PCC then had been facing with mismanagement of municipal solid waste.

Social responses

Phuntsholing city is second largest urban area besides Thimphu, the capital city of Bhutan. It is mainly a commercial hub which provides accommodation facilities, transportation, institutions, etc. Unquestionably, Phuntsholing city has faced rapid urbanization and high rate of rural-urban migration. In 2007, its urban area had about 22,500 of total population with 3,377 households (PCC, 2007). Most of them have used the city as a dumping and littering ground. Since 2005, PCC had just started solid waste management in order to curb open dumping by the locals. Doubtlessly, local people had not been clearly informed about this new management of solid waste.

Generally, local residents' concept of solid waste management is confined to cleanliness at their home so that there is a lack of their environmental awareness for especially public hygiene. Further, most people thought the PCC is the sole responsible agency to keep the city clean. This misunderstanding has led them to ignore their own responsibility of managing waste properly. Lack of collaboration between local people and the PCC can be noticed, for instances dirty roads, spillover of solid waste from the bins, etc. The researcher will show results of local opinions in solid waste management as follows.

In 2007, the researcher took a field survey by interviewing 338 respondents in municipality of Phuntsholing city which is around 10 % of the total households. Following process of solid waste management, opinions of local residents can be shown into 1) waste storage, 2) waste separation, 3) access to public containers, 4) waste collection and transportation, 5) waste collection fee, and 6) overall performance of PCC's service.

1. Waster storage

Local residents employed several types of waste storage containers at their households. Around 70 % of total samples used their own dustbins in forms of tins, carton box and plastic container whereas the rest used other materials such as plastic bag and nearby public container. Evidently, waste storage of local people depended upon their convenience, although there was a public regulation of ban on plastic. This action reflected of no collaboration between the local people and the PCC and the failure of information dissemination in solid waste management (Table 4.14).

Table 4.14 Waste storage containers at households in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Own plastic bag	47	13.90
Own dust bins	237	70.12
Public containers	54	15.98
Total	338	100.00

Source: Survey in November 2007

2. Waste separation

Generally, waste separation at household level is considered the best practice for reuse and recycle of waste. However, around 77 % of total samples did not separate waste because they thought it was not an important action and did not encourage any sound practice. Only 23 % of them separated waste because they

wanted to gain income by sorting valuable material for sale. Obviously, the survey revealed that about 82 % of total samples showed their collaboration to separate waste at home, if PCC has an action plan and put it into enforcement (Tables 4.15 and 4.16).

Table 4.15 Residents practice of waste separation in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (Separate their waste)	158	23.10
No (Do not separate their waste)	180	76.90
Total	338	100.00

Source: Survey in November 2007

Table 4.16 Resident's willingness to separate their waste in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (Willing to separate)	278	82.30
No (Not willing to separate)	60	17.80
Total	338	100.00

Source: Survey in November 2007

3. Access to public containers

Outside local households, PCC provided different types of public bins or containers to store household wastes. The survey revealed about 80 % had an access to PCC's waste containers while the rest of 20 % had no access by leaving their waste on the roadside or any open space (Table 4.17). However, the distribution of containers in three zones of the city was not well served to most residents because there had been no assessment of correct capacity of containers based on waste generation. As seen in high capacity containers such as masonry concrete and metallic sheet trolley bin were likely to serve only in confined area. In addition, residents almost not utilized them in full capacity.

Table 4.17 Access to public waste storage containers in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (Access to waste storage containers)	270	79.88
No (No Access)	68	20.12
Total	338	100.00

Source: Survey in November 2007

4. Waste collection and transportation

In practice, PCC had provided waste collection service of twice a day in three zones for its final disposal. Nevertheless, the survey showed different frequency of waste collection and transportation in all zones. More than half of total samples or about 66 % reported frequency of waste collection was about two times a day from the main roadsides, whereas around 25 % had only once a day and the rest had at least once to twice a week (Table 4.18). Reasons of these diverse occurrences were due to the poor road network and road surface condition which resulted in ineffective access of vehicles to waste containers.

Table 4.18 Frequency of waste collection service in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Daily once	84	24.85
Daily twice	222	65.68
Twice a week	14	4.14
Once a week	6	1.78
Others	12	3.55
Total	338	100.00

Source: Survey in November 2007

5. Waste collection fee

Obviously, no one clearly knew how residents paid for waste collection fee. The survey revealed that about 4 % of the samples thought they paid this fee through the tax payment for public services. Moreover, no one knew how much he or she paid for this. Consultation with the concerned authorities of PCC and the counter bills (Jamtsho.S, pers.comm. in November 2007) also confirmed that local residents were liable to local public services charges such as property tax, water and electricity charges, which were collected on monthly basis but there were no specific charges for waste collection fee. However, most people or about 88 % were willing to pay for waste collection and disposal if the city is cleaner or has a better urban environment (Tables 4.19 and 4.20).

Table 4.19 Payments for waste collection service in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (They pay for service)	14	4.14
No (Do not pay)	324	95.86
Total	338	100.00

Source: Survey in November 2007

Table 4.20 Resident's willingness to pay for improved waste collection service in Phuntsholing city in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (Willing to pay)	298	88.17
No (Not willing to pay)	40	11.83
Total	338	100.00

Source: Survey in November 2007

6. Overall performance of PCC's service

At present, Phuntsholing city was not so much clean and tidy. Around 77 and 80 % of total samples complained about flies, insects, and other vectors and about bad odor from waste containers reflecting poor management of waste collection respectively. However, most people or around 84 % of total samples were pleased with the overall performance of PCC in solid waste management because the PCC had just been established and they had started their work since 2005 (Tables 4.21 and 4.22).

Table 4.21 Complaints about current waste management service in Phuntsholing city in 2007

Existence of bad odors from waste storage areas			Existence of flies, insects and vectors from waste storage areas	
Responses	Total respondents		Total respondents	
	(Numbers)	(%)	(Numbers)	(%)
Yes	270	79.88	261	77.22
No	68	20.12	77	22.78
Total	338	100	338	100.00

Source: Survey in November 2007

Table 4.22 Resident's satisfaction towards current waste management service in 2007

Responses	Total respondents	
	(Numbers)	(%)
Yes (Satisfied)	283	83.73
No (Not satisfied)	55	16.27
Total	338	100.00

Source: Survey in November 2007

4.4 Conclusion

This chapter had presented the results of MSW characteristics and management study conducted in Phuntsholing city in November, 2007. Initially, chapter begins with results and discussion of MSW characteristicistics including waste generation rate and its composition, followed by discussion about existing waste management system including technical, financial, policy, planning and implementations and finally social collaboration in the city.

