INVENT

HANDBOOK

Innovative Education Modules and Tools for the Environmental Sector, particularly in Integrated Waste Management

Part I

Curricula and Modules

ASIA LINK

EUROPEAID CO-OPERATION OFFICE

January 2009

HOCHSCHULE BREMEN UNIVERSITY OF APPLIED SCIENCES

TECHNISCHE UNIVERSITÄT DRESDEN

HHL. LEIPZIG GRADUATE SCHOOL OF MANAGEMENT

CARDIFF UNIVERSITY PRIFYSGOL CAERDYD

The handbook has been produced by the following consortium, within the framwork of the INVENT-project: „Integrated Waste Management Modules of different courses of Graduate Studies“

Project leader:

Hochschule Bremen,
University of Applied Schiences, Germany
Dr. rer.nat. Martin Wittmaier
Dipl.-Ing. Stefanie Langer M.Sc.
Dipl.-Geoökol. Sebastian Wolff

Technische Universität Dresden,
Technical University of Dresden, Germany
Prof. Dr.-Ing. habil. B. Bilitewski
Prof. Dr. rer.nat. P. Werner
Dr.-Ing. Catalin Stefan
Dipl.-Ing. Daniel Schingnitz

Handelshochschule Leipzig,
Leipzig Graduate School of Management, Germany
Prof. Dr. Hans Wiesmeth
Ms. Rhama Parthasarathy M.A.

Cardiff University, United Kingdom
Dr. C.F. Wooldridge
Mr. Joe Green

Can Tho University, Vietnam
Dr. Do Ngoc Quynh
Mr. Le Hoang Viet
Mr. Nguyen Vo Chau Ngan
Mr. Nguyen Xuan Hoang

Hanoi University of Science, Vietnam
Prof. Dr. Nguyen Thi Diem Trang
Ms. Pham Hai Minh

Royal University of Agriculture, Cambodia
Prof. Dr. Visalsok Touch
Mr. Keo Samell

National University of Laos, Laos
Assoc. Prof. Souphab Khouangvichit
Mr. Phetala Daladone

King Mongkut’s University of Technology Thonburi
Prof. Dr. Suvit Tia
Dr. Warinthorn Songkasiri
Mr. Terry Commins

January 2009

Curricula and content of the courses related to waste management and renewable energy from biomass/waste

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
<u>General Approach:</u> • Introduction to systems and processes for reduction, reuse, recycling, treatment and final disposal of wastes • Understanding the processes of waste management • Linking and applying scientific and engineering knowledge for environmental technology problems and solutions, particularly for waste management and renewable energy. • Understanding methods and tools to realize, structure and elaborate problems related to environmental engineering, especially waste treatment and to find and present sustainable solutions, which are technical sensible and organisationally and legally applicable • target-oriented development and justification of engineering solutions • Transfer potential: Environmental Engineering, Chemical Engineering, Biotechnology, Physical Technics, Civil Engineering, Mechanical Engineering	<u>Teaching methods:</u> • Lectures as basic instrument • Training, short seminars, Projects, presentations and laboratory work for exemplary application of the developed skills • Excursions to selected facilities and sites • Literature research • Small engineering projects (based on case studies)	*1.Direct curriculum (INVENT main concept of the course): course* at School of Bio-reso and Technology, KMUTT Co Number: BIT 641 Course Name: Treatment and Utilization of Biological Wastes Semester: 2 of each academic year Course content: 1. Waste minimization and Integrated waste management (IWM) 2. Biological wastewater 3. Solid wastes 4. Utilization of wastes 5. Renewable energy 6. Integrated waste management 7. Clean development mechanism 2. Part of overall curriculum (INVENT Integrated Waste Management concept is				1. Master course "Waste Management and Contaminated Site Treatment" implemented every two year since 2005 2. Master course "Environmental Chemistry" related to waste management implemented every year 3. Study program of Bachelor Degree in Chemistry and Env. Science received Course with topics of Waste Management (INVENT's handbook is the main study material) 4. Workshop "The way to circular economy for Vietnam" (2007) and "Mechanical -

Module / Content		Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
			part of the overall curriculum): Master courses at School of bio-resources and technology, KMUTT - Treatment and utilization of biological wastes - Energy system design - Bio-energy conversion - Wastewater Treatment - Advanced wastewater treatment - treatment and utilization of solid wastes 3. Part of overall curriculum: Master courses at Chemical Engineering Department, Faculty of Engineering, KMUTT - Waste Treatment - Thermal Power system - Hazardous Materials & Safe Disposal of Hazardous Waste - Environment & Energy				Biological Treatment of Municipal Solid Waste - Fundamentals and Experiences"(2008) presented content of waste management

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
Lecture 1: Introduction to Integrated Waste Management						
• Correlation between economic growth and waste quantity • Principles of Integrated Waste Management • Principles of waste avoidance and waste reduction • Planning of waste management systems; regulatory framework, aims, costs	Learning Outcomes: • Have an awareness of the growing problem of waste disposal • Be aware of the key concepts of waste avoidance and reduction • Be aware of the planning aspects of waste management systems	Module 1 of Course “Treatment and Utilization of Biological Wastes” for M.S. students of school of bio-resources and technology, KMUTT	Agricultural Waste Mangement • Roles and Responsibilities • Sitting to minimize odour • Manure Storage • Use of manure • Dead animal management	Course “Pollution, its effects and management” (3 Credits) for (second semester, Year II) of Bachelor of Environment Sciences and Environment Management at Faculty of Environment Sciences, NUOL	- A part of course on “Solid Waste Management and Treatment” (3 credits) teaching for Bachelor students in Environment Engineering. - A part of course on “Hazardous Waste Management” (2credits) teaching for Bachelor student in Environment Science. - A part of course on “Waste Evaluation and Management” (2 credits) teaching for Master student in Environment Science. - A part of course on “Urban Environment Planning and Management” (2 credits) teaching for Master student in Environment Management.	

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
Lecture 2: Framework conditions of Waste management						
• General country facts • Policies and Strategies • Stakeholders • Economic framework • Socio-cultural and socio-economic framework	<u>Learning Outcomes</u>: • Be aware of the waste management legislative and policy structures • Be aware of the current waste situations • Understand the issues waste is causing	- a part of course on "treatment and utilization of biological wastes" : Module 5 (integrated waste management and Industrial ecology)		Course on "Solid waste Management" (3credits) for (first semester, Year III) of Bachelor of Environment Management and Environment Sciences at Faculty of Environment Sciences, NUOL	- A part of course on "Solid Waste Management and Treatment" (3 credits) teaching for Bachelor students in Environment Engineering. - A part of course on "Waste Evaluation and Management" (2 credits) teaching for Master student in Environment Science.	There are governmental annual report on Environment with solid waste's issues; Vietnam environmental law stated in 2005; 3R policy as the most concern in all courses.
Lecture 3: Waste quantities and characteristics						
• Definition of Waste • Quantity, generation and composition of waste • Municipal solid waste	<u>Learning Outcomes</u>: • Definition of 'waste' • Knowledge of waste types, characteristics and their composition • To be able to give country-specific examples of waste sources	- a part of course on "treatment and utilization of biological wastes" : Module 2 (wastewaters: sources and characterization), Module 3 (solid wastes: sources and characterization)		Course on " Hazardous waste management" (3credits) for (Second semester, Year III) of Bachelor of Environment Management at Faculty of Environment Sciences, NUOL	- A part of course on "Solid Waste Management and Treatment" (3 credits) teaching for Bachelor students in Environment Engineering.	The affect of Urbanization and industrialization to Waste quantity and characteristics is the most concern in courses.

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
Lecture 4: Waste collection						
• Collection systems and collection methods • Transfer of waste and transfer stations • Transportation systems • Street cleaning • Handling of fluid wastes • Handling of hazardous wastes	Learning Outcomes: • Be aware of the options for waste collection and storage • Be aware of the logistics of waste transport • What are advantages and disadvantages of street cleaning • Outline the options for the handling of solid and hazardous waste	- a part of course on “treatment and utilization of biological wastes” : Module 2 (wastewaters: sources and characterization), Module 3 (solid wastes: sources and characterization)		Course on “Integrated Urban Planning Development” (3 credits) for (second semester, Year IV) of Bachelors of Environment Sciences and Environment Management at Faculty of Environment Sciences, NUOL	- A part of course on “Solid Waste Management and Treatment” (3 credits) teaching for Bachelor students in Environment Engineering.	Analyse the involvement of private enterprises in to waste collection; study how to organize and develop the Waste service, especially in suburban.
Lecture 5: Waste processing, treatment and recycling						
• Manual and mechanical separation • Waste recycling • Thermal waste treatment • Biological waste treatment • Physical and chemical treatment process	Learning Outcomes: • Be aware of the options of waste separation • Be aware of the stages in thermal, biological, chemical and physical waste treatment • Knowledge of the use of material in waste recycling	• - part of course on “Bio-energy conversion” teaching master degree student in school of bio-resources and technology, KMUTT • - a part of course on “treatment and utilization of biological wastes	Soil Fertility Management • Role of Organic Matter and Humus • Cover crop • Compost • Commercial Organic Fertilizer • Characteristic s of Organic Fertilizers		- A part of course on “Solid Waste Management and Treatment” (3 credits) teaching for Bachelor students in Environment Engineering. - A part of course on “Organic Waste Management and Recycling” (2 credits) teaching for Bachelor students in Environment Engineering. - A part of course on “Biogas and	Study the problem of Recycling villages and waste treatment technology in direction waste to energy (MBT, RDF)

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
			Soil Conservation • The use of natural and man-made fertilizer		Farm" (2credits) teaching for Bachelor student in Environment Science.	
Lecture 6: Waste Disposal						
• Basic principles of waste disposal • Landfill construction, operation and management • Completed landfills and rehabilitation	Learning Outcomes: • Be aware to define sanitary landfill • Know the stages of landfill construction and management • Be aware of the options used for leachate management	- a part of course on "treatment and utilization of biological wastes" : Module 2 (wastewaters:), Module 3 (solid wastes), Module 4 (utilization of wastes) for master degree students in School of bio-resources and technology, KMUTT	Renewable Energy • Advanced environmenta l design • Renewable Energy Technology • Ventilation in Architecture and Planning • Building design in different climates • Energy efficient systems		- A part of course on "Solid Waste Management and Treatment" (3 credits) teaching for Bachelor students in Environment Engineering.	Study the land filling's situation; sanitary landfill and the emission.
Lecture 7: Economic and socio-economic aspects of waste management						
• Factors to be considered in waste management systems • Environmental economics • Socio-cultural aspects • Waste management in South-East Asian countries	Learning Outcomes: • Be aware of the impact considerations of waste management systems				- A part of course on "Environment Economics" (2 credits) teaching for Bachelor students in Environment	Study problems of environmental fee; cooperation between public and private sector in implementation of

Module / Content	Teaching Methods/ Learning Outcomes	KMUTT	RUA	NUOL	CTU	HUS
	• What are the benefits associated with an efficient renewable energy solution • The importance of economics in understanding environmental problems				Engineering. - A part of course on "Environment Economics" (2 credits) teaching for Master student in Environment Science.	integrated waste management.
Lecture 8: Assessing Sustainability of Waste Management						
• Modelling a waste management system; Material Flow Analysis, Characterisation of waste, software • Assessment of waste management options; Economic Assessment, Assessment of ecological and socio-cultural impact	Learning Outcomes: • Be aware of Material flow analysis • Be aware of the key aspects for efficiency analysis	- part of course on "waste" teaching master degree student in school of bio-resources and technology, KMUTT			- A part of course on "Environment Planning" (2 credits) teaching for Bachelor students in Environment Engineering. - A part of course on "Urban Environment Planning and Management" (2 credits) teaching for Master student in Environment Management.	Study the Upcoming technologies and conceptual modelling; Planning and Precalculation of Waste Management Plants

Table of Contents

List of figures

List of tables

0 Introduction to the Project

0.1 Background

Countries in the Southeast Asian region, like Vietnam, Thailand, Cambodia and Laos, are in a state of rapid transition and it can be assumed that the environmental sector, including fields like waste management, the production of energy from renewable sources, integrated product policy, etc. will undergo a rapid increase in importance in the near future. In order to be able to adopt serious measures to ensure environmentally sound production of goods and effective treatment and disposal of waste streams without hindering economic growth, experts educated and trained in integrated solutions for waste and energy issues are needed.

0.2 The project INVENT

The 18-month project aims at raising environmental awareness, promoting possible solutions to the waste problem by using integrated waste systems and thus meeting market requirements by the development of education modules and tools on integrated waste management. The modules and tools will comprise physically attended courses, as well as e-learning and multimedia teaching made available in the form of a free-of-charge distance learning package globally accessible through the Internet. Furthermore training courses will be held in the Asian partner countries in order to provide knowledge on integrated solutions to environmental problems. The main target groups are students of higher education programmes and teaching staff but also undergraduate students, stakeholders, engineers and managers working in the environmental sector will be addressed. The expected results of these activities are an increase in national and international study opportunities for European and Asian students, along with a reduction in the environmental impact.

During the period from July 2007 to January 2009 an international and interdisciplinary consortium of institutions of higher education from Thailand, Vietnam, Cambodia, Laos, the UK and Germany jointly carry out the project with the objective to create innovative education modules and tools for the environmental sector relating to integrated waste management in different courses of study in the participating universities in Thailand, Vietnam, Cambodia and Laos, and to improve education of integrated waste management in the participating European universities. The project aims at supporting environ-mental knowledge, especially in integrated waste management, of students from vari-ous fields of study, such as engineering, natural sciences, economics, architecture, agriculture, as well as social science and management courses. The modules will have transferable applications for those countries with similar framework conditions, and their principles will be applicable worldwide.

0.3 Aims and Objectives

Specific Objectives

The specific objective is to create innovative education modules and tools for the environmental sector relating to integrated waste management in different courses of study at institutions of higher education in the participating universities in Thailand, Vietnam, Cambodia and Laos, and to improve education of integrated waste management in the participating European universities. These modules and tools will comprise physically attended courses, as well as e-learning and multimedia teaching made available in the form of a free-of-charge distance learning package globally accessible through the Internet. Furthermore, they will have transferable applications for those countries with similar framework conditions, and their principles will be applicable worldwide. The comprehensively designed courses can be applied efficiently to various disciplines in programmes of higher education in which an environmentally sound basis, particularly in respect to integrated waste management, is required. The modules will enhance the career prospects of the participating graduate students, who will be taught practical, modern knowledge and skills, as well as being provided with innovative tools, which can be utilised in their future professional activities. The main focus of the courses will be on the production of renewable energy from wastes and residues, while appropriate techniques, economic, socio-cultural and gender aspects, as well as ecological issues, will be given due consideration. The integrated approach will allow the participants to develop wide-ranging perspectives, which is more beneficial and efficient than just technical knowledge alone.

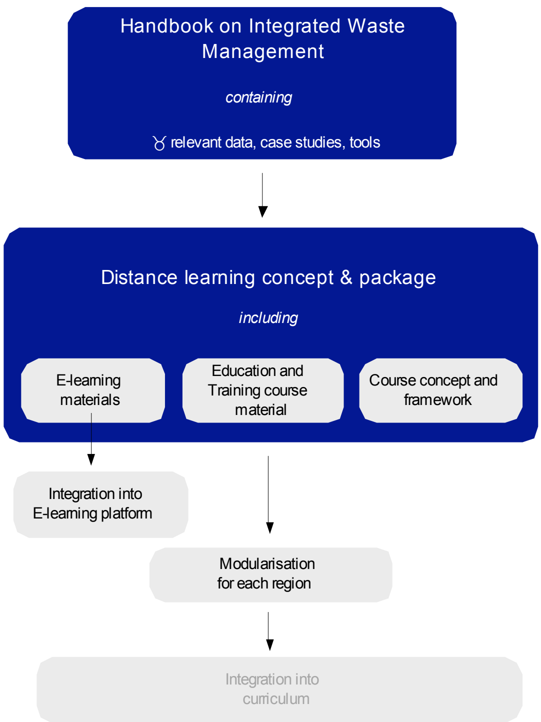


Figure 0.3-1: Education package

Overall objective(s)

1. To enhance economic (and human) relations between Asia and the European Union by increasing mutual awareness and understanding, exchanges and economic cooperation in the environmental sector.

2. To encourage the creation of an environmentally sound basis, especially in integrated waste management and renewable energy, for the future development of higher education programmes in Thailand, Vietnam, Cambodia, and Laos, not least, because increasing economic development and population growth in Asia are major factors that contribute to many environmental, energy supply and health problems.

3. To strengthen the skills and mobility of the participants through an exchange of knowledge and experience between European and Asian countries in matters relating to the environment.

4. To promote EU higher education, particularly in respect to environmentally related courses in particular countries, and to provide Asian students with more information about the EU graduate programme of study. The expected results of this action are an increase in national and international study opportunities for European and Asian students, along with a reduction in the environmental impact of economic development and population growth.

5. To foster co-operation between European Union and Asian countries through joint preparation of course application procedures and course materials on a modular basis, as well as contributing to further integration of international aspects of environmental good practice into higher education and degree courses.

Main Activities and Outputs

1. **Handbook** on integrated waste management containing course framework and material for application in the participating institutions of higher education in Thailand, Vietnam, Laos and Cambodia

2. **Distance learning package** including multimedia material on integrated waste management

3. **E-learning platform** available via the Internet

4. One **Training Course** on selected issues of integrated waste management, implemented in each participating Asian countries including a Course Folder

5. One **Workshop** in each Asian partner

0.4 Target group

Direct target group

The direct target group comprises students of higher education programmes conducted by the participating institutions. The project aims at supporting environmental knowledge, especially in integrated waste management, of students from various fields of study, such as engineering, natural sciences, economics, architecture, agriculture, as well as social science and management courses. The estimated number of students belonging to target groups in higher education programmes at the participating institutions is approximately 1800. Furthermore teaching staff engaged in higher education programmes at the participating institutions will directly benefit from these innovative learning strategies.

Indirect target groups

A much wider group will be reached, such as undergraduate students studying other courses at the participating universities but nevertheless interested in the project or other interested parties, such as stakeholders, engineers, managers, students and teaching staff worldwide, who will utilize the project website, distance- and e-learning contents or the handbook for their education, research, projects and career.

1 Introduction to Integrated Waste Management

1.1 Background

Proper understanding of an issue, can only lead to an appropriate prescription of corrective measures. Therefore, before analysing the technical and economic solutions, it is necessary to understand what waste is and how can it be managed.

Educational objective of the chapter

To introduce the readers as to what could be the reason behind waste generation; what the developed countries have done to check the problem; learning from the experience of the industrialised countries to have the problem checked before it is late.

1.1.1 Why Waste quantity increasing?

Rapidly developing economies often, experience a significant increase in waste quantities of discarded packaging materials; wastes from industrial production processes, sometimes, with hazardous components. Growth in GDP and individual consumption influence the volumes of wastes. Rapid urbanisation and associated growth of industries generate solid waste that outstrips the assimilative capacity of the natural environment and the administrative capacity of the municipal authorities to handle. Unsustainable life styles of affluent demand more of disposable products. Buying new products has become far an attractive option than repairing the old ones. Economic activities are the key drivers behind resource use. Material consumption is also positively correlated to negative externalities of environmental impact. Quantity of waste is an indicator of the material efficiency of the society and an excessive waste quantity represents an enormous loss of resources in the form of materials and energy. A deficient concept of waste management may, therefore, result in uncontrolled waste disposal and an uncontrolled incineration thereby, resulting in environmental pollution with a substantial health impact on the population. As an immediate consequence, a carefully designed environmental policy now can help to prevent a great deal of environmental pollution with enormous clean-up costs in the future. Much of the activities of solid waste management are, in fact, a subset of the activities under the broader topic of human settlements management. Chapter 21 of Agenda 21 on solid waste management has some important focus areas: Waste minimisation, promotion of waste recycling and reuse and promoting environmentally sound disposal of waste. While the area of waste minimisation is linked to curtailing unsustainable consumption patterns which depends on national policy design, promoting waste recycling and reuse depends on local informal sector which depends, further, on the potential of income generation. Promoting environmentally sound disposal of waste requires the collaboration of local and national authorities finding suitable economic and legal instruments and implements them effectively so as to make it sustainable. Decoupling of economic growth from the use of natural resources from the waste generation and emissions has been the core strategy, of European Union, with an aim to reap the benefits of environmental protection and continued economic growth. The goal of the policy measure is to encourage further development of re-use and recycling techniques that highlight solid waste as a valuable resource than only something to dump at landfill sites.

Table 1.1-1: Quantity of Wastes Germany (in tones) [EuroStat, BMU]

Type	1990	2001	2005	2006
Domestic and bulky waste	33,887,545	19,142,000	16,781,200	16,686,900
Wastes for recycling	4,901,457	20,564,000	20,002,800	20,481,300
Waste from households	38,789,002	39,706,000	37,253,100	37,331,100[1]
Total municipal wastes	54,027,460	47,815,000	41,035,410[2]	Not available

[1] estimated
[2] provisional

To design a policy instrument for managing wastes of a particular region, it is essential to understand the composition and the quantity of wastes from that particular region. In Germany, whereas in the year 1990 (Table 1) the quantity of household wastes collected separately and recycled was below 5 million tonnes out of a total of 38.8 million tonnes, in 2001 the quantity of waste recycled has quadrupled with the overall waste quantity only with a slight increase.

1.1.2 **Correlation between economic growth and waste quantity**

The relationship between a steady increase in incomes and the environmental quality has been analysed by a large section (SHAFIK AND BANDYOPADHYAY 1992; PANAYOTOU, 1993; GROSSMANN AND KRUEGER 1993; SELDEN AND SONG 1994) of economic scientists. Their studies suggest that the correlation between economic growth and environmental quality whether positive or negative is not fixed along the development path of a country but it may change from positive to negative as a country reaches a level of income after which the population may demand a better environmental quality and infrastructure. The inverted relationship between income and environmental quality has been named as Environmental Kuznets Curve by analogy with the income-inequality relationship postulated by Kuznets (KUZNETS 1966).

A review of the available evidence on instances of pollution abatement (OECD, 1991) suggests that the strongest link between income and pollution in fact, is via an induced policy response. With the help of EKC analysis, GROSSMAN and KRUEGER (1995) claim that poverty, only, delays pollution abatement but do not prevent it. They speculate that low income countries could start to reduce pollution long before they reach the income levels at which high income countries have done so. Better policies such as more secure property rights and better enforcement of contracts and effective environmental regulations can help flatten the Environmental Kuznets curve and reduce the environmental price of economic growth (PANAYOTOU, 1997).

A society's ability to decide upon and enforce environmental regulations at any level of economic development may be easier with income equality and open democratic structures. This forms the reason for a link between the two different Kuznets curves; the increase in equality with higher development helping the implementation of environmental regulatory policies that bring about the improving side of the Environmental Kuznets Curve (MAGNANI, 2000; LOPEZ and MITRA 2000).

1.1.3 Can waste generation be delinked from economic growth?

1.1.3.1 Socio-economic statistics

The two most important priorities of sustainable waste management are: minimising the environmental impact of waste with an overall objective of reducing waste generation; reduction of resource use with complete or partial recovery or recycling of materials (Ristic, 2005). An index for total municipal waste generation from 1990 to 1996 in Germany (Eurostat) shows a steep increase in municipal waste to 14% and wastes from mining and quarrying amounting to 29% of total waste generated. Total waste generation reported in OECD Europe increased by approximately 10% between 1990 and 1995 while the GDP grew by 6.5% approximately (EEA, 2001). With a substantial transformation of the concept of waste management accompanied by a closed substance cycle and Waste Management Act the German waste management has evolved into materials flow management (IFEU, 2004) as waste forms an integral part of the total material flow through the economy and it is increasingly being considered in the context of material flow as a whole (Ristic, 2005). Germany, hence, with its move away from the throw-away economy adapts itself to a close substance cycle of waste management. The sum total of household wastes of Germany has remained constant over the years in spite of its growth rate of 15% between 1992 and 2001. This signifies a decoupling[3] between economic growth and waste quantity. The material recycling ratio which is 12% in 1990 increased to more than 54% in 2006. After deducting the sorting and treatment residues, the figure arrived at, thereby, indicates an increase in the material recycling ratio of waste for recycling from 12% in 1990 to more than 46% in 2001 (Table 1.1-1). Wastes from households alone produced a saving of 25 million tonnes of CO2 equivalent from the impacts of waste in the year 2001 compared to the 1990 level and an anticipated saving of 30 million tonnes by the year 2005 (IFEU, 2006).

[3] As one of the key sustainability indicators, it explores the impact of economic activity on environment system. The decoupling can be either absolute or relative depending on the magnitude of the impact.

1.1.3.2 Decoupling of Environmental impact and economic growth

The European Union's efforts in the past decade to decouple economic growth from the material and energy consumption reflect in the measures taken by the member states.

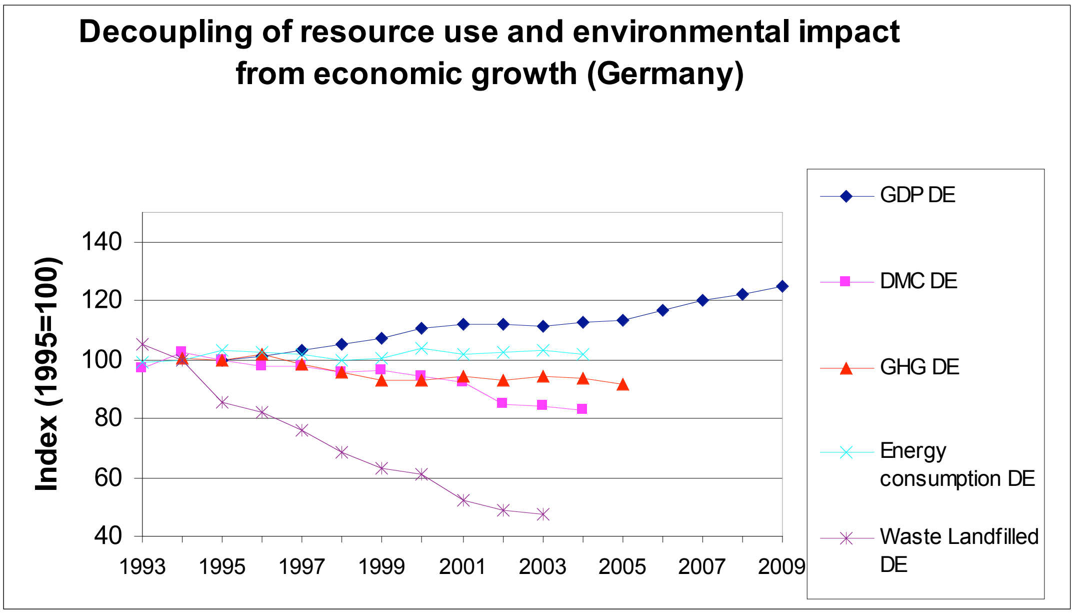


Figure 1.1-1: Decoupling (Germany)

The indicator Domestic Material Consumption (DMC) is defined as the total amount of material directly used in an economy. DMC equals Direct Material Input (DMI) minus exports. DMI measures the direct input of materials for the use in the economy. DMI equals Domestic Extraction (DE) plus imports. The indicator GHG emissions show the key source category. A key source category is defined as an emission source category that has a significant influence on a country's greenhouse gas inventory in terms of the absolute level of emissions, the trend in emissions, or both. The different greenhouse gases are weighed by their global warming potential, and the results are expressed in CO_2 equivalents. The gross inland consumption is calculated as follows: primary production + recovered products + total imports + variations of stocks - total exports - bunkers. It corresponds to the addition of final consumption, distribution losses, transformation losses and statistical differences

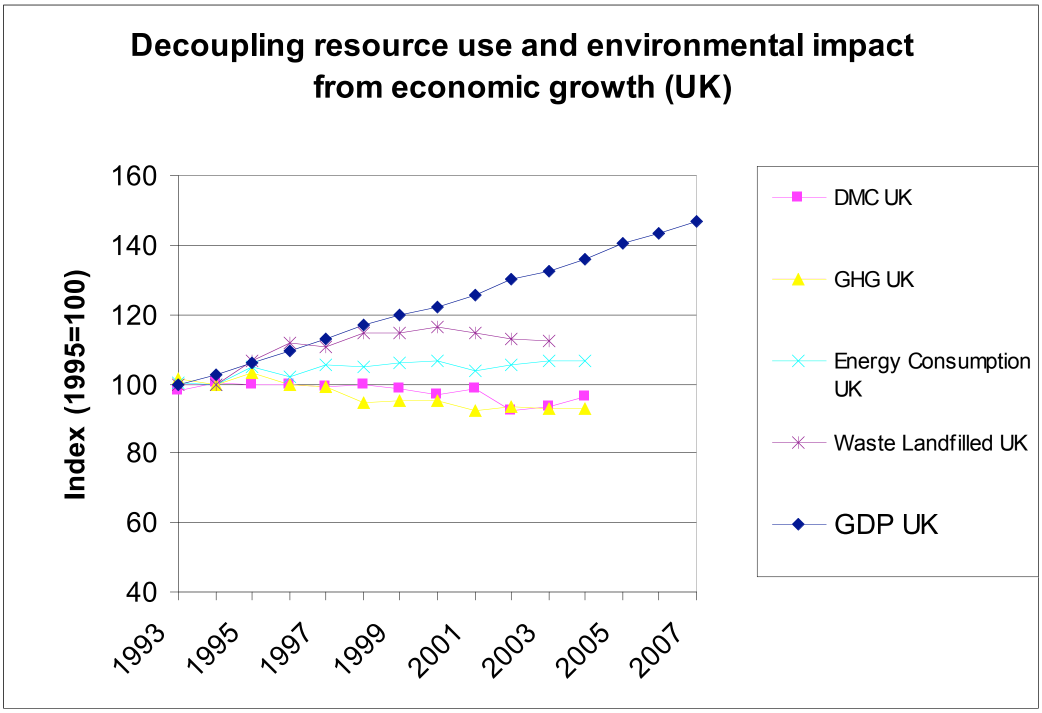


Figure 1.1-2: Decoupling (UK)

The figures above portray the decoupling efforts of Germany and United Kingdom. Greenhouse gas emissions and the amount of municipal wastes going to landfill have been used as proxy indicators for environmental impacts, which show a relative decoupling. The increase in the resource consumption comprising material (DMC) and energy consumption do not show a proportional increase to the economic growth rate. Although, the economists do agree that the resource use in some of the European Union member countries has become efficient, they however, apprehend the need for more stringent measures to achieve an absolute decoupling towards the decrease in the actual consumption of materials and also energy in particular.

1.1.3.3 Definitions of parameters used to explain Decoupling

<u>Municipal Waste Land filled kg per capita</u>

This indicator presents the share of municipal waste collected by or on behalf of municipal authorities and incinerated or disposed of through landfill. The bulk of this waste stream is from households, though 'similar' wastes from sources such as commerce, offices and public institutions are included. Landfill is defined as deposit of waste into or onto land, including specially engineered landfill, and temporary storage of over one year on permanent sites. The definition covers both landfill in internal sites (i.e. where a generator of waste is carrying out its own waste disposal at the place of generation) and in external sites. Incineration means thermal treatment of waste in an incineration or a co-incineration plant.

1.1.4 An attempt to sustainable waste management:

The handling of resources is a significant component of any strategy for sustainable development (IFEU, 2006). Within the European Union, each year there has been around 1.3 billion tonnes of waste created out of which, around 40 million tonnes are found to be hazardous. This roughly amounts to approximately 3.5 tonnes of solid waste per head. It was between 1990 and 1995 the amount of waste generated only in Europe increased by 10% and according to the OECD estimates, Europe may generate around 45% more waste by 2020, than it did in 1995.

However, the waste sector’s contribution to sustainable development in Germany can be seen in the country's recycling quota, which is the highest in the world, and which saves on both resources and primary energy. Almost 62% of municipal waste and 64% of industrial waste in Germany is recycled. The recycling quota is even higher for construction waste (86%), packaging (84%), batteries (82%) and graphical paper (80%). Over the past 15 years the emission of greenhouse gas pollutants from waste management has been reduced by 30 million tonnes of CO_2 equivalents per year (BMU, Germany)

1.1.5 Need for emissions reduction

The EU has committed to reducing its overall emissions to 20% below the 1990 levels of emissions by the year 2020 and it is willing to scale up the reduction up to 30%, if the other developed countries make comparable efforts towards emissions reduction. It has set a target of 20%, for the member countries, increase in the use of renewable energy sources by 2020. The Kyoto protocol encourages governments to cooperate with one another to improve energy efficiency, reform the energy sector, promote renewable forms of energy, and limit methane emissions from waste management and energy systems.

1.2 Principles of Integrated Waste Management (IWM)

Educational objective of the chapter

- The first step of integrated waste management is to avoid waste.
- The 3 main principles of integrated waste management are to reduce, reuse or recycle waste.
- A main part of integrated waste management is to raise the public awareness.

1.2.1 The Definition

Waste management is sustainable only, if the relation between reutilised substances and amount of waste generated is increasing significantly, over a period of time. The concept of integrated waste management, as per the general understanding, is based on the strategy of the three “R”: Reduce, Reuse and Recycle. Material production, cost and energy can be saved by using less and reusing and recycling more. The problem will then, be to identify the “optimal” level of the three R with optimality with respect to individual situation of each group of relevant stakeholders.

Stakeholders of the concept:

- Individual households, who as consumers benefit from the clean environment, and they gain clean energy produced out of the sufficient supply of packaging materials;
- Individuals, who profit directly from collecting the discarded materials for reuse or recycling purposes;
- Companies, which profit from the production and usage of packaging materials and the profit from the recycling activities thereof.

The optimality concept- in accordance to the Pareto Principle-ideally be based on the well-being of individuals; companies are, as usual, considered to be “owned” by either individuals (in the case of private enterprises) or the general public (in the case of public enterprises) and the profits of the companies are valuable for their owners. According to Pareto Principle, optimal levels of the three R are then given, if there is no other allocation with different levels of the three R that would increase the well-being of some individuals without hurting some other.

Given the definition, it is clear that the optimality concept itself depends on the concrete situation in a country, in particular, on the current state of the environment, the economic growth process, the innovative potential of the industry and the international trade relations. Therefore, it leaves some room for implementation. This can be illustrated by the examples which rather, demonstrate the challenges associated with the practical application of the concept of Integrated Waste Management.

1.2.2 Practicability Considerations

The practical implementation of a concept of Integrated Waste Management is not an easy thing to do. It is the missing information on preferences of households, on markets for recycled material, on possible technological innovations, which matters most.

Therefore, the question of a practical concept for Integrated Waste Management is essential and should be handled with great care. As environmental commodities with characteristics of public commodities play a substantial role in this context the market mechanism alone cannot be expected to provide an optimal solution. Modifications to the framework conditions are necessary; in addition to that we could use some plausibility considerations to approximate an optimal solution.

Not only in Germany, the three R “Reduce”, “Reuse”, “Recycle” are interpreted to give priority to the reduction of waste. Waste which cannot be avoided should – if feasible – be reused and the rest should be recycled, which includes combustion to generate energy from renewable sources. In addition to that, the depositing of untreated biodegradable material and of municipal solid waste containing organics ceased in Germany in June 2005.

If one agrees that source reduction strategies have many favourable environmental impacts, including reducing greenhouse gas production, saving energy, and conserving resources, in addition to reducing the volume of the waste stream, and that biodegradable material should be – if technically and economically feasible – used to generate energy from renewable sources, this approach is probably in agreement with the optimality principle.

1.2.3 Economic Viability

The question of implementing a concept of Integrated Waste Management should therefore assign priority to appropriate reduction and reuse strategies, complemented by recycling activities. Of course, all these strategies and activities have to be technically and economically viable or “reasonable”, given the framework conditions of a particular country.

What do we understand by economic viability of certain strategies and actions in the context of waste management? The Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (Germany, September 1994) addresses this issue in Article 5: Basic Obligations of Closed Substance Cycle Waste Management. Paragraph 4 states: “The obligation to recover waste is to be met, to the extent this is technically possible and economically reasonable, especially when a market exists, or can be created, for an extracted substance or for extracted energy…. Waste recovery is economically reasonable if the costs it entails are not disproportionate in comparison with the costs waste disposal would entail.”

This last statement is difficult to verify in practical situations. This can be judged from the experiences with the Renewable Energy Sources Act in Germany (view the remarks to Example 4 above). Nevertheless, it is a consequence of the optimality criterion introduced and explained earlier. For the practical implementation one would have to conduct a Benefit-Cost-Analysis on the basis of the available information to single out the best strategy or the best alternative.

1.3 Waste Avoidance and Reduction: the initiatives from government

1.3.1 Measures of EU towards wastes management

The objective of EU in coordinating waste management in its member states is to limit the generation of waste and to optimise the organisation of waste treatment and disposal. The strategy of EU under waste management is firstly, to set out guidelines describing measures aiming at reducing the pressure of production of waste and its management on the environment. The main thrust of the strategy is on amending the legislation to improve implementation, and on preventing waste and promoting effective recycling (Directive 2006/12/EC). The objective underlying the strategy is to reduce the negative impact of the waste, from cradle to grave, on the environment. And this can be effectively managed through recycling. This approach means that every item of waste is seen not only as a source of pollution to be reduced, but also as a potential resource to be exploited.

Table 1.3-1: Economic instruments, regulations and waste management systems [European Topic Centre]

Type of instrument	Ban (on land filling)
Year	• Land fill Ordinance, 2001 • Ordinance on use of waste for back filling In underground mines, 2002
Types of banned wastes streams	Liquid waste, infectious waste, explosive waste Restriction on organic substance going to landfill According to the Ordinance: • Municipal waste may contain only up to 5% of C Content in the wastes land filled • Mechanical and biologically treated municipal w Contain up to 18% carbon content
Purpose	To limit the organic waste going to land fills
Sanctions	Non compliance an administrative offence; can be fined 50,000
Targets achieved	Data not available

1.3.2 Source reduction, recycling, land-filling – the hierarchy in the order of preference

1.3.2.1 Source reduction

Disseminating best available techniques or eco-design of products is an important factor in achieving the goal of source reduction. Under the new proposal for a framework Directive on waste, the Member States of the European Union are required to develop programmes to prevent waste generation. These programmes include specific prevention targets to be implemented at the most appropriate level and which must be made public. Hussein et al (2007) in their review of European household waste management schemes state that the quantities of waste for diversion to recycling are higher than those of reduction. The source reduction schemes are understood to have attracted less attention than waste recycling schemes (Skumatz, 2000).

1.3.2.2 Recycling

The Directive 1999/31/EC aims at promoting the recycling sector in order to reintroduce waste into the economic cycle in the form of quality products, while at the same time minimising the negative environmental impact of doing so. The strategy stresses on biodegradable waste, two-thirds of which must be redirected to be disposed of using methods other than landfill as is required under the Directive of 1999. The strategy provides, for Member States to adopt management strategies, and for this matter to be included in revision of the IPPC Directive and the Directive on the use of sewage sludge in agricultural sector. At present, 49% of EU municipal waste is disposed of through landfill, 18% is incinerated and 33% is recycled or composted (EC, 2006). The diversion of municipal waste away from landfill is expected to continue and the municipal waste sent to landfill may reach a level around 34% in 2020. Recycling of waste is assumed to reach a level of 42% and incineration of waste with energy recovery 23% in 2020. However, the assumed level of landfill may, still, be too high. Eurostat in its recently published Structural Indicators for 2006 has mentioned the landfill rate in the EU-15 to be 34% in 2006 and 41% for the EU-27 (ETC/RWM, 2008).
The Packaging Directive (2004/12/EC) provides for the prevention and generation of packaging wastes and promoting the reuse systems for packaging. The targets set for the recycling and recovery of packaging waste until December, 2008 will be:

- 55-70% recycling
- 60-75% recovery

Therefore, the strategy is to open new waste management possibilities so as to reduce the amount of wastes sent to landfills through measures to recover more compost and energy from waste and to improve the quantity and quality of recycling. This, apart from achieving efficiency improvement and cost-effectiveness, also will reduce greenhouse gas emissions.

The benefits of recycling are that there will be a reduction in the amount of waste being disposed of and there is conservation of natural resources. European Commission's strategies aim at creating, applying cleaner, and more efficient and more sustainable energy solutions for the benefit of a wider spectrum. Among the European Union members, countries with more than 25% of material recovery and incinerating fall under Group 1 countries. Denmark and Sweden are the countries falling under this category with a highest municipal waste incineration. Denmark has a history of incinerating since 1903 and with a Directive in 1993 it was decided that waste should be preferred to other fuels for producing heat as by-product of electric power generation. In 2005, waste incineration, producing heat and electricity, supplied 4% of the total energy consumption in Denmark.

Germany and Austria fall under the second category of Group 2 countries. They introduced packaging and waste management systems in 1994. In 2004 and in 2005 Austria and Germany reinforced a ban on biodegradable waste being land filled. Composting and recycling levels, apart from their highest material recovery rates in the EU, have been consistently high. While Germany's main material recovery operation is recycling, Austria opts for composting and the rates is the largest in Europe, ranging around 40%, since the late 1990s

The United Kingdom falling under the Group 3 countries has implemented market-based instruments. The United Kingdom introduced the Landfill Allowance Trading Scheme (LATS) in 2005. This scheme gives the local authorities the flexibility in meeting tough Landfill Directive targets on biodegradable municipal waste. Like in any other emission trading, the allowances can be traded under this scheme too.

Strategies to recycling vary among member states as different local authorities have different methods of collecting waste materials according to the availabilities of facilities to recycle and reprocess. However, the most commonly separated materials are glass, paper, plastic bottles, tins and cans and textiles. The recovery of paper, cardboard and plastics proved to be the most influencing factor in the reduction of toxic air pollution (Wenisch et al 2004)

Household waste accounts for 9% of the total UK waste and a high proportion of it is land filled and the recycling rates are quite low. Recycling although environmentally beneficial is not followed much due to various reasons. In UK, however, the Landfill gas is a resource to be profitably harnessed to maximise the methane gas resource available on Landfill sites.

The statutory driver behind the household waste recycling is the EC Landfill Directive 1999(EC 1999). This directive aims at reducing the environmental impact of the landfill wastes in the surroundings. In the case of UK, the directive's target is to reduce the biodegradable waste going to landfills to 75% of the 1995 levels, by 2010. To improve recycling the government established WRAP (Waste & Resources Action Programme) in 2001. The programme has been set up to stimulate markets for recycled materials.

Recycling plastics; Some Observations

Plastic recycling is not very common as there are only a few facilities to handle the material. Under the household plastics there are only three types of plastics and therefore, collecting them offers great potential for increasing household plastic recycling. One of the reasons for the household plastic bags not much recycled is that their low density makes their collection and recycling uneconomical.

The economic aspects of recycling

There is a lack of viable markets for the recycled products. This leads to under utilised facilities of shredding and reprocessing. In 2002 UK had an estimated capacity of 400 kt to shred plastic but only half the capacity is understood to have been utilised (POST, 2005).

Reprocessing plants are run by private authorities who need to be sure of the market potentials for the recycled materials before they invest. If the processing facilities are far from the collection site, it may be uneconomical as the benefit of recycling will be nullified by the transport costs. The cost of a treatment facility can also be dependent on a few other aspects like the cost of the land, the current collection system, and the other facilities being considered by the local authorities of the area under study.

The technical and environmental implications of pre-sorting of waste may have impact on the treatment process. The pre-sorting and collection of household waste lead to qualitative and quantitative changes in fluxes at the incinerator inlet that affect outlet fluxes (Wenisch et al 2004). In some cases, the social and environmental cost of collecting, sorting and transporting the recovered material may be greater than the savings reaped from avoiding the use of primary materials. The amalgamated materials are difficult to recycle because of the varied components having different properties.

1.3.2.3 Land-filling

The Landfill Directive (1999/31/EC) specifies the maximum amount of municipal wastes that are biodegradable that can be land filled. The targets are set on the basis of biodegradable municipal wastes (BMW) generated in the year 1995.