It was found that current waste generation rate is about 0.40 kg/capita.day. The waste composition study revealed the dominance of organic materials, especially food and yard wastes of 31%, which can be composted. Further, there was also high fraction of 46% recyclable materials that can be reused and recycled. As a whole, about 77% of the waste had potential for waste recovery.

In general, current waste management system was found to be ineffective in various aspects. Technically, the selection and use of inappropriate technologies to existing situation of city had led to inadequate provision of required facilities. Furthermore, financial constraints, lack of policy, planning and implementations of municipality and lack of social collaboration had compounded the problems to effectively manage the current waste management system.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The purpose of this chapter is to provide the conclusions drawn from the present study on municipal solid waste characterization and management study findings that was conducted in Phuntsholing city, Bhutan. Further, it aims to provide suitable recommendations as alternatives to improve its current municipal solid waste management system for the city. In general, increase in population, rapid urbanization and its economic growth in Phuntsholing city has led to increasing its quantity and change in its composition of the waste generated, which is poorly managed in terms of technical, financial, policy and planning, and social collaboration aspects.

First and foremost, the availability of reliable information on waste generation rate and composition holds its prime importance to design and planning of all the aspects of municipal solid waste management system. The study found that there was lack of any authentic data on both quantity and quality of waste. The waste generation rate estimation from the field survey in November 2007 showed increasing trend in waste generation with its major composition in forms of organic and recyclable components. Possibly, the organic components can be composted and used as soil conditioner, while other recyclables can be recovered through recycling processes. As such, there is high potential for waste reduction through waste recovery. Currently, Phuntsholing City Corporation as only public agency for the city, has tried to manage all kinds of waste generated but are encountered with many problems without any study being conducted since its establishment to assess the existing problems and alternatives for its improvement.

The technical aspects of solid waste management focused on the existing waste storage, collection and transportation, waste recovery and disposal system. It was found that lack of proper planning based on current existing information about the waste had led to inappropriate use and distribution of waste storage bins throughout the city. Waste collection and transportation was encountered with problems of high frequencies and under capacity utilization of vehicle capacity due to use of inappropriate collection vehicle that mismatched the current waste collection system. Moreover, despite prevalence of high waste recovery potential through composting and recycling, there was lack of or/and improper methods of waste recovery practices in the city. At the final disposal site, PCC did not operate it properly. There were mainly two problems especially the contamination of ground water or surface water due to uncontrolled leachate and air pollution by open burning. As such, current waste management system was technically inefficient and its performance remained low.

Financial aspects looked at investment cost, operation and maintenance costs and mechanism of cost reduction and control methods. Findings revealed that though initial investment cost was supported by donor agencies and central government funding, but financial constraints were mainly from operation and maintenance costs. In addition, lack of cost reduction and control mechanisms and lack of user charge for the service worsened the constraints. While some cost reduction measures such as waste volume reduction through waste recovery by informal waste scavengers were adopted, their methods were improperly done at waste disposal site which obviously did not reduce the cost. Clearly, improper financial accounting procedures due to non-autonomy of the municipality had created misallocation of the revenues generated from general local taxes.

In terms of policy and planning management in general, there were wide policy gaps along with poor enforcement primarily at national/central level. Policies and implementation plans at the municipality level did not exist. As such, current waste management system had worked without any clear direction of its working procedures and thus municipality is encountered with mismanagement of municipal solid waste in the city.

Regarding social collaboration between public and the municipality, there was lack of clear information about new management of solid waste and doubtlessly local residents' awareness was poor. While there was high willingness of public participation, current management system had taken very limited measures to encourage publics to participate in local solid waste management. Therefore, the present study identified some alternatives and recommendations, which may be useful to integrate in current municipal solid waste management system for its improvement.

5.2 Recommendations

5.2.1 Estimation of solid waste generation based on waste classification by source and considering seasonal variation for proper design and planning of current waste management system.

Present waste generation estimation based on actual amount of waste collection revealed that actual amount of waste generation is higher than actual amount of waste generated from sources due to waste diversions at waste storage points. Furthermore, evidence from other studies reveals that its estimation based on actual waste generation from source, taking into account of whole seasonal variation would provide more reliable data. Therefore, a further study on waste estimation based on waste classification by source considering whole seasonal variations is recommended.

5.2.2 Solid waste composition considering its seasonal variation for proper design and planning of effective waste management system in the city.

Present waste composition was estimated in November 2007 which was representative of a season. Evidence from other studies revealed waste will vary with seasonal variations. Therefore, further study considering whole seasonal variation is recommended to obtain reliable data about its composition.

5.2.3 Introduce waste separation at source by putrecible (food and yard wastes), recyclables and others for waste reduction, reuse and recycle as long term goals.

For waste volume reduction through reuse and recycle, waste separation at source is intrinsic step. It obviously demands public participation. Social survey revealed high opportunity for waste separation at household level, whereby about 82 percent of the local residents were willing to separate their waste at home if PCC had action plans. Further, since waste composition results showed dominance in putrecibles (food and yard wastes) followed by recyclables, and others (inert, misc.), waste separation at source into compostables, recyclables and others is recommended for waste reduction, reuse and recyclable as long term goals.

5.2.4 Waste recovery at appropriate place for composting and recycling as short term goals

Recycling

Current waste recovery for reuse and recycling was conducted with the help of waste scavenging at waste disposal site, which was not appropriate because this practice did not intend to reduce waste volume destined to landfill, nor does it reduce the burden of waste collection and transportation cost. Therefore, waste recovery for recycling at appropriate sites such as at waste storage points would bring advantage in terms of collection and transportation cost as well as waste volume reduction destined to landfill, which would increase the life span of current landfill site.

Composting

Provision of waste composting would depend upon the quantity of its material content in the waste stream and also availability of its market for its viability. Current waste composition estimation reveals highest fraction of putrecibles (31.04 percent) of the total waste. Therefore, composting is recommended in order to reduce waste

volume destined to landfill site and at the same to generate revenue for waste management.

5.2.5 Selection of appropriate waste storage bins and distribution of adequate number of bins according to existing waste generation information for reducing open dumping in open spaces.

Current waste storage bins are of mostly fixed and heavy type (metallic sheet trolley and masonry concrete bins) which had no flexibility to changing its locations, nor convenient for its use. Moreover, their use is highly unsuitable during rainy season due to its open nature and it did not intend to serve its basic purpose of maintaining aesthetic and hygienic conditions. Also, current waste storage bins are distributed mismatching with current waste generation, as such use of high capacity bins had been confined to certain location which resulted to improper numbers of bin coverage in the city. Selection and provision of appropriate of storage bins such as existing metallic sheet swing bins or plastic containers considering current waste generation information is highly recommended.

5.2.6 Selection of appropriate waste collection vehicle according to existing mixed waste collection system and improvement of existing vehicle capacity utilization to reduce waste collection frequency.

Current waste collection system was all mixed types including construction and demolition waste were collected along with solid waste stream. As such, use of compactor trucks for waste compaction is unsuitable in the city. Moreover, these high performance vehicles were mostly encountered with under utilization of their capacity. Therefore, selection and use of appropriate waste collection vehicle according to current mixed waste collection system such as opens trucks and other simple small vehicle are recommended. Further, existing vehicle capacities had to be improved through development of daily work monitoring procedures to reduce more frequent waste collection and transportation.

5.2.7 Closely control and upgrade existing landfill operation system

The means of waste volume reduction destined to landfill through open burning would bring about adverse impact to both local and global environment due to air pollution and ultimately an impact to human health. As such, waste volume reduction has to be controlled through waste recovery for composting and recycling and improved means of waste compaction at landfill site. Moreover, while operation of landfill through provision of perfect liner system and leachate treatment system might be impractical for small landfill site, however, measures for leachate minimization must be adopted through re-circulation and evaporation process as it is suitable due to its location in hot tropical zone. In addition, leachate storage facilities had to be upgraded to facilitate adequate generated leachate storage so as to prevent it overflows and ultimately to reduce contamination of nearby surface and ground water.

5.2.8 Autonomy of municipality regards to financial operation to prevent misallocation of funds generated for intended purpose of waste management.

Due to non autonomy of the municipality, whatever the revenues generated from general local taxes collected from residents were transferred to central government before being distributed to local level. As such, solid waste service revenues flow into general municipal account that intends to be absorbed by overall expenditures instead of being directly applied to intended purpose of waste management. As a result, misallocation funds were visible. Therefore, autonomy of municipality is primarily recommended in term of financial operation. Through autonomy, the municipality can conduct financial dealing such as collect fees and taxes and obtain direct benefits derived from sources and can be used directly without the consent of central government.

5.2.9 Cost reductions to reduce financial burden on recurrent operation and maintenance cost of waste management by increasing management capacity building and proper utilization of existing resources.

Initially, there is need to develop human capacity in the municipality in term of additional human resource and trainings. Only through strengthened such capacity, it would provide effective waste management service. For instance, most waste workers were untrained and there was under utilization of existing vehicle capacity, the waste collection system then remained inefficient and costly. Therefore, specific recommendations are suggested for the improvement of municipal financial capacity for current waste management system as follows:

- Reinforce and follow up with cost recovery practices,
- Introduce cost effective collection methods,
- Introduce and initiate public participation to waste management,
- Lower cost by increasing management capacity buildings.Improve capacity utilization of existing equipments/vehicle

5.2.10 Introduce user charge for waste management service to generate revenue to meet its recurrent operation and maintenance cost

In the city, there was no direct user charge applied for waste management service. As such, current waste management system was encountered with high expenses especially in operation and maintenance costs without sources of revenue generation. In fact, some fund injection was necessary to compensate partial cost of operations. Therefore, it was recommended for further study about appropriate rate of user charge scheme.

5.2.11 Policy and implementation plans at municipality level

Policy and planning is essential to provide clear direction in working procedures. As evident from the existing organization structure of PCC with regards to waste management, there is no policy and planning department which can create working guidelines. Organization structure revealed their main focus on technical aspects. As such, their management was done on ad hoc basis and worked under no clear cut working procedures. Therefore, establishment of planning department in existing organization structure is highly recommended.

5.2.12 Public awareness programs and education about new management of solid waste to both public and children for fulfillment of both short and long term goals

Public education and awareness programs are highly recommended for both general public and childhood level. For general publics, media awareness through television, education and campaigns focusing on specific issues introducing new innovative alternatives needs to be adopted frequently for fulfillment of short term goals. At youth level, clubbing civic values and responsibilities in education curriculum is important for long term goals so that the youth will grow up as responsible adults.

5.2.13 Immediate littering clean up campaigns

Immediate mass clean up campaigns is also recommended to curb immediate goals to clean up the open dumplings in open spaces, and uncollected waste from all corners of the city. This short term clean up campaigns would also provide some advantage to maintain implementation plans and other follow-up regulations regarding waste management.

REFERENCES

Abu Qdais, H.A. (2007). Techno-economic assessment of municipal solid waste management in Jordan. *Waste Management,* 27, 1666-1672.

Agdag, O.N. (2008). Comparison of old and new municipal solid waste management system in Denizli, Turkey.*Waste Management*, doi10.1016/j.wasman.2008.01.012.

AI-Khatib, I.A., Arafat, H.A., Basheer, T., Shawahneh, H., Salahat, A., Eid, J., and Ali W. (2007). Trends and problems of solid waste management in developing countries: A case study in seven Palestinian districts. *Waste Management*, doi:10.1016/j.wasman.2006.11.006.

Alam, R., Chowdhury, M.A.I., Hasan, G.M.J., Karanjit, B., and Shrestha, L.R. (2007). Generation, storage, collection and transportation of municipal solid waste. A case study in the city of Katmandu, Capital of Nepal. *Waste Management,* doi:10.1016/j.wasman.2006.01.024.

Amponsah, S.K., and Salhi, S. (2004). The investigation of a class of capacitated Arc Routing problem: The collection of garbage in developing countries. *Waste Management,* 24, 711-721.

APO, (2007). *Solid Waste Management: Issues and Challenges in Asia.* Retrieved March 20, 2008, from http://www.apo-tokyo.org/00e-books/IS-22_SolidWasteMgt/IS-22_SolidWasteMgt.pdf.

Arntzen, J.W and Fidzani, N.H. (2000). *Human and Solid Waste Management in Africa: A case study of Accra, Gaborone and Harare.* Economic Instrument for Environment Management., Earthscan publication, London.

Aymoh, M.K.O., Oke, S.A., and Adedeji, W.O. (2007). An approach to tackling environmental and health impacts of municipal solid waste disposal in developing countries. *Journal of Environment Management*, 43, 601-621.