- 75% reduction by 16th July, 2006
- 50% reduction by 16th July, 2009
- 35% reduction by 16th July, 2016

The countries that currently meet the stringent BMW landfill targets include Denmark, the Netherlands, Luxembourg, Belgium, Austria, Germany and Sweden. These countries divert BMW from landfill by using the treatment options mentioned below: (DBDH 2004)

- material recycling for paper and card board waste
- biological treatment of food and garden waste mainly by composting
- incinerating mixed municipal waste

The Landfill Directive expects the member states to set up national strategies for BMW management. In order to divert BMW from landfill, all national strategies may have measures for the reduction, reuse, recycling and biological treatment of BMW as well as incineration with energy recovery. Energy recovery from waste is, however, a small fraction with respect to the energy independence of countries. The role played by waste incineration is not insignificant given the 22% of renewable energy that the European Union plans to impose on the member countries from 2010 onwards (WENICH ET Al 2004). If there is a substantial increase in reuse and recycling measures the BMW generation may not be a threat.

The targets set above may be postponed for a period of four years in member states like UK, Greece, Portugal and Ireland where more than 80% municipal solid waste was land-filled in the year 1995. This will also apply to the ten new member states. In England, currently, 67% of the municipal solid waste generated is land filled, 9% incinerated and 23.5% recycled or composted (DEFRA, 2006).

Continuous growth imposes economic and environmental costs on the society in most of the European countries. However, Germany, the Netherlands, Sweden, Denmark and Iceland have been successful in decoupling economic growth and a growth in waste production. This decoupling is one of the main objectives of the Sixth EU Environmental Action Programme (2001-2010) (EEA, 2002)

The level of waste generation, implementation of waste management policies in EU can be answered with the help of two important environmental headline indicators as projecting one single indicator can not be representative providing a comprehensive and reliable picture of waste management and treatment of various waste categories in the EU member states. They are: i) municipal waste land filled in relation to municipal waste generated; ii) generation of hazardous waste, while in the first case a reduction in the amount of waste land filled indicates a positive development, the second indicator can give the overall trend of the heavy direct Impact on the environment and the related treatment capacity needs.

Germany's areas of priority under waste management are:

- No more land filling of untreated municipal wastes
- Utilising wastes of high calorific value through mechanical biological treatment
- Developing technologies for waste treatment

<u>Waste Storage Ordinance, Germany</u>
The Ordinance came into force since 1 June 2005. Thereby, it becomes it become mandatory that wastes can no longer be land filled in Germany without a pre-treatment. As the digester gas methane emitted from landfills has been found to be causing 21 times more damage to the climate than carbon dioxide (CO2), the Ordinance has been implemented. Domestic waste landfills became contaminated sites which result in costs for rehabilitation and after-care amounting to billions. Landfills with poor liners and a lack of technical monitoring will be gradually be closed down by 2009. Local authorities alone have invested €7.5 billion, especially over the past four years. Another significant outcome is around 15,000 jobs have also, been created.

The indirect benefits of Landfill Directive of EU
Energy recovery from waste provides a double environmental benefit - firstly, the diversion of waste from landfill and, secondly, the recovery of energy, displacing fossil fuel alternatives and reducing greenhouse gas emissions. Unfortunately, the fuel is not as energy-rich as coal and is therefore, not always economically viable for companies to utilise. The government can give subsidies and this will create the incentives required to encourage firms to use this type of fuel. The Landfill Directive (1999/31/EC) works as a driver behind the new incineration plants of EU to recover heat as well as electricity. The framework stresses the preferred hierarchy of waste management. Where waste generation is unavoidable, it should be reused. Recycling, including biological treatment, may be the next best option after reuse. Disposal should be the least preferred option in contrast to using waste a source of energy as the best preferred option.

1.3.3 The consumption pattern of countries in transition

A vast majority of the consumers of the developing countries are aware of the environmental friendly products and their usage but their demand has been spiralling upward. In South Asian countries, the low income groups generate much less waste per person than the middle and upper income groups and the urban poor play an ecologically positive role as they usually reclaim, reuse or recycle wastes of wealthier households. The middle and upper income groups consume most of the goods which constitute hazardous or toxic waste. In the case of developed countries a vast majority of consumers are aware of the environmentally friendlier products. But, their growing demand adds to further scale effects of operation. The areas of food consumption, transport and home energy use are responsible for the majority of direct and indirect pressures on resources in most of the developed nations. Therefore, a sustainable consumption and production taking economic, environmental and social issues into account to harness cooperation among a variety of agents at every phase of production and consumption of a product (UNSCD, 2001). An efficient resource consumption is the ideal way to source reduction and it requires a change in the consumption pattern of the urban Middle and High income groups.

1.4 Planning of Waste Management Systems

1.4.1 Regulatory framework

In Germany the legislation is passed at different political levels. The Basic Constitutional Law governs the legislative authority of the federal government and the federal states. Federal waste laws are supplemented by state waste laws (Bilitewski, 1994). The development of waste management concepts, waste balance and waste disposal plans for municipalities and also the rising of (hazardous) waste disposal fees are determined by these state laws.
There are also:

- Rules: between the federal government and the federal states to substantiate specific aims
- Administrative regulations: first, they are binding inside the administration and can be applied to third parties only with an explicit administrative act
- Technical rules and guidances: they become legally binding when they are mention in court decisions, regulations and/or laws

The waste management system in Germany based on the Recycling Economy Law. The main intention is advancement of recycling. On the other hand, waste which can neither be recycled nor treated shall be excluded permanent from the recycling and be disposed in an environmentally complaint way. With this policy a recycling-based economy that protects resources and the environment shall be achieved. The law is aimed at promoting product durability, use of secondary raw materials and at enabling products to be returned after use. The political credo of modern waste policy is shown in Figure 1.4-1. The order of preferable activities ranges from avoidance to environmentally sound disposal.

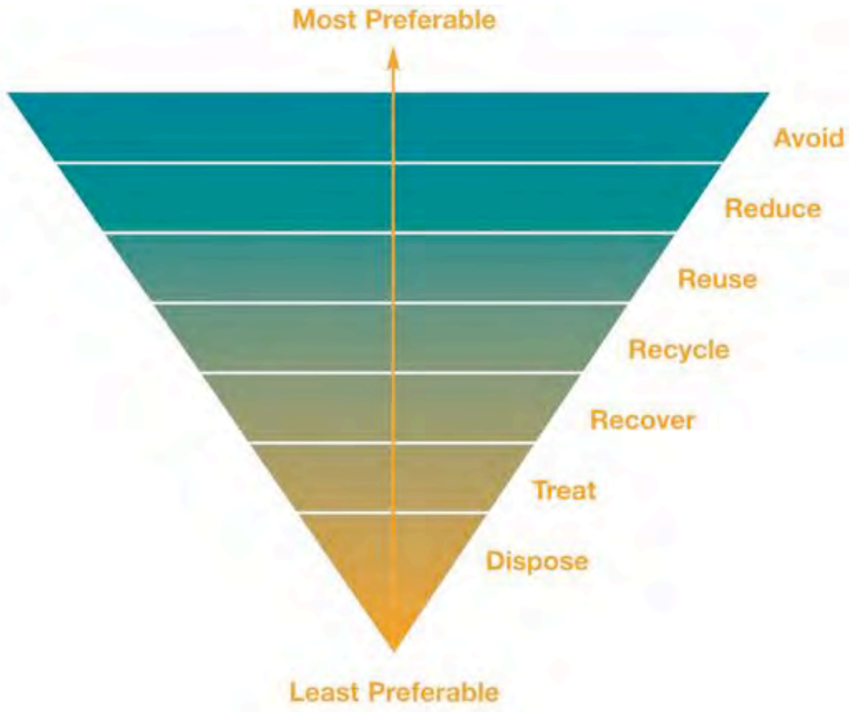


Figure 1.4-1: Hierarchy of Waste Management[4]

For planning a waste management system different points must be considered:

- to show the aims and organisation of a municipal waste management
- to know the relationship between inventory, attributes, amounts and origin of waste (for example municipal waste, construction waste, production waste, hazardous waste) at this time and how to treat, recover and disposal the waste (for example facilities, material recovery, incineration, composting, landfill)
- future development in waste volumes and treatment capacities and also the strategies and measures of reduction, recycling, recovery and disposal
- to show the development of costs

1.4.2 Aims and organisation on municipal waste management

Approximately 20 years before the German government legislated regulations for waste treatment, avoidance of emissions and political parameter for landfill (BMU). Milliards were invested in an environmentally friendly waste disposal. But soon it was visible that waste removal was not enough: utilisation of resources and recycling have to be the main aims. So the product responsibility gets started as another central idea of the waste management system. Anyone who develops, produces, processes or treats products must assume responsibility for these products. The instruments for avoidance and treatment shall work in the run-up to waste appearance. The overall concept of German waste management is shown in Figure 1.4-2.

[4]http://www.envirocentre.ie/Content.aspx?ID=96448806-bc07-4f5a-9e67-cb684d985609&PID=518accea-eec4-4cdf-b034-78ce58eacb4d

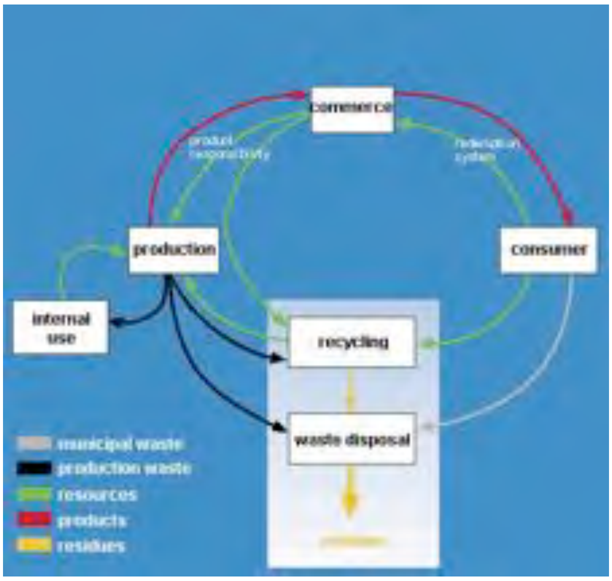


Figure 1.4-2: Overall concept of german waste management[5]

The waste management law and the recycling and waste act continue this politics extensively. According to the law the product responsibility can be moved by legal measures (laws, orders, and administrative regulations) as well as by voluntary self obligations of the manufacturers and distributors.

1.4.3 Inventory on nature, amounts and origin of wastes currently existing and its collection and description of measures for reduction, recycling and treatment of the waste

To clean the waste in the right way you have to get a general idea about the components, exact data on quality and composition as well as the chemical and physical properties of waste materials. This is necessary in order to design waste-processing facilities. It will be distinguished for example in household waste, bulky waste, household-like commercial waste and in commercial and manufacturing waste.

The first one encompasses the waste quantities which are collected by municipal services as well as those wastes that are delivered by street-cleaning companies, private citizens and commercial establishments. This can be for example (Bilitewski, 1994):

- household waste: waste, predominantly from private households, associated with municipal or private collection, regulate pick-up and disposal services
- household-like commercial waste: waste from commercial establishments, businesses, the service sector, public institutions, and industries that possess characteristics or qualities that allow their collection and disposal with household waste
- open market waste: waste generated in markets, fairs, etc., such as vegetables, fruits and nonreusable packaging material
- street sweepings: waste generated during street cleaning, including road surface breakup, tire tread, leaf litter and roadsalt

Under the second one is generally known waste from e. g. agriculture and forestry, manufacturing industries, commerce and transportation and so on. You can differ in various waste groups:

- excavated material, construction debris
- metallurgical slag
- acids, caustics, laboratory waste
- water treatment sludge
- medical waste and so on

[5] http://www.bmu.de/abfallwirtschaft/fb/abfallpolitik/doc/2959.php

Besides, it must be differentiated in hazardous and non hazardous waste. For dumping waste it must be distinguished in two groups, because waste can offer different pollutant content (BMU):

- non hazardous waste: e.g. household waste, household-like commercial waste, paper, cardboard, wood, glass, plastics, metals
- hazardous waste: e. g. old colours and varnish, batteries with cadmium, nickel or plumb, brake fluids, printing inks, pastes and synthetic resin, fluorescent lamps, photo chemicals, gear oils and lubricating oils

Hazardous waste originates in commercial, industries or public institutions. It has a high probability of containing contaminants, because of their properties, concentration or quantity.

The Figure 1.4-3 shows some examples for the origin of hazardous waste. The most of it results in the manufacturing industries and the public and personal services.

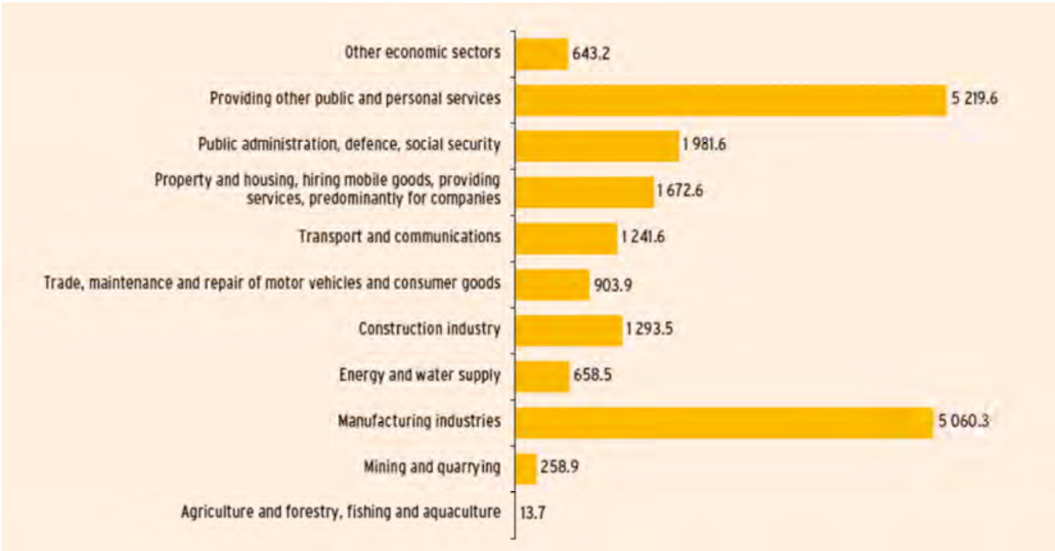


Figure 1.4-3: Origin of hazardous waste in 1.000 t (Umweltbundesamt, 2005)

The waste management activities can be reduced to two main intentions:

a) household, city and municipal waste has to be removed regularly
b) the collected waste must be disposed of in a manner that does not adversely affect the collective good.

Bilitewski (1994) describes that aside from the organizational, structural and technical measures of waste treatment (like for example reduction of fewer goods, waste separation, composting and so on - see chapter 1.2) the following should be considered:

- controlled land filling should be the last method of residual waste disposal, when waste treatment is neither economically nor technically feasible
- thermal treatment of waste for energy recovery and the reduction of the total waste quantity
- biological treatment of organic waste (biological-natural cycle)
- chemical-physical conversation of hazardous and reactive organic and inorganic waste into a form which allows environmentally appropriate storage followed by thermal or material recovery or disposal
- treating and processing waste into primary and secondary materials and the associated conversation of primary resources and primary energy (raw material recycling)

An example for waste accumulation, the amount and utilisation for Germany (2006) is exemplary shown in Table 1.4-1. It also offers the amount of hazardous and non hazardous waste

Table 1.4-1: Amount of waste, disposal and utilisation for Germany 2006/1.000 t (Statistisches Bundesamt, 2008)

Amount of waste generated	overall	Disposal overall	thereof			Utilisation overall	thereof		Utilisation/ recycling
			Landfill	incineration	Treatment for disposal		thermal	material	
	1.000 t								%
Municipal waste	46.426	13729	307	11.135	2.287	32.697	3.871	28.826	70
hazardous waste	393	29	3	19	8	364	29	334	93
non harzadous waste	46.033	13.699	304	11.116	2.279	32.333	3.842	28.491	70
Thereof: household waste	40.827	11.451	159	9.343	1.949	29.377	3.340	26.037	72
hazardous waste	356	29	3	19	8	327	11	316	92
non harzadous waste	40.472	11.442	156	9.325	1.941	29.050	3.329	25.721	72
Commerce and industries	56.146	9.328	5.200	2.446	1.682	46.819	7.613	39.206	83
hazardous waste	9.123	2.699	534	866	1.299	6.424	755	5.669	70
non harzadous waste	47.023	6.629	4.666	1.580	383	40.394	6.857	33.537	86
.....									
.....									
Waste accumulation overall	372.906	96.016	73.627	15.853	6.537	276.889	17.965	258.924	74
hazardous waste	23.207	7.713	3.907	1.120	2.686	15.494	1.751	13.743	67
non harzadous waste	349.699	88.303	69.720	14.733	3.851	261.395	16.214	245.181	75

As is apparent, 25 % of waste have to be disposal in a different way, but the biggest part of waste can be utilize (74 %) by a thermal or material recycling.

Figure 1.4-4 shows the development of waste and the generation for the years 1999 to 2006. It will be differ in construction and demolition waste and other waste, like municipal waste, mining rubble, production and industrial waste. It is visible that construction and demolition waste have the most part of it. Overall it is cognizable that the amount of waste has to be reduced.

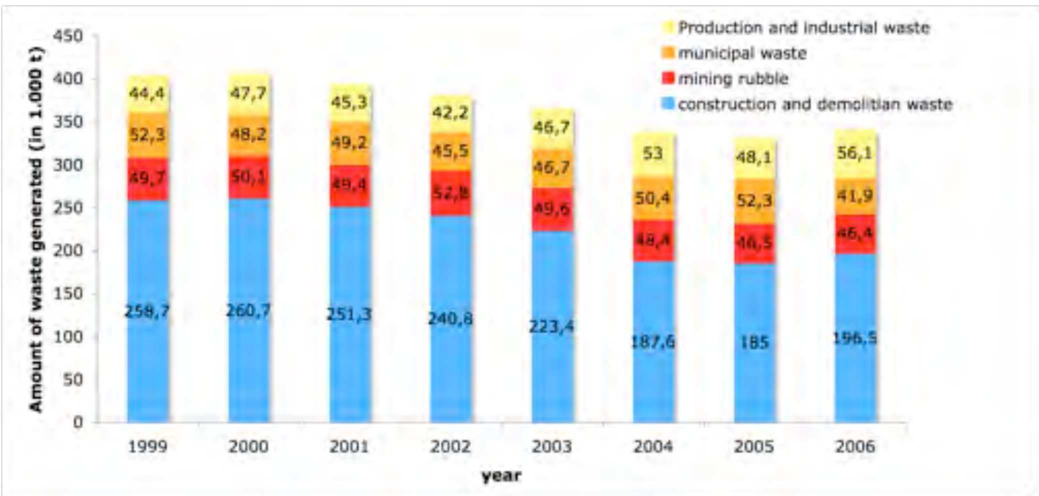


Figure 1.4-4: Amount of waste generated in 1.000 t (Umweltbundesamt, 2005; Statistisches Bundesamt 2006, 2007)

1.4.4 Future development in waste volumes and treatment capacities and also the strategies and measures of reduction, recycling, recovery and disposal

“Waste management is a generic term that has become widely accepted. It encompasses the sum of all measures of waste avoidance, non-harmful treatment, recovery, reuse and final disposal of wastes of all types while giving due consideration to ecological and economic aspects” (Bilitewski, 1994).

In this context the expansion of renewable energies should be mention, because with thermal recycling can be achieve a lot of positive aims:

- surely controllable waste treatment with extremely low emission
- reduction of the risk potential of waste that has to be deposited
- maximum degree of waste volume
- production of secondary raw materials of the thermal treatment
- utilisation of combined heat and power generation which is contained in the waste

More details and extensive description to this theme are discussed in the following chapters. Backgrounds and the aims of sustainable politic as well as the advantages of changing from landfill to renewable energy are also mention.

1.4.5 Costs

An environmentally and orderly disposal is a communal assignment. The operating of disposal has to collect and to transport the waste. The cost involved and the fees for waste disposal systems are covered by dues. The height of the waste disposal fees is directed by the size of the bin.

Standard benefits of the waste disposal are covered by these dues.

- waste consultation
- residual waste disposal
- bio-waste disposal
- bulky waste disposal
- paper disposal
- problem waste disposal

In Germany exists two systems of dues (Bilitewski, 1994):

a) lump-sum system
b) token coin system

At the first one the due is collected by the type of bin or per resident. The citizen has to pay a flat sum which is independent from the claim amount of services. It means a flat assessment. Avoidance or recycling will be unhonored.

At the token coin system the citizen has to attach a coin at the bin. On this way it is signalized that the bin can be emptied. So residents are able to reduce the rates by sparing resources. This system is source-related. Today most of the bio-waste containers (for example) are equipped with a transponder (Kompostierbare Abfälle). This one allows an electronic recording by emptying. The collected biomass can be used for renewable energy. But this is tainted with some problems (see chapter 1.4.11.4).

1.4.6 The significance of renewable energy

Renewable energy has an important role to play in reducing CO_2 emissions. A sustainable energy policy is in part reliant upon increasing the share of renewable energy, which may at the same time help improve the security of energy supply by reducing the Community's growing dependence on imported energy sources. The proportion of electricity from renewable energy measures the contribution of electricity produced from renewable energy sources in relation to national electricity consumption, which comprises total gross national electricity generation from all fuels, plus electricity imports minus electricity exports.

The European Parliament and Council set indicative targets in 2001 for the promotion of electricity from renewable energy sources, whereby 22% of the EU-15's gross electricity consumption should be electricity produced from renewable sources by 2010; the target for the EU-25 is 21%. These targets also represent an important contribution towards complying with the commitments made by the European Union under the 1997 Kyoto Protocol.

Renewable energy sources include renewable non-fossil energy sources such as wind, solar, geothermal, hydro-power and energy from biomass/wastes. The latter refers to electricity generated from the combustion of wood and wood wastes, other solid wastes of a renewable nature (for example, straw), biogas (including landfill, sewage, and farm gas) and liquid bio-fuels, and from municipal solid waste incineration.

With the increase in petrol prices and escalating natural gas prices, some countries through legislation try to encourage the use of biogas which has between 55% and 65% methane content. The co digestion units which treat different types of wastes simultaneously contributed to the 4.7 million tonne of biogas produced in the European Union in the year 2005 and the main exploited source for their contribution was the rubbish dumps. However, the United Kingdom leads in primary energy production from biogas. The largest part of the biogas is valorised in the form of electricity and this is due to the Renewable Obligation Certificate System in force in the United Kingdom since the year 2002. This system, in fact, imposes that the electricity suppliers increase the share of renewable electricity in the electricity production. This obligation was initially 3% (2002-03); 4.3 %(2003-04); 4.9 %(2004-05); 5.5 %(2005-06); and it is expected to reach 15.4% in 2026-2027. Germany increased its primary biogas energy production in 2005 to 23.1% with respect to 2004 following United Kingdom with a 26.1% increase.

Biomass originates from waste streams apart from forest, agriculture and their related industries. It represents two third of the renewable energy sources in Europe. Biomass for heat accounts for 96% of the renewable heat.

1.4.7 The goal set for 2020

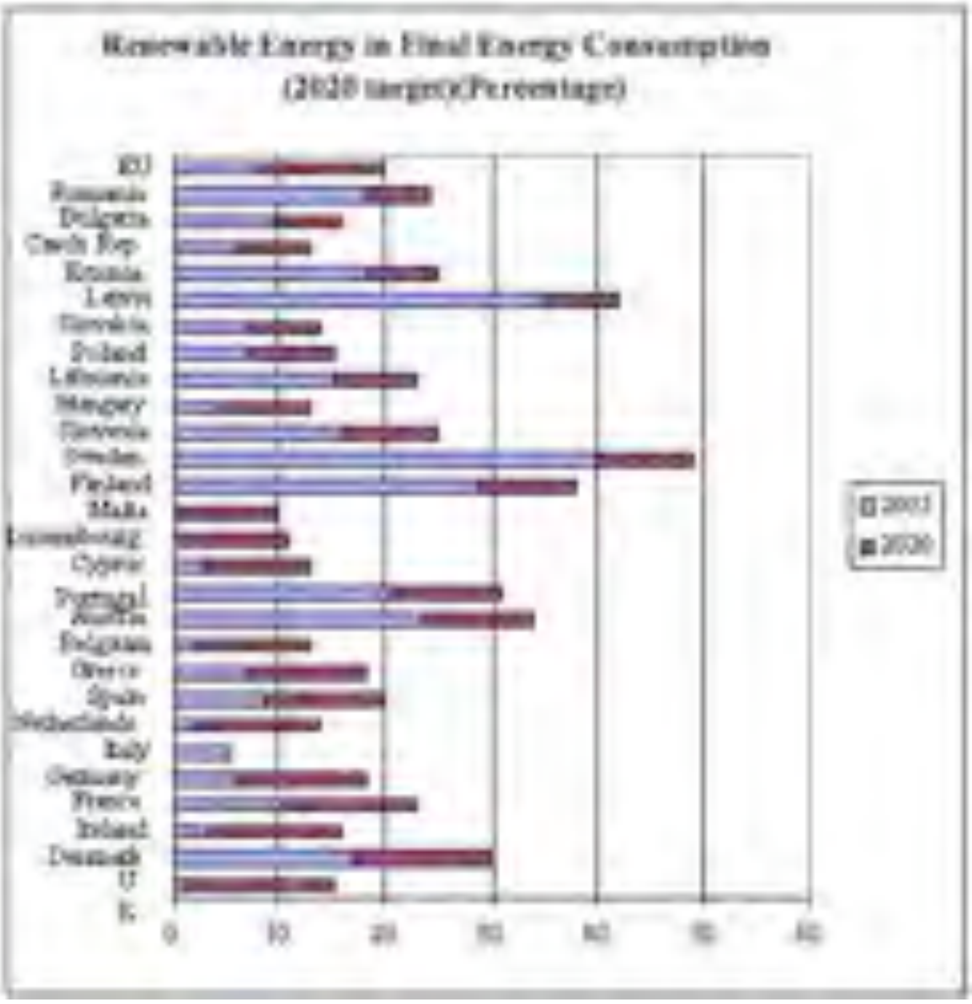


Figure 1.4-5: Source: DG TREN & EuroStat

The European Union's Sixth Environment Action Programme (2002-2012) targets waste prevention and waste management as one of the top priorities in its action plan. While the primary objective of the EU is to delink the generation of wastes from its economic activity sustainable patterns of consumption followed by a sustainable resource usage may help a lot in waste prevention initiatives leading to significant reduction in waste generation.

The long-term strategy of the European Commission is to help Europe become a recycling society that may seek to avoid waste and use waste as a resource. The action plan of EU, therefore, has three basic principles in its approach to waste management initiatives. i) Waste prevention ii) waste recycling and reuse iii) improving the final disposal and monitoring of wastes.

1.4.8 Drivers behind the paradigm shift from non renewable to renewable sources of energy

The goal towards a low carbon economy in the future must work in tandem with the absolute priority of maintaining security of supply. In reality, this means a balanced, diverse, energy mix with no over-reliance on a single method of energy generation. Approximately, half of the fossil fuel input to the EU economy is imported. The domestic extraction of fossil fuels shows a decrease by a similar amount. The share of their imports increased steadily throughout the 1990s and in the EU-15 the increase between 1992 and 2000, was more than 10% (Fig-3) Between 1995 and 2004 energy consumption in the EU-25 rose by 11% and energy production from all sources of energy fell by 4.2% , the import of energy rose to 56% in 2005. The energy dependence rate[6] of Germany is 65.1% and for United Kingdom it is 13.0% (http://ec.europa.eu/eurostat/). This dependency on imported fossil energy is expected, further, to rise.

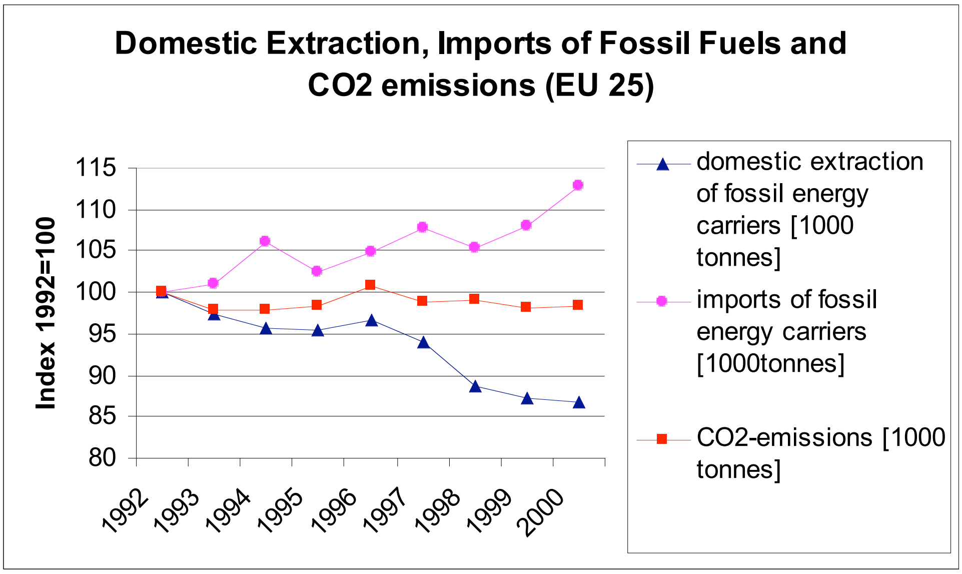


Figure 1.4-6: Source: EEA Report/No 7/2006

The reason is attributed to the depletion of resources for example, the North Sea oil fields (EEA, 2004). Political and economic instability in the oil producing regions affect the security of supply of oil. This problem holds very relevant to EU whose dependency on imported fossil energy explains the situation. To ascertain whether the alternative fuels provide net benefits over the fossil fuels they replace need a thorough accounting of the direct and indirect inputs and outputs of their full production and life cycle (Hill et al 2006). The wide spectrum of sustainable development can be addressed effectively only with the help of determining the security of supply of the non renewable resources and shifting some of the burden on renewable resources of energy. The net benefit of the alternative fuels should be a single package containing factors like net environmental benefits over the fossil fuel it replaces, economic competitiveness, sufficient supplies to have a meaningful impact on the energy demands and a net energy gain over the energy sources which have been used in their production. The argument behind seeking the help of developing countries to address the issue of augmenting renewable energy resources usage is: the population of the South Asian countries who are undergoing a rapid development, is reasonably high and if there is a proportionate increase in their per capita demand for energy from non-renewable resources, it may leave a strong impact on the overall scenario of depletable resources of energy.

1.4.8.1 Reasons for the shift from landfill to renewable energy from waste

- scarce land fill sites
- The leachate leaks through the landfill liners contaminating the groundwater quality in the surrounding areas.
- regulatory drivers
- Methane (CH4) emissions from biodegradable waste, contributing to climate change and local hazards such as fire risk.
- non-sustainable use of land
- Odour

1.4.9 Cost-benefit aspect of renewable energy

A cost-benefit analysis calculates the difference between the monetised value of costs and benefits for evaluating alternatives. To arrive at a decision, all the benefits and impacts are weighed against the costs covering the investment, initial as well as the recurring ones. The comparison leads to the net, positive or negative, benefits of any technological choice. However, under some circumstances the monetised value of environmental damage or the social benefits can not be measured in terms of

[6] Energy dependence rate is defined as net imports divided by gross consumption, expressed as a percentage.

money. Renewable energy sources and their technology use too suffer from similar lacunae. The social indicators like the improvement in the quality of life, less pollution, rebound effects on biodiversity may be considered as proxies reflecting improved environmental conditions.

1.4.10 Developing countries and waste management

In many countries of the developed nations the management of solid and liquid wastes is being undertaken by the private sector under contracts given to the local authorities. There is a wide spectrum of potential areas of an investment return in the waste management sector. Some studies conducted by the World Bank and the UNDP show the existence of informal waste management networks in developing countries. The local authorities share their knowledge on techniques through partnerships as to how to tackle the issue of solid wastes. The informal management of waste could not only reduce the waste collection costs but it could also improve income generation and generate employment avenues among the urban poor.

1.4.11 Potentialities of renewable energy

Many of the word nations have been undergoing fluctuations in the cost of natural gas, oil and electricity due to global economics, market deregulation and political events in some parts of the world. But, the renewable energy may not undergo such fluctuations as they come from resources like biological waste, sunshine, wind, water. The certainty of their supply removes the price fluctuations which is absent in the case of fossil fuels.

Renewable energy can be developed in such a way that every household or a cluster of households could have their own renewable power generating equipment. The energy losses and equipment needed to transmit power over long distances is, thereby, minimised too.

One of the publications (ENERGIE, 2001) funded by the European Union's Fifth Framework Programme for Research, Technological Development and Demonstration (RTD), highlights the potential for innovative non-nuclear energy technologies to become widely applied. Their cost-benefit analysis compares the energy recovery from a municipal solid waste incinerator and having fuel recovery from the process with the base line scenario of Landfill. The fuel recovery case includes three processes for the production of recovered fuel from selected non-hazardous combustible waste with a low yield of fluff, medium yield of soft pellets and a high yield in the form of hard pellets. The storage fuel may be used in four different combustion technologies. Their report concludes it is beneficial at the macro economic level to direct residual waste to energy/fuel recovery than to dump them in the land fills. The level of benefit, although, may depend upon factors like the yield of the recovered fuel, the composition of waste and the saleability of energy from the municipal solid waste. The analysis of the recovery scenario under discussion depicts a significant reduction of Green House Gas emissions (GHG), CO_2 and methane compared to the baseline scenario of land-filling.

Investigating overall scenarios and regional conditions with 45 data sets, the study shows an economic benefit that can be achieved for the national welfare is in the order of 15-40 Euro/person. The research also finds that fuel and energy recovery can save 2-5 GJ/person (50-125 kg of oil equivalent). This result corresponds to 10% solid fuel consumption and a 2-4% of total fossil fuel consumption in Europe. And it is a significant contribution to the Kyoto targets.

The challenges of climate change, secured energy supply and the competitiveness of the region and the countries are multifaceted issues which require policy measures that harness sustainable, secure and competitive energy. The Kyoto targets for 2020 to reduce green house gas emissions by 20% and ensure 20% of renewable energy sources in the EU energy mix and an EU global primary energy use reduction by 20% by 2020 are the motivating issues in the EU's cost-effective low carbon technologies (EC, 2007). Unlike the countries like United States, Japan and Denmark who were in the forefront developing new forms of waste disposal, Germany has been in the forefront utilising refuse to produce heat, gradually including burning sludge (Bergmeier 2003).

1.4.11.1 Share of electricity from renewable energy to gross electricity consumption

The ratio of electricity from renewable energy sources to total electricity consumption in Germany and United Kingdom is shown in the following figure:

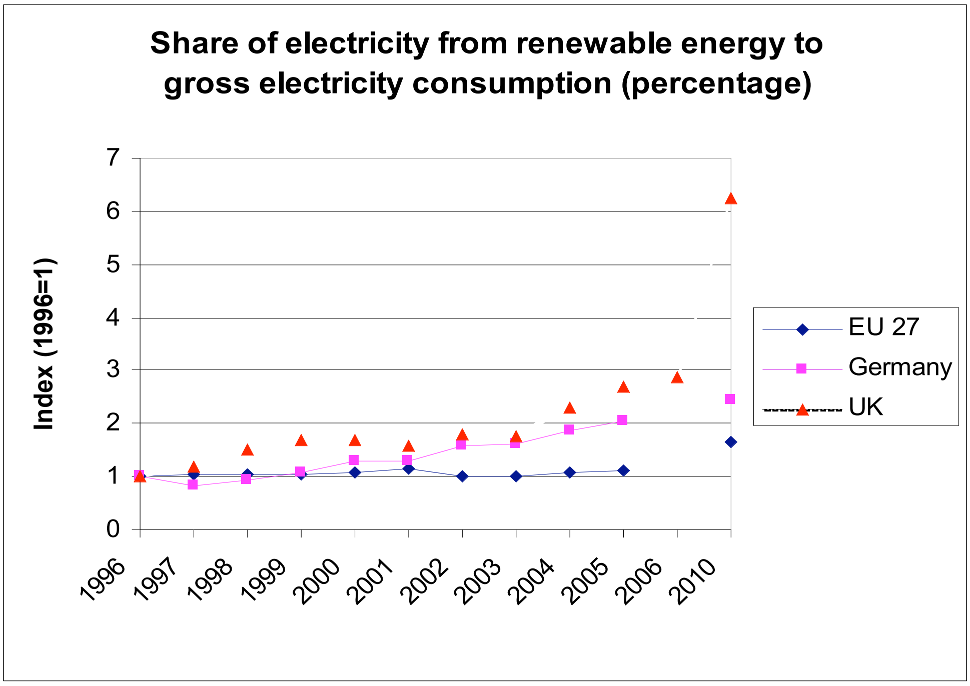


Figure 1.4-7: Data Source: EuroStat

This indicator is the ratio between the electricity produced from renewable energy sources and the gross national electricity consumption for a given calendar year. It measures the contribution of electricity produced from renewable energy sources to the national electricity consumption. Electricity produced from renewable energy sources comprises the electricity generation from hydro plants (excluding pumping), wind, solar, geothermal and electricity from biomass/wastes. Gross national electricity consumption comprises the total gross national electricity generation from all fuels (including autoproduction), plus electricity imports, minus exports.

1.4.11.2 Primary Energy Production of Renewable Solid Municipal Waste in the EU (in MToe)*

Table 1.4-2: Energy Prod. and Municipal Waste EurObserv'ER 2006 * Estimation

Country	2004	2005	Growth
Germany	0.624	0.605	-3.1%
France	0.957	0.920	-3.9%
Denmark	0.686	0.685	-0.1%
Italy	0.653	0.751	15.1%
Netherlands	0.623	0.669	7.5%
United Kingdom	0.463	0.460	0.7%
Total EU	5.144	5.346	3.9%

1.4.11.3 Incineration

Direct combustion of urban waste functions as the principal means of treating household waste in Europe. Incineration plants make it possible to produce heat and electricity. It is, however, not possible to distinguish only the organic share of the solid urban waste that alone can be qualified as being renewable. The incineration of waste at plants with energy recovery is regarded as contributing to realising the objectives mentioned above (http://europa.eu). However, the ten new member states may postpone their achieving the targets by the next four years. The Incineration Directive sets stringent operation and technical requirements on emission limits for incineration plants (2000/76/EC).

1.4.11.4 Limitations of renewable energy option

Despite the high technical potentials, the increased use of biomass is viewed with a little scepticism. Using biomass is cheaper to using fossil fuels. But, the plant to convert biomass into heat requires high initial investment. The reason being, as the energy density of biomass is lower to produce same energy output a larger storage area is required and therefore a bigger boiler is required. The price of biomass fuels also, depend on the demand and supply conditions. If the market for the renewable energy is developed well through information dissemination and education, the initial investment can be adjusted within a short term. If the demand for the renewable energy goes up, the scale effect may lead to reduced price of renewable energy. Apart from the above, biomass has a few disadvantages. The differing qualities of biomass, low efficiency per unit and the regional and seasonal irregularities make its use less popular.

The initial investment risk in renewable energy is more since the technologies of renewable energies are not proven nor they are in high demand thereby making venture risk an important element of financial arrangements (EC, 2006). It may be argued that sometimes, the risk coverage, contrary to the popular belief on the high initial cost, is the main limiting factor in the commercialisation of renewable energy technologies.

Low energy prices have always been focussed during the design of energy policy. In the case of conventional energy sources, the calculation of the rate of return, hidden or indirect subsidies on pricing of resources and infrastructure are not taken into account while analysing their cost-benefit relation. But, the surprising element is that energy prices have never been the real market prices. They have, rather, been influenced by the political decisions. Therefore, forecasting the price variations is difficult as they do not rely on free market mechanisms. On the other hand, renewable energy technologies do not support their economic justification. They justify their social and environmental benefits. Therefore, there is a growing need to create a level playing field supporting renewable sources of energy to compete with the conventional sources of energy.

1.4.11.5 Energy Production from Biomass in EU

Table 1.4-3: Energy from Biomass: Source: EurObserv'er, 2006

Country	2005	2006
France	9.78	9.61
Germany	7.75	8.82
Poland	4.18	4.30
Spain	4.18	4.33
United Kingdom	0.88	0.80
Total EU	59.29	62.41

Definition: Primary Energy Production (imports and exports excluded) of solid biomass (in Mtoe)

In the year 2005, the European Union produced 10.7 TWh of electricity, representing 6.7% growth with respect to 2004. The Biomass Action Plan of EU in 2005 redefined the objective for all the 25 member states. The European Commission states that the objectives of the Action Plan shall lead to an increase in the use of biomass to approximately 150 Mtoe in 2010. The European Commission's white paper for a Community Strategy sets out its strategy with an aim to double the share of renewable energies in gross domestic energy consumption in European Union by 2010 from 6% to 12%. The European commission's efforts are to have 0.30 point increase with respect to 2004. The European Commission projects the share of Biomass to 13.8% in 2004 and 15.8% in 2005. The European commission's energy policy focuses mainly on developing a strong lobby for renewable energy. The main reasons behind this goal are: renewable energy may help in their attempt to reduce Carbon Dioxide emissions; increasing share of renewable energy may help enhance sustainability; renewable energy sources may yield to be economically competitive compared to the conventional energy sources in the medium to long term (EC 2006).

1.4.11.6 Advantages of Biomass

- Secured supply and a decreased dependence on imported energy
- Very high conversion efficiency into final energy
- Convenient possibilities for private households.
- Biomass can be stored. Therefore, bio heat can be produced on demand
- Possibility for cogeneration
- Bio fuel cheaper than fossil fuels
- Business opportunities for entrepreneurs for setting up Small and Medium sized Enterprises.
- Job creation
- Socially benign behaviour
- Reduced environmental impact with decreased GHG.

Research studies at Biomass Logistics Technology, Austria cite that replacing one million tonne of fossil fuels with biomass heating installations require 7000 MW capacity and it creates employment opportunities to 7000 people in a year. To operate one million tonne capacity of biomass installations create up to 4000 permanent jobs.

1.4.11.7 Scope for Asia

ASEAN countries have world largest biomass reserves accounting for nearly 108 million tonnes. This includes wood, paper and pulp, palm oil and rice husks (Frost & Sullivan Market Insight, 2006). Developing countries consume only 30% of world energy although the population of developing world constitute a major fraction of the total world population. If the developing countries consume energy in proportion to their population size following the footsteps of the developed nations then the non renewable energy resources will be depleted at a faster rate. Therefore, the South Asian countries may have to develop their modern biomass cogeneration technologies not only to satisfy their increasing energy needs but preserve their environment and bio diversity too.

1.4.11.8 Need for the developing countries to shift their dependence from non renewable to alternative energy sources

The community can be seen as three separate parts like economic part; social part; and environmental part. But, if we observe the community taking into account the links between economy, environment and society the complex mix of their interdependence can be understood. Sustainability is influenced by the actions and decisions of the individuals, communities, organisations, companies, local, regional, federal and national governments and the international bodies. Many developing countries face difficulties in integrating climate change concerns in their policies due to lack of resources and institutional capacities. Capacity building, for example to integrate climate change and socio-economic assessments into vulnerability and adaptation assessments, helps to identify effective adaptation options and their associated costs. And poverty has been considered as the major factor in vulnerability. Future vulnerability depends not only upon the climate change but also on the type of development path (UNFCCC) a country chooses. The issue of poverty eradication an indicator of sustainability (World Commission on Environment and Development, 1997) indicates how the access to commercial energy can play a significant role in economic growth of a region. Alternative energy sources are gaining highest priority in terms of energy availability, while market reforms clubbed together with appropriate regulation can accelerate cleaner technologies that may address the issues of energy availability and their acceptability efficiently.