Bernstein, J., Cassidy, G., Ayres, Kudat, A., Cartwright, K., and Mausolff, C. (2004). *Social assessment and public participation in municipal solid Waste management*. World Bank. Retrieved February 20, 2008, from http://www.worldbank.org/urban/uswm/socialassesstoolkit.pdf.

Buenrostro, O., Bocco, G., and Cram, S. (2001). Classification of source of municipal solid waste in developing countries. *Resource, Conservation and Recycling*, 32, 29-41.

Burley, S.J. (2007). The use of chemical composition data in waste management planning: A case study. *Waste Management*, 27, 327-336.

Cascadia Consulting Group, Inc. (1999). *Statewide waste characterization study.* Result and final report prepared by Cascadia consulting group, Inc. in cooperation with Calfornia Integrated waste management Board. Retrieved August 21, 2007, from www.ciwmb.ca.gov/publications.

Cascadia Consulting Group, Inc. (2004). *Statewide waste characterization study.* Contractors report to the Calfornia Integrated Waste Management Board produced under contract by Cascadia Consulting Group, Inc. Retrieved August 21, 2007, from www.ciwmb.ca.gov/publications.

Cascadia Consulting Group, Inc. (2006). *Detailed characterization of commercial self-haul and drop-box waste.* Contractor's report to Calfornia integrated waste management board produced under contract by Cascadia Consulting Group, Inc. Retrieved February 5, 2008, from www.ciwmb.ca.gov/publications.

Chang, N.B., and Davila, E. (2007). Municipal solid waste characterization and management strategies for the Lower Rio Grande Valley Texas. *Waste Management*, doi:10.1016/j.wasman.2007.04.002.

Cochran, W. G. (1963). *Sampling techniques*, 2nd Ed., New York: John Wiley and Sons, Inc.

Criner, G.K., Allen, T.G., and Schatzer, R.J. (2001). Composting economics: production and utilization in agriculture. In P.J. Stofella and B.A. Kahn (Eds.), *Composting utilization in horticultural cropping systems* (pp. 241-260). Boca Raton, FL: Lewis Publishers.

Dyson, B and Chang, N.B. (2005). Forecasting municipal solid waste generation in a fast growing urban region with system dynamics modeling. *Waste Management*, 25, 669-679.

EI-Hamouz, A.M. (2007). Logistical management and private sector involvement in reducing the cost of municipal solid waste collection services in the Tubas areas of West Bank. *Journal of Waste Management*, 28, 260-271.

ENPHO, (2007). Analysis of urban environmental issues of Nepal. Retrieved April 20, 2008, from environment and public health organization web http://www.enpho.org/adobe/WB%20Final%20Report%20_3rd%20Draft.pdf.

Gidarakos, E., Havas, G., and Ntzamalis, P. (2006). Municipal solid waste composition determination supporting integrated solid waste management system in Crete. *Waste Management*, 26, 668-679.

Hui, Y., Liao, W., Fenwei, S., and Gang, H. (2006). Urban solid waste management in Chongqing: Challenges and opportunities. *Waste Management,* 26, 1052-11062.

Israel, G.D. (1992). *Sampling the evidence of extension program impact.* Program evaluation and organizational development, IFAS, university of Florida. PEOD-5. Retrieved July 25, 2007, from http://edis.ifas.ufl.edu.

Jin, J., Wang, Z., and Ran, S. (2006). Solid waste management in Macao: practices and challenges. *Waste Management,* 26, 1045-1051.

Joos, W., Carabias, V., Winistoerfer, H., and Stuecheli, A. (1999). Social aspects of public waste management in Switzerland. *Waste Management,* 19, 417-425.

Kuensel, (2006). *Waste management ineffective*. Bhutan National News Paper 2006. Retrieved June 26, 2007, from http://www.kuenselonline.com/.

Kumar, S. (2005). Municipal solid waste management in India: Present Practices and Future Challenge. Retrieved December 30, 2007, from http://www.adb.org/Documents/Events/2005/SanitationWastewater_Management/paper-Kumar.pdf.

Magrinho,A., Didelet,F., and Semiao,V. (2006). Municipal solid waste disposal in Portugal. *Waste Management*, 26, 1477-11489.

METAP, (2000). *Solid Waste Management Strategy for METAP for Mashreq and Maghreb Countries.* Mediterranean Environmental Technical Assistance Program (METAP). Retrieved March 10, 2008, from http://www.metap.org/files/SW/SWMStrategy.pdf.

Mihelcic and Hutzler, (1999). *Solid Waste Management: Supplement to Fundamentals of Environmental Engineering*, John Wiley and Sons, Inc.

MOC, (1999). *Bhutan Municipal Act 1999.* Ministry of Communication, Thimphu.

MoWHS and UNEP, (2006). *Draft Integrated Solid Waste Management Strategy.* Ministry of Works and Human Settlement and UNEP.

Nair, C. (1993). *Solid waste management in emerging industrialized countries.* Retrieved February 15, 2007, from http://www.eco-web.com/editorial/01060.html.

Nas, S. S., and Bayram, A. (2007). Municipal solid waste characteristics and management in Gumushane, Turkey. *Waste Management*, doi:10.1016/j.wasman.2007.09-039.

NEC, (1999). *National Environment Strategy, "The Middle path",* Thimphu.

NEC, (2000). *Brief Report on State of Environment.* National Environment Commission Secrétariat, Thimphu.

NEC, (2002). *Environmental Codes of Practice for Hazardous Waste Management,* Thimphu.

Neuman, C.G. (2003). *Social Research Method*, Boston, Pearson Education, Inc.

Ojeda-Benitez, S., Armijo de Vega, C., and Ramirez-Barreto, M.E. (2003). Characterization and quantification of household solid waste in Mexican city. *Resource, Conservation and Recycling,* 39, 211-222.

Pasang, H., Moore, G.A., and Sittorus, G. (2006). Neighborhood-based waste management: A solution for solid waste problems in Jakarta. Indonesia. *Waste Management*, 27, 1924-1938.

PCC, (2005). Municipal solid waste management plan, Phuntsholing.

PCC, (2007). Yearly Records of Municipal Solid Waste Management in Phuntsholing. Solid Waste Management Division, Phuntsholing.

PHCB, (2005). Population and Housing Census of Bhutan. Retrieved August 20, 2007, from www.bhutancensus.gov.bt/faq.htm-14K.