1.4.12 Public Awarneness

1.4.12.1 Raising public awareness- can it work as an informal regulation?

The incentive behind the developed countries efforts to finding a solution to fall back has been because of the increased pressure on energy supply. And they also understood that depending on corn could be an economic blunder. But, they were not the only reasons behind their success. The countries could promote the renewable energy projects through making the public aware. And as with awareness increase, the compatibility with existing land use was considered by the provinces and local municipalities to bring the Acts into force. Therefore, the challenge of the local municipalities and the scientific communities of the developing countries will be to provide information and opportunities for renewable energy facilities, including large scale operations, while ensuring that adverse effects are eliminated or minimised. Some studies (eg. Mongkolnchaiarunya, 2005) cite how a few projects could motivate the residents of a rural area, with emphasis on poorer communities, of Thailand to bring recyclables for exchange of eggs to keep their surroundings cleaner. This signifies the community empowerment through self-reliance establishing new relationships of more equality and less dependence between poor communities and local municipal administration in Asian countries.

The role of educational institutions in raising awareness among the public and accelerating societal acceptance to alternative energy sources is quite significant. They can act as a bridge between the producers of renewable energy, the researchers and the users of renewable energy. They can disseminate information in such a way so as to raise the societal acceptance for more and more reliance on renewable energy sources. Education can empower the local communities to enforce higher environmental standards thereby acting as informal regulation (Pargal and Wheeler, 1995).

The discussions on technology transfer, the renewable energy technologies, and clean development mechanism often, overlook the most significant aspect i.e. the societal acceptance. Stimulating societal acceptance is the prerequisite in the introduction and adoption of new technologies. The acceptance and adoption is preceded by processes like information dissemination, knowledge sharing, interaction among various groups discussing the advantage and complexity of the net benefit. The acceptance may be reflecting in the attitudes, behaviour and their willingness to investing in such projects. Despite an active participation of a large group of people from the developed and the developing countries in various discussions and seminars there is, still, a reluctant passive attitude for alternative energy sources and the renewable energy technologies prevalent. This can be due to finding site for the installations, outlay of the up-front capital investments to quote the most significant reasons.

The term social acceptance includes two different concepts ‘social’ and ‘acceptance’ with potentially different approaches. While social refers to the society consisting different groups like consumers and producers, acceptance may range between a passive consent and an active approval in the form of an active involvement. The societal acceptance, therefore, implies a broad spectrum of social groups considered and the degree of their accepting, a new initiative, involved. Social acceptance may have few dimensions like socio-political, community and market acceptance (Wüstenhagen et al, 2007). A study which reviews 30 surveys of the public attitude in UK for alternative energy technologies show that the opinion of the public in general supports investment in renewable energy technologies but, in terms of a passive consent (McGowan and Sauter, 2005). In the case of renewable energy technologies a generally favourable public attitude often, co-exists with resistance to specific development (Owens and Driffil, 2006). A research report (Federal Ministry of Environment, 2006) cites a rough estimate of the potential and consumption in the area of biomass in Thailand to be 24,000 ktoe/year (279,120 GWh) yet to be exploited. The study however, states the energy prices and the monopolistic structure of the energy market as a barrier. The Clean Development Mechanism (CDM) provides financial incentives for shifting to a less emissions-intensive economy. While it can lower some of the key barriers to renewable energy development with regard to the financial and economic aspects, it may not nullify all existing obstacles. There it requires the host country’s support and boost the initiatives and acceptance from the public.

Learning outcome:

The reader should have understood the basic principles behind integrated waste management and how can waste management systems be planned?

☑ Self-assessment

1. *What is decoupling of resource use and environmental impact?*
2. *How public awareness can bring changes under the existing scenario?*
3. *What has to be considered while planning waste management systems?*

Further reading

German:

Abfallwirtschaftsplanung – Münster (Germany):http://www.bezirksregierung-muenster.de/aufgaben/Organisation/Dezernate/Dezernat_52/Planung_der_Abfallwirtschaft_/index.html

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit – Abfallpolitik in Deutschland: http://www.bmu.de/abfallwirtschaft/fb/abfallpolitik/doc/2959.php

Kommunale Abfallwirtschaftskonzepte unter besonderer Berücksichtigung der Ökologie, Krüger, Frank Ulrich, 2001, Berlin: http://edocs.tu-berlin.de/diss/2001/krueger_frank.pdf

Abfallmanagement und Abfallrecht – Wien:
http://www.wien.gv.at/umweltschutz/abfall/

Gebühren Abfallentsorgung – Stadt Warendorf:
http://www.entsorgungsbetriebe-warendorf.de/sites/abfaelle_gebuehren.php

Kompostierbare Abfälle:
http://www.eigenbetrieb-abfallentsorgung.de/Abfall/abfall_biotonne.htm

Thermische Behandlung und energetische Verwertung von Abfällen –
http://www.elke-hartleib.de/thermischeabfallbehandlung.htm

English:

Bilitewski, B. et al (1994) : Waste Management, Springer Verlag Berlin Heidelberg

den Boer, Emila et al., 2005: Waste management planning and optimisation – Handbook for municipal waste prognosis and sustainability assesment of waste management sytems. Ibidem Verlag Stuttgart

National waste management policy and legislation (Ireland):
http://www.envirocentre.ie/Content.aspx?ID=96448806-bc07-4f5a-9e67-cb684d985609&PID=518accea-eec4-4cdf-b034-78ce58eacb4d

MIMES/Waste - A systems engineering model for the strategic planning of regional waste management systems http://www.entek.chalmers.se/~josu/art-jsundb.htm

Complete System of municipal waste management:
http://envis.praha-mesto.cz/rocenky/Pr04_html/aB4_02.htm

Planning and Waste Management – The Scottish Government:
http://www.scotland.gov.uk/Publications/1996/06/nppg10

Waste policy in Germany and the EU – Info-Tasks:
http://www.bmu.de/english/waste_management/doc/3432.php

1.5 References

Abu-Qudais M and Abu-Qdais H A (2000): Energy content of municipal solid waste in Jordan and its potential utilisation Energy Conversion & Management Vol. 41 pp 983-991

Basu, S (1995): Burning at the seams The Hindu Survey of the Environment Kasturi & Sons Ltd., Chennai pp 131-134

Bergmeier, M (2003): The history of waste energy recovery in Germany since 1920 Energy 28 pp 1359-1374

Bhide A.D (1994): Methane emissions from landfills Journal IAEM Vol. 21 pp 1-7

Bhoyar R.V., Titus S.K, Bhide A.D and Khanna P (1996): Municipal and industrial solid waste management Journal IAEM, Vol. 23 pp 53-64

DBDH (2004): The Danish Board of District Heating News from DBDH 4/2004

DEFRA (2006): Department of Environment Food and Rural Affairs Statistical release London UK

Demirbas A (2000): Recent advances in biomass conversion technologies Energy Education Science and Technology Vol. 6 pp 19-41

Demirbas A (2004): Combustion characteristics of different biomass fuels Progress in Energy and Combustion Science Vol. 30 pp 219-230

Diaz L F and Golueke C G (1987): Solid waste management in developing countries BioCycle Vol. 28 50-52

EC (1999): Directive 99/31/EC on the Landfill Waste

EC (2006): Innovation and Technological Development in Energy

EC (2006) Directive 2006/12/EC European Parliament and of the Council 2006 on waste

EC (2006): Strategy on the Prevention and recycling of waste

EC (2007): Towards a low carbon future – A European Strategic Energy Technology Plan COM (2007) 723 Final

EEA (2001): Indicator Fact Sheet Signals 2001 – Chapter Waste

EEA (2007): The road from land filling to recycling: Common destination, different routes

EEA (2007): How rapidly are renewable energy technologies being implemented? Indicator: Renewable Energy

EEA (2007b): Communication on the mid-term review of the Sixth Community Environment Action Programme COM (2007) 225 final

EIA: Energy Information Administration USA

ETC/RWM (2008): Municipal waste management and green house gases Working Paper 2008/1
Frost & Sullivan Market Insight (2006): Fuel cells Market in South East Asia: Restraints in Power Generation.

Federal Ministry of Environment (2006): Promoting Renewable Energy Technologies in Developing Countries Through the Clean Development Mechanism Research Report No. 203 41 141

Grossman G M and Krueger A B(1993): Environmental impacts of a North American free trade agreement The US-Mexico Free Trade Agreement (Cambridge MA, MIT Press)

Grossmann G M and Krueger A B(1995): Economic Growth and the Environment, Quarterly Journal of Economics 110(2) pp 353-377
Harker J H and Backhurst J R (1981): Fuel and Energy London Academic Press 1981

Hill, J., Nelson, E., Tilman, D., Polasky, S., Tiffany, D (2006): Environmental, economic and energetic costs and benefits of bio diesel and ethanol bio fuels Proceedings of the National Academy of Sciences (PNAS) Vol. 103 (30)

Hussaini, I.G., Garg, A., Kim, K.H., Marchant, J., Pollard, S.J.T., Smith, R (2007): European household waste management schemes: Their effectiveness and applicability in England Resources, Conservation and Recycling 51 pp 248-263

IFEU (2004)
Institute für Entsorgung und Umwelttechnik (2004): The contribution of waste management to sustainable development in Germany Special supplement to BMU magazine ‘Umwelt’ No. 10/2004

Integrated Wastes Service Association (2006) Waste-to-energy: Fact sheet Washington

Kaltschmitt M and Vogel A (2004): Alternative Biofuels in Europe- Status and Prospects Vortrag: Berg-Hüttenmänischer Tag 2004, Freiberg Germany

Lopez R and Mitra S (2000): Corruption, Pollution and Kuznets Environment Curve, Journal of Environmental Economics and Management 40(2) pp 137-150

Magnani E (2000): The Environmental Kuznets Curve, environmental protection policy and income distribution, Journal of Ecological Economics 32 pp 431-443

McGowan, F., Sauter, R (2005): Public opinion on energy research: a desk study for the research councils

Owens.,S and Driffil.,L (2006): How to change attitudes and behaviours in the context of energy Foresight July pp 1-18

Panayatou T (1993): Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development ILO Technology and Employment Programme Working Paper WP238 (Geneva)

Panayatou T (1997): Demystifying the environmental kuznets curve: Turning a black box into a policy tool, Journal of Environment and Development Economics 2 pp 465-484

Pargal, S and Wheeler D (1995): Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia

Parliamentary Office of Science and Technology (2005): Recycling Household Waste No. 252/2005

Ristic G (2005): Basic Indicators of Integrated Solid Waste Management Series: Working and Living Environmental Protection Vol. 2(5) pp 383-392

Scheffer K (2000): Biomasse-gespeicherte Sonnenenergie aus der Vielfalt der Pflanzenarten-Potentiale, Bereitstellung, Konversion in: Forschungs- Verbund Sonnenenergie Themenheft pp 34-39

Selden, T.M and Song D (1994): Environmental Quality and Development: Is there a Kuznets curve for air pollution emissions? Journal of Environmental Economics and Management Vol. 27(2), pp 147-162

Shafik N and Bandyopadhyay S (1992): Economic growth and environmental quality: time series and cross section evidence Working papers for Word Development Report World Bank Washington DC

Skumatz L A (2000) Measuring source reduction: pay as you throw/variable charging rates as example Seattle, WA: Skumatz Economic Research Associates Inc.

Umwelt Bundesamt (2007) Electronic Newsletter Environmental Technology Germany (03/2007)

United Nations Commission on Sustainable Development: Solid Waste Management and Sewage Related Issues Chapter 21 Agenda 21

UNFCCC: United Nations Framework Convention on Climate Change Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries.

Wenisch, S., Rousseaux, P., Metivier-Pignon, H (2004): Analysis of technical and environmental parameters for waste-to-energy and recycling: household waste case study International Journal of Thermal Sciences 43 pp 519-529

Wüstenhagen., R, Wolsink., M and Bürer., M.J (2007): Social acceptance of renewable energy innovation: An introduction to the concept Energy Policy 35 pp 2683-2691

Statistisches Bundesamt (Hrsg.): Statistisches Jahrbuch 2006 für die Bundesrepublik Deutschland. Wiesbaden 2006

Statistisches Bundesamt (Hrsg.): Statistisches Jahrbuch 2007 für die Bundesrepublik Deutschland. Wiesbaden 2007

Umweltbundesamt (Hrsg.): Data on the environment – The state of the environment in Germany, 2005 edition, Dessau 2005

Internet sources:

http://www5.gtz.de/gate/publications/BiogasDigestVol1.pdf

http://www.un.org/esa/sustdev

http://www.destatis.de/jetspeed/portal/cms

http://ec.europa.eu/eurostat

www.aebiom.org

http://eea.europa.eu

http://ec.europa.eu

http://ec.europa.eu/eurostat/

http://eea.europa.eu

http://www.un.org/esa/sustdev

http://www.destatis.de/jetspeed/portal/cms

2 Framework Conditions for Waste Management in Lao PDR, Vietnam, Cambodia and Thailand

Educational objective of the chapter

- General facts about Lao PDR, Vietnam, Cambodia and Thailand
- Different framework conditions: Policies and Strategies, Stakeholders, Economic and Socio-economic framwork conditions

2.1 Cambodia

2.1.1 General Facts

Figure 2.1-1: Map of Cambodia

Table 2.1-1: A summary of general facts of Cambodia (NIS, 2006)

People		Geography and Climate	
Population	14.0 millions	Total land area	181,035 Km^2
Population Growth Rate	2.0%	Land border	2,600 Km
Average Population Density	82 pp/km^2	Coastline	440 Km
Ethnicity: Khmer	96%	Length (North to South) Width (East to West)	440 Km 560 Km
Religion	Buddhism	Average annual temperature	27.7ºC
Language	Khmer	Average annual rainfall ▪ Central lowland regions ▪ Highland areas	 1,400 mm 5,000 mm
Infant Mortality Rate	95/1000	Humidity (daytime) ▪ Dry season ▪ Rainy season	 50% 60%
Maternal Mortality	4/1000	**Government Administration**	
General Fertility Rate	129/1000	Number of provinces/municipalities	24
Life Expectancy	54.4 years	Number of districts	185
Net enrollment Ratio for Primary School	91.9	Number of communes	1,621
Literacy Rate (15-44)	79%	Number of villages	13,886

2.1.2 Policies and Strategies

Current situations of solid waste management in Cambodia

The management, collection and transportation of solid wastes in Cambodia are still weak, as a result of a number of factors, including a low budget, a shortage of all types of equipment needed for the transportation, collection and storage of waste, weak laws and enforcement and no overall management plan. Transportation and collection processes are complicated and the services are slow and unpredictable (Cotter, 2000).

Figure 2.1-2: Truck used to transport waste from a open market (Deum Kor Market) in Phnom Penh

Figure 2.1-3: Waste used to make compost at COMPED

National, regional, future plan

The Office of Solid Waste Management and Pollution Control have proposed measures to improve sanitary conditions and cleanliness in the municipality of Phnom Penh and to reduce the volume of solid waste. The reduction approach includes the following recommended measures:

- Increase education and training for the general population to understand solid waste management and ways to avoid dangers which occur due to their own carelessness.
- Prohibit companies which import materials and equipment which cannot be recycled.
- Decrease the importation of second hand products.
- Offer incentives to attract investment companies to invest in the recycling plants.
- Organize and place public bins in suitable places to make collection easier.
- Introduce clear and enforceable policies and regulations.

Below are the principles that have been set in the Waste Management Program (WMP) to establish liquid and solid waste management in Cambodia (Kokusai Kogyo Co., 2005):

- Political will and financial affordability are prerequisites for adequate management
- Health, economy and environment are equally important factors
- Stepwise approaches are essential to explore alternatives and integrated solutions
- National and local governments are to take responsibility in creating enabling environment for sustainable solutions
- Commitment and involvement of all stakeholders has to be assured from the beginning
- Public and private partnership and other new financial mechanisms are to be explored
- Linking wastewater management systems to other sectors, e.g. industry, agriculture, etc.
- Sustainable solutions for waste management will be built upon pollution prevention and law-cost technologies.

Based on the above key principles, following improvements have been proposed by WMP to establish sustainable solid waste management (SWM) (Kokusai Kogyo Co., 2005):

- To set up waste inventories throughout the country to assess the actual and potential impact of waste on the living environment in provinces and cities
- To review and develop guidelines and standards for waste management in Cambodia in accordance with national and local requirements
- To enforce all pollution sources to implement the guidelines and standards for waste management as well as to raise their awareness of proper waste management
- To disseminate the waste management guidelines and standards to all stakeholders, including local communities, NGO, etc
- To promote the 3Rs (Reduce, Reuse and Recycle)
- To promote cleaner production to minimize or eliminate the use of toxin or hazardous wastes from industries.

Instruments, Laws

The *Law on Environmental Protection and Natural Resource Management, which* was approved in 1999, has 27 articles dealing with general provisions, national and regional environmental plans, environmental impact assessment, natural resource management, environmental protection, monitoring, record-keeping, and inspection, public participation and access to information, environmental endowment fund, interim provisions, and a section on penalties. In addition, the law contains three sub-decrees on water pollution control, solid waste management, and air and noise pollution control (Heisler, 2004).

The Solid Waste Management Sub-Decree:

The sub-decree on Solid Waste Management (SWM), enacted in April, 1999, was established to regulate SWM in a proper technical and safe manner to protect human health and the environment. The sub-decree sets the overall framework for SWM in Cambodia and applies to all activities related to “the disposal, storage, collection, transport, recycling, and dumping of waste.

2.1.3 Stakeholders

Several groups of stakeholders, including waste producers, waste pickers, regulators, legislators, contractors, educators, NGOs, media and the general public, are involved in waste management in Cambodia. Although each of these stakeholders plays a potential role, three groups (municipalities and industry (generators), governments (regulators) and legislators provide the key to effective national waste management policies and strategies that integrate the responsibilities of all stakeholders in making waste management a successful venture.

Ministry of Environment (MOE)

MOE was established by a Royal Decree in 1993 with important missions to protect and upgrade the environmental quality and public health by means of prevention, reduction, and control of pollution, sustainable natural resource management and biodiversity in Cambodia. Solid waste in Cambodia is co-managed by MOE and respective municipal or provincial authority. Under the supervision of MOE, Department of Environment Pollution Control (DEPC) has been established to control and monitor all wastes, toxic and hazardous substances.

Private Sector
Because the government has limited budget for SWM or other environmental management concerns, private companies are encouraged to be involved in the larger provincial towns to collect waste from markets as well as from residential areas surrounding the markets. Indeed, private sector participation in municipal services has witnessed increased interests in recent years to reform the weak performance of public sector, reduce costs, improve efficiency, and ensure environmental protection (Vin et al., 2005).

There are two main private companies responsible for waste management in Phnom Penh. CINTRI (Cambodia) Co., Ltd. is a profit waste management firm responsible for waste collection and transport, as well as for cleansing services for Phnom Penh city. The company now has a monopoly on waste services and a contract of fifty years. Phnom Penh Waste Management, PPWM, which operates under the DPWT, only has the capacity to collect 2.1% of the waste from the city (JICA, 2004). Hence, CINTRI definitely fills an important need in the city. However, CINTRI"s monopoly means that there is no open market for waste services and hence no bidding between competitors working to get the price down (JICA, 2004).

The second company is Sarom Trading Company Co. Ltd, which is a privately owned enterprise that currently collects, transports and disposes of all of Cambodia's hazardous waste at its site, located around 20 km from Phnom Penh in Ang Snoul, Kandal Province. The contract between the industries and Sarom Trading center is a coordinated effort among GMAC—the industry association, the Ministry of Industry, the Ministry of Environment, and the company itself. The individual industries are completely responsible for paying a fee to Sarom Trading center (Heisler, 2004).

Waste Pickers
Currently, there are approximately 3000 waste pickers in Phnom Penh, about 50% of whom are children. They, being poor, make their living by sorting through garbage on the street or in front of people's homes to collect materials such as aluminum, glass, and plastics to sell to waste collectors. In Phnom Penh, most of the waste pickers live on the periphery of the disposal site in Stung Mean Chey, in Phum Prek Tal and Phum Damnak Thom. They work at nigh in public places, sorting solid waste without protection such as gloves or masks because of the lack knowledge on safe waste handing techniques, sanitation and basic health care, thus being vulnerable to dangers such as disease, injury, and assault (MPP & ADB, 2006).

NGOs
There are several NGOs providing various programs to child waste pickers and are also involved in community-based development projects such as micro-credit finance, in cooperation with Village Development Committees (VDC). In Phnom Penh, Community Sanitation and Recycling Organization (SCARO) and Cambodian Education and Waste management Organization (COMPED) are the only specialized NGOs on waste management. The two NGOs are mainly working on:

- Organizing community development and facilitating infrastructure development activities.
- Conducting outreach, education, and health care activities for waste pickers, poor community residents and school children.
- Developing IEC materials to support education and outreach activities
- Organizing waste pickers into self-help groups.
- Producing compost from waste

2.1.4 Economic framework

After almost 30 years of civil war, Cambodia began to rebuild its economy in the early 1990s, with the support of the International Monetary Fund (IMF). Political stability and macroeconomic reforms such as banking systems, government revenue collection, and improved governance have resulted in a rapid increase in economic growth. In the last decade, Cambodia's economy, after being integrated in regional and global economies, has grown well with an average growth rate of more than seven percent per year (Table 2.1-2), as a consequence of export growth (EIC, 2006). The economy grew remarkably in 2005, with estimated nominal GDP being 25,350 billion Riels in current prices (NIS, 2006). Presented in Table 2.1-3 is the growth rate of the GDP by sectors. The industrial sector showed the fastest growth rate with an average of 15 percent per annum, due mainly to a boom in the garment industry; totally, there are 258 garment factories employing 300, 0000 workers as of December, 2005. The service sector, imparted mainly by the tourism sector, grew moderately with a rate of six percent per annum. The growth of agriculture GDP has shown to be erratic, due mainly to a high dependency on weather conditions (EIC, 2006).

Table 2.1-2: Key Macroeconomic indicators, projections for 2006-2010 [RGC, 2006]

	2005	2006	2007	2008	2009	2010
GDP (constant prices) billion riels	19,294	20,452	21,679	22,936	24,290	25,747
Real GDP-% increase	7.0	6.0	6.0	5.8	5.9	6.0
Inflation in Riels (%)	6.2	3.5	3.0	3.0	3.0	3.0
Foreign Direct Investment (US$ million)	216	227	249	274	302	332
Gross Foreign Reserves (mths of import)	2.5	2.5	2.5	2.6	2.8	3.0
Riels/US$ Parity (exchange rate)	4,128	4,219	4,228	4,278	4,328	4,378
Exports (US$ million)	2,707	2,931	3,172	3,395	3,643	3,918
Imports (US$ million)	3,738	4,169	4,513	4,827	5,172	5,527
Current Account Balance (%GDP) (including official transfer)	-4.1	-5.4	-4.9	-4.0	-3.3	-2.6
Fiscal Sector (% of GDP)						
Budget Revenue	**11.8**	**12.2**	**12.8**	**13.2**	**13.5**	**13.8**
Tax Revenue	8.7	9.4	9.4	9.4	9.3	9.2
Non-Tax Revenue	2.5	2.6	2.6	2.6	2.7	2.7
Budget Expenditure	**14.9**	**17.0**	**17.2**	**17.1**	**16.9**	**16.5**
Capital Expenditure	5.3	6.6	6.6	6.3	6.2	5.9
Current Expenditure	9.6	10.5	10.7	10.7	10.7	10.8
Current Balance	**1.6**	**1.5**	**2.0**	**2.3**	**2.6**	**2.9**

Table 2.1-3: GDP growth rate by sector and total (constant 2000 Prices) [NIS, 2006]

Sector	Growth rate (%)											
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Agriculture	9.9	3.5	1.2	5.5	5.1	3.7	-1.2	4.5	-2.2	12.1	1.2	16.6
Industry	14.2	18.9	4.4	16.8	6.2	21.2	31.2	11.4	17.3	12.1	16.4	12.1
Services	0.6	8.3	9.2	2.9	5.0	14.6	8.9	8.7	6.3	4.4	11.7	12.1
Taxes less subsidies	80.8	1.8	14.3	5.3	-2.4	39.2	4.5	2.5	12.6	1.8	21.4	11.4
Total	**9.2**	**6.5**	**5.3**	**5.7**	**5.0**	**12.6**	**8.4**	**7.7**	**6.2**	**8.6**	**10.0**	**13.4**

2.1.5 Socio cultural and socio-economic framework

As a result of two decades of war and tragic loss of million lives during the Khmer Rough's regime (1975-79), Cambodia presents the highest poverty rate in Southeast Asia, with 35% of total poverty and 20% of food poverty in 2004. The socio-economic conditions in rural areas were found to be more obvious in rural areas than urban areas (Table 2.1-4). With a Human Development Index score of 0.543, Cambodia is ranked as 130th out of 173 countries in the world. Access to education and health services is still limited (NIS, 2006).

Table 2.1-4: Comparison of socio-economic indicators between rural and urban population

Indicator	Rural	Urban
Average monthly income (riels)	314,247	1,139,553
Adult literacy (%)	64.9	79.1
Access to drinking water (%)	23.7	60.3
Access to electricity (%)	8.6	53.6
Access to toilet facility (%)	8.6	49.0
Educational levels beyond primary school (%)	12.8	31.4

The total employment increased from 3.9 millions in 1993 to 7.5 millions in 2004, of which agricultural, industry, and services sector accounted for 60.3, 12.5 and 27.2%, respectively (NIS, 2006). Employment status differs greatly between urban and rural areas. In urban areas, 30 per cent of the labor force is paid employees and only 27 per cent is unpaid family workers, whereas only 10 per cent of workers are paid employees and 48 per cent are unpaid family workers in rural areas (NIS, 2005).

The strategies of RGC, as presented in the Second Socio-Economic Development Plan 2001-2005 (SEDPII), are:

- To foster broad-based sustainable economic growth in which private sector plays the leading role to maintain an economic growth of 6-7%.
- To promote social and cultural development by improving the access of the poor to education, health, water and sanitation, power, credit, markets, information and appropriate technology.
- To promote the sustainable management and use of natural resources and the environment.
- To improve the governance environment through effective implementation of the Governance Action Plan (GAP).

2.2 Vietnam

2.2.1 General Facts of Vietnam

Geography

Vietnam lies on the eastern seaboard of the Indochina Penisula, has a total mainland area of 331,690 km^2, bordering China (1,281 km) to the north and Laos (2,130 km) and Cambodia (1.228 km) to the west, the Gulf of Thailand to the South and the Pacific Ocean to the East. The country stretches from latitudes 8°10' to 23°24'N and has an 3,444 km long of coastline, over 3,000 islands. Mountains and hill cover four-fifths of Vietnam’s territory with the Truongson range stretching over 1400 km. Mount Fansipan (3,143 m) is the highest peak in Southeast Asia. The country's two main cultivated areas are the Red River Delta (15,000 sq. km) in the north and the Mekong Delta (40,000 sq.km) in the south.

Figure 2.2-1: Map of Vietnam

Climate

Vietnam is located in the tropical and temperate zone characterized by high temperature and humidity all year round, especially in rainy season. The annual mean temperature is over 20 degrees Celsius through out the country (Hanoi 23.4°C, Hue 25.1°C, Ho Chi Minh City 26.9°C). Low land areas receive around 1,500 mm of rain per year, while mountainous areas receive 2,000 mm to 3,000 mm. The average air humidity is over 80% and can reach 90% in rainy season.

Vietnam has two seasons: cool and dry from November to April and hot and rainy from May to October. The difference between summer and winter temperature is dramatic in north (varying up to 20 or 30 degrees Celsius). The south is warm all year round, with seasonal variations in temperature averaging just three degrees Celsius.

Inhabitants

According to General Statistic Office, at January 1st, 2006, Vietnam has a population of an estimated 84.156 million people (Table 2.2-1) of which the Viet people comprise 85%. The minority of the population consists of 54 ethnic groups who live mostly in the mountainous areas in the Central Highlands and the North. The urban population ist about 25% and the population growth rate 1,2%. The average density is 242 people/km^2.

Ethnic groups in the North generally live between altitudes of 25m and 2,000m above sea level. The most well known of these are the Tay (also the most populous), the White Tai and Black Tai (distinguished by the colour of their clothes) and the Hmong (Meo). In the South, geographic locations of ethnic hilltribes are much more distinct with some living in the plains as well as the hills. The most well known of these are Hoa, Khmer, Cham.

Economic, industry

Environmental situation in Vietnam is going to an urgent fact. Main reason is the unsustainable development of the country. The development in economic is not going well with protection of environment. This situation therefore bring for air pollution and polluted water from industrial waste water and solid waste.

Vietnam is a developing, densely-populated country that has had to recover from the ravages of war, the loss of financial support from the old Soviet Bloc, and the rigidities of a centrally-planned economy. Substantial progress was achieved from 1986 to 1996 in moving forward from an extremely low starting point - growth averaged around 9% per year from 1993 to 1997. GDP growth of 8.5% in 1997 fell to 6% in 1998 and 5% in 1999. Growth then rose to 6% to 7% in 2000-2002 even against the background of global recession. Since the Party elected new leadership in 2001, Vietnamese authorities have reaffirmed their commitment to economic liberalization and have moved to implement the structural reforms needed to modernize the economy and to produce more competitive, export-driven industries. The US-Vietnam Bilateral Trade Agreement entered into force near the end of 2001 and is expected to significantly increase Vietnam's exports to the US.

Table 2.2-1: Vietnam inhabitants profiles (January 1st, 2006)

	Population (thousand people)	Area (*) (Km^2)	Population density (people/km^2)
Whole country	84155.8	331211.6	254
Red river delta	18207.9	14862.5	1225
North East	9458.5	64025.2	148
North West	2606.9	37533.8	69
North Central Coast	10668.3	51552	207
South Central Coast	7131.4	33166.1	215
Central Highlands	4868.9	54659.6	89
South East	13798.4	34807.7	396
Mekong River Delta	17415.5	40604.7	429

Data of General statistic Office

Following the conclusion of bilateral negotiations with interested WTO members and completion of multilateral negotiations in 2006, the WTO General Council approved the terms for Vietnam's membership on November 7, 2006. Vietnam formally acceded to the WTO as its 150th member on January 11, 2007. Vietnam was granted unconditional normal trade relations (NTR) status by the United States through a Presidential Proclamation signed by President Bush on December 29, 2006. To meet the obligations of WTO membership, Vietnam revised nearly all of its trade and investment laws and guiding regulations. As a result, foreign investors and those seeking to sell goods and services to the increasingly affluent Vietnamese population will benefit from the improved legislative framework and lower trade barriers. In 2007, Vietnam got an amazing GDP growth rate of around 8.5%.

Land use

After regulation of general department of land management of Vietnam, on using aspect, land is classified into 5 groups: (1) Agricultural land, (2) Forestry land, 3) Land for special use, (4) Residential land, (5) Not yet used land (see Table 2.2-2).

Environment issues

Like many other developing countries, the environment in Vietnam is deteriorating, particularly in densely populated areas, in industrial regions or base, and in sea port.

Various kind of Environment problems have been meet with: logging and slash-and-burn agricultural practices contribute to deforestation and soil degradation; water pollution by industrial refuse or waste; overfishing threaten marine life populations; groundwater contamination limits potable water supply; growing urban industrialization and population migration are rapidly degrading environment in Hanoi and Ho Chi Minh City (air pollution, noise pollution and water pollution); acid rains have also detected, toxic chemical pollution too; the use of chemical fertilizers and insecticides in agriculture certainly affects the surface and underground water, but its consequences are still not clearly understood.

Table 2.2-2: Vietnam land use profile in 2006 (at January 1st, 2006)

	Total area (thousand hectare)	In which			
		Agricultural land	Forestry land	Land for special use	Residential land
Whole country	33121.2	9412.2	14437.3	1401.0	602.7
Red river delta	1486.2	760.3	123.3	230.5	116.5
North East	6402.4	978.8	3551.0	202.7	79.9
North West	3753.4	499.5	1773.6	42.3	32.7
North Central Coast	5155.2	804.9	2854.0	194.1	97.9
South Central Coast	3316.7	583.8	1459.8	193.8	54.2
Central Highlands	5466.0	1597.1	3067.8	124.5	41.6
South East	3480.9	1611.9	1251.6	193.6	71.4
Mekong River Delta	4060.4	2575.9	356.2	219.5	108.5

Data of General statistic Office

There are three main types of solid waste: municipal solid waste, healthcare solid waste and industrial waste. Waste generation estimated around 15 million tons per year (2004), but the number will be soon bigger in the next decade, according to this development. The urbanization and the rapid development in industry as well as modernization in healthcare will bring a big amount in hazardous waste. If there is no suitable solution damage in people health and environment is foreseen [VEaSM 2005].

The environmental situation of Vietnam was for the first time stated in the National Report in 1994, from then exists every year the Annual Report on “Environmental Status”.

Waste problem is increased rapidly. There are three main reasons:

- Vietnam is on the way of industrialize and urbanization. Industry rate of development is about 12 - 15 % / year since continuously two recent decades.
- Many production processes equipped by old technologies therefore material consumption must be 2 - 3 times higher based on one product, corespondent with higher waste generation.
- People have less care about environmental protection.

It is to noticed that waste management is the integration of “waste” into the economic allocation problems, concerning legal aspect, connecting to social and economic condition, especially doing waste management need to understand well the waste characteristic in particular and the domestic waste situation in general.

Natural resources

Vietnam’s most valuable natural resource is its land, particularly the fertile, alluvial soils in the Red and Mekong deltas. Some 26 percent of the land is currently being cultivated Most mining activities take place in the northern provinces of the country, where anthracite coal, phosphate rock, gypsum, tin, zinc, iron, antimony, and chromite are extracted. Coal and apatite are mined extensively. The total coal production in 2001 was 10 million metric tons.

In recent years, large petroleum and natural gas deposits have been discovered along the continental shelf in the South China Sea. With assistance from the Soviet Union, Vietnam began extracting oil from its first oil field in the mid-1980s. Additional oil fields have since become productive. In the late 1990s petroleum accounted for nearly one third of Vietnam’s export revenues.

2.2.2 Introduction to the Mekong Delta

The Mekong delta (MD), Vietnam, is the most downstream part of the Mekong river basin. With a population of 17.4 million inhabitants living in 4 million hectares of land (data of General Statistic Office – on 1/1/2006), MD has great potentials for agricultural production. MD is the most important agricultural production region for the whole country, Vietnam. It supplies for more than 50 % of staple food and 60% of fish production and accounts for 27% of the total GDP of Vietnam. Rice and fishery products contribute significantly to the nation’s export earning.

The MD is divided into 13 administrative units. It comprise 12 provinces: Long An, Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Dong Thap, An Giang, Hau Giang, Kien Giang, Soc Trang, Bac Lieu, Ca Mau provinces and one city: Cantho City.

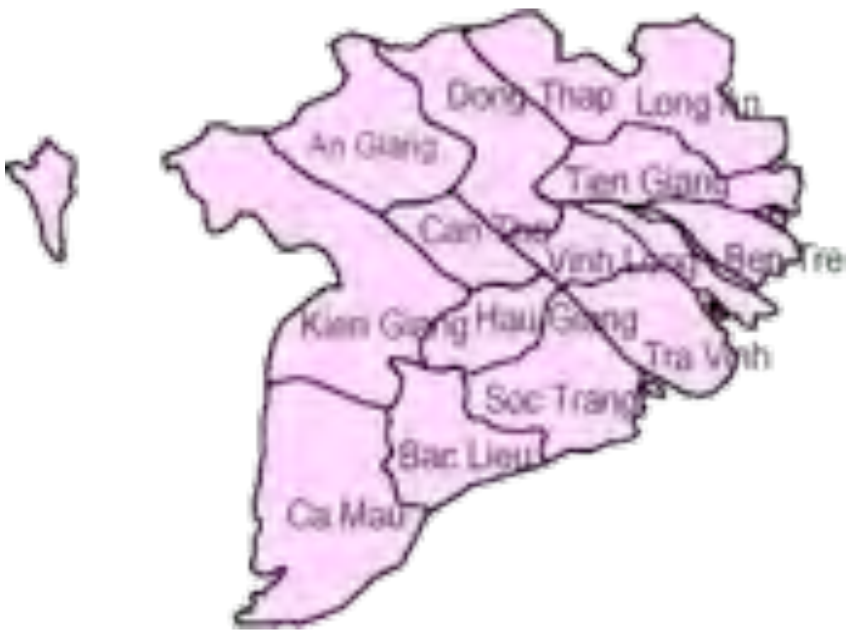


Figure 2.2-2: Map of the Mekong delta

2.2.3 Legal frame work for solid waste management in Vietnam

2.2.3.1 Legal frame work, policies and strategies

Policy on solid waste management in urban and industrial areas of Vietnam is issued in 10/07/1999, demonstrated in Decision 152/1999/QD-TTG of Prime Minister.

The National Environmental Action Plan 2001 - 2005 (NEAP) is focusing on five programs, among them Program 2 concerning: Improve solid waste management capacity, especially hazardous waste management in densely populated urban areas and industrial zones.

This program includes the following action:

Develop a national strategy for solid and hazardous waste management

The strategy will include the development of sanitary landfills, improved urban planning regulations and hazardous waste management guidelines. It will identify institutional relationships and administrative requirements, financial requirements for addressing priorities and HRD implications.

Develop sanitary landfills

Main population centres will develop sanitary landfills, according to the following time schedule:

- 2002: Hue, Haiphong, Danang
- 2003: Dongnai, Quinhon
- 2004: Baria-Vungtau, Nhatrang, Halong
- 2005: Thainguyen, Thudaumot

In addition, waste separation will be promoted throughout the country in an attempt to reduce the necessity for new landfills and expensive treatment facilities. By the year 2005, waste separation will be in place in at least 20 major centres in the country.

Recycling, re-use and reclamation of waste products will be promoted and private sector involvement will be encouraged. At least ten private sector enterprises will be in operation by the end of the plan period.

Improve hazardous waste management

Vietnam is still predominantly an agricultural society. However, hazardous waste is becoming a major problem. The main source for hazardous waste in industrial production, in particular metallurgy and chemical industry. Hazardous waste treatment facilities will be developed in Hanoi, Danang and Ho Chi Minh City, to act as collection and treatment locations for the three major development zones of the country.

Improve hospital waste management

There are currently 815 state-owned hospitals in operation and three private hospitals, but few of these have adequate waste treatment facilities. Not all hospital waste is hazardous, and it is estimated that only 16% of their solid waste needs special treatment. Before the end of 2005, environmental management systems will be introduced in all hospitals, as well as in the private health clinics. This will include waste separation guidelines and training and awareness about sanitation and environmental issues.

Incinerators will be installed at twenty main hospitals during the plan period, especially those that deal with infectious diseases. This will include 3 hospitals in Hanoi and Ho Chi Minh City respectively, and 12 general hospitals in rural provinces. The cost of the actual plants was covered through ODA, but Government will ensure that the running costs of the facilities are included in the budget of respective hospitals. By 2005, at least forty hospitals will have effective wastewater treatment facilities.

Raise awareness

During the period 2001 - 2005, programs have been implemented in the following cities and rural areas:

- By 2003: Hanoi, Dong Thap
- From 2002 to 2004: Ho Chi Minh city, Quang Ninh
- From 2003 to 2005: Hai Phong, Quang Ngai

This program will require financial incentives. A list of economic policy instruments was prepared in 2002 that was used to promote private sector involvement. Studies were carried out in 2002 and 2003 to determine opportunities to increase cost recovery associated with collection and disposal of solid waste. There are a short term proposal (to 2005) and a long one (to 2020) [2].

For 2005 it was stated for complete the waste management plan in every urban and industrial area. Segregating hazardous waste all from source and occasional for municipal waste in some selected places. Collection, transportation and treatment of 75 - 90 % amount of generated waste, suitable for each municipality. Healthcare waste is mostly treated in incinerator in big cities.

The Vietnamese government has issued a series of legal texts for solid waste management from the environmental protection law to the decree, circular, joint circular and standards as listed in the following.

Environmental protection legislation

Law on Environmental protection passed on November 29, 2005, took into effect from July 1st, 2006. This law replaced the Environmental protection law 1993.

Decree No 80/2006/NĐ-CP on August 09, 2006 of the Government detailing the implementation of the law on environmental protection.

Decree No 81/2006/NĐ-CP on August 09, 2006 of the Government promulgating the Regulation on sanction against Administrative violation in the field of protection of the environment. This decree replace the decree No 121/2004/NĐ-CP.

Decree No 59/2007/NĐ-CP of the Government promulgating the Regulation on the solid waste management activities, the right and duty of the person related to solid waste management.

Decision No 256/2003/QĐ-TTg, issue on August 7, 2004 by the Prime Minister on approving the National strategy on Environmental Protection up to year 2010 and Vision to 2020.

Decision No 153/2004/QĐ-TTg, issue on April 2nd, 2003 by the Prime Minister on provision sustainable development in Vietnam.

Decision No 64/2003/QĐ-TTg, issue on April 22nd, 2003 by the Prime Minister approving the plan for managing the establishments causing seriously environmental pollution.

Solid and hazardous waste legislation

Anouncement No 50/TB-VPCP dated on March 19, 2007 on the conclusion of the Prime Minister at the seminar on Applying Solid waste treatment technologies that were studied in Vietnam.

Decision 23/2006/QĐ-BTNMT dated on December 26, 2006 of Ministry of Natural Resource and Environment on promulgating the list of hazardous waste.

Circular No. 12/2006/TT-BTNMT dated on December 26, 2006 of Ministry of Natural Resource and Environment on the instruction of the condition, documentation, registration and code of hazardous waste management.

Decree No 23/2005/CT-TTg on June 21, 2005 of the Prime Minister on strengthening the activities on solid waste mangement in urban areas and industrial zones.

Decree No 13/2003/NĐ-CP on February 19, 2003 of the Government providing the provisions for the commodities prescribed as being dangerous/toxic and their transportation via roads.

Circular No 02/2001/TT-BKHCNMT dated on February 15, 2001 by Ministry of Science Technology and Environment on instruction the treatment of waste of special encourage investment.

Decision No 155/1999/QĐ-TTg issued on July 16 1999 of the Prime Minister promulgating the regulation on hazardous waste management.

Directive No. 199/TTg on April 3rd, 1997 of the Prime Minister on urgent measures to manage solid waste in urban areas and industrial zones.

Decision No 152/1999/QĐ-TTg issued on July 10, 1999 of the Prime Minister approving the National strategy for solid waste management in Industrial and urban Areas until 2020.

Inter-ministerial circular No 1590/1997/TTLT/BKHCNMT-BXD, October 17, 1997 of the Ministry of Construction, and Ministry of Science, Technology and Environment giving instruction to implement Directive 199/TTg by the Prime Minister on urgent measure on management solid waste in urban areas and industrial zones.

Decision No 60/2002/QĐ-BKHCNMT dated August 8, 2002, of Ministry of Science, Technology and Environment guiding the implementation of hazardous waste burying technique.

Toxic subtances legislations

Decision No 23/2006/QĐ-BTNMT by Minister of Ministry of Natural resource and environment promulgating the list of hazardous waste.

Directive No 29/1998/CT-TTg dated August 25, 1998 of The Prime Minister on strengthening the management of the use of plant protection chemicals and persistent organic pollutants.

Decision 1970/1999/QĐ-BKHCNMT issued on November 10, 1999 by the Minister of ministry of Science, Technology and Environment on the technological procedures applied to disposal of banned plant protection chemicals that content the phosphorous organic compounds.

Decision 1971/1999/QĐ-BKHCNMT issued on November 10, 1999 by the Minister of ministry of Science, Technology and Environment on the technological procedures applied to disposal and reuse of cyanide.

Decision 1972/1999/QĐ-BKHCNMT issued on November 10, 1999 by the Minister of ministry of Science, Technology and Environment on the technological procedures applied to disposal of banned plant protection chemicals that content the chlorinated organic compounds.

Medical waste legislation

Decision No. 62/2001/QĐ-BKHCNMT, November 21, 2001, promulgating the technical requirements for incinerators of medical waste.

Inter-ministerial circular No. 2237/1999/TTLT/BKHCNMT-BYT, December 28, 1999, guiding the implementation of the regulations on safe application of radioactive techniques in medical services.

Decision No. 2575/1999/QĐ-BYT, August 27, 1999, of the Minister of Health promulgating the regulations on medical waste management.

Official letter No. 4527-ĐTg, June 8, 1996,of the Ministry of Health guiding the treatment of solid waste from hospitals.

Legislation on Recycling

Official letter No. 1146/BKHCNMT-MTg dated on May 6, 2002, of Minister for Science, Technology and Environment approving the National Action Plan for Cleaner Production.

Decision 03/2004/QD-BTNMT, April 2, 2004, of MONRE on importing waste as materials for domestic production.

Legislation on Waste Management Infrastructure facilities

Inter-ministerial circular No. 01/2001/TTLT- BKHCNMT-BXD, January 18, 2001, guiding the regulations and environmental protection applied for the space planning of the siting, construction, and operation of landfills.

Inter-ministerial circular No. 10/2000/TTBXD, August 8, 2000, guiding the preparation of EIA reports for the planning of construction projects, including solid waste management during and after construction.

Inter-ministerial circular No. 29/1999/QD-BXD, October 22, 1999, promulgating the regulations of environmental protection applied for the construction sector.

Fees and Charges

Ordinance No. 38/2001/PL-UBTVQH, August 28, 2001, of the Standing Committee of the National Assembly on prescribing Fees and Charges. This is generally supported by local regulations issues by People's Councils or Committees.

Governmental Decree No. 57/2002/ND-CP dated on June 3, 2002, providing the details on the implementation of the Ordinance No. 38/2001/PL-UBTVQH on prescribing Fees and Charges.

Circular No. 63/2002/TT-BTC dated on July 24, 2002, of Ministry of Finance guiding the implementation of provisions on Fees and Charges.

Circular No. 45/2006/TT-BTC dated on May 25th 2006 of Ministry of Finance to change and complement the circular 63/2002/TT-BTC on fee and charges.

Circular No. 71/2003/TT-BTC dated on July 30, 2003, of Ministry of Finance guiding the implementation of the provisions on the fees and charges for solid waste collection and treatment (prescribed as one of "Hygienic services").

Decision No 13/2007/QĐ-BXD of the Minister of Ministry of construction issued on April 23, 2007 on "Norm of collection, transportation, treatment, landfilling municipal solid waste".

Standards

TCVN 6696-2000 requirements for environmental protection for sanitary landfills.

TCVN 6705-2000 non-hazardous solid waste - Classification.

TCVN 6706-2000 hazardous solid wastes - Classification.

TCVN 6707-2000 prevention and warning signs for hazardous waste.

TCVN 7241:2003 Health care solid waste incinerators - Determination method of dusts concentration in fluegas.

TCXDVN 261:2001 - Landfill - Standard for designing.

TCXDVN 320:2004 – Hazardous waste Landfill - Standard for designing.

International Conventions

Vietnam is a signatory to a number of major international conventions, of which at least there are three relating to waste management.

Kyoto Protocol and the Clean Development Mechanism (CDM). Vietnam ratified the Kyoto Protocol in 2002 and has prepared a National Strategy Study for the CDM that allows industrialized countries to purchase "carbon credits" from projects in developing countries and count those emissions reductions against their commitments. Collection and use of landfill methane is one of the technologies that can financially benefit most under the CDM as it can increase the financial internal rate of return of these types of projects between 5% and 10%.

Basel Convention on the Control of Trans-boundary Movement of Hazardous Waste and Their disposal. The Basel Convention entered into force in 1992 with Vietnam ratifying it in 1995. The Convention focuses on the transport and treatment of hazardous waste. The Competent Authority and Focal Point to the Basel Convention is VEPA. Vietnam has undertaken many activities to implement the convention, including training, waste inventories, strategies, legal reform, technical guidelines, and promulgating a hazardous waste management classification system.

Stockholm Convention on Persistent Organic Pollutants (POPs). This convention has been adopted in response to the need to manage, reduce, and eliminate POPs, which are posing health and environmental concerns. Vietnam signed the POPs convention in 2001 and ratified it in 2002. The Ministry of Natural Resources and Environment (MONRE) is currently developing a National Implementation Plan.

Circular No 10/2006/TT-BTNMT issued on December 12, 2006 by Ministry of Natural resource and Environment instruction on the development of proposal on clean development mechanism (CDM) in the framework of Kyoto protocol.

2.2.3.2 Institutional frame work

The main Ministry responsible for the environment affairs in Vietnam is the Ministry of Natural Resources and Environment (MoNRE). There are three main administrative units of MoNRE that play key roles in waste management. Additionally, five other ministries and the provincial People Committees (PC) are also directly involved in waste management activities. Some other ministries have specific roles to play in SWM.

2.2.3.3 Agencies at national level

Ministry of Natural Resources and Environment (MoNRE): a central agency in charge of environmental management and protection in Vietnam. Its role in waste management is to issue guidelines, regulations, and standards on waste management in coordination with other ministries, compile annual and long-term waste management plans, formulate policies and strategies, plan and allocate budgets for research and development relating to waste treatment projects (specific task of Department of the Environment (DoE) - an administrative unit of MoNRE), and appraise and approve EIAs for waste treatment projects (specific task of Department of the Environmental Impacts Assessment and Appraisal - EIA Department), inspect the operation of waste treatment facilities, supervise waste management activities, raise public awareness, approve recycling and treatment technologies (Vietnam Environmental Protection Agency – VEPA). It is noteworthy that this ministry has just been formed recently in August 2002. Its precursor is the Ministry of Science, Technology and Environment (MOSTE). The former MOSTE was separated into two new ministries: Ministry of Natural Resources and Environment, and Ministry of Science and Technology.

Ministry of Construction (MOC): a central ministry with the highest authority in municipal solid waste management and landfill siting. Its responsibilities and jurisdiction in solid waste management are diverse as follows:

- Formulating policy and legislation, planning and construction of solid waste facilities.

- Developing and managing plans for the construction of waste-related infrastructure nationally and provincially

Ministry of Industry (MOI): with respect to waste management, this ministry is concerned mostly with industrial waste. Its responsibilities are: direct, inspect, supervise, and take measures to force businesses and establishments to strictly comply with regulations on industrial waste managements; and coordinate with waste disposal units in disposal of industrial waste (Directive No.199/TTg, 1997).

Ministry of Health (MOH): similar to MOI, MOH involves in only hospital waste. Its responsibilities in terms of waste management are basically assessing the impacts of solid waste on human health, inspecting and supervising hospital waste treatment activities (Directive No.199/TTg, 1997).

Ministry of Planning and Investment (MPI): the most influential policy maker at the ministry level because its main task is to propose to the Government for approval of the overall national allocation of state budget. Regarding waste management, MPI together with MOF consider and provide funding and financial sources for other ministries, government agencies, and localities to implement waste management plans based on their annual and long-term waste management plans (Directive No.199/TTg, 1997). Furthermore, MPI in coordination with MOF also issue economic incentives to facilitate waste management activities.

Ministry of Finance (MOF): together with MPI allocate budgets for waste management activities. However, it focuses more specifically on financial and pricing issues (Directive No.199, 1997).

Ministry of Culture and Information (MCI): direct the dissemination and popularization of legal documents on waste management in order to raise awareness and responsibility of the public (Directive No.199, 1997).

Ministry of transportation (MOT): its responsibilities are planning and managing infrastructure for air, land, railway and maritime transport nationally and provincially; overseeing the URENCOs.

Ministry of Finance (MOF): together with MPI allocate budgets for waste management activities. However, it focuses more specifically on financial and pricing issues (Directive No.199/TTg, 1997).
Ministry of Culture and Information (MCI): direct the dissemination and popularization of legal documents on waste management in order to raise awareness and responsibility of the public (Directive No.199, 1997).

2.2.3.4 Agencies at local level

People's Council: the local representative of state authority. It is elected by local people and has highest authority at local levels.

People's Committee (PPC): the executive branch of the People's Council, responsible for state administration at the local level. PPC directly exercise their environmental management function under the national government. Its responsibilities in waste management are as follows:

- Implement state management regulations on environmental protection in their respective localities, direct their functional agencies in organizing, coordinating with the functional agencies of the central level in working out annual and long-term plans for waste management, and taking measures to help their localities well perform their tasks for environmental hygiene (Directive No.199, 1997).

- Make approval of waste treatment projects in their localities based on demographic, socio-economic, and industrial conditions of each locality (Inter-ministerial Circular No.1590, 1997).

- Mobilize investment capital from various sources for the construction of landfills and work out mechanisms to encourage non-governmental organizations to take part in waste management activities (Inter-ministerial Circular No.1590, 1997).

- Direct the provincial/municipal DNRE and DOC in carrying out waste treatment projects in terms of design, construction, monitoring, EIA, etc., according to Vietnam's environmental and construction standards (Inter-ministerial Circular No.1590, 1997).

- Direct the provincial/municipal TUPWS and URENCO in organizing waste collection, transport, and treatment activities and make approval of waste collection and treatment fees based on recommendations of provincial/municipal DFP (Inter-ministerial Circular No.1590, 1997).

Chief Architect Office (CAO): the main agency responsible for spatial planning in the two largest cities in Vietnam: Hanoi and Hochiminh City. There are currently only 2 CAOs in the country, namely Hanoi Chief Architect Office and Hochiminh City Architect Office. Other provinces and cities do not have this kind of office. Instead, they have Institutes for Urban and Rural Planning (IURP) operating under Departments of Construction (DOC), which are responsible for spatial planning of the province or city. Under Hanoi and Hochiminh City CAOs, there are also IURPs operating as the consultants for CAOs in drawing up urban master plans that should help to avoid or reduce urban environmental problems. Such urban master plans should indicate locations of waste treatment projects such as waste transfer stations and landfill sites. Apart from CAO and IURP under it, Hanoi and Hochiminh City also have their DOCs. These DOCs work independently from CAOs in terms of spatial planning and focus more specifically on housing and construction issues.

Department of Construction (DOC): an agency at the provincial level, operating under influences of both PPC and MOC. Its responsibilities in waste management and landfill siting are: supervising the implementation of urban master plans of the province or city that have been carried out by NIURP and approved by the Prime Minister, organizing the designing and construction of landfill projects according to environmental and construction standards, supporting PPC in making decisions on waste treatment facility projects, and reporting and proposing appropriate landfill sites to PPC for approval in coordination with DNRE.

Institute for Urban and Rural Planning (IURP): a planning arm of DOC, focuses specifically on spatial planning of the province or city. It has responsibilities for drawing up detailed plans for areas in the province or city. However, urban master plans, which indicate proposed landfill sites, are often carried out by NIURP with approval of the national government.

Department of Natural Resources and Environment (DoNRE): similar to DOC, it also operates under the influences of both parties: PPC in terms of administrative and political relations and MNRE in terms of collaboration, support, and technical guidance. DNRE plays an important role in waste management with respect to monitoring environmental quality, managing and implementing waste management policies and regulations issued by MNRE and PPC, appraising EIAs for waste treatment projects, and coordinating with DOC and URENCO in considering and choosing candidate landfill sites, all of which are then proposed to PPC for approval of the most appropriate site.
Urban Environment Company (URENCO): the main company in charge of waste collection, transport, and treatment in the province or city. The name URENCO varies from province to province and from city to city. For example, in Hanoi, its official name is URENCO; in Viettri (Phutho Province), it is called Urban Environment Services Company; in Hochiminh City, it is named Waste Disposal Company, in some provinces in the Mekong delta, it is named Urban Public Work Company. However, no matter how the name of the company varies, it is always the only company directly responsible for waste management activities. For this reason, the term URENCO will be used to refer to the same agency in different provinces or cities throughout this report. It is worth noting that in Hanoi and Hochiminh city, URENCO operates under and agency named Transport and Urban Public Works Service (TUPWS). In other provinces and cities, URENCO is an independent agency. Regarding landfill projects, URENCO is often assigned to be the only agency being the owner of the landfill project, who then also manages and operates the landfill over its operation life. Besides URENCO is also in charge of solid waste collecting, keeping hygiene for public place, public lighting, planting and taking care of trees along the street.

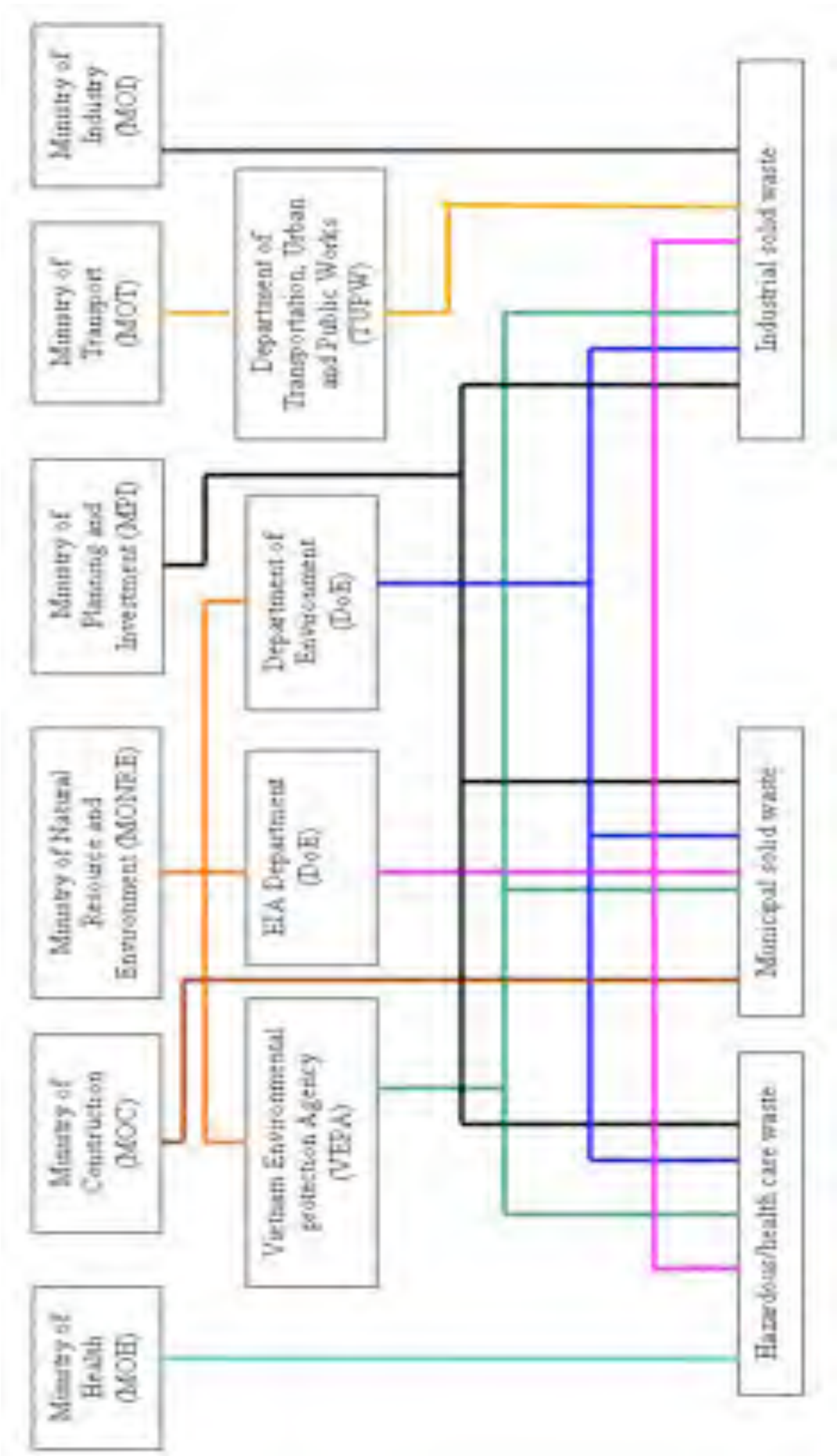


Figure 2.2-3: Structure of waste policy

2.2.3.5 Stakeholders

Responsibilities on waste management in Vietnam are declared for [Trang, 2008]:

The Ministry of Natural Resources and Environment

- Directive and responsibility on policy and strategy for environmental protection
- Issue the permission on hazardous waste processing for the allowed and suitable organizations over country
- Issue the policy on using ground for waste processing.

The Ministry of Construction

- In cooperation with the Ministry of Resource and Environment but chair for preparing the national plan on collection, recycle, disposal and treatment of municipal solid waste and hazardous waste
- Chair and cooperate with the municipalities on waste management plan of areas, provinces, cities and industrial parks
- Chair and cooperate with the Ministry of Resource and Environment for preparing documents relate to technical standards of waste treatment, processing, recycling, disposal and land filling for both municipal and hazardous waste

The Ministry of Planning and Investment, Ministry of Finance

- Finance source construction according to the national plan
- Establish the guideline for using the financial source for waste management.

The Ministry of Health

- All aspect concerning health's influence from municipal solid waste
- Guideline on policy and implementation concerning the management of hazardous health care waste
- Take care on working condition concerning environmental safe

The Ministry of Industry: Guideline on policy concerning the management of industrial waste

- Take care the activity of industrial park and area also in waste aspect
- Take care and support the industrial park on waste management.

The Ministry of Transport: Guideline on policy concerning the management of municipal solid waste

- Take care the aspect of waste transportation route (roads, railways, shifts, …)
- Take care the activity of the Urban Environment Companies (URENCOs).

The Province People's Committee / Municipalities

- Take care the aspect of waste management at city / province level
- Issue permission on waste processing at city / province level.

Urban Environment Company, Department of Transportation, Department of Construction

Collection and disposal the municipal solid waste and hazardous health care waste. Collection and disposal the industrial waste according to contracts related to industrial waste.

Director board of industrial zone

Take care the aspect of industrial waste management of their own.

2.2.3.6 Development of environmental law by national agencies

Environmental law was passed by the national assembly on November 29th, 2005 and took into effect from July 1st, 2006. With 15 chapters and 136 articles, this law detailed some regulations that could apply directly without any instruction. However, there are still many articles need to be detailed by national agencies. The task in development of the law by agencies was divided as shown in table 2.1.

Table 2.2-3: Task of national agencies in development legal text related to implementation of Environmental law

No	Legal text needed to be developed	Agency in charge
1	Decree of the Government detailing the implementation of the law on environmental protection.	**Ministry of natural resource and environment (MoNRE)**
2	Decree of the Government promulgating the Regulation on sanction against Administrative violation in the field of protection of the environment	
3	Decree of the government promulgating the organization and activities of the agencies in charge of environmental protection.	**Ministry of Internal Affair**
4	Decree of the Government on prescribing Fees and Charges on environmental protection	**Ministry of Finance**
5	Decree of the Government to favour the environmental protection activities and to determine the lost due to environmental pollution and degradation.	**MoNRE**
6	Decision of the prime Minister on production, importation, transportation trade and use of firework.	**Ministry of Defense**
7	Decision of the prime Minister to pay a security for improvement, recovery the environment on natural resource exploitation.	**MoNRE**
8	Decision of the prime Minister on water environment protection at river valley	**MoNRE**
9	Decision of the prime Minister on approval the general plan on hazardous waste and domestic waste management.	**Ministry of construction (MoC)**
10	Item 2 article 74: technical standard, guiding on verify, determine the hazardous waste treatment facilities.	**MoC**
11	Item 2 article 75: technical standard, guiding on verify, determine the hazardous waste landfill sites.	
12	Item 3 article 79: technical standard, guiding on verify, determine the domestic waste recycling, treatment facilities and landfill sites.	
13	Item 2 article 41: guiding on verify, determine the motor, vehicle and other car that meet the environmental standard.	**Ministry of transportation**
14	Item 8 article 121: implementation of environmental law and related regulation on transportation infrastructure and transportation activity.	
15	Item 5 article 42: implementation of environmental protection measure on importation and transit of goods	**Ministry of Trade**
16	Item 5 article 43: standard, condition of organization, individual that import scraps	

17	Item 5 article 46: implementation of environmental protection measure on agricultural production.	**Ministry of Agriculture and rural development**
18	Item 8 article 121: implementation of environmental law and related regulation on production, use of agricultural chemicals, fertilizer, waste on agricultural production; management of plant varieties, transgenesis domestic animal, irrigation, forest protection area and clean water for rural area.	
19	Item 6 article 47: implementation and verifying of the implementation of environmental protection law and related regulation on aquaculture production.	**Ministry of Aquaculture**
20	Item 6 article 121: implementation of environmental protection measure and related regulations on production, exploitation, processing aqua-cultural product; transgenesis aqua-creature nad their products; marine protection area.	
21	Item 4 article 107: developing and implementation of environmental education program and training the human resource to serve for environmental protection activities	**Ministry of Education and Training**
22	Item 4 article 108: developing technologies on environmental protection.	**Ministry of Science and Technology**
23	Item 5 article 121: implementation of environmental protection law and related regulations in the field of industry; handling the facilities that create serious environmental pollution; developing the environmental protection industry.	**Ministry of Industry**
24	Item 5 article 39: verifying of the implementation of environmental protection law at hospital and health care center.	**Ministry of Health**
25	Item 9 article 121: management of medical waste; environmental protection at health care center, hygiene and safety of food and burial activities.	
26	Item 3 article 45: implementation of environmental protection law in tourism activities	**General Office of Tourism**

2.2.4 Economic framework for renewable energy

Recently, due to natural resource depletion and global climate change the recovery energy from organic solid waste by anaerobic digestion is getting highest priority in most countries. Therefore, this section gives the information on economic framework for renewable energy (RE) from waste.

2.2.4.1 Macroeconomic considerations

Rapid economic growth

Vietnam is a country of rapid economic growth. This growth needs an expansion of the electricity production. Currently energy consumption is rather low. Increasing industrialization and foreign industry investment will need more electricity production in next time.

Changes in agriculture sector

Agriculture is under change. There is e.g. a program to increase rice quality in Mekong delta. There will be investment in more modern technologies for rice processing.

With this structural change it is also possible to introduce biomass using energy production technologies more.

Livestock farming is currently done by very small farmers. It can be expected that this situation will change. Under pressure of competition farming size has to increase and farming has to become more intensive. But bigger scale livestock farming will create bigger problems with the manure.

2.2.4.2 The electricity sector

Main target in the electricity sector: extension of the electricity grid

Main target of the electricity sector in Vietnam is to improve and to extend the electricity network. This goal is formulated in the “Rural Electrification Master Plan". The role of RE is mentioned there but it is not given an extra strong position. This attitude to RE seems to change slowly. So in the Prime Minister’s Decree No.102/2003/ND-CP about Energy Conservation from September 2003 was stated that it is necessary to conserve fossil fuels (coal, oil, natural gas) through the promotion of renewable energy.

But there is not yet an official special detailed plan for promotion of RE. A first step did World Bank together with EVN, Ministry of Industry and some other participants with start of implementation of "Renewable Energy Action Plan" (REAP) (see ASTAE 1999 and REAP 1999). But until now it seems that this plan does not show much effect. Currently there is a need for a legal framework and funding. This plan does not see energy from biomass as a priority instead it expect more from hydro and wind energy.

There are some Research & Development programs initiated from the Ministry of Science, Technology and Environment which also focus on the development of small scale furnaces/boilers using agricultural wastes and agro-industries residues as fuel.

2.2.5 Solid waste management in the Mekong delta

2.2.5.1 Waste generation

The data on waste generation rate of the provinces in the Mekong delta is very poor, most of available data is for the domestic solid waste at the big town, very few or none data for suburban or rural area.

Moreover these data are hardly comparable because of the method of separation is difference from province to province.

The per capita solid waste generation rate is vary from province to province in accordance to the economic development level but the quantity is rather low in comparison to those of developed provinces and cities in Vietnam and the difference is not much. It varies from 0.3 kg/capita*day (for the whole province including rural area) to 1.2 kg/capita*day (for the urban area only).

Like the other regions in Vietnam the solid waste concentrated in urban area due to the higher income, difference lifestyles, larger quantity of commercial activities, and more intense industrialization found in urban areas. The solid waste generation rate is around 1 - 1.2 kg/capita*day at urban area (Soctrang town) in comparison to more or less 0.3 kg/capita*day at rural area.
The municipal solid waste component is also different between urban and rural area. The hazardous waste (such as batteries and household solvents) and non-degradable waste (such as plastic, metal, and glass) was found more in urban waste. In contrast, most of domestic waste at rural area (99% of cultivation waste and 65% of domestic waste) is easily degradable organic waste. However, due to low awareness about the environmental pollution the pesticide containers are threatening the environment.

Figure 2.2-4: The pesticide containers were discharged without control

Industrial waste is concentrated in economic zones, industrial parks, and urban area. Because of the level of industrialization the industrial waste in Hochiminh city and its surrounding provinces shared nearly 50% of the total quantity of industrial waste of the whole country, while the industrial waste in the Mekong delta is only 10%.

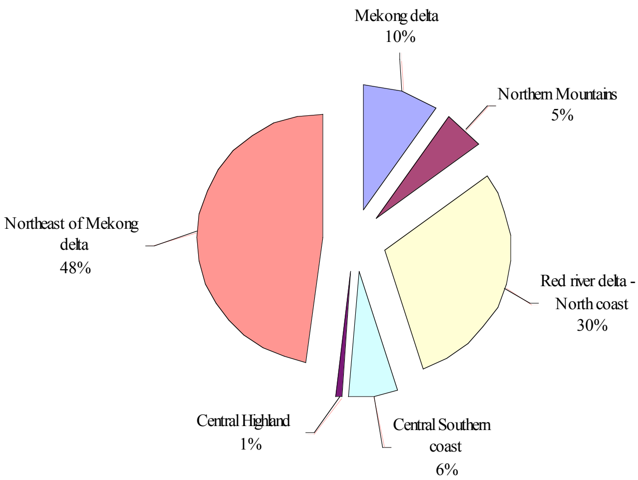


Figure 2.2-5: Industrial waste generation by region (MOI, survey 2000-2003)

The hazardous waste in the Mekong delta could be divided into three main categories: industrial hazardous waste (concentrated in urban area); agricultural hazardous waste (mainly pesticides and pesticide containers – concentrated in rural area); healthcare hazardous waste. Among which agricultural hazardous waste shares a biggest percentage of total agricultural hazardous waste of the whole country due to this is the largest agricultural production area.

2.2.5.2 Projection for solid waste generation rate in the Mekong delta

The solid waste generation rate is affected by many factors including: population growth, income and consumption growth, urbanization rate, industrialization rate and the policy of the Government…

Gathering these factors the waste generation rate in the Mekong delta continues to increase but the composition may change.

The population growth rate in the Mekong delta is high in comparison to some regions in the country, therefore the total solid waste quantity will increase more rapidly.

The Mekong delta is the largest agricultural and aqua-cultural production area with contributes significantly in the exportation of the whole country. Therefore, the Government gives the favor conditions to develop this region. As a result this region will develop quickly in the next few years leading to the increase the quantity of domestic solid waste, industrial waste and healthcare waste.

Recently the farmer in the Mekong delta applied many advanced agricultural production methods, if this trend would continue and enlarge the consumption of agricultural chemicals will decrease significantly leading to the fall in agricultural hazardous waste quantity.

Solid waste generated from agricultural cultivation was estimated as total amount of waste generated from cultivation of main crops in each zone. The amount was calculated by multiplying the total area of cultivated land per crop type by average biomass post-harvest residue per crop type per hectare. As a result of the trend of shifting from mono-crop cultivation (2 - 3 rice crops annually) to rotational cultivation (rice and vegetation) and the use of rice straw for mushroom production, the solid waste generated from agricultural cultivation may decrease.

The ratio of biodegradable component is expected to decrease because of the change in using package (from leaves to plastic bag and can).

Table 2.2-4: Summary of some solid waste components in the Mekong Delta

Province (source)	Biodegradable	Waste paper	Metals	Glass	Textile	Plastic, rubber	Brick, ceramic	Hazardous components	Miscellanous
Cantho (5)	79.65	2.79	0.70	1.52	1.86	9.57	3.10	0.03	0.76
CaMau (14)	57.3	4.5	0.1	0.5	1.4	6.1	2.1	-	28
SocTrang (10)	70.35	4.12	0.78	0.66	3.11	7.24	9.63	-	4.11
DongThap	NA	NA	NA	NA	NA	NA	NA	NA	NA
AnGiang	NA	NA	NA	NA	NA	NA	NA	NA	NA
TienGiang (7)	77.53	3.89	0.23	0.21	-	6.37	2.14	0.06	9.57
LongAn (4)	76.3	5.1	0.37	0.7	-	13.63	2.68	0.15	4.08
BenTre (9)	73.85	6.5	1.75	0.85	-	5.2	1.6	0.3	9.95
TraVinh (12)	87.25	2.05	0.45	-	-	3.16	2.04	-	5.05
VinhLong (8)	66.25	11.5	0.55	4	6.5	9.45	0.75	-	1
BacLieu (11)	53.34	4.51	4.59	4.91	-	4.44	10.81	2.78	14.62
HauGiang (6)	82.6	1.8	0.4	0.9	1.5	5.7	1.6	4	1.5
KienGiang (13)	72.52	6.38	1.27	1.64	1.29	7.69	7.49		1.72

As mentioned above there is no standard procedure for determining the solid components. There for each province has their own way to separate the solid waste components. As a result their data are hardly comparable. In addition, in their data we could not find the explanation for the term (organic waste, miscellanous…). The biodegradable components in solid waste of the province is rather high (from 53.34% to 87.35%), therefore the most suitable methods for treating it is composting or producing biogas for energy recovery. The components such as waste paper, metals, glass shared a low portion due to they are collected by househoder, solid waste collector and solid waste picker to sell for the recyclying industries. In addition the construction waste such as brick, ceramic… also low due to they are used for making the floor for the new building or street construction.

2.3 Laos

2.3.1 General facts on Laos

Lao PDR has a remarkable range of natural resources and environmental riches, despite being categorized as a 'least developed country'. With almost half of the country under forest cover and abundance of water and a low population density, Lao PDR has a diversity of species that is found in few other countries in the region. The country's economic development is largely dependent on its natural resources, mainly water (for hydropower), forests and minerals.

Once the Land of a Million Elephant, Lao PDR is now confronted with numerous environmental challenges. The unsustainable exploitation of resources has resulted in degradation of land and loss of natural habitats. This degradation, combined with declining water quality and increasing threats to air quality, is disproportionately impacting the poorest groups in the country.

According to World Bank & STEA, one of the main challenging Laos has been facing is on the urban environmental management aiming to improve, through local governments and Urban Development and Administration Authorities, sewage systems, solid waste collection, recycling and disposal. As it is the fact that the generation of solid waste in urban areas in Lao PDR is on the rise, and poses an emerging threat to the quality of surface and ground water. Expanding urban populations, combined with poor collection and largely inadequate disposal facilities, are compounding the level of pollution. The average daily urban waste production is 0.75 kg per capita. Vientiane Capital City and the four secondary towns (Luangprabang, Thakhek, Savannakhet and Pakse) account for 0.8-1.4 kg per capita per day (0.8 kg, 1.0 kg, 0.8 kg, 1.0 kg, 1.4 kg respectively), consisting of 30% organic material, 30% plastic, 25% glass cans and metals and 15% paper.

Hazardous and toxic wastes such as batteries, old paint cans, aerosols and other refuse are also mixed with these wastes. The comparatively low content of organic material in municipal solid waste is mainly due to the fact that a large proportion of food waste is recycled as animal feed even in urban areas. According to a recent survey in 57 urban areas, only Vientiane City and the four secondary towns (Luangprabang, Thakhek, Savannakhet and Pakse) use landfills for solid waste disposal with the site area of 15 ha, 9 ha, 13.5 ha and 13.5 ha respectively for four secondary towns.

Hazardous chemicals of concern include heavy metals such as mercury, lead, cadmium, arsenic, chromium, copper, and zinc as well as persistent organic pollutants such as dioxins and furans, polychlorinated biphenyls, and various pesticides and herbicides that are now banned globally. At present their environmental impact is still poorly understood in Lao PDR. STEA[7] (currently it is called WREA[8]) initiated an inventory of Hazardous chemicals in December 2003, and the National Hazardous Chemicals Strategy and Action Plan is currently being revised.

Despite the existence of landfills in Vientiane and the four secondary towns, collection services are limited to accessible areas and profitable target groups such as markets and high-income households. The average collection ratio for urban households in the five larger urban areas is 45 percent. Only in Luang Prabang does the collection ratio reach more than 50 percent. In smaller towns, solid waste collection is often limited to commercial establishments in the town centre and the market place.

In Vientiane 1997, only 5 percent of urban households were served by a solid waste collection system and only 10 percent of the solid waste generated was estimated to be collected.

Today, with improvements in the solid waste management system, 48 percent of the urban households in Vientiane are now served by solid waste collection services. About half of the solid waste generated is now collected and disposed of at the sanitary landfill facility located 18 kilometers from the city center. It accepts domestic, construction, industrial and hospital waste, and provides separation for hospital waste within fenced compound. The waste is collected by Vientiane Municipal Services.

[7] Science Technology and Environment Agency
[8] The Water Resources and Environment Administration

There are limited environmental and social safeguards concerning handling of waste, no regular covering with soil, no leachate control, and the site is adjacent to agricultural land. The landfill is accessible to scavengers and animals. Rudimentary recycling is undertaken for plastics, paper, and scrap metals. At the recycling area and unpleasant smell is produced.

In response to declining environmental conditions, the country has made important strides in instituting changes in partnership with local communicates and international organizations. Over the past five years, the country has invested millions of dollars in improving environmental management, focusing on building capacity among Government agencies and raising awareness more broadly, establishing protocols for monitoring and managing environment indicators and in Lao PDR are many and varied, requiring a more strategic approach.

Approximately 70 percent of municipal solid waste consists of plastic, paper, glass, cans and metals, which have the potential to be recycled commercially, and reused in various manufacturing and industrial activities. However, the current scale of recycling in Lao PDR is still very modest.

Hard rubbish will be collected at segregated points and purchased by Lao Chareon (the only one company in Laos who run business on waste). Glass, paper and plastics will be collected. Organic refuse will also be gathered and used to make compost, which besides being sold will also improve farming yields in the local area.

Schools and villagers are being encouraged to collect and recycle rubbish through a system supported by local NGO, PADETC[9], UNDP and the government. A private company, Lao Chareon Recycling Center has agreed to buy all the rubbish that villagers can bring to any of the 60 recycling centers.

2.3.2 Policies and strategies

National Policies

According to World Bank & STEA, Since the 1992 Earth Summit, Lao PDR has formulated several National Policies and Strategies on the environment, of which the key documents are outlined in Table 1.

The Government has approved its 2020 vision in the form of the National Environment Strategy (NES), which also includes the second National Environmental Action Plan (NEAP) for 2006-2010. The key components focus on:

1. Sustainable management of natural resources
2. Improved environmental management of industries and infrastructure, urban development, tourism, and special economic sectors
3. Strengthening of the institutional framework for environmental management and capacity building
4. Improved private sector involvement in environment management
5. Promoting appropriate financing instruments and mechanisms
6. Improved international cooperation

National strategies

According to the country report 2001, the Government has adopted the 2020 Development Strategy consisting of three stages of development efforts:

1. Implementation of the New Economic Mechanism. This stage of the strategy is nearly completed.
2. Structural transformation and capacity building. Government efforts are currently focused on this stage. They include the construction of physical infrastructure and the establishment of enabling policy and institutional frameworks that improve the capacity within the country. The completion of this stage will allow the success of the next stage.
3. People-centred development

[9] The Participatory Development Training Center

Instruments and Laws

The government has formulated a wide array of legislation and regulations for environmental conservation and protection (Table 2). The Environmental Protection Law of 1999, supported by its Implementing Decree (2002), is the principal environmental legislation in the country. It includes responsibilities of national environmental agencies, measures for the protection, mitigation and restoration of the environment as well as guidelines for environmental management and monitoring. Apart from that Lao PDR has joined a number of multilateral environmental agreements, and has delegated their implementation among the various ministries and agencies (Table 3)

Environmental legislation has evolved quickly in Lao PDR Inconsistencies have surfaced in different legislation as a result of different ministries leading the development of sectoral legislation. Principal inconsistencies included conflicting provisions, overlapping mandates given to different ministries, and lack of implementing regulations and supporting environmental standards. The Government is working to address these issues, and to formulate a national system for standardizing and enforcing environmental regulations.

Table 2.3-1: Summary of Current Key Environment Policies and Strategies

Year	Title	Agency
1994	First National Environmental Action Plan	STEA
1997	Draft National Resettlement Policy for Major Projects	CPI, STEA
	Draft Public Involvement Guidelines	CPI, STEA
	Sector Strategy & Guideline National Framework - Rural Water Supply & Environmental Health Sector	MoH
1998	Water Sector Strategy and Action Plan 1998-2006	WRCC/ PMO
1999	The Government Strategic Vision for the Agricultural Sector	DoP/MAF
2000	Draft Policy on Water & Water Resources Law	WRCC/ PMO
	Lao PDR Food Security Strategy in the period of 2001-2010	MAF
	Forest Vision for 2020	MAF
	Hydropower Development Strategy	MIEM
2001	5th National Socio-Economic Development Plan	CPI
	Master Plan Study Integrated Agricultural Development Lao PDR	MAF
	Power Sector Environment Policy	MIEM
	Social Impact Statement for Electricity Projects	MIEM
	Agriculture and Forestry Sector Development Plan	MAF
2003	Draft National Environmental Quality Monitoring Program (NEQMP) 2003-2010. Final Consultation Workshop, Vientiane, March 24, 2003	STEA
	Draft Policy on Resettlement	STEA
	National Public Involvement Guidelines	STEA
2004	National Biodiversity Strategy and Action Plan, years 2010 and 2020, June 2004	STEA
	National Strategy on Environment Education and Awareness to the years 2020 and Action Plan for the years 2006-2010, June 2004	STEA
	National Environmental Strategy years up to the year 2020, and the Environment Action Plan, 2006-2010	STEA
	National Growth and Poverty Eradication Strategy (NGPES)	
2005	National Policy on Environmental and Social Sustainability of the Hydropower Sector in Lao PDR	MIEM/ STEA
	Decree 192 on Compensation and Resettlement - 7 July 2005	Prime Minister
	Implementing Regulations and Technical Guidelines on Compensation and Resettlement on 11 November 2005	STEA
	Adopted Implementing Regulations and Technical Guidelines on Compensation and Resettlement on 18 November 2005	MIEM

Table 2.3-2: Key Environment Laws and Regulations

Law	Regulated Activities	Key Contents	Responsible Ministries
Forestry Law (1996)	States principles, regulations and standards for the use of forest lands and resources. Promotes the conservation and rehabilitation of forest resources. Defines roles and authorities of forest management and inspection organizations.	• Specified procedures for getting approvals from authorized agency is required for individuals and organizations to possess and use natural forests • Individuals and organizations have obligation to preserve forest resources including water sources, marine animals and wildlife	MAF
Water and Water Resource Law (1996)	Regulates the management, exploitation, development, protection and sustainable use of water and water resources	• MAF is responsible for the survey and inventory of water resources • Classifies scale of water use into small, medium and large, the latter two require permits	WRCC
Land Law (1997)	Provides rules on management, protection and use of land	• All individuals and organizations have obligation to protect the land to ensure that there is no soil erosion, land slip, soil degradation and negative impact on the natural or social environment	MAF, MEM, MCTPC, MIC, MND, MoInt, MF
Mining Law (1997)	Provides a system of management for the conservation, exploration, mining and processing of minerals for local consumption and export	• Licensees are required to preserve and restore the land utilized during mining and to rehabilitate the land after mine closure and to guarantee that the project shall have no serious negative impacts • Any person or entity licensed to develop mineral resources shall utilize procedures to limit adverse environmental impacts	MEM / DGM
	Specifies principles, rules and measures to manage, monitor, restore and protect the environment, natural resources and biodiversity. Ensure the sustainable socio-economic development.	• All persons and organizations residing in Lao PDR have an obligation to protect the environment • STEA is responsible for overall environmental oversight and coordination • Each sector responsible for development projects shall issue its own regulations for EIA, based on general EIA regulation issued by STEA	STEA / DoE
Industrial Law (1999)	Regulates the establishment and management of business in industry and handicraft sector	• All businesses shall ensure the protection of the environment in accordance with EPL • Wastes shall be treated in accordance with the relevant waste discharge regulations	MIH / DOI
	Establishes uniform environmental assessment requirements and procedures for all development projects	• Organizational responsibilities are specified • Procedures and methods for the EA • Requirements for the Environmental Management Plans, Environmental Monitoring and Evaluation, and Public Involvement	STEA / DoE
Implementing Decree of the EPL (2001)	Outlines requirements for the preparation of detailed sector regulations, and provides assistance in achieving the goals of the National Socio-Economic Development Plan (NSEDP)	• Ministries and ministerial equivalents shall: • Issue and implement sectoral regulations • Prepare technical standards and regulations on construction, operation, maintenance, repair, innovation and expansion • Issue regulations to protect and control pollution • Establish or Improve the EMMUs	STEA / DoE
Electricity Law (1997)	Provides a framework to manage all electricity activities (generation, transmission and distribution)	• The planning and execution of power projects must take into account social and environmental impact, including those upon ecosystems and wildlife habitats, as well as ensuring economic returns	MEM/ DoE

Table 2.3-3: Lao PDR International Agreement

Year	Convention	Focal Points	Remarks and Status in Lao PDR
1997	ASEAN Agreement on the Conservation of Nature and Natural Resources	MAF ASEAN	Lao PDR became a full member of the "Association of Southeast Asian Nations" (ASEAN) in 1997. The government has been engaged in implementing the "Hanoi Action Plan" and its environmental strategic plan and is considering a number of agreements with significant influences on the national development and environmental protection.
1987	Protection of the World Cultural and Natural Heritage	MIC	The Government accepted accession to the "Convention for the Protection of the World Cultural and Natural Heritage" on 20 March 1987 and is taking the legal, scientific, technical, administrative and financial measures necessary for identification, protection, conservation, and rehabilitation of designated heritage sites in the country. Luang Prabang town was designated as the first site and others are being proposed.
1995	Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin	LNMC	The Government signed the "Agreement on the Cooperation for Sustainable Development of Mekong River Basin" together with other members of the Mekong River Commission on 5 April 1995 and is implementing the "Mekong River Programs".
1995	United Nations Convention to Combat Desertification (CCD)	STEA	The Government has been a signatory of the "United Nations Convention to Combat Desertification" (CCD) since 30 August 1995 and accepted accession to the Convention on 20 September 1996. The Government adopted the "National Action Plan" (NAP) to combat desertification in 1999 and is revising it.
1995	United Nations Framework Convention for Climate Change (UNFCCC)	STEA	The Government has accepted accession to the "United Nations Framework Convention on Climate Change" (UNFCCC) on 4 April 1995. The first "National Communication" was issued in 2000.
1996	Convention on Biological Diversity (CBD)	STEA	The Government has accepted accession to the "Convention on Biological Diversity" (CBD) on 20 September 1996 and has finalized its "National Biodiversity Strategy and Action Plan" (NBSAP) for conservation and sustainable use of the nation's biodiversity in 2004. In 2004, the Government signed the convention.
1998	Montreal Protocol	STEA	The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in September 1987. The Protocol was adjusted to accelerate the phase out schedules, and has also been amended to introduce other kinds of control measures and to add new controlled substances to the list. Governments are not legally bound until they ratify the Protocol as well as the Amendment. Lao PDR has ratified the Protocol, but not yet the amendment.
1998	Vienna Convention on the Protocol of the Ozone Layer	STEA	The Government accepted accession to the "Vienna Convention for the protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer" on 21 August 1998 and has finalized the "National Action Plan" to deal with this issue in the beginning of 2004.
2000	Millennium Declaration	MOFA	In September 2000, Lao PDR adopted the Millennium Declaration. The Declaration includes the Millennium Development Goals (MDG), a set of development goals related to peace, security and development concerns, including environment, human rights, and governance. The MDG incorporate most of the goals and targets set at the global conferences and world summits of the 1990s.
2004	Convention on International Trade in Endangered Species of Flora and Fauna (CITES)	MAF and STEA	Lao PDR has sign the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in May 2004. CITES entered into force in July 1975 and now has more than 115 member countries. These countries act by banning commercial international trade in an agreed list of endangered species and by regulating and monitoring trade in others that might become endangered.
-	Stockholm Convention on Persistent Organic Pollutants	STEA	Signed but not yet ratified.
-	Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention)	MAF	Under preparation.