Pokharel, D., and Viraraghavan, T. (2005). Municipal solid waste management in Nepal: Practices and challenges. *Waste Management,* 25, 555-562.

PWD and MOC, (1995). *Water and Sanitation Rules 1995.* Ministry of Communication and Public Works Department, Thimphu.

Raji, D. V., Wakhare, P. D., and Deshpande, A. W. (2001). An approach to assess level of satisfaction of residents in relation to solid waste management system. *Waste Management and Research*, 19, 12-19.

Rathi, S. (2006). Alternative approaches for better municipal solid waste management in Mumbai, India. *Waste Management*, 26, 1192-1200.

Rhyner, C.R., Schwartz, L.J., Wenger, R.B., and Kohrell, M.G. (1995). *Waste management and resource recovery.* Boca Raton, FL: CRC Press, Inc.

Saundra, C.L. (1994). Private Sector Participation in Municipal Solid Waste Service in Developing Countries. Retrieved May 10, 2008, from http://www.worldbank.org/html/fpd/urban/mun_fin/toolkit/private_sector_part. Html.

Schubeler, P., Wehrle, K., and Christen J. (1996**).** *Conceptual framework for municipal solid waste management in Low-Income Countries.* UNDP/UNCHS (Habitat)/World Bank/SDC collaborative Programme on municipal solid waste management in Low-Income countries. Retrieved October 10, 2007, from http://www.eawag.ch/organization/abteilungen/sandec/publications_swm/downloads_swm/conceptualframework-swm-Schebuler.pdf.

Sha Ato, R., Aboho, S. Y., Oketunde, F.O., Eneji, I.S., Unazi, G., and Agwa, S. (2007). Survey solid waste generation and composition in a rapidly growing urban area in Central Nigeria. *Waste Management,* 27, 352-358.

Sharholy, M., Ahmad, K., Vaishya, R.C., and Gupta, R.D. (2006). Municipal solid waste characteristic and Management in Allahabad, India. *Waste Management,* 27,490-496.

Talyan, V., Dahiya, R. P., and Sreekrishna, T.R. (2007). State of municipal solid waste management in Delhi, the capital of India. *Waste Management,* 28, 1276-1287.

Tammemagi, H. (1999). The Waste Crisis: Landfills, Incinerators, and the Search for a Sustainable Future. Oxford University Press, New York.

TCC and NEC, (1992). *Action Plan for Thimphu*, Thimphu City Corporation and National Environment Commission, Thimphu.

Tchobanoglous, G., Thiensen, H., and Vigil, S. (1993). *Integrated solid waste management, engineering principles and management Issues*, McGraw- Hill, Inc.New York.

Tinmaz, E., and Demir, E. 2006. Research on solid waste management system: To improve the existing situation in Corlu town of Turkey. *Waste Management,* 26, 307-314.

Vidanarachi, C. K., Yuen, S. T. S., and Pilapitiya, S. (2006). Municipal solid waste management in southern province of Sri Lanka: Problems, issues and challenges. *Waste Management,* 26, 920-930.

Viniegra, M.E.I., Cortes, I.I, and Cuevas, E.M, (2001). *Economic valuation of the environmental impact of solid waste management: A Case Study*. Retrieved January 28, 2008, from http://www.bu.edu/econ/ied/neudc/papers/Ibarraran-final.pdf.

Vishvanathan, C and Trankler, J. (2007). *Municipal solid waste management in Asia: A comparative analysis.* Retrieved February 30, 2008, from http://www.swlf.ait.ac.th/data/Kasetsart%20University%20National%20Seminar%20on%20Solid%20Waste%20Landfill%20Ma/MSWM%20in%20Asia-final.pdf.

WHO, (1996). Healthy cities-healthy islands. *Guides for municipal solid waste management in pacific island countries.* Retrieved September 16, 2007, from http://www.wpro.who.int/NR/rdonlyres/3E5F4D58-4C17-4C23-B957-7EE74509216E/0/pacificguide.pdf.

World Bank, (1999). *What a waste: Solid Waste Management in Asia.* Urban development sector unit, East Asia, and pacific region, World Bank, Washington, D.E. Retrieved March 30, 2008, from http/:www.worldbank.org/html/fpd/urban/publicat/whatawaste.pdf.

APPENDIX

APPENDIX I

FIELD RECORD OF WASTE COLLECTED BY EACH VEHICLE TO ESTIMATE WASTE GENERATION IN PHUNTSHOLING CITY

Table 1: Waste collection in Phuntsholing city in November 2007

Date	Day		Compactor truck no.2		Compactor truck no.1		Open truck no.1		Three vehicle	
			Vehicle No. BG-2-0492		Vehicle No. BG-2-0494		Vehicle No. BG-2-0359			
			Gross weight (kg)	Net weight (kg)	Gross weight (kg)	Net weight (kg)	Gross weight (kg)	Net weight (kg)	Gross weight (kg)	Net weight (kg)
29.10.07	Mon	AM	5,300	1,270	6,100	1,100	8,400	3,200	19,800	5,570
		PM	5,110	1,080	6,330	1,330	7,300	2,100	18,740	4,510
30.10.07	Tues	AM	4,730	700	6,060	1,060	7,070	1,870	17,860	3,630
		PM	5,210	1,180	6,700	1,700	7,200	2,000	19,110	4,880
31.10.07	Wed	AM	5,300	1,270	6,200	1,200	6,700	1,500	18,200	3,970
		PM	4,970	940	7,200	2,200	7,900	2,700	20,070	5,840
1.11.07	Thur	AM	5,260	1,230	6,600	1,600	8,500	3,300	20,360	6,130
		PM	4,920	890	6,000	1,000	7,700	2,500	18,620	4,390
2.11.07	Fri	AM	4,530	500	6,600	1,600	7,120	1,920	18,250	4,020
		PM	4,780	750	6,400	1,400	7,500	2,300	18,680	4,450
3.11.07	Sat	AM	5,320	1,290	6,680	1,680	6,800	1,600	18,800	4,570
		PM	5,210	1,180	6,200	1,200	7,500	2,300	18,910	4,680
4.11.07	Sun	AM	5,260	1,230	6,800	1,800	8,300	3,100	20,360	6,130
Total	**-**	**-**	**65,900**	**13,510**	**83,870**	**18,870**	**97,990**	**30,390**	**247,760**	**62,770**

Source: Survey in November 2007

Table 2: Vehicle capacity and volume of waste collected by each vehicle in Phuntsholing city in 2007