Laos has many laws. However, environmental law is mainly on forest, water, mining, land, industries and electricity. This can be indicated that specific law on waste management required to be amended and here are some examples of the law on solid waste management in Laos

1. Environmental Law (Article 22)
2. Environmental Decree (Article 9.4)
3. Governor's Speeching on Solid Waste Management
4. Some Rules and Guidelines for Vientiane Urban Cleaning
5. Project Activities in Solid Waste Management (Raise Awareness on Participatory in SWM)

Article: 22

All kinds of littering are forbidden. Waste disposal sites required. Waste Separation before its disposal. Reuse must be supported.

Decree on the implementation of the EPL (No. 102/PM, 04/06/2001)

Article 9.4

> The Ministry of Public Health shall issue regulations…related to the treatment of solid waste…and to define disposal sites or treatment facilities by using appropriate methods to protect the health of humans and natural environment.

2.3.3 Stakeholders

The institutional structure for environmental management in Lao PDR consists of:

1. National committees that guide inter-sectoral coordination among agencies
2. STEA (WREA) as the main manager, monitor and coordinator of environment matters at the national level, and other relevant ministries with the mandate to mitigate environment and social issues arising from their sectoral development activities
3. Provincial and district entities that have developed responsibility for environmental protection at the local level; and
4. Mass organizations which support the government in promoting participation and awareness.

Besides the institutions dealing with all affairs on environmental management, there are some organizations working on waste management in particular

Public sector

1. Vientiane Urban Development Authority (VUDA)
2. Educational Institution

Private Sector

1. Lao Chaleon Recycling Center
2. Vientiane Garbage company

   The two companies are the private companies which buy recycle waste from small retailers and from households which collect own waste to sell.

3. Village community

   Each community especially in urban area is supposed to keep their own areas clean and compile to the environmental laws.

NGOs

1. PDETC focusing on solid waste in community
2. JPFR[10]

Schools and villagers are being encouraged to collect and recycle rubbish through a system supported by local NGO, PADETC[11], UNDP and the government. A private company, Lao Chareon Recycling Center has agreed to buy all the rubbish that villagers can bring to any of the 60 recycling centers.

2.3.4 Economic framework

Lao PDR economic performance has continued to improve. In the year 2005 to 2006 the real GDP grew from 7.0 to 7.3 percent. This growth is in large part due to foreign investment inflows in mining and hydro-power and growing mineral exports, but the share of non-mining contributions increased in the year 2005 reaching 4.9 out of 7.3 percent. Agriculture, manufacturing and services sectors are expected to sustain growth, due to rising FDI in agriculture, manufacturing, and increasing trend in

[10] Japan Fund and Poverty Reduction
[11] The Participatory Development Training Center

services (especially tourism). Inflation (of Consumer Price Index) has continued to remain in single digits. For example, after rising early in 2005, it dropped remarkably during the last few months, to 5.5 percent in September and 3.7 percent in October 2006. Implementation of reforms in various areas continued during the period under review, even if at a somewhat uneven pace. More steps have been taken towards creating a better investment and business environment and a more open trade regime; the trade reform action matrix has been finalized, and it is expected that donor coordination in trade-related areas will take place around this program. The program of strengthening public expenditure management has sustained momentum and actions to increase transparency in the State-Owned Enterprise (SOE) sector have continued. Implementation of the National Growth and Poverty-Eradication Strategy (NGPES) progressed further with the Government completing the final draft of the next National Socioeconomic Development Plan (NSEDP, 2006-2010), the successor to the NGPES. The Plan was presented to donors at a Pre-Round Table Meeting in October 2006. The RTM meeting was scheduled to take place in late November. Though official development assistance (ODA) inflows as a share of GDP have been declining for a couple of years (mainly due to fast economic growth), there is new momentum in donor support for policy reform implementation, side by side with continued strong support for health and education sectors. Budget support is on the rise, with Japan Bank for International Cooperation (JBIC) and European Commission (EC) joining the poverty reduction support operation (PRSO) co-financing, as are initiatives for setting up multi-donor trust funds (MDTFs) in two key reform areas, adding to the technical assistance support that is already being provided. The Government is also seeking greater donor coordination and harmonization of foreign assistance through more organized joint Government donor working groups, in support of policy reform as well as investments in health, education, infrastructure and agriculture.

In the 1990s, Lao PDR grew at an annual average rate of 6.3 percent, and the incidence of poverty fell from 45 percent to 39 percent of the population in 1997-98 and to 33.5 percent in 2002-03. The crisis years of 1998 and 1999 saw inflation climb to an annual average of 110 percent and growth fall to 4 percent, but the resolution of the regional crisis and Lao’s own policies stabilized the economy and resumed growth of around 6 percent. The adoption of a stabilization program since 2000 and the implementation of a phased program of reforms since 2001 – in public expenditure management, banking, state-owned enterprises, forestry, trade and private sector – has contributed to this improvement. During 2000-03, inflation has averaged 15 percent and real GDP growth averaged around 5.6 percent annually. The approval of Nam Theun 2 hydro-power project by the World Bank Board on March 31, 2005 and by the Asian Development Bank Board on April 4, 2005 means that various financing partners have committed a total of US$ 1,450 million to Lao PDR to finance US$1,250 million of project cost and US$200 million of contingency. This investment is expected to occur between now and 2009. The resulting annual inflow is very large relative to the size of the Lao PDR economy, and will have significant growth effects during that period, even though most of this will be comprised of imports. (The World Bank 2006)

2.3.4.1 Socio Cultural framework

The Lao People's Democratic Republic, a land-locked country in the South-East Asia, borders with the People's Republic of China (North), Viet-Nam (East), Kampuchea (South), Thailand (West) and Burma (North-West). Laos was formerly a part of the French Indo-China.

Community life is generally centered in two main areas: the Buddhist temple and the animist spiritual house. "Pagodas" are known to be a sacred cultural center for the people. The great importance is attached to the literature (The Institute for Cultural Democracy 1998)

General Directions of Cultural Policy

The decisive turnpoint in cultural activities occurred in 1975 with the liberation of whole country. The Government and the People's Revolutionary Party adopted attitudes towards cultural and educational policies by stressing the cultural identity and the use of national language. According to these attitudes, the purpose of cultural policy is to mobilize the people to take more active part in all cultural fields. Thus, the cultural activities like other social and economic activities have been affected by the "spirit of masses."

The "cultural dimension" has been determined as one of the most important factors in overall development plan. In this way, the Government faces with the following tasks:

- To preserve and revitalize cultural heritage by integrating vernacular cultures - folk tales and folk songs, handicrafts and art, museums and archaeological sites - into every day life;
- To draw upon innovation and eradicate inappropriate traditions;
- To train competent staff in the field of culture and education;
- To encourage the area of cultural services (*e.g.,* participation in the art);
- To stimulate creativity

Administrative and Institutional Structures

Public and Semi-public Bodies

The Ministry of Information and Culture is responsible for cultural policy. There is a little co-ordination between different ministries and institutes which deal with cultural affairs.

Cultural Development

In relation to the book development, particular attention is paid to providing books of functional nature for "neo-literates" and the masses outside the school system. Within the goals of the World Decade for Cultural Development, the mobilization of public for participation in cultural development includes the following national characteristics:

- Building and improving facilities and infrastructure;
- Esthetic education;
- Promoting creativity among artists;
- Reviving cultural industries.

It is expected that cultural tourism will contribute to the activities of craftsmen, and consequently to the income increase of the communities.

International Cultural Cooperation

Laos participates in the programmes of UNESCO and Asian Cultural Centers for Unesco (ACCU), and within the latter, particularly in the field of book development.

2.3.4.2 Socio-economic framework

According to the Sixth National Socio Economic Development Plan (2006-2010) , 2006, the overall Development strategy are as the following

The Sixth Plan is based on:

1. The Long-Term Strategy of Socio Economic Development to the Year 2020;
2. The Strategy on Industrialization and Modernization;
3. The National Growth and Poverty Eradication Strategy (NGPES);
4. The Regional Development Strategy;
5. The analysis of the international and domestic contexts for the development of the Lao PDR.

A. Development Context

1. International context

It is hoped that the general trends of peace, stability and cooperation for development in today's world will continue over the next five-year period (2006-2010). The world economy has been recovering and advancing, with the growth rate in the period 2006-2010 likely to be slightly higher than that during the preceding five years (2001-2005). Official development assistance (ODA) has been growing and is expected to rise significantly during the next five years. The international financial markets are likely to be more active, with foreign direct investment (FDI) and indirect investment flows recovering and expanding. However, the rapid, sustained and large increases (more then doubling) in petroleum (oil) prices in the past 18 months continue to have adverse impacts on the global economy in general, and particularly the low-income oil-importing countries and the lives of the poor people in these countries (including the Lao PDR).

The 2005 World Summit in September at the UN Headquarters in New York has reiterated the commitment of the community of nations to eradicate poverty and achieve the Millennium Development Goals (MDGs). The Summit also emphasized the need to increase aid to the least developed countries (LDCs) and Assist them in implementing the Brussels Program of Action for LDCs (2001-2010). Accordingly, bilateral and multilateral relations would widen and strengthen among nations, and between nations and international organizations. Theses developments in the international arena will help the Lao PDR take advantage of increased opportunities to push forward its development, reduce poverty and successfully implement the industrialization and modernization strategy, narrowing the gap with neighboring countries in the region, while improving the country's status in the global community of nations.

2. Domestic context

Significant progress has been made in such aspects as democracy, human rights and ethnic peoples. Not withstanding, there is a risk that some external reactionary forces might try to provoke these and other issues and support extremist groups within the country to destabilize the socio-economic situation. The government and the people of the Lao PDR need to be ready to face such eventualities.

By the end of the Fifth Plan (2001-2005), the production capacity and ability of many industries increased substantially, and the economic structure changed significantly. The quality of growth in many industries and regions has improved somewhat, with the enterprises and the national economy adapted better to the international markets. The market-economy mechanism has been established gradually and is operating effectively. New and more radical policies introduced in the recent five years had positive impacts; attracting more investment from the society, especially utilizing internal resources for targeted investments and bringing about structural changes in the economy.

The country has been recognized in the region and globally as having a dynamic economy within a stable political situation, and a safe destination for investment. Socio-political stability is an important foundation and the most positive element for socio-economic development, which is an advantage that he Lao PDR enjoys at this juncture. Increased regional and global integration including the accession to (full membership of) the WTO should boost the dynamism of the economy and accelerate the country's development.

However, the country faces many challenges in the coming five years. These include the moderate size of the economy and the small-scale of much of the domestic production; low GDP per capita; insufficient domestic income, savings and investment to increase production and accelerate development; and weak financial and monetary systems. Economic and social infrastructure is not yet adequate to meet the growing development needs. The technological base is low and far behind that in other countries in the region. The ability of Lao enterprises for regional and international economic integration is below required standards. But implementation schedules of commitments under AFTA, WTO and other international agreements will put increased pressures on enterprises to adapt. The services sector is still growing slowly. The quality of human resources is inadequate to achieve the development goals in the new Plan period, without substantial strengthening. The effectiveness of state administration is still limited. Erratic weather and climate changes, widespread diseases such as SARS and bird flu could reappear.

B. Overall Development Strategy

1. Background

The 7th Party Congress has set out the Ten-Year Socio-Economic Development Strategy (2001–2010) for the country, which includes improving and building the economic infrastructure to ensure fast and sustainable economic growth, with emphasis on agricultural production, eliminating forest fires and deforestation, reducing the number of poor households, promoting industrialization and modernization. The country's human resources are to be developed step-by-step both in quality and quantity to cater to the emerging needs and make the country a regional centre of services of exchange. The strategy encourages socialist-oriented industrialization and modernization with infrastructure development to prepare the nation for graduation from the Least Developed Country (LDC) status by 2020 and to achieve improved well-being for all the Lao peoples. The objectives set out in the Strategy support the achievement of the MDGs and the implementation of the Brussels Program of Action for Least Developed Countries. The Sixth National Socio Economic Development Plan (NSEDP) covering the five-year period 2006-2010 plays a crucial role in implementing the socio-economic development policy guidelines set out by the 7th Party Congress. It is the vehicle for facilitating the implementation of the second half of the Socio-Economic Development Strategy (2001–2010) approved by the Congress. Thus, the Sixth Plan institutionalizes and concretizes directives and tasks that will be carried out further during the five-year period 2006–2010, to ensure that the overall targets outlined in the Ten-Year Strategy (2001–2010) are achieved.

2. Overall Goals of the Plan

The main goals of the Sixth Plan (2006-2010) are to translate all the policies and targets of the Ten-Year Development Strategy (2001-2010). The goals are:

- Accelerate and sustain rapid economic growth and improve people's quality of life;
- Further develop the market economy with a socialist orientation;
- Restructure the economy and the employment pattern through a market economy based on the country's rich natural resources and international integration;
- Continue to enlarge and develop effectively external economic relations including international integration;
- Create a breakthrough in human resources with changes in education and training both in terms of quality and quantity;
- Harness the advances/achievements in science and technology for the country's development;
- Utilize human, science and technology factors as key resources for development;
- Continue poverty reduction, creating jobs and eliminating social evils;
- Manage the natural resources in a sustainable way and protect the environment;
- Develop the culture and society synchronously with economic growth;
- Continue strengthening socio-economic infrastructure as fundamental for development in the Plan to build a stronger base for the next five-year plan;
- Maintain political stability and social cohesion; and
- Protect the sovereignty, territorial integrity and national security.

The overall directions for the Sixth Plan (2006-2010) include transforming the multi-sectoral economy from uneven performance to fast and stable development within the market mechanisms guided by the State. It will include comprehensive reform and swift restructuring of the economy to best utilize its strengths and advantages, producing high value-added goods and services to meet the domestic demand step-by step and increase exports. It will require the mobilization of all resources including a renewed drive for internal resources to take full advantage of the opportunities.

3. Development Approaches

The main approaches are to:

- Promote economic development, with human development as a key vehicle, connecting with fast, effective and sustainable development;
- Increase the competitiveness and utilize the comparative advantages to implement effectively international economic commitments in the framework of the ASEAN and other bilateral and multilateral commitments, including WTO;
- Strengthen the positive linkages between economic growth and social development, in addressing social issues such as poverty and other social evils, and help keep the socio-political situation stable. Economic growth should be accompanied by social progress and equity, as well as environmental protection; and
- Accelerate the building of a comprehensive socio-economic infrastructure and further developing the market-oriented economy with a socialist orientation, to form the basis for industrialization and modernization.

Thus, the Sixth Plan (2006-2010) is seen to be a break-through plan for creating a fast but firm and qualitatively enhanced development, lifting the society to new heights both in material and moral wellbeing, significantly improving the quality of life of all the people and boosting the nation's status in the international arena. The goals coincide with the MDGs and those in the Brussels Program of Action for Least Developed Countries.

C. Plan Targets and Tasks

1. Targets

The 7 th Party Congress has also set some specific targets, including an average annual GDP growth rate of more than 7 percent during the first decade of the new millennium (2001 to 2010), with the population growth rate slowing down to an annual average of about 2.4 percent by 2010 and GDP per capita reaching USD 700-750 by the end of the decade. The Sixth Plan (2006-2010) will maintain and build on these targets as follows:

(a) Economic Targets

- Total GDP in 2010 (in 2000 prices) is projected to be about twice that in 2000. The GDP 6 annual average growth rate in the Sixth Plan period (2006-2010) would reach 7.5 percent (main scenario), with agriculture, forestry and fisheries growing at 4 percent, industry and construction at 12.6 percent and services at 8.0 percent. In particular, the growth rate in industry will be accelerated because many of the electricity and cement plants under construction should start production by the end of the Plan. Therefore, the GDP growth will be accelerated from 7.2 percent in 2006 to 8.2-9.0 percent in 2010.
- The structure of the economy will shift with the share of agriculture, forestry and fisheries in GDP declining to 38.5 percent, while those of industry and construction rising to 34.5 percent and services to 27.0 percent.
- Exports for the five years are predicted to be USD 3.13 billion, growing at an annual average of 11.9 percent; while imports are projected to grow at an annual average of 9.4 percent.
- The rise in consumer prices (inflation) will be kept around 6-6.5 percent per annum.
- GDP at current prices in 2010 is projected to be 59,500 billion Kip, or USD 4.97 billion (the exchange rate is corrected at 2 percent each year allowing for a modest depreciation of the Kip). GDP per capita is estimated to reach USD 806, higher than the target (USD 700-750) set in the Socio-Economic Development Strategy (2001-2010).

2. Tasks

As indicated earlier under the Overall Goals, the main tasks for the Sixth Plan are:

1 Restructuring the economy and employment and accelerating in the direction of improving effectiveness and bringing into play the comparative advantages of goods, sectors and regions. This is to be accomplished through improvements in quality, effectiveness and competitiveness of each commodity and enterprise, and the economy as a whole;
2 Intensifying the multi-faceted economy, with the public sector playing a decisive role in formulating and developing businesses such as domestic, international, collective and individual (household) enterprises to improve the market economic mechanism with a socialist orientation. This will include the creation of a fair, transparent, stable, open and highly competitive environment for private investment and business;
3 The network of small and medium enterprises will be intensively developed. This will gradually restore the health of corporate finances, and help reorganize and resolve the debts in the corporate system;
4 Investment in socio-economic development will be rigorously increased. An optimal investment structure will be built to make the economic mechanism work effectively and be competitive. It is also visualized to improve the infrastructure, investing appropriately in the main economic areas, and providing more investment to distressed areas;
5 Foreign trade will be expanded and improved, with a favorable environment created for the growth of exports, and attracting investment and technology from abroad. The country intends to actively integrate into the international economy, on a cautious but effective schedule, implementing bilateral and multilateral commitments at national, local and business levels;
6 Reforms will be continued to make the financial and monetary systems healthy, improving the national capacity, financial resources, and economic performance in all areas. The stability of all macro-economic indicators will be maintained, controlling inflation and the

budget deficit, and gradually building and expanding the credit market to meet the socio-economic development needs;

7 Reforms will be continued to make basic and comprehensive changes in education and training, science and technology, to improve the quality of human resources with optimal structure; to provide elementary education for all; and utilize modern technology in the more advanced areas such as economic centers and urban areas;

8 The economy will be developed in harmony with social development and environmental protection, creating jobs, decreasing the number of unemployed people, solving effectively social issues, including reducing significantly the number of poor households, caring for credited people, fighting the social evils, and improving the quality of life and morals of the people;

9 Administrative reforms will be speeded up in the direction of reforming and improving effectiveness, and making relations with residents and businesses public and transparent. Bureaucracy and corruption will be reduced. A fundamental reform of the civil service salaries system will be implemented; and

10 The socio-political situation will be kept stable to maintain an environment conducive to national defense and security.

2.4 Thailand

2.4.1 General Facts

Geography

Location: Southeastern Asia,
bordering the Andaman Sea and the Gulf of Thailand,
southeast of Myanmar

Area: *total:* 514,000 sq km
Land: 511,770 sq km
Water: 2,230 sq km

The kingdom of Thailand, lying off the southeast coast of Asia, is a gateway to Indochina, Myanmar and Southern China. The country comprises 76 provinces that are further divided into districts, sub-districts and villages. Bangkok is the capital city and centre of political, commercial, industrial and cultural activities. Its shape and geography divide into four natural regions -- the North, the Central Plains, the Northeast plateau, and the peninsula South. Each of the four geographical regions differs from the others in population, basic resources, natural features, and level of social and economic development.

Climate

Thailand has a tropical monsoon climate with three distinct seasons-hot and dry from February to May (average temperature 34 degrees Celsius and 75% humidity); rainy with plenty of sunshine from June to October (average day temperature 29 degrees Celsius and 87% humidity); and cool from November to January (temperatures range from 32 degrees Celsius to below 20 degrees Celsius with a drop in humidity).

Population

Since 1911, Thailand has taken frequent national censuses organized by the National Statistical Office. A large majority of the population (80%) are ethic Thai, along with strong communities whose ethnic origins lie in China (10%), Malay (3%), India and the rest (Mons, Khmers, hilltribes). About 6 million people reside in the capital city of Bangkok.
From the 2000 National censuses, Thailand had in 2000 about 61 million people. This total was divided about equally between males and females. The regional breakdown was approximately 20.5 million in the Center (which included the Bangkok metropolitan area), 20.8 million in the Northeast, 11.4 million in the North, and 8.1 million in the South. As in most Southeast Asian nations, the population was youthful and agrarian; approximately 25 percent of the population was between the ages of 15 and 29.

Religion: Buddhism (93.8%), Muslim (4.6%), Christian (0.8%), and others (0.8%)

Language

Thailand's official language is Thai. The core Thai--the Central Thai, the Northeastern Thai (Thai-Lao), the Northern Thai, and the Southern Thai--spoke dialects of one of the languages of the Tai language family.

Government

Thailand has had a constitutional monarchy with His Majesty King Bhumibol Adulyadej, or King Rama IX, the ninth king of the Chakri Dynasty, the present king. Parliament is composed of 2 houses, The House of Representatives and the Senate. Both representatives and senators are elected by the people. A prime minister elected from among the representatives leads the government.

Environment

The 1997-1998 Asian financial crisis brought an end to Thailand's economic boom and turned the spotlight on to the effects of rapid industrialization on the country's environment. One of the most visible environmental side effect of Thailand's industrial development is the growing problem of air pollution, where thick smoke often chokes city streets in Bangkok. Although traffic congestion has proven to be a difficult problem to tackle, the Thai government has instituted a number of measures to address urban air pollution problems, including phasing out leaded gasoline. In addition, the country suffers from increased levels of industrial wastewater, a dramatic rise in domestic sewage and hazardous wastes, and severe degradation of its water and coastal resources. Marine pollution is another threat, with increased risks if an offshore gas pipeline linking Thailand and Malaysia proceeds as planned.

2.4.2 Policies and Strategies

2.4.2.1 Solid Waste

Solid Waste Generation

The amount of solid waste has increased every year, particularly the proportion of waste that is difficult to reprocess. Total solid waste throughout the country was 13.5 million tons in 1997, of which 24 percent came from Bangkok, 35 percent from other urban areas and the remaining 41 percent from rural areas.
Thailand’s current solid waste management strategy focuses on bulk collection and mass disposal. Recently, Thai government is trying to implement an ‘integrated waste management system” that includes waste sorting, composting, and incineration. The government also set up a national policy to (1) improve solid waste disposal and processing procedures through privatization of waste eliminating works, (2) support and encourage proper solid waste separation, (3) encourage recycling and reuse, and (4) support local government to build up capacities for waste management.

Solid Waste Law and Regulations

The Environmental Quality Promotion Act, promulgated in 1992, has been the main framework for integrating Thailand's decentralized domestic waste management scheme into a more systematic approach. Several solid waste management regulations have been promulgated and waste disposal areas have been declared. All hospitals have to separate contaminated wastes from domestic wastes and appropriate waste treatment facilities have been established. Municipalities are encouraged to set up waste management action plans. Areas declared as environmental conservation or pollution control zones are being managed intensively. In 1995, a public enterprise called the "Waste Water Management Organization" was established to run a comprehensive waste water management system in the BMR and other areas designated by the Government. During the first half of the 7th National Plan, Thailand finished constructing 40 projects, valued at more than 60 billion baht, of domestic waste water treatment plants in priority urban centers. By the year 1998, the BMR will be able to treat 50% of domestic wastewater, and other urban areas will be able to treat 25%. Investment in 45 hospital waste treatment plants is underway.
Thailand has promoted solid waste management efficiency by improving existing solid waste management systems and promoting the private sector's involvement in solid waste management. The BMA has expanded its organic fertilizer plant capacity and contracted the private sector to collect and sanitarily dump solid wastes. The private sector, in cooperation with the Ministry of Industry, operates a pioneer industrial solid waste treatment plant. Another four plants are scheduled by the year 1997. In 1996, 333 hospital contaminated solid waste treatment plants were operational. This number accounts for about 40% of total hospitals in the country.

2.4.2.2 Industrial Waste and Animal Waste

Expansion of the industrial and economic sectors has resulted in the increase of industrial waste. Thai law related to the industrial waste management and recycling contains three Acts, namely the National Environmental Quality Act B.E. 2535, the Factory Act B.E> 2535, and the Hazardous Substance Act B.E. 2535.

2.4.2.3 Legislation

Thailand has an intact environmental legislation framework. Compliaces with legislations are vital to companies existed in Thailand. The hierarchy of Thai laws is as follows:

- The Constitution, the most recent being the 1997 Constitution;
- "Acts" passed by the Parliament;
- "Regulations" and "Notifications" enacted by the respective Ministries.

The following list is laws and regulations related to the handling of oil contaminated water.

Law and Regulations related to Ministry of Industrial Works

- Factory of Act B.E.2535
- Hazardous Substance Act B.E. 2535

- Hazardous Substance Act (2nd Issue) B.E. 2544
- The Ministerial Regulation No. 15 (B.E. 2544) Issued Pursuant to the Factory Act B.E. 2535
- The Ministerial Regulation No. 11 (B.E. 2539) Issued Pursuant to the Factory Act B.E. 2535
- The Ministerial Regulation, No. 2 (B.E. 2535) Issued Pursuant to the Factory Act B.E. 2535
- The Ministry of Industry Notice Subject: The Support Measure for the Target Industries
- The Ministry of Industry Notice, Subject: Prescription of the Content Values of Contaminants in Air Emitted from the Factory in Case of Use of Processed Used-oiland Synthetic Fuel as Fuel in Industrial Furnaces B.E. 2548
- The Ministry of Industry Notice Subject: Prescription of the Content Values of Air Contaminants Emitted from the Factory B.E. 2548

Law and Regulations related to Ministry of Natural Resources and Environment

- Enhancement and Conservation of the National Environmental Quality Act 1992
- Notification of MOSTE on Types and Sizes of Projects or Activities of Government Agencies, State Enterprises or Private Persons Required to Prepare an Environmental Impact Assessment Report 1992 (24 August 1992)
- Groundwater Act 1977
- Groundwater Act (No. 2) 1992
- Regulations on Prevention and Combating of Oil Pollution

Law and Regulations related to Industrial Estates and Land Use and Planning

- Industrial Estate Authority of Thailand Act (No. 3) 1996
- Construction Building Control Act 1979
- City Planning Act 1975
- Land Reform for Agriculture Act 1975
- Investment Promotion Act 1977

2.4.3 Stakeholders

Many groups are directly and indirectly involved in the waste management issues. Stakeholders can be local government and authorities, environmental organizations, residents, producers of wastes, Environmental management is conducted on a national basis by the Ministry of Science, Technology and Environment (MOSTE). The main departments under MOSTE are the Office of Environmental Policy and Planning (OEPP), the Pollution Control Department (PCD) and the Department of Environmental Quality Promotion (DEQP). These are further divided into several divisions and regional offices which take charge of specific environmental concerns at the national and provincial levels.

The OEPP is the main body tasked with policy formulation and the development of environmental management plans. It coordinates with other national and provincial agencies in the development and implementation of these plans. The OEPP also coordinates the implementation of the Environmental Impact Assessment (EIA) system in Thailand, and is responsible for international cooperation. The PCD, as its name suggests, takes charge of pollution issues, and is the body charged specifically with implementing pollution control laws and emission standards. The DEQP is responsible for promoting public education on the environment, and takes charge of environmental information, public and media relations, research and training as well as NGO liaison.

Apart from these three agencies, there exist a myriad of other bodies operating under the aegis of MOSTE which take charge of specific environmental issues. These include the Department of Energy Development and Promotion, the Department of Science Service, the Office of the National Research Council of Thailand (NRCT), the Office of Atomic Energy for Peace, the Thailand Institute of Scientific and Technological Research (TISTR), the National Science and Technology Development Agency (NSTDA) and the Waste Water Management Authority (WMA).

In Thailand, the responsibility over natural resource management resides primarily with the sectoral ministries. In particular, the Ministry of Agriculture and Cooperatives and the Ministry of Interior, together with their constituent departments, enjoy broad jurisdiction over numerous natural resource sectors. The following is a list of competences:

2.4.4 Economic Framework

Thailand's economy is heavily agricultural, with rice by far the leading crop. Other commercial crops include rubber, corn, tapioca, cotton, tobacco, and sugarcane. Marine and freshwater fisheries are important, and some of the deep-sea catches (mackerel, shrimp, and crab) are exported. In addition, Thailand is a major exporter of farmed shrimp. Tin, tungsten, lead, zinc, and antimony are mined for export. Industries are centered mainly in the processing of agricultural products, such as rice milling, followed by sugar refining, textile spinning and weaving, and the processing of rubber, tobacco, and forest products. During the 1980s and 1990s, electronics became important, causing a substantial rise in the per capita GDP. Thailand also has a small steel mill, oil refineries, tin smelters, and vehicle and machine assembly plants.

The economy has experienced strong growth over the past 3 years. The country's real gross domestic product (GDP) grew 5.3% in 2002, up from only 1.9% in 2001. Real GDP growth for 2003 is projected at 6.4%. Longer-term annual growth rates in 2004 and beyond are projected in the range of 5.8% - 6.6%.

Thailand's key trading partners are the US, EU, Japan, ASEAN, and China.
In the last three decades Thailand has been quite successful in improving its economy. It has been increasing its role in the world economy. Thailand's international trade has increased from US $56113 million in 1990 to US $156331 million in 2003. However, Thailand is moderately indebted as debt service ratio was 59 percent of export of goods and services. The GDP of Thailand has increased rapidly. It has increased from US $85,345 million in1990 to US $142,953 million in 2003 with average annual economic growth estimated as of 2004 is 7 percent.

Thailand has successfully reformed and improved in its administration in various sections, including that of public health due to which the quality of life of Thailand's people has partially improved. It can be seen that the Human Development Index (HDI) of the year 1990 was found to be 0.715, ranking medium at 76 from 177 countries worldwide; which has improved in terms of HDI value as 0.784 with ranking as 74 among 177 countries in 2004.

Similarly, Thailand has performed well in terms of Gender Development as Gender Development Index was 0.781 ranking at 58 among 177 countries in 2004 (Human Development Report, 2006).

Thailand's labour force is abundant. It has been able to export some of its labour force, but it is not much. (Annual Thailand Statistics of the Bureau of National Statistics, Books 40, 45, 49). In the year 1990, Thailand had a total workforce of 31,749,600 persons of which 710,000 were unemployed i.e. about 2.24 percent of the total workforce. In the year 1998, within the period of the Financial Crisis, there were 33,352,900 working persons, of them 1,137,900 were unemployed, or about 3.41 percent of unemployment rate. However, in 2002 when the economy started to recover, the unemployment rate has declined to 1.76 percent with 616,000 unemployed out of 34,969,600 working persons.

3.5 percent of population are living on less than US$ 1-/day in Thailand (Thailand Health Profile 2001-04).

The living standard in Thailand has been much improved, as one can see that 57 percent of the population living in poverty in year 1962 has gone down to 11.4 percent in the year 1996. However, in the year 1997, the financial crisis also hit Thailand, like other economies around the world. The economic growth has slowed down; as a result, unemployment increased, and so did the amount of people living in poverty due to lowered incomes. The rising inflation, which was as high as 8.1 percent, also hit the economy. Consequently, the percentage of population living in poverty increased to 15.9 percent. In the year 1999, the number of households having income below the line of poverty which is set at 20,000 baths per household per year, was 3,917,717 (data from the Household Social Welfare Census under the Project of Hiring the Volunteer Students and Financial Professionals for Strengthening Social Welfare in Villages, 1999). Later on, as the economy improved, the percentage of population living in abject poverty has decreased to 14.2 percent in the year 2000 i.e. 8.9 million people. This suggests that the economic condition has significant impact at the grass-root level. During the period from 2000 to 2002, the economic growth has sustained and the income level of Thai people has increased, the percentage of population living in poverty was 13.1 percent (8.2 million people) in year 2001, and 9.8 percent (6.2 million people) in year 2002. Among the population living in poverty, 86.2 percent were in rural areas. About 2 in 3 of them lived in the North Eastern region of Thailand.

2.4.5 Socio-cultural and Socio-Economic Framework

Poverty data from the latest Socio-economic Survey shows that the majority of the poor reside in the agricultural sector in the rural areas of the Northeast. Poverty maps by district, which are being developed by the National Statistics Office, could help identify poor households at the district level. Poverty fell between 2004 and 2006, but at a relatively slow pace. The poverty headcount ratio fell from 11.2 in 2004 to 9.6 in 2006, leaving 6.1 million people living below the national poverty line of

1,386 Baht/person/month. Apart from the increase in poverty during 1997-2000 as a result of the crisis, the recent reduction in the poverty rate of 1.6 percentage point in 2004-06 was the lowest since 1990. Part of the reason was low crop production, especially in main crops such as rice.

Table 2.4-1: Thailand Poverty Headcount Ratio Classified by Region, 1996-2006 (Percent of total population) [NESDB, 2006]

	1996	**2000**	**2004**	**2006**
Thailand	14.8	21.0	11.2	9.6
Northeast	24.5	35.3	18.6	16.8
North	17.8	23.1	15.7	12.0
South	10.3	16.6	6.0	5.5
Central	6.1	9.0	4.5	3.3
Bangkok	1.2	1.7	0.8	0.5
Urban	9.9	8.6	4.6	3.6
Rural	22.9	26.5	14.2	12.0

*2006 National Poverty Line is 1,386 Baht/head/month

Poverty continues to be concentrated in the households engaged in agricultural activities in the rural areas of the North and Northeastern regions. Poverty remains highest in the North East, with a poverty headcount rate of 16.8 percent, although this is down from 24.5 percent in 2006. Poverty in the rural areas is down to 12 percent of the population almost half the rate in 1996 □ although this is still over 3 times that of the urban areas (3.6 percent). Almost half of poor households derive their incomes from agriculture, fishing and forestry (Figure 6). Another important group among the poor is the elderly the age of the head of household is highly correlated with poverty, especially in the rural areas.

Learning outcome:

By completing this section you should be aware ot the waste management legislative and policy structures of Cambodia, Lao PDR, Vietnam and Thailand and also the current waste situation in these countries. You should understand the issues waste is causing.

☑ Self-assessment

- What are the differences in national strategies?
- Outline the role of the private sector!
- What kind of instruments and laws are equal in all countries?
- Outline the varieties of economic framework conditions!

2.5 References

Cotter, S. (2000). Solid Waste (Chapter 24). *In Environment: Concepts and Issues. A focus on Cambodia*, Ed., Noelle O'Brien. Ministry of Environment, Phnom Penh, Cambodia.

Heisler, T. (2004). Lessons from Experience: A Comparative Look at Solid Waste Management Policies in Cambodia, India, The Philippines and Sri Lanka. The Waste-Econ Programme.

Kham Kimsour (2008). Strategies for improving waste management in Meanchey District, Phnom Penh. MSc. Thesis. Royal University of Agriculture, Phnom Penh, Cambodia.

Kokusai Kogyo CO., Ltd. (2005). The study on solid waste management in the Municipality of Phnom Penh in the Kingdom of Cambodia. Draft Final Report (2), Municipality of Phnom Penh, Cambodia.

Municipality of Phnom Penh (MPP) and Asian Development Bank (ADB) (2006). Partnerships for a cleaner city: Lessons on managing the urban environment. Phnom Penh, Cambodia.

National Institute of Statistics (NIS) (2005). Cambodia inter-censal population survey 2004. Ministry of Planning, Kingdom of Cambodia.

Royal Government of Cambodia (RGC) (2001) Second Five Year Socio-economic Development Plan 2001-2005. Ministry of Planning, Phnom Penh, Cambodia.

Royal Government of Cambodia (RGC) (2006) National Strategic Development Plan 2006-2010. Ministry of Planning, Phnom Penh, Cambodia.

Vin, S., Nitivattananon, V. and Amin, A.T.M. N. (2005). Assessment of solid waste contracted services: Case study of waste collection in Siem Reap town, Cambodia. International Conference on Integrated Solid Waste Management in Southeast Asian Cities. Siem Reap, Cambodia. Nowarat Coowanitwong, Prajapati Shapkota, and Peachie Ann Aquino, Asian Institute of Technology, Thailand.

Socialist Republic of Vietnam – The Government website.
http://www.chinhphu.vn/portal/page?_pageid=439,1090503&_dad=portal&_schema=PORTAL

General Statistic Office of Vietnam. http://www.gso.gov.vn/

World Bank; MONRE; CIDA. (2004). Vietnam Environmental Monitor 2004.

Dinh Xuan Thang (2001). Surveying, Evaluating and Sugessting measure for managing the solid waste problem in Long An province. Institute of Environment and resource – HCM city.

Cantho Environmental Monitoring station (2006). Cantho environmental monitor 2006. Department of Natural Resource and Environment of Cantho city.

Department of Natural Resource and Environment of Haugiang province (2007). Haugiang environmental monitor 2007. Department of Natural Resource and Environment of Haugiang province.

Environmental protection center (1996). Environmental impact assessment of landfill construction project of Mytho city – Tiengiang province. Environmental protection center.

Institute of Environment and sustainable development (2003). Report on Environmental pollution and source of pollutant at Vinhlong province. Department of Science – Technolgy and environment of Vinhlong province.

Department of Natural Resource and Environment of Bentre province (2005). Environmental situation of Bentre province 2005. Department of Natural Resource and Environment of Bentre province.

Soctrang URENCO (2005). Annual Report 2005. Soctrang URENCO.

Cantho Environmental Monitoring station (2007). Report on Environmental situation of Baclieu province 2007. Department of Natural Resource and Environment of Baclieu province.

Travinh URENCO (2006). Annual Report 2006. Travinh URENCO.

Rachgia URENCO (2002). Report on Solid waste component analysis. Rachgia URENCO.

Camau Design Consultant Company (2000). Report on Feasibility study of project on collection, transportation and treatment of solid waste at Camau city. Department of Construction Camau province.

Committee for Planning and Investment 2006, *Sixth National Socio Economic Development Plan (2006-2010)*, p I, II, III, IV, 39, 40, 41, 42, 43, 44.

Country Report 2001, *the implementation of the habitat agenda in the Lao People's Democratic Republic,* P. 5.

FONGKHAMDENG Bounnao, *Actions Implication for Waste Recycling and Waste Separation Demonstrations*, Urban Planning Division, DHUP, MCTPC.

The Institute for Cultural Democracy 1998, *Cultural Policy in the Lao People's Democratic Republic*, Viewed 1/12/2008
http://www.wwcd.org/policy/clink/Laos.html

The World Bank & STEA, no date, *Lao PDR Environment Monitor,* p V, IX, 38,39,40,46,47,48,50.

The World Bank 2006, *Economic framework*, Lao PDR Economic Monitor.

VEaSM - Vietnam Environment and Science Magazine, maithanhtuyet@khoahoc.net, 21/4/2005

Nguyen Trung Thang, Institute for Resource and Environment Policy and Strategy, Hanoi Workshop, 4/2008

Nguyen Danh Son, Institute of Sustainable Development in North's area Vietnam, Hanoi Workshop, 4/2008

Vietnam Environment Law, 2005

3 Waste Quantities and Characteristics

Educational objective of the chapter

The objective of this chapter is to learn about the country specific characteristics of waste.
- Waste Quantities
- Waste Characteristics
- Waste composition
- Factors of influence
- Definition of waste

3.1 Definition of Waste

Solid wastes are materials, which no longer have any useful purpose in their present form or condition. Solid waste management can be defined as the disposal of waste materials (also known as rubbish, garbage, trash), generated from household and industrial sources, in a cost effective way, without degrading the environment (Cotter, 2000).

Waste is an unwanted or undesired material or substance. It is also referred to as rubbish, trash, garbage, or junk depending upon the type of material and the regional terminology. In living organisms, waste relates to unwanted substances or toxins that are expelled from them.

The European Union defines waste as an object the holder discards, intends to discard or is required to discard is waste under the Waste Framework Directive (European Directive 75/442/EC as amended).

Once a substance or object has become waste, it will remain waste until it has been fully recovered and no longer poses a potential threat to the environment or to human health."

The UK's Environmental Protection Act 1990 indicated waste includes any substance which constitutes a scrap material, an effluent or other unwanted surplus arising from the application of any process or any substance or article which requires to be disposed of which has been broken, worn out, contaminated or otherwise spoiled; this is supplemented with anything which is discarded otherwise dealt with as if it were waste shall be presumed to be waste unless the contrary is proved.

According to the Notification of the Ministry of Industry B.E. 2548, waste and discarded materials are identified as follows.

Industrial waste is defined as waste and discarded materials resulted from industrial activities including raw materials, intermediates, sub-quality products, production processes and water effluent containing hazardous properties.

According to the Environmental Quality Conservation Act B.E. 2535, waste includes garbage, manure, wastewater, air emission, pollution or any other hazardous substances, which are emitted or discharged from pollution sources including sludge and their remaining in forms of solid, liquid, and gas.

3.2 Waste Quantity, Generation and Composition in Cambodia

3.2.1 Municipal Solid Waste

Municipal solid waste (MSW) –generated from households, offices, hotels, shops, schools and other institutions– is composed of food waste, paper, plastic, rags, metal and glass. Table 3.2-1 shows the estimated quantity of solid waste generated per day in some municipalities and provinces in Cambodia. It is obvious that Phnom Penh, with a population of 1.3 millions, creates the largest amount of solid waste. The expected waste amount for various sources based in population and waste generation projections in Phnom Penh is shown in Table 3.2-2. An analysis of ratio of carbon and nitrogen contained in the waste of household, restaurants, and market showed a C/N ratio of 15.8 to 18.3 for kitchen waste and 24.3 to 20.2% for grass and wood waste, indicating that these wastes are suitable for composting.

Table 3.2-1: Quantity of solid waste generated per day in Cambodia [Cotter, 2000]

Town / Province	Quantity / Day
Phnom Penh	464 tons
Sihanouk Ville	15 tons
Siem Reap	17 tons
Banteay Meanchey	12 m^3
Kampong Speu	30 tons
Pursat	21 m^3
Kampong Chhnang	10 m^3
Kampong Cham	15 m^3
Kampot	16 m^3
Preah Vihear	5 m^3
Kep (Kampot)	6 m^3
Svay Rieng	1 ton
Prey Veng	30-50 m^3

Table 3.2-2: Collection Amount of Waste in Phnom Penh (t/day)

Collection amount	2007	2008	2009	2010	2011	2012	2013	2014	2015
Household	91.6	103.0	115.7	129.4	140.5	171.5	183.8	196.8	224.1
Commercial-Restaurants	7.6	8.4	9.2	10.3	11.1	12.1	13.0	13.9	15.0
Commercial-Others	19.3	21.8	24.8	27.9	30.8	34.2	37.4	40.9	44.9
Market	12.6	14.1	15.7	17.6	19.3	21.2	22.9	24.7	27.0
Hotel	0.4	0.4	0.6	0.6	0.6	0.6	0.7	0.8	0.8
Office	0.2	0.2	0.1	0.2	0.2	0.3	0.3	0.3	0.3
Schools	1.3	1.4	1.6	1.8	1.9	2.1	2.2	2.4	2.6
Factories	15.1	16.3	17.7	19.1	20.1	21.1	22.2	23.3	24.5
Hospitals	0.6	0.8	1.0	1.1	1.4	1.5	1.8	2.0	2.3
Slaughter House	3.9	4.3	4.6	4.9	5.2	5.4	5.7	6.1	6.3
Unidentified source	8.4	9.2	10.0	10.9	11.8	12.7	13.7	15.0	16.2
Street Sweeping	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.9
TOTAL	**161.4**	**180.4**	**201.6**	**224.4**	**243.6**	**283.4**	**304.4**	**327.0**	**364.9**

3.2.2 Sewage Sludge

Sewage systems in Cambodia, especially Cin cities and urban areas, are still in bad conditions. Standing water in the streets around housing settlements and market places remains a problem, due to the lack of drainage system and environmental infrastructure and facilities. Where they are available, the lack of maintenance is apparent (MPP and ADB, 2006). Residents throw their garbage on streets, clogging the sewage system and when it rains, many areas in cities are flooded (Kham, 2008). Sewage, on the other hand, is discharged into lakes without treatment. Edible aquatic plants, especially water spinach, are grown on the untreated water, the safety of which has been questioned by many researchers.

3.2.3 Industrial waste

Industrial solid waste in Cambodia, as elsewhere, encompasses a wide range of materials of varying environmental toxicity. Typically this range would include paper, packaging materials, waste from food processing, oils, solvents, resins, paints and sludge, glass, ceramics, stones, metals, plastics, rubber, leather, wood, cloth, straw, abrasives, etc. As with municipal solid waste, the absence of a regularly up-dated and systematic database on industrial solid waste ensures that the exact rates of generation are largely unknown.

Figure 3.2-1: Discharge site of sewage system in Phnom Penh

Table 3.2-3: Industrial Waste Flow in Phnom Penh City in 2003 [Kakusai Kogyo Co., Ltd, 2005]

Waste Flow Component	Discharge Ratio (g/employee/day)	Waste Amount (tons/day)	No. of Generation Sources
Waste Generation Amount	334.8	58.2	173,942
Recycling	---	0.1	---
Final Disposal Amount	---	58.1	---

In Phnom Penh, the textile and garment industries account for 80% and 97% of the total number of factories and employees respectively and 82% of the total amount of IW is discharged by these industries. Almost all factories separate HIW from non-HIW. Few factories conduct reuse, recycling or treatment of waste on-site. CINTRI and Sarom Trading Company each collect half of the waste discharged from industries. Because there are no clear standards or regulations for IW treatment and disposal, some factories have been reported to discharge HIW mixed with non-HIW (Kakusai Kogyo Co., Ltd., 2005).

3.2.4 Factors influencing quantity and composition of waste

There are several factors influencing quantity and composition of waste in Cambodia, including:

1. Generation source– household waste tends to produce the largest amount of waste (Table 3.2-4).
2. Household incomes– The average household waste generation ratio in Phnom Penh is found to be 487 g/person/day, which is similar to that of other developing countries. The increase in the generation ratio by level is proportionate to the household income level, with high household incomes producing larger amount of waste than do middle and low ones (Table 3.2-5).
3. Season–with few exceptional cases, larger amount of waste is produced in dry season than that of rainy season (Table 3.2-6).

Table 3.2-4: Daily waste discharge amount in Phnom Penh City in 2003 [Kokusai Kogyo CO., Ltd., 2005]

Generation Source	Unit	Number of generation sources	Generation Ratio			Daily Generation Amount (Ton/day)		
			Dry season	Rainy season	Average	Dry season	Rainy season	Average
Household Waste	g/person/day	1,199,414	498	476	487	597.3	570.9	584.1
Commercial Waste (restaurant)	g/table/ day	27,808	1,940	1,387	1,664	54.0	38.6	46.3
Commercial waste (Other Shop)	g/shop/ day	33,524	4,566	4,437	4,502	153.1	148.8	151.0
Market Waste	g/stall/ day	51.766	1,700	1,945	1,823	88.0	100.7	94.4
School Waste	g/student/day	385,013	18	21	20	6,9	8.1	7.5
Street Sweeping Waste	g/km/d	56	47,235	59,510	53,373	2.6	3.3	3.0
Hotel Waste	g/room/ day	13,385	199	263	231	2.7	3.5	3.1
Office Waste	g/office/ day	368	2,946	4,174	3,560	1.1	1.5	1.3
Total						905.7	875.4	890.6

Table 3.2-5: Household waste discharge ratio as classified by household incomes [Kokusai Kogyo CO., Ltd., 2005]

Household characteristics	Average monthly income (riel)	Population by Income level	Generation Ratio (g/person/day)	
			Dry season	Rainy season
High Income Household	3,708,000	10%	668.5	646.2
Middle Income Household	1,291,000	30%	545.3	501.4
Low Income Household	636,000	60%	445.9	435.2
Weight Average	---	---	489.0	476.1

Note: 1 US$ = 4000 Riels

Table 3.2-6: Waste composition in Phnom Penh [Kokusai Kogyo CO., Ltd., 2005]

Classification				Total		
				dry season	rainy season	average
Physical Composition (WET Base)	Apparent Specific Gravity		kg/l	0.25	0.24	0.25
	Combustible Waste	Paper	%	6.3	6.5	6.4
		Rubber and Leather	%	0.0	0.1	0.1
		Kitchen Waste	%	65.8	61.2	63.3
		Textile	%	2.3	2.7	2.5
		Plastic	%	17.1	13.8	15.5
		Grass and Wood	%	3.0	10.5	6.8
		Sub- Total	%	94.5	94.8	94.6
	Incombustible Waste	Metal	%	0.3	0.9	0.6
		Bottle and Glass	%	1.3	1.1	1.2
		Ceramic and Stone	%	2.1	0.9	1.5
		Others	%	1.8	2.3	2.1
		Sub-Total	%	5.5	5.2	5.4
	Total		%	100.0	100.0	100.0

3.3 Waste Characteristics in Thailand

3.3.1 Quantity, Generation and Composition

This section describes wastes based on the renewable energy generated (i.e., bio-ethanol, biodiesel, biogas, and municipal solid waste).

3.3.1.1 Ethanol Production

In Thailand, the three major types of feedstock and/or energy crops available for bio-ethanol production are sugarcane, molasses and cassava. Table 3.3-1 and Table 3.3-2 shows the estimation of ethanol production from sugar cane and molasses and cassava, respectively. Table 3.3-3 describes potential agricultural products that can be used for bio-ethanol production and its price and method of current utilization.

Table 3.3-1: Estimated Sugar Cane and Molasses Production

year	Sugar cane production from survey (million tons/year)	Sugar cane production (million tons/year)	molasses (tons/year)	Ethanol production (L/year) From molasses
2006	45.9	47.92	2,396,000	349,000,000
2007	58.69	57.02	2,851,200	462,800,000
2008	66.52	59.90	2,995,200	498,800,000

Table 3.3-2: Estimation of cassava root production, its utilization in various industries and the amount of ethanol produced between 2007-2017

Year	Cassava root production (millions tons)*	Amount of fresh cassava roots (million tons)			Ethanol production (million liters/day)	Ethanol production (million liters/year)
		For starch production	For chip/pellet production	For ethanol production		
2007	23.28	12	9	**2.28**	**1.08**	**387.6**
2008	27.45	12	9	**6.45**	**3.05**	**1,096.5**
2009	29.7	12	9	**8.7**	**4.11**	**1,479.0**
2010	29.7	12	9	**8.7**	**4.11**	**1,479.0**
2011	29.7	12	9	**8.7**	**4.11**	**1,479.0**

Table 3.3-3: Price of agricultural by-products

By-products	Price	Utilization
Rice straw	variable	Animal feed, soil coverage
Rice husk	1,200 Bath/ton	Burning for energy
Broken rice	14 Bath/kilogram	Rice flour production, animal feed
Corn husk and cob	-	Animal feed, compost, etc.
Palm empty bunches	350 Bath/ton	Mushroom cultivation, burning for energy
Palm shell	1,550 Bath/ton	Burning for energy
Palm kernel cake	-	Burning for energy
Palm fiber	-	Burning for energy

Source: Field study survey (2006)

3.3.1.2 Bio-Diesel Production

Table 3.3-4 and Table 3.3-5 estimate the quantity of palm oil and used vegetable oil that can be used for bio-diesel production.

Table 3.3-4: palm oil amount for biodisel production

Year	Planted Area M rai[12]	CPO[13] M liter	B100		B10	
			M liter/year	M liter/day	M liter/year	M liter/day
2550	2.74	107.42	107.42	0.29	1,074.30	2.94
2551	2.89	167.67	167.67	0.45	1,676.71	4.59

Table 3.3-5: Accessibility of provision of used vegetable oil (UVO).

Sources	Amount m litre	accessibility
household	47.2	limited
Food caterer & restaurants	22.5	accessible
large factories	3.4	highly accessible
vendors	1.3	limited

3.3.1.3 Biogas Production

Biogas is a high effective source for renewable energy. Currently, approximately 2,300 biogas systems exist in Thailand. Various wastes, such as wastewater from agro-industries and animal manure, are available as the sources of biogas. Two major sources for biogas production are wastewaters from cassava starch factories and pig farms. Table 3.3-6 to Table 3.3-18 present waste composition and quantiy of each type of biomass for biogas production.

Table 3.3-6: Waste Composition from Pig Farm

Type	Data from field survey				
	COD (mg/kg)	BOD (mg/kg)	TS (mg/kg)	VS (mg/kg)	TKN (mg/kg)
Swines	230,130	121,150	390,350	266,550	7,593
hogs	163,740	67,801	250,000	180,000	8,000

Table 3.3-7: Quantity of Waste Generated from Cattle/Dairy Cow

Type	Unit	Amount
Dairy cow	Kg/head/day	15
Cattle	Kg/head/day	5

Table 3.3-8: Waste Composition from cattle/dairy cow

Type	Data from field survey				
	COD (mg/kg)	BOD (mg/kg)	TS (mg/kg)	VS (mg/kg)	TKN (mg/kg)
Dairy Cow	160,977	120,630	197,000	170,420	3,750
Cattle	124,550	105,260	205,600	165,220	4,360

[12] 1 hectare = 6.25 rai
[13] CPO: Crude Palm Oil

Table 3.3-9: Waste Composition from Cassava Starch Factory

Type	pH	COD (mg/L)	BOD (mg/L)	TS (mg/L)	SS (mg/L)	TKN (mg/L)	TDS (mg/L)
WW from Separator	5.54-6.48	10,540-19,048	5,074-12,165	7,410-18,885	1,475-11,330	197-292	4,730-8,875
Combined WW	4.99-6.33	12,996-19,278	6,465-12,646	12,549-19,844	5,790-7,965	228-512	5,583-12,851

Table 3.3-10: Waste Composition from Crude Palm Oil Factory

Source		pH	Temp (^oC)	COD (mg/L)	BOD (mg/L)	TS (mg/L)	TVS (mg/L)	SS (mg/L)	Oil (mg/L)
KMUTT 2007	Min	4.21	50	30,424	10,475	53,030	45,275	11,625	1,880
	Max	4.86	76	94,053	56,900	97,420	80,100	40,725	8,580
	Aver	4.64	65	62,032	29,172	65,674	56,148	23,179	5,010
Puetpaiboon U. and Chotwattanasak J., 2005	Aver	4.69 - 4.85	40-45	21,560-39,200	16,950 24,600	ND	ND	ND	ND
Itroj,2004	Min	4.5	ND	58,750	17,000	ND	ND	9,233	ND
	Max	5.38		64,883	21,000			12,260	
	Aver	5.05		61,816	19,000			10,746	
Factory Dept, 1997	Aver	4-5	75-90	90,000	30,000	ND	ND	34,000	8,000
Najafpour., et al., 2006	Aver	3.8-4.4	ND	42,500-62,032	23,000 - 24,500	ND	ND	16,500 - 18,000	4,900-5,300
Peram M Ch Prasada Rao, 1999	Aver	3.98	75.8	98,484	36,246	ND	ND	47,940	ND
Ma Ah Ngan, 1987	Aver	4.2	ND	50,000	25,000	ND	ND	18,000	ND
DEDE 2000	ND	ND	ND	52,000	ND	ND	ND	ND	ND

ND : No Data

Table 3.3-11: Waste Composition from Frozen Seafood Factory

Source		COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Total Solids (mg/L)	Total Volatile Solids (mg/L)	Suspended Solids (mg/L)	Oil & Grease (mg/L)
KMUTT 2007	Min	1,900	1,069	123	3,525	1,370	730	6,383
	Max	4,800	4,013	519	7,715	3,345	1,355	23,250
	Aver	3,513	2,110	319	5,585	2,582	1,034	17,346
Usara ,2005		2,840	925	ND	ND	ND	937	ND
Nair,1990		1,950	1,300	ND	ND	ND	520	300
Factory Dept+GTZ+PDTI 1994		7,047	5,302	ND	4,533	ND	ND	6,085
		4,574	2,480	ND	2,527	ND	ND	7,178
		2,721	1,852	ND	1,138	ND	ND	1,024
DEDE 2000		6,801	ND	ND	ND	ND	ND	ND

ND : No Data

Table 3.3-12: Quantity of Wastewater Canned Pineapple Factory

Source		Combined WW (cu.m./tons fresh pineapple)	Combined WW (cu.m./tons canned pineapple)
KMUTT 2007	Min	0.32	4.57
	Max	1	14.3
	Aver.	0.66	9.42
Koottatep ,2002		1	14.28
The Division of Pollution Prevention and Environmental Assistance	Min	0.69	9.8
	Max	0.71	10.2
	Aver.	1	14.4
DEDE 2000		0.35	4.98

Table 3.3-13: Waste Composition from Canned Pineapple Factory

Source		pH	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Total Solids (mg/L)	Total Volatile Solids (mg/L)	Suspended Solids (mg/L)
KMUTT 2007	Min	3.81	1,320	573	9	1,837	3,655	205
	Max	4.02	9,128	4,100	36	8,397	6,192	617
	Aver	3.9	5,477	2,563	23	5,070	4,580	452
DEDE 2000		ND	16,486	ND	ND	ND	ND	ND

ND : No Data

Table 3.3-14: Waste Composition from Sugar Factory

Source		COD (mg/L)	BOD (mg/L)	Total Solids (mg/L)	Total Volatile Solids (mg/L)	Suspended Solids (mg/L)	TKN (mg/L)	pH
KMUTT 2007	Min	2,430	787	2,476	2,032	4	133	5.30
	Max	3,805	2,175	8,985	3,505	28	3,754	7.83
	Aver	3,129	1,421	4,408	2,596	16.8	1,050	6.26
Chang , et al., 1990		7,000	2,800	ND	ND	ND	ND	6.5-7.6
Kusum Lata., et al., 2002		1,800-3,200	720-1500	3500	ND	ND	ND	4-7
Lembaga Rendidikan, 2001		540-6,746	254-3,341	ND	ND	80-1,440	ND	ND
DEDE 2000		2,932	ND	ND	ND	ND	ND	ND

ND : NO DATA

Table 3.3-15: Waste Composition from Pig Slaughterhouse

Source		COD (mg/L)	BOD (mg/L)	TKN (mg/L)	TS (mg/L)	Total-N (mg/L)	Total-P (mg/L)	Total Volatile Solids (mg/L)	Suspended Solids (mg/L)	Oil & Grease (mg/L)	pH
KMUTT 2007	Min	1,460	569	112	2,245	ND	ND	1,363	308	156	7.26
	Max	2,770	948	227	3,008	ND	ND	2,096	1,050	950	7.83
	Aver.	1,988	717	169	2,650	ND	ND	1,738	602	466	7.50
Factory Dept 1998		3,480	2500	ND	ND	520	34	ND	ND	20	ND
Effe, 2548		2000-2500	1,000 – 1,500	300 – 600	ND	ND	ND	ND	700-800	10-20	6.5 – 7.5
Hansen and Mortensen, 1992		2,500	1,250	ND	ND	150	25	ND	700	150	7.20
DEDE 2000		2,284	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3.3-16: Waste Composition from Cattle Slaughterhouse

Source	COD (mg/L)	BOD (mg/L)	Total-N (mg/L)	Total-P (mg/L)	Suspended Solids (mg/L)	Oil & Grease (mg/L)	pH
Factory Dept 1998	7,080	2,950	588	3	660	14	ND
Hansen and Mortensen, 1992	4,000	2,000	180	27	1,600	270	7.2
Tritt, 1992	1000-6000	1000-4000	250-700	80-120	ND	ND	ND
DEDE 2000	2,284	ND	ND	ND	ND	ND	ND

Table 3.3-17: Waste Composition from animal farm

Biomass	Amount	Unit	COD (mg/kg)	TVS (mg/kg)
Pig manure				
- Swine	2	kg/head/day	230,000	267,000
- Hog	1.2	kg/head/day	164,000	180,000
- Piglet	0.5	kg/head/day	164,000	180,000
- Native breed	1.2	kg/head/day	164,000	180,000
Cattle manure				
- Cattle	15	kg/head/day	161,000	171,000
- Dairy Cow	5	kg/head/day	125,000	165,000

Table 3.3-18: Characteristics of Biomass Potential for Biogas Production from industries

Biomass	Amount	Unit	COD (mg/L)	TVS (mg/L)
WW – cassava starch	15	cu.m./ton starch	20,000	-
Cassava pulp	1.7	cu.m./ton starch	234,000 (mg/kg)	-
WW – palm oil	0.5	cu.m./ton CPO	60,000	56,000
WW – frozen seafood	30	cu.m./ton canned tuna	4,000	2,500
WW – canned pineapple	10	cu.m./ton canned pineapple	5,500	4,500
WW – sugar	1.7	cu.m./ton sugar	3,100	2,600
WW – pig slaughtherhouse	3	cu.m./ton pig	2,000	-
WW – cattle slaughterhouse	2.5	cu.m./ton cattle	3,000	-
WW – ethanol	20	L/ton ethanol	100,000	60,000

The availability of major wastes in the livestock sector is from pig and cow manures. In 2006, with 6.28 million heads of pigs, 1.3 million tons of manure was collected. The total biogas potential from pig manures was estimated to be 237 millions m^3, with an equivalent energy content of 120 kilo-tons of oil equivalent (ktoe). This could replace 285 GWh (33 MWe) of electricity or 109 million liters of fuel oil. With 8.2 million heads of cattles/cows, 9.2 million tons of manure was collected (i.e., 2.09 million tons from dairy cows and 7.11 million tons from cattles). The total biogas potential from cattle/cow manure was estimated to be 822 million m^3 that was 595 and 226 million m^3 from cattles and dairy cows, respectively. With an equivalent energy content of 430 ktoe, this could replace 986 GWh (115 MWe) of electricity or 378 million liters of fuel oil.

Currently, the biogas systems are the most popular in the pig farms, producing approximately 30 - 40% of the total biogas potential in the year 2006 or equivalent 145 million m^3 biogas a year. The equivalent energy content was 76 ktoe, which could replace 174 GWh (20 MWe) of electricity or 67 million liters of fuel oil.

Table 3.3-19: Potential Biogas Production from animal farm

Biomass	Quantity (million ton/yr)	biogas (million m3/yr)	KTOE	MW	Eq. fuel oil (million L)
Pig	1.30	237	120	33	109
Cattle/cow	9.2	822	430	115	378
Total	**11**	**1,059**	**550**	**148**	**477**

Table 3.3-20 presents the biogas potential from ten agro- and food industrial wastewaters. The ten industries were cassava starch, sugar, palm oil, canning/frozen seafood, slaughter house, canning pineapple, and cassava pulp. Cassava starch wastewater has the highest potential for biogas production of 344 million m^3 (2006), with an equivalent energy content of 167 ktoe. or 413 GWh (18 MWe, PCF=82%), or 158 million liters of fuel oil. Then, the ethanol-distillery spent wash, palm oil mill wastewater, tuna canning wastewater, pineapple canning wastewater, slaughterhouse wastewater, and sugar mill wastewater have the biogas potential from high to low, respectively. The overall potential for biogas production from the industrial wastewaters is 461 ktoe a year.

Table 3.3-20: Potential Biogas Production from Industries

Biomass	No of Factories	Capacity	Unit	Quantity	Unit	biogas (million m3/yr)	methane (million m3/yr)	KTOE	MW	Eq. fuel oil (million L)
WW – starch	69	2,294,865	Ton starch	34.42	million m3/yr	344	207	167	48	158
Cassava pulp	69	2,294,865	Ton starch	3.90	million ton/yr	388	174	141	54	178
WW - ethanol	6	299,300	M3 ethanol	5.99	million m3/yr	150	120	97	21	69
WW – palm oil	58	5,002,721	M3 CPO	2.50	million m3/yr	84	48	39	12	39
WW – canned tuna	52	626,670	Ton canned tuna	18.80	million m3/yr	21	15	12	3	10
WW – canned pineapple	45	486,343	Ton canned pineapple	4.86	million m3/yr	13	7.1	6	2	6
WW - sugar	46	4,630,000	Ton sugar	7.87	million m3/yr	4.17	0.9	0.73	1	2
WW – pig slaughterhouse	2,863	553,382	LWK-ton pig	1.66	million m3/yr	0.45	0.2	0.20	0.06	0.21
WW – cattle slaughterhouse		147,995	LWK-ton cattle	0.37	million m3/yr	0.15	0.1	0.07	0.02	0.07
Total						**1,005**	**571**	**461**	**141**	**462**

3.3.2 Municipal Solid Waste (MSW)

Table 3.3-21: Quantity of MSW in 2004

Area	Population	Quantity of MSW (ton/day)
Central Plain	10,888,712	7,571
North	12,073,235	6,749
North-east	21,549,987	10,454
East	4,074,187	3,013
South	8,499,848	4,804
Total	**57,085,969**	**32,591**

Table 3.3-22: Composition of MSW

Area	**Composition (% wet basis)**				
	North	**Northeast**	**Central**	**East**	**South**
Combustible	**95.31**	**95.02**	**96.57**	**94.10**	**93.37**
Organics	63.81	69.56	64.49	59.34	59.10
Paper	7.18	6.01	7.31	8.40	10.24
Plastic	18.52	15.26	17.62	18.58	18.14
Wood	0.85	0.44	1.30	0.91	0.43
Rubber	0.32	0.49	0.36	0.57	0.63
Textile	1.23	1.00	1.51	1.89	1.40
Others	3.40	2.28	3.99	4.43	3.44
Non-Combustible	**4.70**	**4.99**	**3.44**	**5.91**	**6.63**
Glass	3.11	3.19	1.90	3.31	4.37
Metal	1.59	1.81	1.54	2.60	2.27

Table 3.3-23: Chemical composition of MSW

Chemical Composition	**Bangkok Area**	**Municipality**
%MC	61.33	67.11
%TS	38.67	32.89
%VS	86.16	88.12
%C	47.87	48.82
%H	5.39	5.51
%O	32.54	32.53
%N	0.20	0.88
%P	0.17	0.34
%S	0.00	0.03
Heat of combustion, cal/g by bomb calory meter	7,674	6,237

Table 3.3-24: Properties of MSW

Municipality	**Moisture(%)**	**Organic(%)**	**Heat Value (kcal/kg)**
Metropolitan	66.42	65.17	6,066.44
District	67.33	64.09	6,533.47
Sub-district	68.30	64.36	6,039.92

3.4 Waste Quantities and Characteristics in Vietnam

3.4.1.1 Waste Quantity, Generation and Composition

Solid waste generation in Vietnam is over 15 million tons per year. From it 80 % is classified as municipal solid waste, 17 % industry and 1% hazardous waste (industrial hazardous, healthcare residues and herbicides). The solid waste generation is about 1kg/head/day (Figure 3.4-1) [VEM 2004].

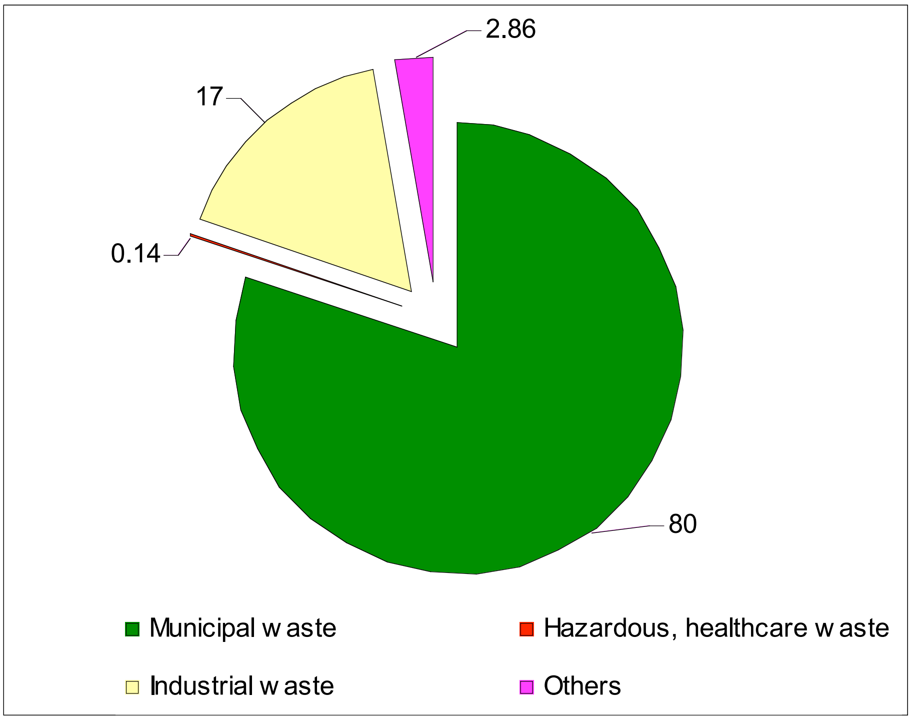


Figure 3.4-1: Ratio of waste quantities

Table 3.4-1: The amount of solid waste generation perday in some cities of Vietnam

Cities	Amount of generation m^3/day	Municipal solid waste (m^3/day)	Ratio of municipal solid waste / total waste
Hà Nội (1)	3027 m^3/ngày	2436 m^3/ngày	80,5 %
Hải Phòng (1)	1123 m^3/ngày	566 m^3/ngày	50,4 %
Quảng Ninh (1)	390 m^3/ngày	384 m^3/ngày	98,5 %
Hải Dương (1)	375 m^3/ngày	313 m^3/ngày	83,5 %
Hưng Yên (1)	56 m^3/ngày	56 m^3/ngày	100,0 %
TPHCM (1)	3500 tấn/ngày (gồm rác sinh hoạt và rác xây dựng)	3000 tấn/ngày	80,0 %
Vĩnh Long (thị xã) (1)	114 tấn/ngày	76 tấn/ngày	66,0%
Bến Tre (thị xã) (1)	63,2 tấn/ngày	58 tấn/ngày	91,8%

The generation rates of solid waste depend on the category of urban area. Hanoi and Ho Chi Minh city produce a large amount of waste in comparison with the others (Figure 3.4-2):

- HCM city: 2,300,000 ton/year
- Hanoi: 720,000 ton/year
- Others: 3,380,000 ton/year

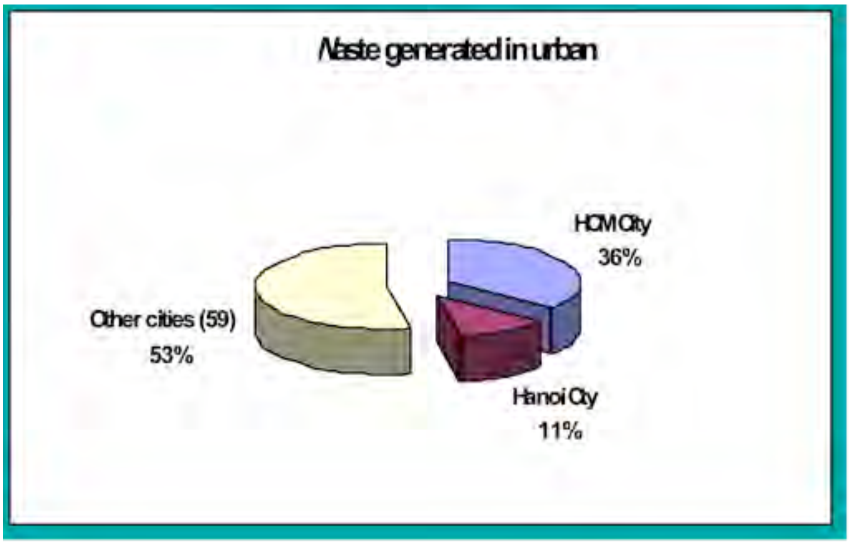


Figure 3.4-2: Waste generation in urban areas

In 2003 the generation of municipal solid waste in Hanoi is about 2000 ton / day, from this about 1368 ton/day are from the inner city. Main components are organic waste: 49 - 60 %: rest of food, vegetable, fruit, …; recycable material 22 29 %: rest of plastic, paper, metall, galss, ...; others 18 - 22 %: rest of wood, gumi, leather, artificial leather, hazardous, ... Collection rate is about 70% (Figure 3.4-3) [Tang The Cuong, 2006].

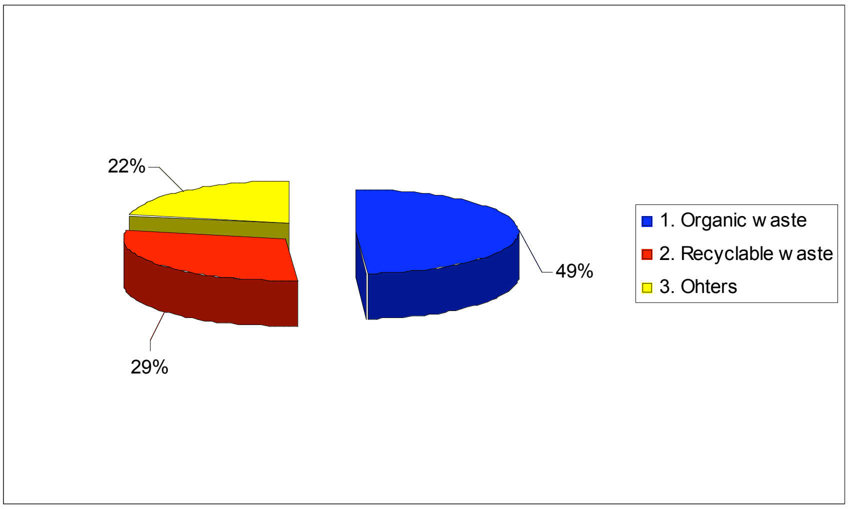


Figure 3.4-3: Components of waste generation in Hanoi

In 2004 however the waste generation in Hanoi has increased to 3855 ton/day. Components are as follows: municipal solid waste (58,97 %); industrial waste (13,40 %); C&D waste (21,60 %); hazardous health care waste (0,045%); sewage sludge (5,95 %) and others (0,035 %) (Figure 3.4-4) [URENCO, 2005].

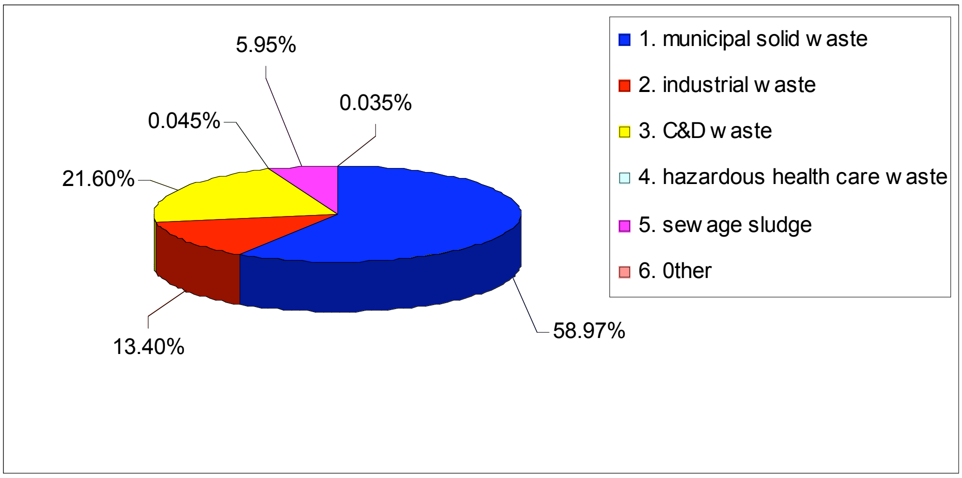


Figure 3.4-4: Components of waste generation in Hanoi in 2004

Household waste amount has changed rapidly from 2002 to 2004 as shows in Figure 3.4-5 [DONRE, 2005].

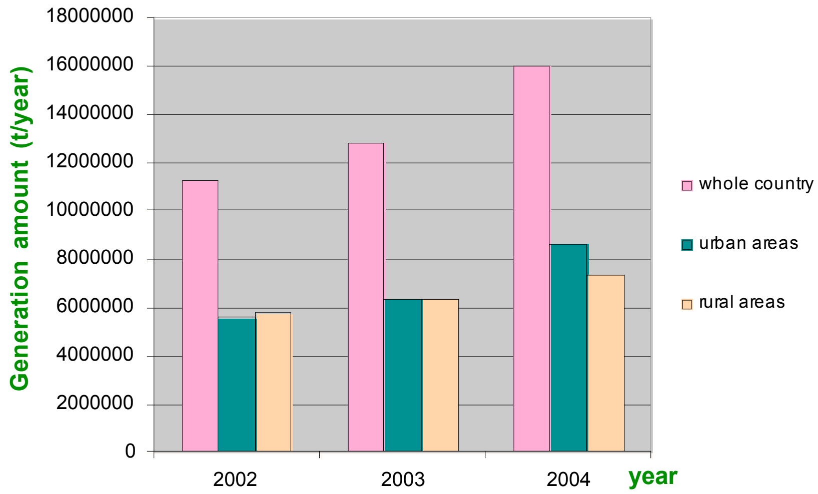


Figure 3.4-5: Household waste amount from 2002 - 2004

Waste generation increases over 10 %/head/year. If there is no suitable policy on waste management the waste amount to 2010 increase by 50 - 60% (about 23 million tons / year) and an over threefold increase in hazardous waste generation, mostly attributable to industrial sources. Considering the high cost of safe collection and disposal, initiatives to reduce waste such as promoting public awareness and cleaner production, and introducing economic incentives based on the Polluters Pay Principle could result in significant savings. For example, a 10% reduction in waste generation could result in an annual disposal savings of approximately VND 200 billion and VND 130 billion for municipal and hazardous healthcare waste, respectively.

Specific gravity of solid waste ranges from 400 - 580 kg/m^3 such as in Ha Noi, 420 kg/m^3 in Da Nang; 580 kg/m^3 in Hai Phong and 500 kg/m^3 in Ho Chi Minh City.
Table 3.4-2 summerized the generation of municipal solid waste in some cities in 2002 [NEA, 2003].

Table 3.4-2: Municipal solid waste generation rate in some urban areas in 2002

	Waste volume per capita	**% Compared to total waste volume**	**% Organic composition**
Urban areas (nationwide)	**0,71**	**50**	**55**
Ho Chi Minh City	1,3	9	
Ha Noi	1,0	6	
Da Nang	0,9	2	
Rural areas (nationwide)	**0,3**	**50**	**60 - 65**

The big picture of Solid Waste Generation in Vietnam, 2003 is described in Table 3.4-3[WBR, 2003]. It is to noticed that the urban areas contain 25% of the country's population but produce about 50% municipal waste. Waste is concentrated in urban areas. This is due to the more affluent lifestyles, larger quantity of commercial activities, and more intense industrialization found in urban areas. These activities also increase the proportion of hazardous waste (such as batteries and household solvents) and non-degradable waste (such as plastic, metal, and glass) found in urban waste. In contrast, people in rural areas produce municipal waste at less than half of the rate of those in urban areas (0.3 kg/person/day vs. 0.7 kg/person/day), and most of the waste (99 % of cultivation waste and 65 % of domestic waste vs. 50 % for urban domestic waste) is easily degradable organic waste (Figure 3.4-6).

Table 3.4-3: The big picture of Solid Waste Generation in Vietnam, 2003

Municipal solid waste generation (tons/yr)	
▪ Urban area	6,400,000
▪ Rural area	6,400,000
National	12,800,000
Industrial waste generation (tons/yr)	
▪ Hazardous	128,400
▪ Non-hazardous	2,510,000
Hazardous Healthcare Waste (tons/yr)	21,000
Hazardous Agricultural Waste (tons/yr)	8,600
Municipal waste generation (kg/capita/day)	
▪ Urban area	0.7
▪ Rural area	0.3
National	0.4
% of Waste Collected	
▪ Urban area	71%
▪ Rural area	<20%
▪ Among urban poor	10-20%
No. of solid waste disposal facilities	
▪ Dumps and poorly operated landfills	74
▪ Sanitary landfills	17

Source: VEM 2004

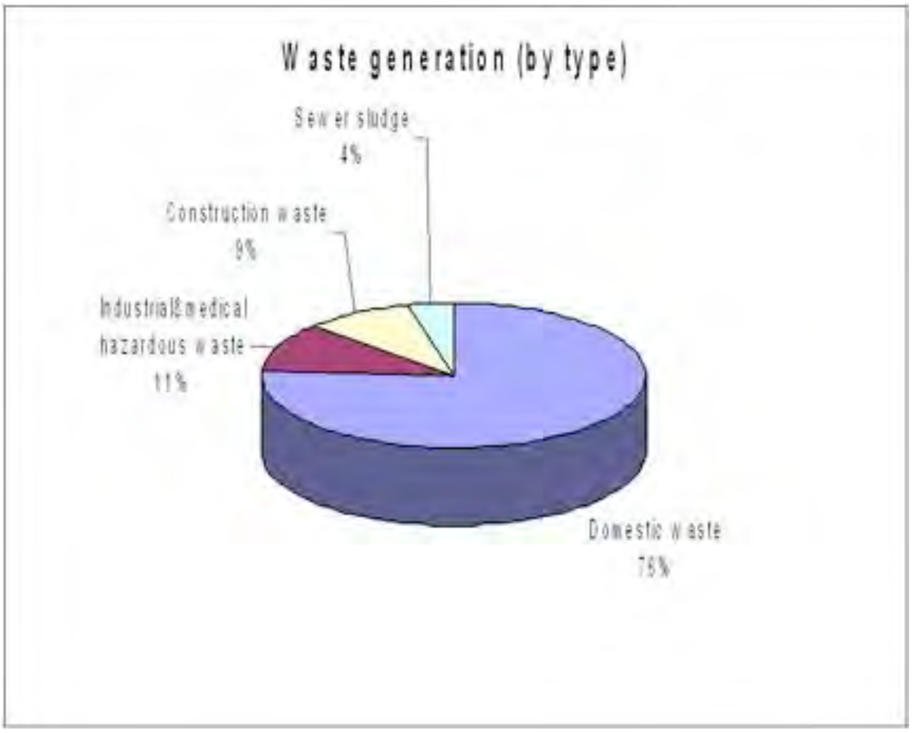


Figure 3.4-6: Waste generation by type

3.4.2 Municipal solid waste

Composition of urban solid waste is very diverse and is characteristic for each town. Generally there are some common characteristics as composition of organic origin accounts for high rate (50.27% -

62.22%) it contains however a lot of soil, sand and fragment of brick, stone, etc; It has typically high moisture content, low specific heat energy (900 Kcal/Kg). Figure 3.4-7 presented composition of household waste in Hanoi [MC at HUS, 2005].

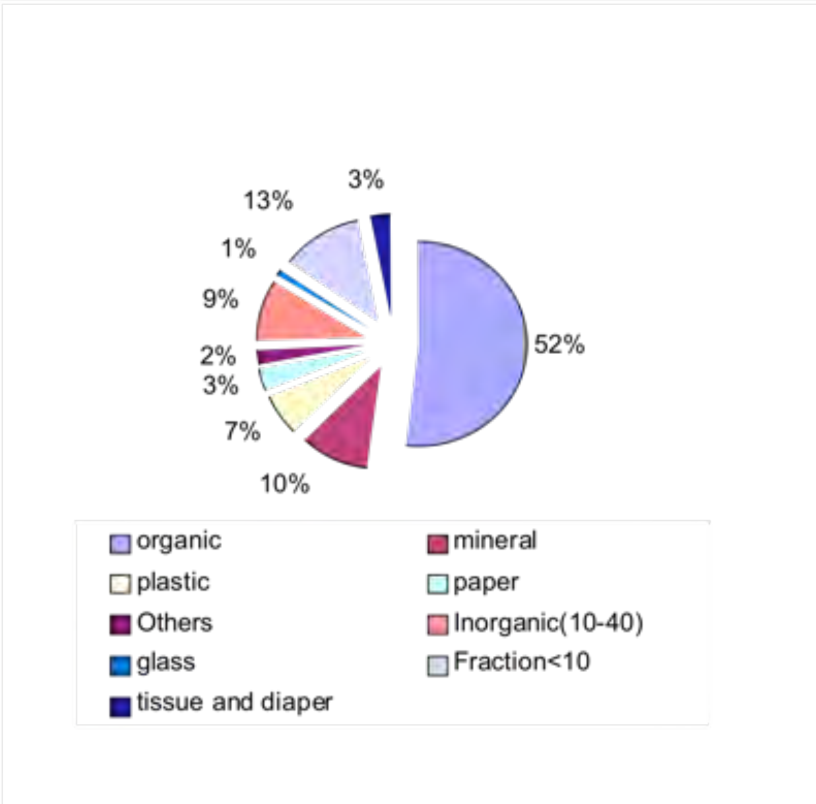


Figure 3.4-7: Composition of household waste in Hanoi, 2005

The composition of domestic solid waste in some areas in the North Vietnam presented in Table 3.4-4and in other cities in Table 3.4-5 [CEETIA, 2003].

Table 3.4-4: Composition of domestic solid waste in some areas in the North Vietnam 2003

Composition of domestic solid waste in some urban areas in the North – Viet Nam
(% of amount

N°	Composition	Ha Noi	Hai Phon	Nam Dinh	Thai Nguyen
Inflammable material		*69.9*	*52.0*	*80.5*	*71.3*
1	Organic	51.9	40.48	65.0	62.0
2	Plastic	7.3	3.10	7.0	6.0
3	Paper. catton	4.5	6.42	4.0	5.0
4	Cloth	3.7	1.10	2.3	1.2
5	Rubber	2.5	1.10	2.2	0.5
Other		*29.6*	*46.3*	*18.3*	*27.9*
6	Metal	7.0	5.5	3.0	2.1
7	Glass	5.1	5.6	2.0	2.2
8	Innert material	17.60	35.0	13.3	20.7
9	*Hazardous waste*	*0.5*	*1.7*	*1.2*	*0.8*
	Moisture %	41.58	52.2	44.6	50.0
	ash %	12.99	7.8	19.5	13.5
	Density, ton/m³	0.40	0.41	0.43	0.45

Table 3.4-5: Composition of household waste in some other cities 2003 (Unit %)

Composition	Hanoi	Hai Phong	Hai Duong	Hạ Long	Ho Chi Minh	Dong Nai	Binh Duong	BRịa-VTàu
Organic	49.1	53.22	49.2	53.7	60.14	71.42	69.36	69.87
Plastic	15.6	8.3	5.7	8.1	3.13	8.63	6.45	2.38
Papers	1.89	6.64	7	12.5	5.35	6.23	5.47	4.12
Metals	6.03	0.3	3.6	0.4	1.24	1.16	1.43	0.86
Glass	7.24	3.75	2.8	4.7	4.12	1.14	2.24	3.47

3.5 Waste Quantities, Generation and Composition in Lao PDR

The generation of solid waste in urban areas in Lao PDR is on rise, and already degrading the quality of surface and ground water. Expanding urban populations, poor collection, and largely inadequate disposal facilities are compounding the level of pollution. The annual waste generation in 2004 was 270,000 tons.

3.5.1 Municipal solid Waste

Domestic waste accounts for the bulk of materials generated. The average urban waste production in Lao PDR is 0.75 kg per capita per day. Vientiane capital and the four secondary towns account for 0.8-1.4 kg per capita per day (table 1.1-1). Solid waste in Lao PDR comprises mainly of organic material, plastic, paper and glass, cans and other metals (Figure 1.1-1). Hazardous and toxic wastes such as batteries, old paint cans, aerosols and other refuse are also mixed with these wastes. The comparatively low content of organic material in municipal solid waste is mainly due to the fact that a large proportion of food waste is recycled as animal feed even in urban areas.