Date	Day		Compactor no.2 Vehicle No. BG-2-0492		Compactortruckno.1 Vehicle No. BG-2-0494		Open truck no.1 Vehicle No. BG-2-0359		Total volume	
			Vehicle capacity (m^3)	Waste volume (m^3)	Vehicle capacity (m^3)	Waste volume (m^3)	Vehicle capacity (m^3)	Waste volume (m^3)	Vehicle capacity (m^3)	Waste volume (m^3)
29.10.07	Mon	AM	5.10	4.10	9.00	6.00	6.00	6.00	20.10	16.10
		PM	5.10	4.10	9.00	6.00	6.00	6.00	20.10	16.10
30.10.07	Tues	AM	5.10	3.10	9.00	6.00	6.00	6.00	20.10	15.10
		PM	5.10	4.10	9.00	7.00	6.00	6.00	20.10	17.10
31.10.07	Wed	AM	5.10	4.10	9.00	7.00	6.00	6.00	20.10	17.10
		PM	5.10	4.10	9.00	7.00	6.00	6.00	20.10	17.10
1.11.07	Thur	AM	5.10	4.10	9.00	6.00	6.00	6.00	20.10	16.10
		PM	5.10	4.10	9.00	5.00	6.00	6.00	20.10	15.10
2.11.07	Fri	AM	5.10	3.10	9.00	7.00	6.00	6.00	20.10	16.10
		PM	5.10	3.10	9.00	6.00	6.00	6.00	20.10	15.10
3.11.07	Sat	AM	5.10	4.10	9.00	6.00	6.00	6.00	20.10	16.10
		PM	5.10	4.10	9.00	5.00	6.00	5.00	20.10	14.10
4.11.07	Sun	AM	5.10	4.10	9.00	7.00	6.00	6.00	20.10	17.10
Total	**-**	**-**	**66.30**	**50.30**	**117.00**	**81.00**	**78.00**	**77.00**	**261.30**	**208.30**

Source: Survey in November 2007

APPENDIX II

FIELD RECORD OF WET-WEIGHT OF THE WASTE COMPONENTS OF WASTE SAMPLES

Table 1: Wet-weight of waste samples in Phuntsholing city in November 2007

Materials	Wet-weight of waste samples						Total weight	
	S 1 (kg)	S 2 (kg)	S 3 (kg)	S 4 (kg)	S 5 (kg)	S 6 (kg)	(kg)	%
Putrecibles	31.80	40.10	35.80	29.90	32.30	42.20	212.10	31.04
Paper	35.50	25.80	19.50	22.20	19.10	16.90	139.00	20.35
Plastics	15.40	10.30	8.50	12.70	12.40	14.80	74.10	10.84
LWTR	12.50	9.20	11.20	9.50	7.60	9.40	59.40	8.70
Ferrous metals	4.20	2.80	3.80	2.40	1.50	1.30	16.00	2.34
Non-ferrous	5.30	3.20	3.50	1.60	2.40	0.70	16.70	2.45
Glass	21.10	10.20	13.80	7.40	10.10	10.80	73.40	10.74
Inert	4.80	8.40	9.60	9.80	10.10	14.80	57.50	8.42
Misc.	5.30	6.20	4.50	6.20	8.50	4.30	35.00	5.12
Total	135.90	116.20	110.20	102.00	104.00	115.20	683.20	100.00

Source: Survey in November 2007.

Note : Samples (S1-S3) were obtained from designated collection spots and samples (S4-S6) were from waste collection vehicles

APPENDIX III

QUESTIONAIRES FOR SOCIAL SURVEY IN PHUNTSHOLING CITY IN NOVEMBER 2007

Questionnaire for social survey to grasp understanding on waste generation, disposal pattern, public participation and opinions about current solid waste management system in Phuntsholing city.

By Mr. Norbu, Post graduate student,

Faculty of Environment and Resource Studies, Mahidol University, Salaya

Table 1: Questionnaire for social survey in Phuntsholing city in 2007

Bio-data
Name/address:
Occupation:
Number of household members:
Type of house: residential/ commercial
Location: near the road/ away from road
A. Waste storage
A1. Where do you store your garbage? (a). Own plastic bag (b). Own duct bins; (c). Public containers
A2. Does Phuntsholing City Corporation provide containers to store your garbage in your area? (a). Yes (b). No
A3. Do you separate your waste at your home? (a). Yes (Go to 4 and 5) (b). No (Go to 6)

A4. If you separate your waste, why do you separate your waste? (a). PCC wants you to separate your waste (b). You gain some materials for sale (c). Others
A5. If you separate your waste, how do you separate your waste? (a). Separate into dry and wet waste (b). Others (specify it please)
A6. If you don't separate your waste, why don't you separate your waste? ……
A7. If you are asked to separate you waste by PCC, are you willing to separate your waste at your house? (a). Yes (Go to 8) (b). No (Go to 9)
A8. If yes, why do you want to separate your waste at your home? ……
A9. If no, why you do not want to separate your waste at your home? ……
B. Waste collection and transportation
B1. Does PCC provide waste collection service in your area? (a). Yes (Go to 2, 3, 4 and 5) (b). No (Go to 10)
B2. If yes, how many times do they collect the waste? (a). Daily once (b). Twice daily (c). Twice a week (d). Once a week (e). Others (specify it please).
B3. Do you pay for the waste collection service? (a). Yes (b). No
B4. How much do you pay per month or per year?

……...
B5. How do you pay for the waste collection service? (a). In terms of tax (b). Others (specify it please).
B6. Are you satisfied with current waste collection service provided by PCC? (a). Yes (Go to B7) (b). No (Go to B8 and 9)
B7. Why do you think current waste collection service is satisfactory? ……...
B8. Why you are not satisfied with current waste collection service? ……...
B9. What is your suggestion to PCC for improvement in waste collection service? ……...
B10. If there is no waste collection service, what is your opinion about provision of waste collection service by PCC? (a). PCC should provide the service (b). Not necessary to provide.
B11. Why do you think PCC should provide waste collection service? ……...
B12. If PCC provides waste collection service, are you willing to pay some amount for the improved waste collection service? (a). Yes (b). No
B13. Why do you want to pay or not to pay for the service? ……...
C. Disposal
C1. Where do you often dump your garbage? (a). Open street (Go to C2) (b). Public containers (Go to C3)
C2. Why do you dump your garbage in the open street? ……...