Table 3.5-1: Average per capita Waste Production, Secondary Towns (MCTPC/NORAD LAO/96/006: Solid Waste Management in Secondary Urban Centres of Lao PDR, 2002 in World Bank & STEA, 2005)

Town	Per capita waste production
Vientiane City of Lao PDR	0.8 kg
Luangprabang	1.0 kg
Savannakhet	1.0 kg
Pakse	1.4 kg

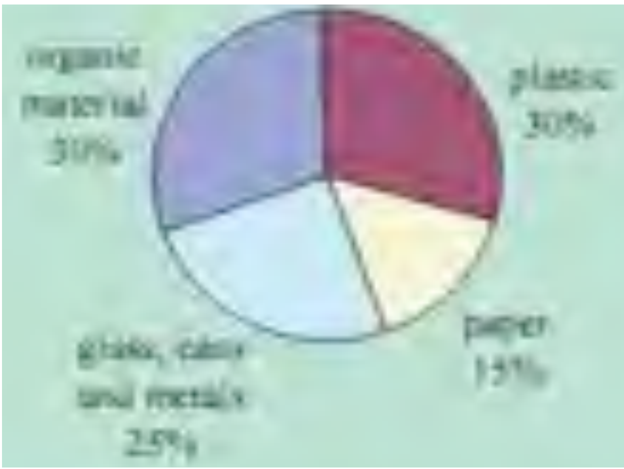


Figure 3.5-1: Waste Composition in Lao PDR (ADB, 2001, Environments in Transition: Cambodia, Lao PDR, Thailand and Vietnam in World Bank & STEA, 2005)

Waste composition
Open Dumpling Predominates

According to a recent survey in 57 urban areas only Vientiane Capital and the four secondary towns of Luangprabang, Thakhek, Savannakhet and Pakse use landfills for solid waste disposal (Table 1.1.-2). However, the disposal areas are small and have no leachate collection and monitoring wells. Elsewhere, open dumping and burning are common practice for waste disposal in Lao PDR of with municipal waste.

Table 3.5-2: Average per capita Waste Production, Secondary Towns (MCTPC/NORAD LAO/96/006: Solid Waste Management in Secondary Urban Centres of Lao PDR, 2002 in World Bank & STEA, 2005)

	Luang Prabang	Thakhek	Savnnakhet	Pakse
Date Started	June 2002	August 2000	August 2000	July 2000
Site Area	15 ha	9 ha	13.5 ha	13.5 ha
Disposal Area	3.5 ha	2.2 ha	4 ha	2.2 ha
Lifespan	10+ yrs	10+ yrs	5-10 yrs	5 yrs
Leachate Pond	Yes	Yes	Yes	Yes
Geotextile Liner	No	No	No	No
Leachate collection	No	No	No	No
Monitoring Wells	No	No	No	No

This improper waste disposal results in environmental impacts such as ground water contamination, leachate, odor, and production of methane which can lead to fire and explosive hazards. All of these increase the risk of disease.

Collection Ratios Low, But Rising
Despite the existence of landfills in Vientiane and the four secondary towns, collection services are limited to accessible areas and profitable target groups such as markets and high-income households. The Average collection ratio for urban households in the five larger urban areas is 45 percent. Only in Luang Prabang does the collection ratio reach more than 50 percent. In smaller towns, solid waste collection is often limited to commercial establishments in the town centre and the market place.

Recycling Minimal
Approximately 70 percent of municipal solid waste consists of plastic, paper, glass, cans and metals, which have the potential to be recyled commercially, and reused in various manufacturing and industrial activities. However, the current scale of recycling in Lao PDR is still very modest

In Vientiane 1997, only 5 percent of urban households were served by a solid waste collection system and only 10 percent of the solid waste generated was estimated to be collected. Today, with improvements in the solid waste management system, 48 percent of the urban households in Vientiane are now served by solid waste collection services. About half of the solid waste generated is now collected and disposed of at the sanitary landfill facility located 18 kilometers from the city center. It accepts domestic, construction, industrial and hospital waste, and provides separation for hospital waste within fenced compound. The waste is collected by Vientiane Municipal Services. There are limited environmental and social safeguards concerning handling of waste, no regular covering with soil, no leachate control, and the site is adjacent to agricultural land. The landfill is accessible to scavengers and animals. Rudimentary recycling is undertaken for plastics, paper, and scrap metals. At the recycling area an unpleasant smell is produced.

3.5.2 Sewage sludge

Sewerage
As of 1996, approximately 98% of urban population and about 16% of rural population had adequate sanitation facilities (WRI 1998). It was also estimated that 68% of households did not have a latrine. Only 20% had a flush toilet and 12% a pit latrine (NSC 1998 in The World Bank & STEA, 2005).

Drainage System
Urban drainage system and its functioning are the key to achieving any environmental improvement to the urban areas. Storm water drainage in most urban areas consists of roadside drains leading ultimately to natural streams or rivers. Drains are generally not adequately interconnected and do not form a network. In the larger towns, drains are lined in the town centre areas, and covered in front of commercial establishments. Water in the drainage system is invariably contaminated with faecal matter from latrines and coliform septic tank effluent, presenting a very direct health risk (STEA 2000c in The World Bank & STEA, 2005). The absence of overall urban drainage plans with a functioning integrated network combined with the lack of clear arrangements for maintenance cause flooding and stagnant water pools over large parts of the urban centers. Investment on infrastructure improvements, as well as efforts to strengthen local resources for operation and maintenance, is not sufficiently aimed at the drainage networks in Lao PDR (STEA 2000c in The World Bank & STEA, 2005). In addition, technical support in the preparation of catchment area based drainage plans, with identification of final point of discharge, for the main urban centres have been lacking (STEA 2000c).

Sewerage System
None of the urban centers are serviced with a sewerage facility. All disposal of human waste occurs on-site. Except for some public facilities at markets and temple grounds, there are no public toilets in existence (STEA

2000c in The World Bank & STEA, 2005). Larger and more modern properties have septic tanks, with septic tank effluents (or overflow) often draining to roadside drains. Small private companies are known possessing vacuum desludging vehicles for the periodic cleaning of septic tanks in the larger urban centres, but operating data indicate very little usage made of such service. Older and lower-income houses use pit-latrines of various improvised types. In some of the traditional villages, households might not have any form of latrine (STEA 2000c in The World Bank & STEA, 2005). Sludge generally ends up in the open roadside drains, or infiltrates on site in the low-density areas. Table 5.1b presents census data on sanitation.
Ground water contamination by wastewater from on-site sanitation systems such as septic tanks is often quoted as "becoming a serious issue". There is no scientific evidence to support such claims (STEA 2000c in The World Bank & STEA, 2005), due to the lack of studies conducted for such purpose. Therefore, policies on urban wastewater management do not take such claims into consideration. Moreover, at the national level, no strategies have been formulated to outline the conditions under which a full or partial sewerage system should be considered for urban areas. In essence, no guidelines have been promulgated to assign responsibility or create manadatory conditions for the construction, operation and maintenance of sewerage systems in urban areas (STEA 2000c in The World Bank & STEA, 2005).

3.5.3 Industrial waste

As it is the fact that Lao PDR relies mainly on agriculture while only quite small faction on industries, the industrial waste produced seems to be inadequately concerned. However, there are some hazardous chemicals from industries the government have been taking into consideration

Hazardous chemicals waste
Hazardous chemicals of concern include heavy metals such as mercury, lead, cadmium, arsenic, chromium, copper, and zinc as well as persistent organic pollutants (POPs) such as dioxins and furans, polychlorinated biphenyls (PCBs), and various pesticides and herbicides that are now banned globally. At present their environmental impact is still poorly understood in Lao PDR. STEA initiated an inventory of hazardous chemicals in December 2003, and the National Hazardous Chemicals Strategy and Action Plan is currently being revised.
Heavy Metal contamination results primarily from industrial activities, which are increasing significantly as the country develops. Of particular concern is lead production and rudimentary metal smelting facilities in the country, as well as releases of mercury, cyanide, copper, cadmium and other heavy metals from mining activities. Surface water quality in areas downstream of industrial and mining activities therefore needs to be carefully monitored to avoid potential human impacts.
Persistent Organic Pollutants Presently, herbicides and pesticides are used only in moderate levels in Lao PDR, mostly as a result of low per-capita incomes and traditional agricultural practices in rural areas. However, there is evidence of banned pesticides and herbicides still being imported into Laos from neighboring countries, and dumping of empty barrels in landfills has been recorded in Vientiane Capital City and other major cites. There is a lack of baseline information on the extent of the problem in the country, and its potential effects on human health.
PCBs are still found in old transformers throughout Lao PDR, but these are being phased out. PCB oils are now being adequately stored in the country, but there are concerns related to historical spills and dumping sites.
Dioxin and furan contamination in Lao PDR occurs mainly from combustion of solid and industrial waste, burning of wood and oil for fuel, and forest fires. However, significant quantities of dioxin were also released during the Indochina War from the use of Agent Orange and other toxic herbicides. Dioxin residues many occur near the Vietnam border and along the former Ho Chi Minh Trail.

3.5.4 Factors influencing quantity and composition of waste

It is a fact that there are numbers of factors affecting the quantity of waste. However, the main factor could be the rapid urbanization and industrialization occurring in Laos which has resulted in changing of human livelihoods. More material wealth also brings more waste, which causes problems of water pollution, air pollution and solid waste. Nowadays, solid wastes created by various activities are one of the most serious problems for environment in Lao. Solid waste generation is becoming more evident in Lao PDR especially in urban areas. It has been estimated that in average 4 - 5 kilograms of solid waste per capita per week are being generated by the city dwellers (Khotsay K & Vilaythong D, 2005). Apart from that there are still many factors including the lacking of knowledge the people on waste, waste management of each household is not good enough, raising awareness and campaign and education is still not effective enough, signing on waste collection system is widely needed, waste collecting of site collectors is not effective, because the people can throw their waste anywhere without considering, lacking of interest and responsibility, the collecting charge avoiding, the rules and regulations is not effectively enforced, the cost of waste collecting fee is too high (Center for Environment and Development Studies, 2006)

Learning outcome:

This chapter provides the information of Waste Quantities, Characteristics and composition in Lao PDR, Thailand, Vietnam and Cambodia.
By completing this section you should be able to define “waste” and have the knowledge of waste types and their composition.

☑ Self-assessment

1. What do you think about the waste in Laos, Thailand, Vietnam and Cambodia in terms of integrated waste management?

2. Please think of other factors which could influence the quantity and composition of waste and how?

3. What is the definition of solid waste management?

3.6 References

Cotter, S. (2000). Solid Waste (Chapter 24). *In Environment: Concepts and Issues. A focus on Cambodia*, Ed., Noelle O'Brien. Ministry of Environment, Phnom Penh, Cambodia.

Heisler, T. (2004). Lessons from Experience: A Comparative Look at Solid Waste Management Policies in Cambodia, India, The Philippines and Sri Lanka. The Waste-Econ Programme.

Kham Kimsour (2008). Strategies for improving waste management in Meanchey District, Phnom Penh. MSc. Thesis. Royal University of Agriculture, Phnom Penh, Cambodia.

Kokusai Kogyo CO., Ltd. (2005). The study on solid waste management in the Municipality of Phnom Penh in the Kingdom of Cambodia. Draft Final Report (2), Municipality of Phnom Penh, Cambodia.

Municipality of Phnom Penh (MPP) and Asian Development Bank (ADB) (2006). Partnerships for a cleaner city: Lessons on managing the urban environment. Phnom Penh, Cambodia.

National Institute of Statistics (NIS) (2005). Cambodia inter-censal population survey 2004. Ministry of Planning, Kingdom of Cambodia.

Royal Government of Cambodia (RGC) (2001) Second Five Year Socio-economic Development Plan 2001-2005. Ministry of Planning, Phnom Penh, Cambodia.

Royal Government of Cambodia (RGC) (2006) National Strategic Development Plan 2006-2010. Ministry of Planning, Phnom Penh, Cambodia.

Vin, S., Nitivattananon, V. and Amin, A.T.M. N. (2005). Assessment of solid waste contracted services: Case study of waste collection in Siem Reap town, Cambodia. International Conference on Integrated Solid Waste Management in Southeast Asian Cities. Siem Reap, Cambodia. Nowarat Coowanitwong, Prajapati Shapkota, and Peachie Ann Aquino, Asian Institute of Technology, Thailand.

Vietnam Environment Monitor 2004

Tang The Cuong, National Institute for Strategy and Policy on Science and Technology (NISTPASS), Hanoi Workshop 11/2006

URENCO Hanoi Report in 2005

Annual Environmental State Reports of DONREs 2005

National Environment Agency Vietnam (NEA) and University of Agriculture report, 1/2003

World Bank Report 2003

Information from practical training, 1st Master Course at HUS, 2005

CEETIA & Annual Environmental State Reports of DONREs 2003

URENCOs Report in 2003

Department of Transportation, Hanoi People Committee 2007

National Environment Agency Vietnam Report, 2004

Institute for Science and Environmental Technology, program KC 08-09

The World Bank & STEA, 2005, *Lao PDR Environment Monitor,* pps 38,39,40

Center for Environment and Development Studies, 2006, the study on the participation of Nongtha Tai villagers in households waste management

Khotsay K & Vilaythong D, 2005, Regional training workshop on the inventory of Hazardous Waste www.basel.int/stratplan/oewg1/projdocs/indonesia/rpt-laos.doc

4 Waste Collection

In waste management systems, the area collection-transfer-transportation plays a central role. It cause for 60 to 80% of the total costs of waste disposal and therefore there are significant saving possibilities on improvements in its organization and implementation.

4.1 Collection Systems

Educational objective of the chapter

- Different collection methods are in use for waste collection.
- To know the different types of containers for storage

The waste collection process contains the way from filling of containers to loading of the collection vehicle. Because of a variety of residential, commercial, and industrial development, it is impossible to collect waste with just one sytem. A variety of collection systems are used that respective municipal requirements to be used accordingly. Each collection method has compatible container systems and vehicles with dedicated loaders.

4.1.1 Collection Methods

4.1.1.1 Simple Emptying Method

The Simple Emptying Method is used for the removal of household and small-scale commercial waste with mobile containers which are drained at the consumer. A lot of different standardized containers are used. These containers are emptied by combination top-loaders that can pick up many different container sizes. Some container systems have been modernized to include self-compactors. With this system it is possible to charge 2 to 3 times to container volume.

Figure 4.1-1: Simple Emptying Method[14]

4.1.1.2 Exchange Method

At this method, full containers are exchanged with empty containers at their location. This method is suitable for high sensity waste, e.g. construction debris and sludge, as well as for low density waste from instituitions or large hotels. Because of economy, these containers have minimum capacities of 4 m^3.

4.1.1.3 One-Way Method

In the one-way method, waste is picked up in clear plastic or paper bags whose volume is limited to a maximum of 110 L. The bags are picked up by hand, so there are no emptied containers to be returned to the curb and the containers are not cleaned.

Figure 4.1-2: Plastic bags[15]

[14] http://www.awista-duesseldorf.de/downloads/muellabfuhr.jpg

4.1.1.4 Non-systematic Collection

The non-systematic collection method is used for collecting bulky waste or extra large particles, e.g. bulky goods.

Figure 4.1-3: Bulky waste[16]

4.1.1.5 Special Collection Systems

Vacuum extraction and hydraulic flushing are two kinds of spezial collection systems. Both the pneumatic vacuum transport sytems and the hydraulic flushing method combine collection and transport processes, but they have low importance.

4.1.1.6 Other Collection Systems

Besides the described systems there are other systems to collect waste. The main systems can be distinguished in collect systems and bring systems. The advantages and disadvantages of each system are described in Table 4.1-1. Maybe a combination of both systems is the right way to collect waste and try to recycle as much as possible.

Table 4.1-1: Advantages and Disadvanteges of collect and bring systems

Collect systems	Bring systems
Collection system	Bring systems
Simple emptying method Exchange method One way method Non systematic collection Special collection systems	Glass collection system Recovered paper collection system Battery collection system Potential recycable point/station
Advantages:	Advantages:
High user friendliness Higher collection rate for resources	Low costs for collection and containers High quality Disconnection in various fractions is possible Higher quality of resources because of higher user motivation
Disadvantages:	Disadvantages:
More expensive High place requirement for container systems on the estate Lower quality of the matters	Lower collection rate Limited number of collecting points

[15]http://www.kinderkrippe-garbsen.de/aktionen/Arbeitseinsatz200706/bilder_gross/IMG_0966.JPG
[16] http://www.etg-entsorgung.de/media/images/IMG_4078.jpg

4.1.2 Container Systems / Storage

Storage means the holding of waste for a temporary period ot time. There are different storage systems in use. In the following, a few of them will be described. To ensure efficient and mechanized waste collection, the number and size of containers must be standardized. Today, wheeled containers with capacities of 110 to 1.000 L, partly as much as 5.000 L, are used for household waste collection.

4.1.2.1 Garbage Cans and Trash Barrels / Eurobin

The smallest, standardized garbage cans are round with capacities of 35 to 50 L. They are made of galvanized sheet metal or plastic. The next in size standardized cans are made exclusively of plastic, with capacities up to 120 L capacities. Furthermore cans with up to 360 L capacity already exists. Finally, small amounts of garbage are collected in a variety of trash barrels and dumpsters.

Figure 4.1-4: 120 L Garbage Can[17]

4.1.2.2 Large-sized Containers

Due to the rising quantities of waste, large sheet metal and plastic containers with wheels were developed. The transport by the consumer and handling by the collection crew is effortless with these containers. The 1.100 L container (Figure 4.1-5) is appropriated for locations where large quantities of waste are generated. These are for example markets, sporting events or businesses. Just as the other large containers (120 – 5.000 L), these Large-sized Containers are also serviced using the simple emptying method.

[17] http://www.ernst-kir.de/link-ziele/120l.jpg

Figure 4.1-5: 1100 L container with ridge bars[18]

Another type of Large-sized containers are the over-sized containers or dumpsters with capacities of up to 40m^3. They are used for commercial and industrial wastes, but also in locations where large quantities of waste are generated on a regular or incidental basis. The most frequent types are charging boxes; open containers with capacities between 7 and 20 m^3, another type are containers with capacities between 10 and 40 m^3(Figure 4.1-6). These containers are serviced using the exchange method.

Figure 4.1-6: charging box (7 m^3) and container (24 m^3)[19]

Other storage units are containers, tanks, containment buildings, drip pads, waste piles, and surface impendent, most of them used to store hazardous waste.

☑ Self-assessment

- Which kinds of containers / storage units do you know?
- In which sizes are the different kinds of containers available?
- What different kinds of collection methods are in use?

[18] http://www.loewe-container.de/images/mgb/1100lr.jpg
[19] http://www.brunner-mulden.ch/Muldengroessen.html

4.2 Transfer and Transport

Educational objective of the chapter

- Transfer stations and why they are necessary
- Different kinds of transportation systems

4.2.1 Transfer

A transfer station is a site where waste is collected and reload into trucks for transport to a landfill or other waste treatment.
A transfer station is a site where waste is collected and reloaded into trucks for transport to a landfill or other waste treatment.
The transportation of waste over long distances in small vehicles is uneconomical. Concerning the tendency to treat or store waste in large centralized falilities, transfer stations has become economical for urban areas that generate large waste quantities.

The relationship between specific transportation costs and waste volume is shown in Figure 4.2-1.

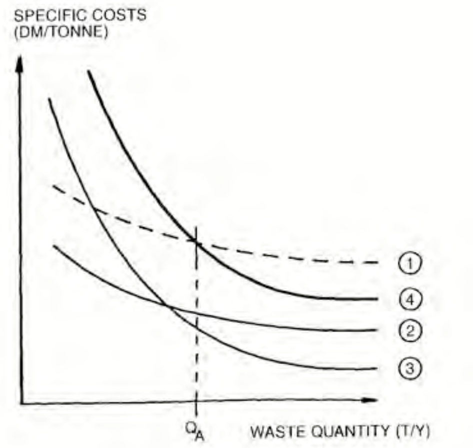


Figure 4.2-1: Comparison of the specific transportation costs of direct transport and transfer station in relation to waste volume [Bilitewski et al., 1997]

- **1.** As the volume of waste increases, the cost for direct transport in collection vehicles to the processing facility decreases.
- **2.** The same applies to transport in large capacity vehicles but, relatively speaking, the costs for the latter are considerably lower.
- **3.** Adding the specific costs for the proposed transfer station operations,
- **4.** and the calculated costs for special transport.

The point where line 1 and 4 intersect represents the break-even point for the economical operation of a transfer station.

4.2.1.1 Delivery

Waste can be delivered either exclusive by municipal vehicles or additional by private vehicles. Considering the variety of private delivery vehicles, an additional cash and scale be needed, as well as more discharge hoppers.

4.2.1.2 Preparation

Preparation means waste processing after it has been delivered to the transfer station.

The waste becomes, direct or indirectly from stock pits, loaded and after this it goes pressed or unpressed together on the long distance transportations.

The partial compacted waste is transported in collection vehicle in open-top trucks or in interchangeable containers. The full payload may not always be reached and so the whole capacity is not completely used.

At transfer stations the compacted waste can be managed by a variety of methods, such as by a wheel loader, hydraulic compactors, or by crushing and grinding. Caterpillars or compacting tractors get only one relatively modest degree of compaction and the waste will once more be loosened up during loading.

There are three methods of hydraulic compaction:

- Interchangeable containers are added to stationary compactors. The coupling and decoupling is automatically done in modern units. Waste gets through a funnel with proportioning belt weighers in the compactor, so that the allowed payload is not crossed. If there is an antechamber press, than the waste comes in the containers already pressed together in bale. The packing press fills the container in a first process and after this the waste is pressed against the reinforced container walls. By this way, waste can be compressed to a density of 600 kg / m3.
- Another possibility are self-compacting units. In this case the waste is loaded from above in the front part of the hopper. A hydraulic bulkhead pushes the waste towards the rear doors. At the unloading process the compactor pushes the waste through the rear doors.
- With a staionary baler bales with a volume of e.g. 1,2m^3 can be formed. During the compaction process the bales are often wrapped with wire and afterwards it is set on on a flatbed semi-trailer. Thereby a high payload is achieved. Advanteges of this process are the simple construction of the transport vehicles and the simple stackability of the bales.

Other ways, in which ways waste can be compacted, are shredders, impact pulverizes or hammermills. To seperate ferrous materials a magnetic separator can be used.

Figure 4.2-2: Stationary baler[20]

[20] http://www.kenmills.co.uk/news.htm

4.2.1.3 Loading and Unloading

The kind of the loading is dependent on the used means of transportation. Long-distance transports can occur on the street, to water or by train. For the street transport mounted high-capacity containers are filled either firmly on the vehicle, or, however, are put to change container on the road semi-trailer. For the rail transport full high-capacity containers are put down on the carriages. Also open high-capacity carriages can be filled on top by tipping from collective vehicles.
For long-distance transport by ship, the waste is dumped onto open barges by collection vehicles. Another way is to dump the waste via compactors into containers, which are placed on the ship via crane.

4.2.1.4 Planning and Setup of Transfer Stations

The most important concerns during the planning process for a transfer station are:

- Location
- Type of waste
- Quality of waste
- Long-distance transport system

The dimensions, structural and technical equipment are depending on these concerns. Also it is necessary to study all transportation costs and requirements. Figure 4.2-3 shows an overview of the different kinds of transfer stations.

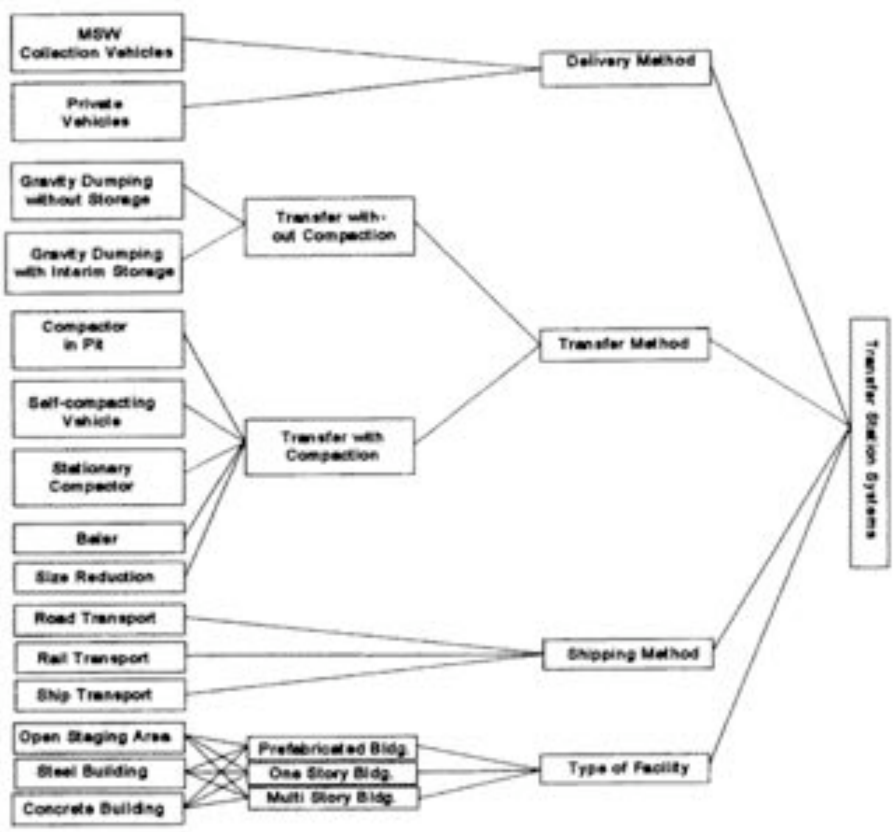


Figure 4.2-3: Various types of transfer stations [Bilitewski et al., 1997]

The layout of a transfer station is characterized by the following needs [Bilitewski et al., 1997]:

- Entry way with bufer zone
- Scale
- Tipping floor for emptying delivery vehicles
- Storage pit for the delivered waste
- Equiptment to move waste from the storage pit to the hoppers, e.g., crane assemblies, moving equipment, and conveyor belts
- Equipment for waste compaction, mostly stationary compactors
- Equipment for movin shipping containers (crane assemblies, container switching assemblies)
- Office space, control and observation platforms, and sanitary facilities

To minimie environmental impacts from transfer stations like dust, noise or odors, transfer stations are normaly constructed aas enclosed facilites. Furthermore other measures can be used to reduce further emissions.

4.2.2 Transportation Systems

Waste transportation systems are all procedures wich started after finishing waste collection and end at disposal or treatment facilities. The position of waste transportation in the waste management system illustrates Figure 4.2-4.

Figure 4.2-4: The role of waste transport in the overall system of waste disposal [Bilitewski et al., 1997]

A distinction is made between local and long-distance transportation. The local transportation starts after the collection of waste at the source to a landfill or transfer station. With long-distance transportation waste will reach from transfer stations to central treatment or disposal facilities. There are different kinds of transportation:

- Full-load transport
- Empty transport
- Intermediate transport (vehicles cannot be filled to capacity)

At transfer stations the waste is reloaded to long-distance transportation vehicles like railway cars, trucks (most variable) or ships.

4.2.2.1 Road Transportation

There are different kinds of collection and transport vehicles:

- Truck carrier with spezial constructional systems (simple emptying method)
- Truck trailer with appliances for transport of containers (exchange method)

Collection vehicles shall pick up as much quantity of waste as possible. By planning the size of collection and transportation vehicles, the following aspects have to be considered [Bilitewski et al., 1997]:

- Payload
- Distance to disposal or transfer station
- Container systems
- Topography, traffic obstructions or limitations
- Road width on collection and transportation routes
- Daily work hours, routines, break schedules of personnel
- Crew size

4.2.2.1.1 Overhead Loading

On the rear side the containers are taken up by means of pneumatic and hydraulic lift-and-tilt devices and are emptied by an adapted opening in the vehicle inside or are dumped about an open chute in the admission device (universal dumping). By tilting the body and concurrently lifting the loading gear the vehicle gets emptied. A loading process reduced in dust can be granted when the collective container and the dumping chute are connected completely with each other. The opening must be tuned in addition to the respective container type and size. Garbage cans are emptied, for example, by a front record with dumping chutes which corresponds to the respective cross section of the container. By the new container systems (MGB 120/240) it is necessary to attach different chutes on the vehicles working independently of each other. Double chutes, as a rule 120/240 and 110-litre-garbage tonnes MGB, can be emptied about the respective system with the support of lift devices that are installed above the chutes. The tilting lift attachment can be independently operated.
A combined chute of several containers is possible by the same opening. By this way it can come for a dust development, because the opening is covered only by hanging mats.
During the empting process the development of dust can be reduced by additional dust collectors with air filters.

It is under discussion that the summit of the garbage fees should be directed after the waste amount. For this, the collection frequency and the waste volume are identifying by stickers fixed on the register containers. The weight or volume is collected by an accounting system. After the collection route the facts are stored on disk and are handed over to the accounting centre.

4.2.2.1.2 Compactors

By the collection of domestic waste, commercial waste similar to domestic waste and bulky waste are closed vehicles with special constructional systems in use. These vehicles have different kinds of compaction appliances. They are loaded with universal or system fills from behind.

<u>Vehicle with a rotary drum compactor</u>
At vehicles with a rotary drum compactor the waste drops into a drum that is rotating. The drum turns with about 4 rotations per minute. The drum is also equiped with an auger welded on the inside. Rotation direction and auger orientation are arranged in a way, that the waste is moved towards to the forward wall. Because of the the continious forward movement the compaction results in a factor of 2 to 4. There is also a shredding and mixture-effect due to this method. This effekt is desired for incineration, for sorting and recycling the mixture-effect is adverse.

<u>Trucks with self contained compactors</u>
These vehicles are loaded over a prechamber. The prechamber is emptied by a hydraulic ram and the content is pressed into the transport container.
To empty the vehicle, the rear door opened and the front board is moved backward. Thereby the load is pushed out (Figure 4.2-5).

Figure 4.2-5: Self contained compactor[21]

The capacity and workload of self contained compactors are all about the same like rotary drum compactor. The maximum factor of compacting is 3 : 1. A mixture and crushing of the waste doesn't occur.

4.2.2.1.3 Extended Transportation Vehicle

Different kinds of extended transportation vehicles with variable internal lift- and set-down systems are used. An assortment of different systems is shown in Figure 4.2-6.

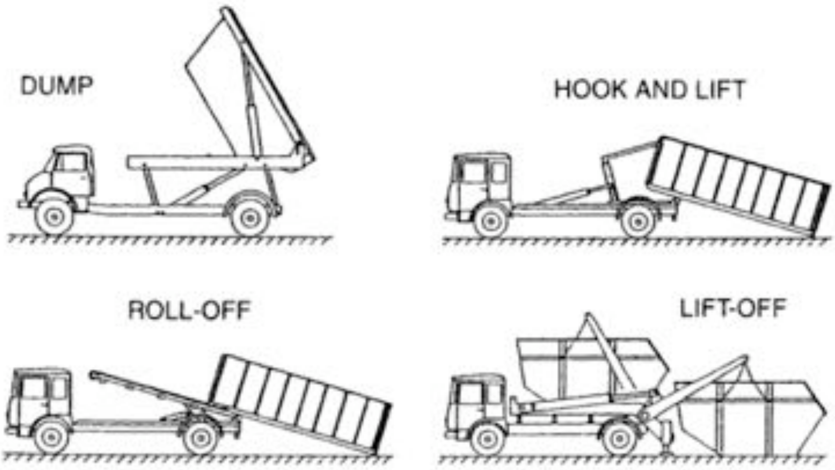


Figure 4.2-6: Container vehicles [Bilitewski et al., 1997]

In vehicles with fixed constructional systems the compaction of the waste can be done before loading or with self-contained compactors. Vehicles without heavy self-contained compactors have lower self-weight and thereby higher payload. But it only can be fully utilised when the waste is precompressed.

In vehicles with self-contained compactors the waste will be put through an opening from above and compressed by a hydraulic ram (see 4.2.2.1.2): Trucks with self contained compactors).

[21] http://www.conorclarke.net/uploaded_images/landfill-761447.jpg

Figure 4.2-7: Lift-off container vehicle[22]

The exchange method used containers with a size from 1,1m^3(see Figure 4.2-7). Commercial and industrial waste often removed by containers with a size from 5 m^3, either in open-top containers or in containers with self-contained compactors, e.g. packaging material can be compacted to about 1/5 of the original volume. Roller compactors are another method to compact the waste. A heavy roller runs through the container and compacted the waste to about ¼ of the original volume.

Stationary compactors reaches a higher compression level than self-contained compactors. They are preferred when there is a continuous flow of waste (additional option: shredding the waste).

At transfer stations the waste is loaded into enclosed containers with a size up to 40 m^3. After filling the containers were set on long-distance transporters. The containers are then transported to their destination by road, rail or ship.

4.2.2.2 Waste Transport by Rail

The transport by rail mostly happens with compacted waste in compactor containers, rotary drum compactors or open-top rail cars for uncompacted waste (Figure 4.2-8).

[22]http://www.reller-container.de/images/reller/containerfahrzeuge/containerfahrzeuge-absetzkipper-1-kl.JPG

Figure 4.2-8: Waste transport by rail in containers[23]

The independent from weather and discharge of the road network is advantageous. If there is no railway siding at transfer stations or disposal facilities, further transfers are necessary wich results in higher transport costs. By planning a new transfer station or waste management plant this point has to be considered. Due to the high quantities and masses which can be carried per train unit, the transport by rail is especially dedicated for high quantity of waste with high density, e.g., scrap metal, slag or rubble. Another advantage: transport by rail is environmentally friendly, i.e., there is a discharge of the road network, a lower specific energy consumption, higher transport safety and more clean-air consideration, as well on shorter distances.

4.2.2.3 Waste Transport by Ship

A multiple of the transportation capacity from the street can be performed on waterway. At transfer stations, waste can be loaded loose in barges or with containers on container ships. The transport to the final destination point often isn't possible without another transfer station. Therefore the transport on waterway is rarely. There are other influences like flood, low tide or ice drift which affected the transport with ships. Furthermore long transport times shall be calculated, that's why only waste which will not decompose can be transported. An example for container transport by ship is shown in Figure 4.2-9.

Figure 4.2-9: Waste transport by ship[24]

[23] http://www.wbrinc.com/images/services2.jpg
[24] http://www.cttfreight.com/one/two/three/ship-container.jpg

☑ Self-assessment

- In which ways waste can be transported?
- What kinds of transportation systems are important?
- What is the reason for a transfer station and how it works?
- Explain the relationship between transport costs and waste volumes!

Learning outcome:

Be aware of the options of waste collection and storage and of the logistics of waste Transport.

4.3 Street Cleaning

Educational objective of the chapter

- Different functions of street cleaning
- Different problems of street cleaning
- Composition of dirt

Street cleaning includes the mechanical or manual cleaning of streets as well as emptying public bins or snow and ice clearance. Primarily function of street cleaning is municipal or urban hygiene.
A lot of functions of street cleaning are listed in Table 4.3-1.

Table 4.3-1: Mechanical and manual functions[25, 26, 27]

Street cleaning	Streets
	footpaths
	passageways
	Landscape areas
	sink traps
	Bus stops
	subways
	Public places
Waste collection	Emptying public bins
	Fly-tipping
Winter service	Snow clearance
	Ice clearance
Others (e.g. organic matter)	leaves disposal
	weed disposal

A lot of different types of street cleaners can be used for street cleaning. They are very flexible: Brooms and rollings can be adapted to particular application, contour and surface as well as contact pressure and engine speed can be variegated. Partly these vehicles have accessory equipment like suction spouts to clean wastebaskets or sink traps, thus relative inaccessibly sections / scopes can be cleaned mechanically.

To flush the mess with much water into the drain system, this method isn't in use in Germany or other European countries. With this method, the problem is only displaced into the drain system but the mess is still existent. It also expends a lot of water.
Dust emissions, which are generated during cleaning the streets, can be minimized by spray aeration with water. In addition equipment for filtering and maybe recycling of the vacuum air is needed. Water consumption can be reduced with integrated water reclaiming plants.

The opposite of mechanical cleaning is Manual Street cleaning (Figure 4.3-1). Manual Street cleaning is used to clean up areas that are not readily accessed by the motorised sweepers. Manual cleaning workers use tools such as brooms, handcarts and shovels. Litter picking is used when it is impractical to utilise mechanical sweepers (i.e. heavily pedestrianised areas).

[25] Wittmaier, 2003
[26] www.stadt-zuerich.ch/internet/erz/home/stadtre/strassen.html
[27] http://www.wien.gv.at/ma48/pdf/strassenreinigung-deutsch.pdf

Figure 4.3-1: Mechanical Street Cleaner (left)[28] and Manual Street Cleaner (right) [29]

Figure 4.3-2: Manual street cleaning[30]

In opposition to manual cleaning the mechanical is although more efficient, but implicates sometimes a few problems. Because of the priming machines the material between the joints can get lost and the flaggings become slack. A special system must be used. Dirt gets in a mechanical way on a deflected plate and after this it will be exhausted in a collecting tray. So the air current works indirectly on the pavement and the flaggings get saved (Figure 4.3-3).

[28] http://www.ettlingen.de/servlet/PB/show/1269469_l1/Kehrmaschinen.JPG
[29] http://www.entsorgung.luebeck.de/images/cm/stadtreinigung.jpg
[30] http://ww2.heidelberg.de/stadtblatt-alt/stbl0903/reingngg.jpg

Figure 4.3-3: street cleaning machine for pavement[31]

Another problem is the traffic calmed area, especially the speed bump. The roller needs to be draft and the suction spouts must be incline, otherwise the machine can be damaged (Figure 4.3-4).

Figure 4.3-4: Attachment to clean (for example) speed bumps in traffic calmed area[32]

Artificial contraction (e.g. flower tubs) complicates the cleaning, because of the small turn radius. For this, a telescopic broom or an adjustable flat brush should be used (Figure 4.3-5).

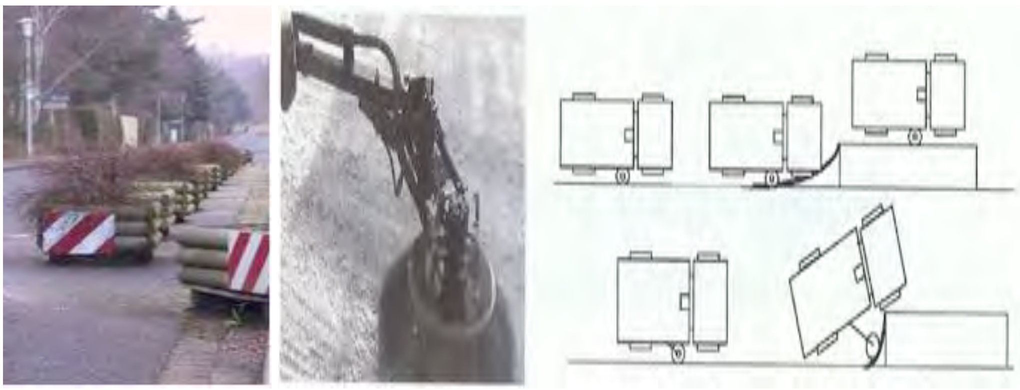


Figure 4.3-5: Flower tubs (left)[33], Cleaning machine with an adjustable flat brush (right)[34]

More than this, the inactive traffic is a big problem for street cleaning. It becomes more and more complicated because of parking cars blocking the roadside. For this, it needs remedy through appropriate measures. For example:

1. no parking at a definite time in a specific zone
2. leaf blower which is blowing the waste on the roadway and an attend street cleaner picks it up

[31] Wittmaier, M. (2003): Straßenreinigung im Wandel der Zeit
[32] Wittmaier, M. (2003): Straßenreinigung im Wandel der Zeit
[33] http://www.burgacker.de/pic/kuebel_th.jpg
[34] Wittmaier, M. (2003): Straßenreinigung im Wandel der Zeit

3. to wash the dirt into a sink trap

Figure 4.3-6: Machine with special sprays to clean below parking cars (left)[35], leaf blower (right)[36]

But all these things imply unresolved problems. No parking often fails in a political way, leaf blowers are too loud and can not use in the wee hours of the morning and the last one only remove the dirt.

Composition and derivation of dirt
Dirt combines all kinds of wastes that accrue in normal street cleaning, public places or cycle paths. Basically vehicles, motorists and cyclist are involved in dirt development, but also building measures to keep streets cultivate (e.g. sludge) and defilements of accidents are the reasons.

Dirt is composed of tire and street abrasion, fuel waste, animal and herbal rubbish, paper, food scraps and so on (

Figure 4.3-7). Constitution and quality of dirt is governed by a lot of things. A decisive role plays the pavement, the manner of use, traffic volume, season, roadability, behaviour of motorists and cyclist and also the frequency of cleaning. Emissions of pollutants can also be very different. Urban streets with only small volume of traffic, but a lot of commercial transport can offer a higher emission than a busy used one. This is caused by the acceleration of the vehicles.

As contamination can be termed e.g. cadmium, plumb, copper and zinc.

Figure 4.3-7: dog's muck (left), bubblegums (right), cigarettes (middle)

Example for total length of cleaning places and the amount of waste exemplified by Munich:

[35] Wittmaier, M. (2003): Straßenreinigung im Wandel der Zeit
[36] http://www.schneeraeumung.com/img/fotostreckesr/fs_str4.html

Table 4.3-2: Street cleaning details for Munich per season[37]

Street cleaning details:	
Total length of Munich road network	2.300 km
Cleaned streets total	1.200 km
Cleaned cycle paths total	900 km
Cleaned footpaths total	800 km
Cleaned places total	104.000 m^2
Quantity of waste	
Brushing total	6.000 t
Brushing daily	25 t
Greenery total	6.000 m^3
Split total	5.500 t
Street cleaners total	232
Employees	400

Treatment of dirt

Material recycling of dirt is very important for environmental protection. Before recycling, dirt has to be pretreating because of the variable concentration of organic, water content, salt content, particle size distribution, contraries and contaminant content and so on. By dry-mechanical and wet-mechanical process contraries and contaminants can be cut off for elimination, mineral fraction (e.g. sand) and parts with a high concentration of organic can be achieve for application and respectively for subsequent treatment.

The concentration of organic can be reduced, petroleum-derived hydrocarbon and polynuclear aromatic hydrocarbons can be decomposed by biological treatment. After this, a composting of unpolluted and organic fraction (wood, greenery) is possible.

☑ Self-assessment

- What are the main functions and objectives of street cleaning?
- What are the problems for an efficient street cleaning?

[37]http://www.muenchen.de/cms/prod1/mde/_de/rubriken/Rathaus/35_bau/20_serviceleistungen/10_mobil/20_strreinigung/faltbl/strassenreinigungbr.pdf

4.4 Handling of fluid wastes

Educational objective of the chapter

The chapter 4.4 shortly describes the two main types of wastewater collection systems, emphasising their advantages and disadvantages.

4.4.1 Integrated approach

Together with solid waste, the liquid waste emerging from different spectra of activities should play an important role in the overall waste management strategies. An integrated waste management policy on municipal waste should take in consideration, apart from municipal solid waste, also municipal wastewater and stormwater, as well as wastewater from local industries. This should be approached from two perspectives:

Principle of separation, which means that different types of waste should not be mixed, e.g. dumping solid waste on places where water bodies are present (rivers, sewage channels etc.) should not be permitted. Mixing the waste types would only increase the treatment difficulties and raise the general costs (for instance, solids have to be separated from a stormwater pipe before discharging the water into river).

Integrated approach, which means that all waste types should be considered together in order to achieve environmental and public health improvement (Figure 4.4-1). Nevertheless, the waste still has to be separately collected and managed.