C3. Why do you use public containers? ……
D. Complaint about current waste management service
D2. Most of the waste in your area is left uncollected? (a). Yes (b). No
D3. There is too much of bad odor/smell from waste storage areas? (a). Yes (b). No
D4. There are so much of flies and insects form waste storage areas? (a). Yes (b). No
D5. There is so much of waste spillage during waste collection and transportation? (a). Yes (b). No
D6. How is the workers performance? (a). Their service is good (b). Their service is not good
D7. If workers performance is not good, what is your suggestion for improvement? ……
E. Satisfaction towards current waste management service
E1. Are you satisfied with current waste management service in your area/home? (a). Satisfied (Go to E2) (b). Not satisfied (Go to E3)
E2. Why do you think current waste management service is satisfactory? ……
E3. Why do you think current waste management service is not satisfactory? ……
E4. What is your suggestion to PCC for improving the current waste management service? ……

Table 2: Respondent's analysis in Phuntsholing city in 2007

Question	Responses	Respondents (%)
A.1	a. Own plastic bag	13.91
	b. Own duct bins	70.12
	c. Public containers	15.98
A.2	a. Yes	79.88
	b. No	20.12
A.3	a. Yes	23.08
	b. No	76.92
A.4	a. PCC wants you to separate your waste	1.48
	b. You gain some materials for sale	97.93
	c. Others	1.48
A.5	a. Separate into dry and wet waste	5.33
	b. Others	94.67
A.6	- Time constraint and separated materials may land up in the same landfill site. - Others (e.g. No use of separation, dirty work, etc)	80.00 20.00
A.7	a. Yes	82.25
	b. No	17.75
A.8	- Gain financial benefits from sale of wasted items and maintain hygiene at home. - Others (e.g. Usual practice)	88.50 11.50
A.9	- No time and there is no use of separating waste. - Others (e.g. Dirty work, no workers at home, etc)	85.00 15.00
B.1	a. Yes	92.31
	b. No	7.69
B.2	a. Daily once	24.85
	b. Twice daily	65.68

	c. Twice a week	4.14
	d. Once a week	1.78
	e. Others	3.55
B.3	a. Yes	4.14
	b. No	95.86
B.4	- Do not know but feel it is paid along with other bills. - Others (e.g. Water charge gone high, may be charged with water bills)	98.00 2.00
B.5	a. In terms of tax	0.59
	b. Others	99.41
B.6	a. Yes	84.62
	b. No	15.38
B.7	- PCC is maintaining the city clean and they collect individuals waste with no charge. - Others (e.g. Provided alternatives for our disposal)	95.00 5.00
B.8	- At times, Waste remains uncollected in our area. - Others (e.g. Workers skip our area, flies, bad smell from storage area, etc)	67.50 32.50
B.9	- Provide more sweepers and sufficient number of waste bins. - Strict supervision of workers. - Others (e.g. More vehicles, regular service, etc)	60.00 24.80 15.20
B.10	a. PCC should provide the service	43.79
	b. Not necessary to provide	56.21
B.11	- Keep city clean. - Others (e.g. Their responsibility, etc)	92.80 7.20
B.12	a. Yes	88.17
	b. No	11.83

B.13	- Want pay because they are providing service to keep our surrounding clean. - Others (e.g. Give cooperation, etc)	99.00 1.00
	- Do not want to pay because we must be paying with other bills. - Others (e.g. Cannot afford, generate less waste, etc)	94.00 6.00
C.1	a. Open street	19.53
	b. Public containers	80.47
C.2	- There is no waste storage bins nearby. - PCC allows us to store our waste in some areas. - Others (e.g. No options, usual practice, etc)	97.80 1.20 1.00
C.3	- PCC provided waste storage facilities in our areas, storage bins are easily accessible. - Others (e.g. PCC advised us, our bins gets filled up)	99.20
D.1	a. Yes	43.2
	b. No	56.8
D.2	a. Yes	50.89
	b. No	49.11
D.3	a. Yes	79.88
	b. No	20.12
D.4	a. Yes	77.22
	b. No	22.78
D.5	a. Yes	39.19
	b. No	60.95
D.6	a. Their service is good	79.88
	b. Their service is not good	20.12
D.7	- Strict supervision of waste workers required and provide training.	68.40

	- Others (e.g. Provide basic necessities, etc)	31.60
E.1	a. Satisfied	83.73
	b. Not satisfied	16.27
E.2	- City cleanliness improved compared to previous years, PCC collects waste from individuals with free service. - Others (e.g. Doing good for us, etc)	89.00 11.00
E.3	- Waste not collected sometimes, bad smells from storage areas especially during rainy season. - Others (e.g. Spillage of waste, backyards not clean)	55.00 45.00
E.4	- PCC need to conduct mass clean up. - Most of the people are not aware of handling waste; they need to conduct some awareness programs. - There is need to inform about do's and don'ts of individuals and enforce some kind of penalties for the defaulters. - Need to improve waste storage facility.	29.00 21.25 19.34 30.41

APPENDIX IV

POLICY REVIEW OF BHUTAN PERTAINING TO SOLID WASTE MANAGEMENT

Water and Sanitation rules 1995

Water and sanitation rules 1995 were prepared by public works division of ministry of communication (PWD and MOC, 1995). The motive behind the regulation was the fact that, in the urban areas due to uncontrolled waste disposal, it had resulted to aesthetically unsound, unhealthy conditions, waste of resource and landfill sites. Therefore, this policy was to safeguard public health, maintain its aesthetic conditions, and to reduce the quantity of waste that is disposed. The formulated rules tend to ensure the prerequisites to sustainable urban development and it spells out concepts for efficient management of the urban utilities with clear delineation of the responsibilities of the city corporations and the residents. The rules oriented to waste management are summarized under different category of rules; general, specific and amendment rules. General rule focus on ways of disposing the generated waste, specific rules for waste generators and amendment rules for municipalities.

General rules

Provisions for littering and unauthorized dumping clearly states that all solid waste, unless specifically explained in the rules, shall be disposed off in receptacles provided or approved by the city corporation. It also prohibits littering and unauthorized dumping of solid waste not only in Thimphu but throughout the country.

The rules not only prohibit any individuals from damaging any public waste collection equipment, including use-me bins, bin supports, and steel containers but also restricts burning of waste, disposal of hot ashes, and activities that potentially cause damage to public waste collection equipment. Further, it prohibits any person

from removing public waste collection facilities from locations assigned by City Corporation.

Burning of solid waste within the city boundaries is permitted under no circumstances of threat to public health, safety, property and the environment. The city corporation may order the burning of solid waste be ceased under conditions including, but not limited to, nuisance smoke, fire hazard, or poor air quality. It also requires the ashes from burnt solid waste to be disposed off in the same manner as household waste but not in condition of causing fire.

The rules also require composting within the city limits to be conducted in a manner that prevents animals or weather from scattering the composting materials and which does not create unreasonable odors, vermin or other nuisance.

Scrap dealing is permitted under the condition that scrap dealers are required to have valid licenses, city corporations approved locations, accept legally obtained scrap, store scraps in enclosed compounds with no threat to public health and safety, maintain cleanliness of the storage to prevent rats and vermin, segregate and store hazardous and inflammable waste under roofed area to prevent seepage/leakage into the environment. They are also required to dispose off the unsold scraps and associated solid wastes in a way that is approved by City Corporation.

Specific rules

These rules are for urban entities that generate waste. The rules require all residents, business and institutions, as generators of waste within the city boundaries, to manage the solid waste that they generate in a manner that does not threaten the public environment. Specifically, residents are required to dispose off all the solid waste, other than the composted or recycled ones, in a container or bin approved by the city/municipal corporation and containers are required to be emptied at collection locations as per schedules. Vendors and customers at the public markets are required to dispose off all solid waste generated in the bins provided by the city/municipal corporation.

Institutions including health care facilities such as hospitals and clinics are required to abide by certain regulations in the disposal of pathological, infectious, pharmaceutical and other wastes requiring special care. Pathological and infectious wastes are required to be collected in sterilized containers or disposable bag and incinerated at the Jigme Dorji Wangchuck Referral Hospital or treated by decomposition in slaked lime. The rules also prohibits disposal of special hospital waste and pharmaceutical waste in the city/municipal corporation's public waste bins or containers. Health facilities are required to collect special hospital waste and prevent accidental contact with waste collection workers or public. Incinerated ash and fully decomposed treatment residues shall be disposed off in the same manner as waste from residences.

Offices, schools, and institutions are required to provide sufficient receptacles for solid waste. The non recycled contents are required to be emptied into a container or bin approved by the city/municipal corporation at an established location. Non-domestic solid waste generated at construction or demolition sites, including, but not limited to, concrete and brick rubbles and wood waste, is prohibited for dumping without the disposal instructions from the city corporation.

Vehicle repair workshops within the city boundaries are required to dispose off solid waste that they generate in ways that do not threaten the environment or the health and safety of the workers and public. They are subject to sanitary inspection for compliance of the rules including;

- Storage of waste oil in drums under conditions that minimize risk of fire and accidental spillage or leakage; prevent flow of oil into water bodies,
- Disposal to city's landfill site is prohibited. Disposal is permissible only through methods that include burning of oil waste in appropriate apparatus or shipping to an oil recovery business,
- The rules also requires chemical industries to dispose off chemical wastes either through shipment to qualified recycling business for recovery or by minimizing the impacts through neutralization and evaporation process,

- Industries located within the city limits are required to minimize quantity of industrial waste and dispose off in ways that do to threaten the environment, health and safety of its workers and the public. They are required to provide reports every two years on the type, source, and quantity of industrial wastes it generates. The city/municipal corporations on the basis of the report will provide the directions for disposal.

It is the policy of City Corporation to encourage residence, commercial establishment, institutions and industries, located within the city/municipal boundaries to sell or otherwise recycle recyclable material rather than disposing it.

The rules also contain regulation for collection, transport and disposal of solid waste. The rules require that collection, transport and disposal of solid waste that is generated within the city/municipal boundary shall be done in a manner that protects both the environment and health and safety of the public and the waste workers. It requires that city/municipal corporation to conduct solid waste management by;

- Providing/approving sufficient waste collection receptacles and locations for the public use,
- Collecting solid waste at a frequency and in a manner sufficient to protect public health and prevent visually unattractive condition,
- Transporting solid waste in a manner that prevents its blowing or falling from collection vehicles,
- Disposal of solid waste in city/municipal Corporation approved locations and disposal sites and practices to comply with applicable Royal Governmental environmental standards.

The rules also provides for sanctioning of fines or labor contributions to clean up solid waste within the city as may be specified by the city corporation from time to time. The respective municipalities are authorized to amend the rules from time to time if necessary. The documents grants the city corporation with authority to enforce the rules contained therein, and also enact and enforce solid waste management rules in future.

Bhutan Municipal Act 1999

This Act was prepared by Ministry of Works and Human Settlement (MOC, 1999). It was aimed to enable the establishment of municipal city corporation as legal entities with perpetual successories, and to confer powers as required to forgo partnership between the municipal corporations, the residents, business and industries of municipality for effective development and governance of kingdoms urban communities. The Act does not contain any specific provisions related to urban waste management.

Action plan for Thimphu 1992

It was prepared by National Environment Commission secretariat and Thimphu City Corporation (TCC and NEC, 1992). It was intended to provide first step towards making Thimphu city a model city. While in this action plan, one recommendation was:

- Autonomy of the Thimphu city corporation in administrative and financial matters. Only though such autonomy it is possible to ensure city corporations ability to implement its plans and to develop the necessary sense of responsibility among the citizens; example by correlating fees and taxes directly with benefits derived from sources. However, the mentioned recommendation had remained unimplemented till this date.

BIOGRAPHY

NAME	Mr. Norbu
DATE OF BIRTH	15th March, 1976
PLACE OF BIRTH	Mangthari, Dungmith,Pema Gatshel, Bhutan
PREVIOUS EDUCATION	Sherubtse College,Kanglung University Bachelor of Science (Bio-Mathematic, 1997) Thangul Kunju Musaliar College of Engineering(TKMCE), Kerala University, India BE (Chemical Engineering, 2003)
FELLOWSHIP STUDY GRANT	Thai International Post-Graduate Fellowship Program for the Academic Year 2006, Thailand International Cooperation Agency (TICA)
PREVIOUS POSITION HELD	Assistance Chemical Engineer, Production Department; Head of Environment Department, Bhutan Carbide & Chemicals Ltd., Phuntsholing,Bhutan
HOME ADDRESS	Bhutan Carbide & Chemicals Ltd, Post Box 101, Pasakha, Phuntsholing, Bhutan
EMAIL ADDRESS	noobooz@yahoo.com/ tshering_norbu04@hotmail.com