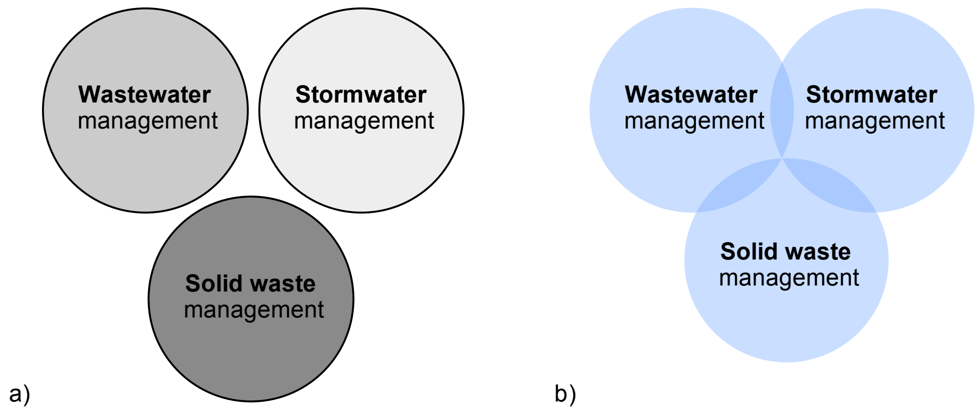


Figure 4.4-1: a) Non-integrated waste management; b) Integrated waste management

The efficiency of an integrated management of the sewage system including domestic wastewater and stormwater leads to the general improvement of the environment through proper drainage and disposal of wastewater, preventing floods through removal of stormwater and overall preserving the water quality. For this, a proper planning and administration is required, combined with an excellent level of knowledge for all technical processes occurring in a sewage system. The next chapter will offer a short overview on the two main types of wastewater collection systems. Wastewater treatment technologies are presented in detail elsewhere and did not make the object of interest for this chapter.

4.4.2 Collection systems

The collection of wastewater and stormwater can be done in two ways: a) by a combined sewer, where both types of water flow together in the same pipe, and b) by separate sewers, in which wastewater and stormwater are kept in separate pipes. Both systems have advantages and disadvantages regarding construction costs, maintenance costs, space availability, and impact to environment.

4.4.2.1 Combined system

The combined system is the most popular system and it requires dimensioning the sewer pipes in such a manner that wastewater and stormwater will be concomitantly carried away. In dry weather, the system carries only the wastewater flow but during rainfall, the flow in sewer increases dramatically as a result of addition of stormwater. In heavy falls, the stormwater could be fifty or even one hundred times the average wastewater flow (Butler and Davis, 2004). This concept is economically not feasible for the whole sewer system because most of the time the sewers will be used at a very small part of their capacity and only during predicted raining times the full capacity will be reached.

A solution against this problem is building a combined sewer overflow (CSO), a structure able to divert flows above a certain level out of the system during medium or heavy rains (a representation of this concept is included in Figure 4.4-2). Besides the economical advantage of not bringing the whole flow into the water treatment plant (TWP), the combined system using a CSO poses an important threat to environment by discharging to watercourse, together with the stormwater, an important part of the wastewater flow. This, although diluted, contributes to important pollution of the receptor by receiving the combined flow during the heavy rains.

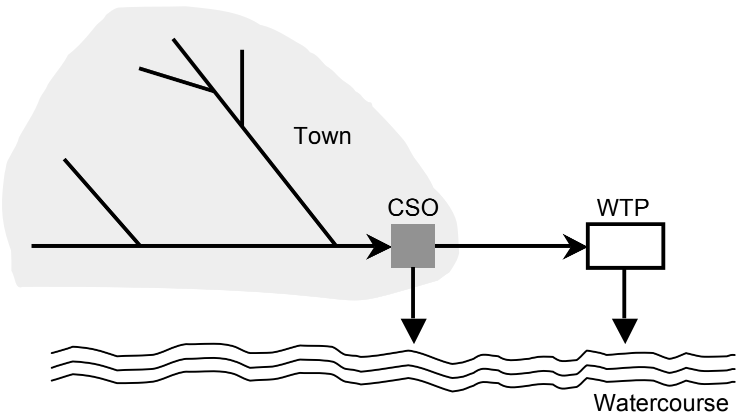


Figure 4.4-2: Schematic plan of a combined system [after Butler and Davis, 2004]

4.4.2.2 Separate system

A solution to the problem described above is the construction of two parallel pipes designed to overtake the two separate flows of wastewater and stormwater. This solution requires high investment costs but it has an obvious advantage against the combined system in regard to environmental protection. The Figure 4.4-3 depicts such a separate system with two pipes, where the separate storm sewer discharges directly to a receiving watercourse and the wastewater sewers discharge their effluent to the WTP.

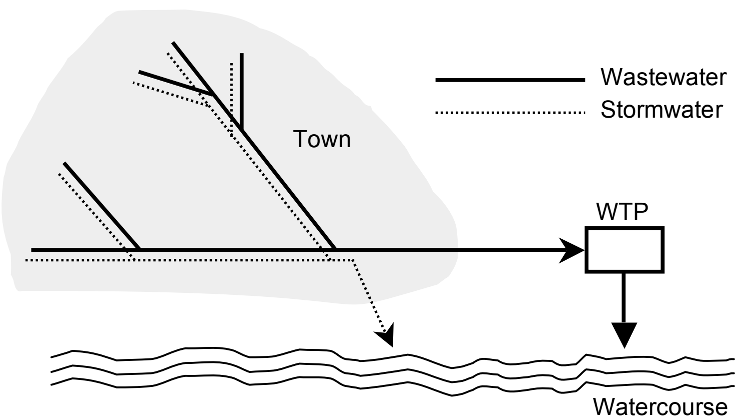


Figure 4.4-3: Schematic plan of a separate system [after Butler and Davis, 2004]

☞ Please note:

To note is also the fact that the separate system would only work properly if the connections or cross-connections at various points are well made and do not allow mixing of the two flows. Even so, both sewers are exposed to infiltrations and exfiltrations, leading to important maintenance efforts.

So, answering the question “which system is better?” is not easy. Many studies have showen the advantage of using separate systems but in the same time scientists claimed that the storm water is not always “clean” and cannot be discharged to rivers without prior treatment, especially when the storm water washes the contaminated streets of high industrialized cities. A summary of advanatges and disadvantages of both combined and separate systems is given in Table 4.4-1:

Table 4.4-1: Separate and combined systems, advantages and disadvantages [after Butler and Davis, 2004]

SEPARATE SYSTEM	**COMBINED SYSTEM**
Advantages	**Disadvantages**
No CSOs – potentially less pollution of watercourses	CSOs necessary to keep main severs and treatment works to feasible size. May cause serious pollution of watercourses.
Smaller wastewater treatment works.	Larger treatment works inlets necessary, probably with provision for stormwater diversion and storage.
Stormwater pumped only if necessary.	Higher pumping costs if pumping of flow to treatment is necessary.
Wastewater and storm sewers may follow own optimum line and depth (for example, stormwater to nearby outfall).	Line is a compromise, and may necessitate long branch connections. Optimum depth for stormwater collection may not suit wastewater.
Wastewater sewer small, and greater velocities maintained at low flows.	Slow, shallow flow in large sewers in dry weather flow may cause deposition and decomposition of solids.
Less variation in flow and strength of wastewater.	Wide variation in flow to pumps, and in flow and strength of wastewater to treatment works.
No road grid in wastewater sewers.	Grid removal necessary.
Any flooding will be by stormwater only.	If flooding and surcharge of manholes occurs, foul conditions will be caused.
Disadvantages	**Advantages**
Extra cost of two pipes.	Lower pipe construction costs.
Additional space occupied in narrow streets in built-up areas.	Economical in space.
More house drains, with risk of wrong connections.	House drainage simpler and cheaper.
No flushing of deposited wastewater solids by stormwater.	Deposited wastewater fluids flushed out in times of storm.
No treatment of stormwater.	Some treatment of stormwater.

A schematic representation of both separate and combine systems in an urban water system is given in Figure 4.4-4, where heavy-bordered boxes indicate “sources” and dashed, heavy-bordered boxes show “sinks”.

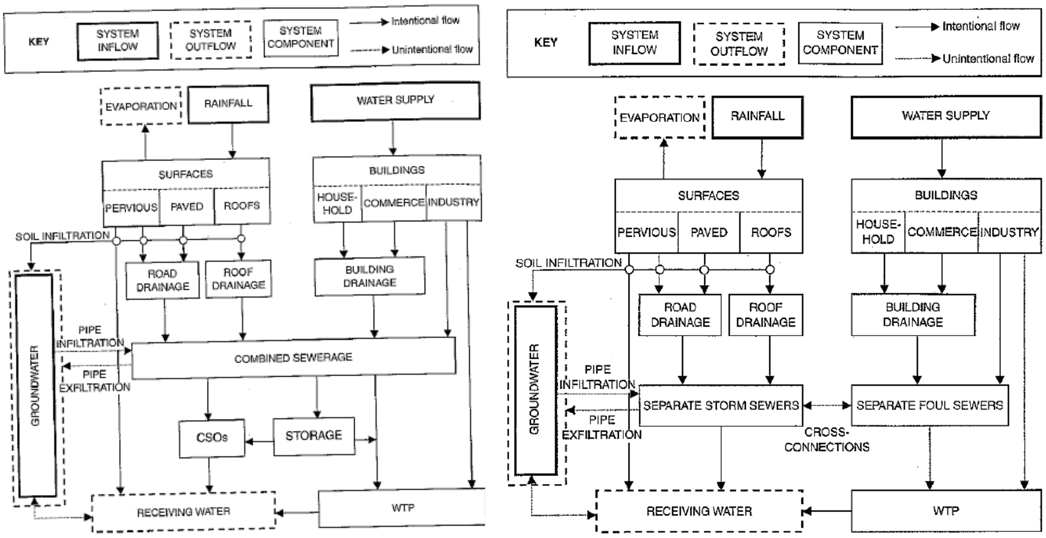


Figure 4.4-4: Combined and separate sewage systems in an urban water system [after Butler and Davis, 2004]

☑ Self-assessment

1. Explain the principle of separation.
2. What is a combined system and how it works?
3. What is a separate system and how it works?
4. What are the advantages and disadvantages of combined systems toward separate systems?

4.5 Handling of hazardous wastes

Educational objective of the chapter

- Hazardous wastes have dangerous or potentially harmful properties.
- Hazardous waste includes e.g. chemicals, pesticides, batteries.
- A special type of storage and treatment of hazardous waste is necessary.

Hazardous waste is a waste with properties that make it dangerous or potentially harmful to human health, environment or other subjects of protection but there is no clear-cut legal definition of the term. Hazardous substances can be radioactive, flammable and explosive or they may contain infectious disease pathogens. Hence there are 4 main characteristics to declare hazardous wastes – ignitability, corrosivity, reactivity and toxicity. This is the cause why there is a big spectrum of hazardous wastes. They can be liquids, solids, sludges or contained gases. They mostly arise from manufacturing processes as by-products or simply discarded commercial products, like cleaning fluids or pesticides.

- Ignitable wastes can create fires under certain conditions, are spontaneously combustible, or have a flash point less than 60 °C (e.g. waste oils and used solvents).
- Corrosive wastes are acids and bases that are capable of corroding metal containers such as storage tanks, drums and barrels (e.g. battery acid).
- Reactive substances are unstable under “normal” conditions. They can cause explosions, toxic fumes, gases or vapour when heated, compressed or heated with water (e.g. lithium-sulphur batteries and explosives).
- Toxic wastes are harmful or fatal when ingested or absorbed (e.g. containing mercury and lead).

Also included in the category of hazardous wastes are types of waste which can not co-dispose with household waste as a result of their properties (e.g. poultry feces and furnace filter dust). Because of raising awareness about the environmental quality, the number of hazardous wastes subject to intensified regulatory oversight is expected to increase in the future. When dealing with waste in need of close monitoring due to their hazard potential for humans and the environment, special organizational and technological measures must be taken. In addition to the requirement for overseeing hazardous waste treatment, storage and disposal facilities, it is also necessary to determine the status of the waste after being collected from the generator and the subsequent transport for treatment or disposal.
The table below shows the fate of the hazardous waste recorded on the basis of consignment notes between 1996 and 2004.

Table 4.5-1: Fate of hazardous waste between 1996 and 2004 in Germany [UBA, 2007]

in 1000 t	1996	1997	1998	1999	2000	2001	2002	2003	2004
Chem./phys treatment	1,822.6	1,826.6	1,975.2	2,331.4	2,500.3	2,473.6	2,839.5	2705	2,951.4
Incineration	903.5	1,109.0	1,112.9	1,069.9	1,265.0	1,167.2	1,439.2	1655.9	1,908.1
Surface landfill	2,806.0	3,068.0	3,217.8	2,722.1	3,462.0	3,511.9	4,638.2	4455.8	5,582.5
Under-ground landfill	410.9	693.4	522.5	446.8	566.8	567.1	280.2	212.2	291.2
Other treatment methods	1,255.2	2,153.0	2,396.1	3,406.2	3,178.2	3,631.8	4,292.3	4264.4	4,842.9
Recovery methods	1,630.6	1,147.2	1,360.6	1,533.9	1,899.2	2,449.9	3,971.1	4611.7	4,469.3
Interim storage	857.0	811.7	787.2	857.4	1,050.4	1,162.7	1,174.6	1355.2	1,659.9
Total	9,685.8	10,025.2	10,584.9	11,510.2	12,861.6	13,801.5	17,460.9	19,270.2	20,045.5

For handling with hazardous waste there is always a legal admission necessary. The construction of containers used for collection, storage and transportation of hazardous waste must meet strict requirements which due consideration of the materials to be transported and their consistency. In Europe it is allowed to transport sludges in open-top vats, water polluting liquids, on the other hand, must be filled in closed, corrosion resistant, possible double-walled tanks. Container storage sites for hazardous liquids and sludges must often be equipped with special safety devices such as secondary contaminant structures. Fencing of larger facilities and locked storage for smaller containers can prevent access by unauthorized persons.

Solid and pasty hazardous waste
For solid and pasty hazardous waste there is a vast array of container types available depending on need and regulatory oversight. The most common containers are open-top vats, closed-top boxes and "Big Bags". Small and very small quantity wastes are loaded into cubic-tank containers which are stackable and have a polyethylene liner inside. So they remain clean inside.

Figure 4.5-1: Storage of vats (left) and Big Bag (right)

Hazardous waste liquids and sludges

Containers and transportation systems for liquids and sludges have been described earlier in section 4.5. The whole equipment for collection, storage and transportation of hazardous liquids and sludges requires not only strict attention to regulatory rules, it also make practical demands on construction and material. In particular, this includes corrosion resistant materials, reliable, leak-proof systems and if it is necessary double lined walls and leak detection systems. For disposal of small waste quantities there are one-way drum. Large waste quantities are vacuumed or filled into separate or attached tanks with built-in vapour recovery systems to inhibit the release of volatile organic compounds.

Treatment facilities and intermediate storage

Due to raised requirements of waste management, an increasing part of the hazardous waste is subject to thermal or chemical/physical treatment prior to landfilling or subsurface disposal. Also a recovery or reuse of materials of the hazardous waste is favoured. The treatment facility, therefore, serves as a multi-functional site for transition, sorting, transfer and treatment. Upon delivery, wastes are subjects to an initial inspection. Depending on contents, characteristics and consistency of the wastes they are placed into appropriate vats or containers. Thence the wastes are treated chemical or physical, if necessary. As a general rule liquids and sludges are dewatered. Subsequently, the hazardous wastes are reassembled to larger units for transport to hazardous waste incinerator or landfills. Such a treatment facility needs specific constructions for buildings which are used for transfer and storage of hazardous substances. All areas of delivery and storage have to be canopied for controlling the rainwater. The floor must be waterproof, resistant against chemicals and enclosed with collection trenches. Immense problems for the surface are chlorinated hydrocarbons which can even diffuse through concrete of high quality. Therefore, a special sealing of the floor is necessary to inhibit the migration of these substances.

It is imperative that waste substances of similar composition be stored together and clearly apart from other incompatible substances with which a negative chemical reaction may occur.

Household hazardous waste

Nearly 0.7 wt.-% of household waste in Germany must be classified as hazardous waste. The main compounds are:

- Detergents and disinfectants,
- Outdated prescriptions, enamel paint removal residues and wood preservatives,
- Used batteries,
- Pesticides and herbicides,
- Other chemicals and
- Electric equipment and light bulbs.

It is necessary to separate these materials from recyclables and the remaining municipal solid waste. Nowadays it is possible to recycle hazardous substances like old batteries, fluorescent tubes and also old refrigerators collected as bulky waste. Although up to 50 wt.-% of household hazardous waste find its way to the municipal solid waste or the sanitary sewers. In Germany it is quiet usual that some kinds of hazardous wastes are picked up at home by special collection trucks or were returned to a place of purchase by the individual waste producer.

Figure 4.5-2: Special truck for the collection of hazardous household waste [Bleiker GmbH, 2007]

Usually it is possible to replace used batteries at every store where you can buy new batteries. The salesmen are committed to accept used batteries.
To keep the waste generator interested and motivated, the participation effort must be kept to a minimum. Indeed, as an incentive to begin the collection of household hazardous waste, disposal must be free of charge to the residents. Normally there must be an intense and continuous public relations campaign conducted to inform the public and to heighten awareness and interest in collection activities. Quantities vary according to season, location and even random fluctuations.

Hazardous waste issues in Asia

Nearly all Asian countries are in the early stages of industrialization and so a lot of their industries lack the capital needed to invest in waste treatment systems or to replace old equipment with modern technologies. In order to save costs many industries import outdated second hand equipment despite government prohibitions and guidelines. However, a number of Asian countries have laws mandating various aspects of hazardous waste management, such as, the methods of handling, treatment and disposal of hazardous wastes.
The usual way of disposal for hazardous wastes is through the use of sanitary landfills as practiced in Malaysia. The Asian countries like Singapore, Malaysia and also Thailand developed incinerators for hazardous wastes. The Philippines actually exhibit a facility for treatment of metal finishing wastewater and also an incineration plant for medical wastes. The other Asian countries normally use a co-disposal of hazardous waste and household waste in open dumps. Sometimes they deposit the toxic waste in sealed containers. Singapore uses off-site hazardous waste management facilities for recovery of 65 percent of the waste. It sends 29 percent of the waste to an integrated hazardous waste management facility for treatment and disposal and exports 3 percent to Europe [UNEP, 2008]. Also Thailand has a hazardous waste management program for its petrochemical, chemical and non-ferrous industries. A hazardous waste treatment plant managed by the Industrial Estate Authority of Thailand has been established. In addition, Thailand has five existing central facilities for industrial hazardous waste recovery and disposal. These consist of three secured landfills with a total capacity of 635,000 tons per year, two plants of secondary fuel and material recovery in cement kilns having a total capacity of 2.73 million tons per year, one solvent recovery plant with a total capacity of 15,000 tons per year, one chemical and solution treatment plant having a capacity of 2,500 tons per year, one used/obsolete chemical and hazardous treatment plant with a capacity of 2,500 tons per year and one electronic recycle plant with a capacity of 20 tons per year [UNEP, 2008]. In Malaysia, the Bukit Nanas Integrated Waste Treatment Plant has facilities for high-temperature incineration, physical and chemical treatment, stabilization and a secure landfill. In

2000, some 84,000 tons of hazardous waste were treated in this plant. In addition, Indonesia has developed a centralized treatment plant for hazardous waste in West Java. The quantities are arranged to 18.8 tons in 1999 [UNEP, 2008].
These are positive examples for the treatment of hazardous waste in Asia. There are even other Asian countries which have no real facilities to treat their hazardous wastes.

☑ Self-assessment

- What are the main properties of hazardous wastes?
- How can you handle hazardous wastes?
- What kind of hazardous wastes can you find in household wastes?

4.6 Factors influencing the development and design of waste collection and storage systems[38]

A lot of factors influencing the developtment and design of waste collection and storage systems.
A few of them are:

- Size of collection area
- Economic structure of the area,
- Residential lifestyle – this topic has a major impact on waste quantities and waste composition, e.g.:
  - Income
  - Household size
  - Age
  - Employment
  - Trends
  - Region (availability of products, baskets of goods)
  - Laws and regulations
- Zoning laws and ordinances
- User demands,
- Choice of appropriate collection system

There are a lot of more factors which have influence on the development. Some of them are presented in the chapters before. These factors are important for an effizient and optimal organisation and implementation of waste collection and transport [Bilitewski et al., 1997].

[38] including economic, socio-economic and socio-cultural aspects

4.7 References

Bilitewski et al., 1994: Abfallwirtschaft- eine Einführung. Springer Verlag Berlin Heidelberg, 2. Auflage

Bilitewski et al., 1997: Waste Management. Springer Verlag Berlin Heidelberg

Habeck-Tropfke, H.-H, 1985: Müll- und Abfalltechnik. Werner-Verlag GmbH Düsseldorf

Wittmaier, Martin, 2003: Straßenreinigung im Wandel der Zeit, TK Verlag Karl Thomé-Kozmiensky

Cord-Landwehr, Klaus, 2000: Einführung in die Abfallwirtschaft. B.G. Teubner Stuttgart, Leipzig, 2. Auflage

[Bleiker GmbH, 2007] SDR-Truck for transporting hazardous waste. Georges Bleiker GmbH, Hefenhofen/Amriswil, Switzerland, http://www.bleikergmbh.ch/

[UNEP, 2008] State of waste Management in South East Asia. United Nations Environment Programme, 2008
http://www.unep.or.jp/ietc/Publications/spc/State_of_waste_Management/6.asp

[UBA, 2007] Waste management: Special waste, hazardous waste and waste requiring special monitoring. Umweltbundesamt, 29.08.2007, Dessau-Roßlau, Germany,
http://www.umweltbundesamt.de/abfallwirtschaft-e/sonderabfall/index.htm

Further information

English:

Eastern Waste Disposal: Waste Transfer Station:
http://www.easternwastedisposal.co.uk/wts.html

Treatment, Storage, and Disposal of Hazardous Waste:
http://www.epa.gov/epaoswer/osw/tsds.htm

den Boer et al., 2005: Waste management planning and optimisation – Handbook for municipal waste prognosis and sustainability assessment of waste management systems. Ibidem-Verlag, Stuttgart

City of Westminster; Waste and Recycling – Storage Requirements:
http://www3.westminster.gov.uk/docstores/publications_store/waste_storage2_2008.pdf

U.S. Environmental Protection Agency; Treatment, Storage, and Disposal of Hazardous Waste:
http://www.epa.gov/epaoswer/osw/tsds.htm

Waste management:
http://esl.jrc.it/envind/sip/wm/Sip_wm03.htm

Brodersen J., Crowe M., and Jacobsen H. (2001): Hazardous waste generation in EEA member countries – Comparability of classification systems and quantities. Topic report 14/2001 of the European Environment Agency

Environmental Agency (2004): Hazardous Waste. A Growing Challenge.
www.environmentagency.gov.uk

GTZ German Development Cooperation (2004): Thailand: Safe Transport and Handling of Dangerous Goods, http://www.gtzth.org/service/project.php?service=12&il=020&in=2

Morselli L., Masoni P., Luzi J., Passarini F., Mezzogori R. (2002): Processes for Hazardous Waste Recycling and Inertization. In Appropriate Environmental and Solid Waste Management and Technologies for Developing Countries, Volume 1, Editors Günay Kocasoy, Tamer Atabarut, Irem Nuhoğlu, Istanbul, July 2002

Slack R. J., Gronow J. R. and Voulvoulis N. (2005): Hazardous Substances in Household Waste. In Proceedings Sardinia 2005, 10th International Waste

German:
Wittmaier, Martin, 2003: Straßenreinigung im Wandel der Zeit, TK Verlag Karl Thomé-Kozmiensky Neuruppin

Container und Entsorgungsprodukte: www.loewe-container.de

5 Waste processing, treatment and recycling

Background

Waste processing and treatment includes a lot of different processes. Aside from the organizational, structural and technical measures of waste treatment, the following should also be considered:

- Controlled landfilling,
- Thermal treatment,
- Biological treatment,
- Chemical-physical conversion,
- Mechanical treatment and
- Recycling

Processing, by definition, falls under the heading of physical treatment by using physical techniques for changing the composition and character of the waste. It is possible to distinguish between thermal and mechanical treatment. Every recycling process represents a conversion of the material. So the process of recycling is also a process of production of new materials. It describes the process of producing secondary raw material and compares a series of activities that involves collecting, sorting, processing or converting used materials into useful goods. All these activities conduce to reduce the amount of waste which has to landfill. So the goal of every recycling process is to use or reuse materials from garbage in order to minimize the amount of waste. Of significance in this recycling process is that the waste processing starts with the separation. A separation of waste at the beginning of the process supports the treatment of the waste and helps to raise the efficiency of the facilities which deals with the waste.

5.1 Manual separation

Educational objective of the chapter

- Manual separation is a cheap, easy and fast way to treat the waste stream.
- Positive sorting involves removal of recyclables from the waste stream.
- Negative sorting removes the discards out of the waste stream.
- In Asian countries manual separation is rampant.

Nowadays manual separation is a most reliable method to separate secondary products of a waste stream. The application of manual separation can take place to sort different qualities of wastepaper, colour specific glass, clear and coloured polyethylene foil or remove contaminating materials out of household or industrial waste streams. With using a selective controlling of the manual separation it is possible to change the items which are sort out in a fast, easy and cheap way. The disadvantages of manual separation are the costs. It is possible to increase the effectiveness and minimize the costs for manual sorting by including mechanical sorting. Therefore magnetic separators, blowers, inclined conveyors and screens prepare the waste stream for the manual separation and help to raise the efficiency rating of sorting personnel.
The manual separation can distinguish between positive and negative sorting. Positive sorting involves hand removal of the recyclables from the waste stream and placement into appropriate bins. The negative sorting means the removal of the discards out of the waste stream. On the basis of this property it is possible to achieve higher collections rates with the negative sorting, but with lower qualities. The positive sorting behaves in the other way. Positive sorting causes a material with a higher quality, but with a slower collection rate. The efficiency rating of sorting personnel is increased substantially when processing mixed source or source separated recyclables, as opposed to removing recyclables from the entire municipal solid waste stream.

Manual separation in Asia
The industry in Asian countries normally is interested in using recycled material when they cost less then the virgin material. The practice of recycling is so market-driven that recycling has become selective. The disposal of those unselected recyclables remains a problem. In most countries of Asia, 2 ways of manual separation plays an important role for the handling of the waste streams. At the one hand the formal and at the other hand the informal separation and recycling of the materials. The formal separation means the separation of the waste in the waste treatment facility after the collection of the waste. The informal separation of the waste can take place in 3 different ways:

- Direct at the source,
- During the collection and
- At the disposal site

The informal waste separation direct at the source means that the waste pickers sort out waste in urban areas before the authorized collection vehicles arrived. However, the manual separation during the collection imply that the collectors segregate recyclable materials during the process of loading and they store them inside the truck or on the sides of the vehicles. Waste pickers risk the danger of potential slides and fires when they do the manual separation direct at the disposal site. Then they often live on or nearby the dumps.
In most of the Asian countries the waste pickers separate and collect the waste, because they have private benefits by doing this. They can sell the materials which they collect. It does not happen, because of an existing or raising environmental awareness. So waste picking means surviving for the waste pickers, but the methods of the waste pickers can reduce the efficiency of the formal collection system and can be detrimental for the collector.

Figure 5.1-1: Manual separation of waste streams in Vietnam

Figure 5.1-2: Manual separation of colour specific plastic foils in Vietnam

Figure 5.1-3: Formal waste collection in Hanoi (waste pickers)

☑ Self-assessment

- What are the positive and negative properties of manual separation of waste streams?
- Which types of manual separation are feasible?
- Where can manual separation take place?

5.2 Mechanical Separation

Educational objective of the chapter

- Mechanical separation includes different types of sorting and separation methods.
- There are aggregates for size reduction, classification, separation and compaction of the waste.
- Mechanical separation helps to pre-treat the waste stream and collect recyclables out of the waste stream.
- The technique allows to separate ferrous/non ferrous metals, light fractions, different types of plastics, glass, inert materials and a lot of other components in a fast and easy way.

Mechanical treatment means the use of different sorting or separation aggregates to recover single materials for reuse from the waste stream of municipal solid waste. It includes a lot of different processes like size reduction, classification, separation and compaction. In the next chapters the typical aggregates will be described.

5.2.1 Size Reduction

Size reduction is the transfer of objects, in this case waste, into smaller particles. Every process of size reduction helps to increase the specific surface of the particle, but there is some information necessary to choose the right aggregate for the size reduction:

- The physical characteristics of the material to be reduced (e.g. particle size, structure, hardness, brittleness and fissionability),
- The future usage of the material (e.g. is there a following physical or chemical processing of the material) and
- The required properties of the final material (e.g. particle size, particle size distribution and average particle size)

On the basis of these points it is possible to select the adequate aggregate for the size reduction of the particular material. The advantages and disadvantages of the possible aggregates are described in the following sections.

Hammer Mills
Basically, hammer mills only vary in the construction of the rotor of the mill. The usually conduce to minimize scrap automobiles, construction, commercial and paper waste. Always, it is possible to differentiate between horizontal or vertical shafts with attached flexible blades.
The vertical version of the mill is characterised by a vertical rotor, which is equipped with hammers. It was designed for the preparation of household wastes. Because of the low initial input, air is drawn out through a side vent at the time of charging. So it is possible to minimize also light weight fractions like paper or plastics with a high capacity. Since there is no limit for the particle size, the particle size distribution is varied by the number of hammers inside the mill. By a raising number of hammers follows a finer particle size and a lower capacity. To control the size of the particle it is necessary to check the distance between the single hammers.
A special version of the hammer mills is the roll crusher used for pre-processing of construction debris. A horizontal travelling grate conveyor feeds the debris to the crusher. The rapidly rotating hammer roller positioned above the conveyor crushes the material.

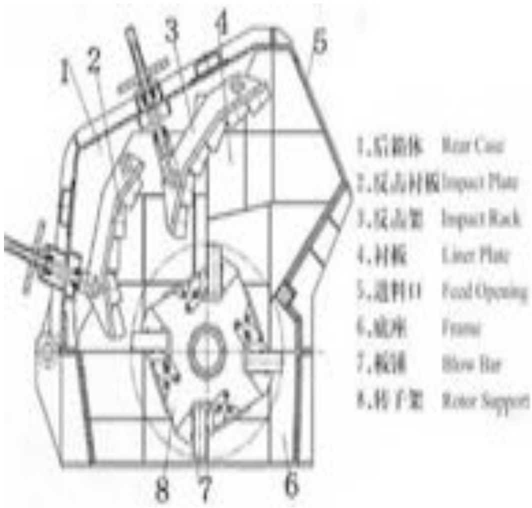


Figure 5.2-1: Principle of a hammer mill (left) and of an impact crusher (right)

Impact Crushers
Impact crushers are made up of multisectional body and breaker plates. A rapidly rotating roller is equipped with exchangeable hammers. Adjustable breaker plates hand above spindles. It is possible to adjust the distance between the breaker plates and the hammers, as well as the inclination of the breaker plates. If crush-resistant material enters the crusher, the breaker plates can withdraw upward and the material is ejected downward. Impact crusher are filled from above and discharged below. The charging material of the crusher is grabbed by the hammers and they slammed the material against the breaker plates. The plates are arranged so that the material remains in the crushing cycle until the material has the right size of the particle that it can pass through the opening between the rotor and the breaker plates. If such a crusher is used for construction debris, it is essential that concrete reinforcement bars are cut-up or shortened so that they do not wind around the rotor and cause the system lock-up.

Chippers
In comparison the hammer mills which are high speed mills (up to 1200 rpm), chippers and roll crusher operates with lower speed. The speed of the shaft has only around 20 to 60 rpm. The mill can be equipped with one or even two horizontal shafts. Because of the rotation of the shafts in opposite direction against a cutting edge the material is drawn towards them. The minimization occurs between the cutting edges regardless if it is hard or soft material. The degree of reduction is decided by the choice of the pitch between the blades and also the width of the tooth face of the rotary cutter. If there is an insufficient size reduction of the particle, it is possible to switch the several aggregates back-to-back. To realize a high feed rate of voluminous or bulky waste it is useful to install hydraulic presses to force the material toward the cutting blades. Massive metal pieces or other unbreakable material can not be reduced. When the force of the motor is exceeded, the rotary blades automatically reverse and the material must be removed by hand. Usually it is better to remove bulky and unbreakable material before it goes to the mill. A better control of the particle size is achieved by adding rapidly turning rotary drum cutters with mesh bottoms. The major problem is the abrasive influence of the material on the mill. Rotary drum cutters are most often used for size reduction of plastics.

Cascade Mills
A cascade mill is a slowly rotating rotary drum. The ratio of diameter to length is approximately 3:1 and the end walls are sloped conical. Round about 17 % of the mills interior capacity is filled with steel balls. At an optimum rotation of 14 to 20 rpm, a mixture of the steel balls and the waste, form an ideal surface area against which the feedstock rolls. With the help of the grinding and rolling action of the steel balls against the waste it is possible to realize a reduction of the particle size. If the waste achieves the right size of the particle, it can discharge through holes in the housing of the mill. Also the steel balls can exit the mill via these holes when sufficient wear has reduced their size. They must be routinely replaced. In this kind of mills also unbreakable materials or massive metal pieces can serve as grinding body. Then the size reduction is called semi-autogenous grinding process.

Rasp Mills
This process is specially developed for the treatment of waste in composting facilities. The rasp mill contains alternating screen segments with 25-44 mm size holes and shredding teeth. The material is dragged in and around by a rasping arm that turns above the screen at 8 to 10 rpm. Easily shredded materials (e.g. kitchen waste, glass, paper and cardboard) discharge the mill after a dwell period of about 20 minutes. The materials which are more resistant (e.g. textiles, metals, plastics) are caught up on teeth segments and are periodically pushed out by the rasping arm through a side discharge. Nowadays rasp mills are less used for size reduction of waste, because of a less size reduction of the waste in comparison with hammer mills. And the other disadvantage is the discontinuous operating control.

Jaw Crusher
A jaw crusher is usually used for hard and brittle material. The material is entering the crusher from above in between two swinging jaws. Due to the moving jaws the material is crushed and ground. It is possible to influence the particle size of the final product with space between the jaws. Usually the jaw crushers are used in construction and demolition industries.

5.2.2 Classification

The process of classification comprehends the screening method and also the air classifier. Both processes and the typical aggregates are described in the following section.

5.2.2.1 Screening

Screening of material is a segregation of various sizes into specific particle size categories. This process can also called classification. By contrast to screening, separation and sorting involves the separation of material into components of different types and characteristics. Waste can be screened according to particle size and also at the same time separated into different material characteristics, assuming that the material remain in the same particle size range. In this case the screening can also be used for separation. Screening is performed by separating particles based on the size of the openings on the screened surface. If the particles are smaller than the openings, they fall through the moving screen and become a part of the fine faction. The other part of the material contained above the screen is considered the oversize fraction. Normally a certain percentage of the fine fraction remains in the oversize fraction. Furthermore, design flaws or wearing of the screen surface can result in oversize material falls to the fine fraction. This fraction is called outsized fraction. A critical role plays the particle which has exactly the same size as the screen openings. These particles have a tendency to get stuck and cause wear on the screen. The efficiency of the screening is based on the relationship between the fine fraction which passes the screen openings and the fine fraction which in the initial feed. The screen efficiency rating is influenced by various factors:

- Machine dependent factors (e.g. screen width and length, screen angle and form, vibration frequency and amplitude, revolutions),
- Screen surface dependent factors (e.g. surface type, opening size, screen material) and
- Screening dependent factors (e.g. feed input, surface dampness, particle size, distribution and fiber content)

Fine grained, damp and sticky material can clog the screen surfaces. In these cases the opening areas are reduced and the screen output decrease. To reduce the clogging it is possible to add screening aids including brushes, chains, screen heaters, air blasts or adding water to increase the capillary pressure between the sticking parts.

Trommel screen
One of the proven classification systems is the trommel screen. It can be used for primary screening as well as for the final screening of the material after the size reduction. Trommel diameter, rotational speed, the size of the screen openings, the type and number of baffles and the inclination of the cylinder are factors which have an influence on the input and screening efficiency. Since the effective screen area is relatively small, deflectors and other wall assemblies are installed to carry the waste as high as possible up the trommel wall in order to receive the maximum screening potential. To increase the screen efficiency rating, spiral shaped deflectors are installed on the trommel walls to transport the material through the trommel regardless of the degree of the trommel. It is also possible to classify the material in more than two fractions by installing different screen openings in succession inside the trommel.

Figure 5.2-2: Trommel screen

Oscillating screen
An oscillating screen belongs to the dynamic screening methods and is been classified as a clog free and productive screening method. It is often used for screening composts. The screen consists of a flexible woven mesh made of rubber or plastic attached to oscillating arms moving in opposite directions. The automatic opposing operation of the arms causes a wave-like motion of the woven mesh with considerable amplitude (30 to 50 mm). Oscillating frequencies of 1/600 to 1/800 minutes are reached, which causes a relatively strong impact of the screening material against the woven mesh.

Bucket screen
Because of the ease of operation and the clog free nature, bucket screens are used for construction and demolition wastes as well as for fine grained materials. By using this aggregate the fine fraction falls into buckets and is carried away from the highest point of the machine via a conveyor. The bucket screen is open at the top and is S-shaped in the active screening area. The coarse grained fraction slides down the inclined surface of the machine. Gravity causes the course fraction to fall back into the wave trough and a conveyor carries the coarse grained fraction away.

Ballistic separator
The ballistic separators were developed for the separation of household and commercial wastes. It allows a separation into 3 fractions: fine, light and heavy. The operation of this aggregate can be described as screening classifier. The main working part of a ballistic separator is the moveable, inclined and perorated plate screen deck. The deck is divided into rows of vibrating elements and the material, depending on gravity and form, is transported up or down. The heavy parts of the waste move to the lowest level. The lighter particles (e.g. plastic foil and paper) move in the opposite direction toward the highest level of the deck. Falling through the perforated bottom of the deck, the third, fine fraction is produced.

Figure 5.2-3: Ballistic separator

Disc Screen
A disc screen is a cascading-type classifier constructed of sorting grates with a number of step-like arranged. The discs are installed so that every disc is spaced in the open notch of the neighbouring shaft. The interstitial distance between the discs determines the size of the screen opening of each grate.

5.2.2.2 Air classifier

The classifier separates according to the falling velocity of the particles. The falling velocity depends on particle form and the specific gravity. The design of an air classifier requires calculation of the waste-loading rate in kg/m³ or the reciprocal value, because above or below a certain value the efficiency separation into light and heavy fractions can no longer occur. Also all the parameters like apparent density, moisture content, waste composition, agglomeration tendency of the waste and any previous size reduction have an influence on the efficiency of the classifier. Two types of classifier are in use for waste processing: the zig-zag air classifier and the rotation air classifier.

Zig-zag air Classifier
Zig-zag air classifier are well proven and often used for the separation of household wastes. The waste is fed into a zig-zag shaped vertical column while being subjected to a stream of air introduced from the bottom. At each corner of the classifier the waste is resorted because the air stream is forced to flow cross-current. This permits a sorting with a low error rate. The components of the waste are sorted into heavy and light fractions. By changing the input or the speed of the air stream it is possible to get a higher selectivity.

Rotary Air Classifier
The rotary air classifier is constructed of three major components: a rotating drum, a screened settling chamber and a compressed air system. It is necessary to use shredded and sorted the waste for the rotary air classifier. Compressed air is injected and so the lightweight material becomes airborne and it is blown down toward the settling chamber. The heavy particles are further transported and dropped from the drums smaller, lower end. The cutting edge can be influenced by a lot of parameters. To minimize the emissions, the majority of the air can be recirculated.

Suction Hood
This is a quiet simple technology. The lightweight fraction is suctioned from a conveyor, a vibrating screen or a trommel screen. The major problem with this classifier usually is the poor degree of separation.

Cross-current Air Classifier
In this kind of air classifier the air is blown perpendicular to the fall direction of the material. Because of the short contact time between the falling material and the air stream, there is a marginal separation. If there is a widely density range of the waste (e.g. shredded automobiles) then there is a successfully use of these classifiers possible. When a focused high velocity air stream is used, the unit is called an impulse air classifier and this one is used successfully in the waste industry.

5.2.3 Separation (Sorting)

The process of sorting takes advantages of the individual physical characteristics of each fraction of the waste. The various kinds of sorting techniques include density, flotation, optical, magnetic and electrical sorting. In practice a lot of developed aggregates prove to be too expensive or not useful for the heterogeneous waste stream. The established separators in the field of waste management are magnetic separators, hydrocyclones, density sorters and flotation separators.

Magnetic Separation
For magnetic separation generally overhead magnetic separation systems are used. This system attracts ferrous material from the waste stream and conveys it away. To be effective the separation system needs one pre-treatment step. It is necessary to reduce the size of the particles in the waste stream. So the ferrous material is separated from the other materials and can easily catch by the magnetic separator. The size of the material is no criterion of limitation, because magnets of all dimensions are available. The ideal particle size of municipal solid waste ranges between 10 to 100 mm.

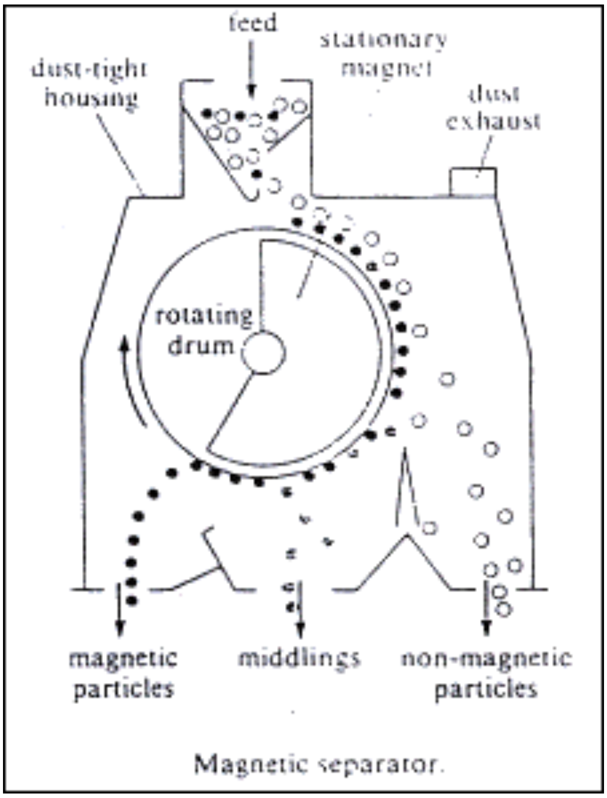


Figure 5.2-4: Principle of a magnetic separator

Eddy Current Separation

The edge current separator provides a mechanism for sorting a waste mixture of similar density grades. This technology relies on the induction of eddy currents in metal objects in response to an electromagnetic field. Eddy currents are created when conductive objects are located in or exposed to a spatially or temporally alternating magnetic field. Eddy currents, their form independent of the circuits form, flow in closed loops within the conductor. According to Lenz's law, the induced electric current produces a magnetic field opposite of the field to which it is exposed. A force is produced against the conductive object, which trusts the object out of the magnetic field. Less conductive objects require less force. With increasing density, greater hurling force is necessary due to the mass inertia of individual objects. Extensive use of this technology began in the United States, where aluminium used beverage cans were reprised.

Figure 5.2-5: Eddy current separator

Optical Sorting
This treatment version for the waste stream was especially developed for sorting mixed, crushed glasses into the different colours. For separation manufactures have developed electro-optical sorters which recognize the colour of the glasses based on their opacity and with the aid of a blast of compressed air, deflect the particle from its flight path into appropriate catch bins. While sorting of glass it is practicable to achieve a purity grade of 98 %. To achieve this degree of separation it is necessary to sieve, to reduce the particle size and to individualise the glasses. Singular glass particles are optically inspected in the following order: flint glass, green glass, brown glass and nontransparents.

Figure 5.2-6: Optical sorting of plastics

Flotation
The typical use for flotation is the sorting of a material mixture having similar specific densities. In the field of waste management flotation is used for removing contaminants in plastics and especially flotation is used at German paper mills. There, they use the flotation for the deinking process to produce high quality graphic paper from paper waste. Because of this process paper waste recycling has increased in the last decade. The principal of deinking relies on the physical wettability of the fibers and the printing ink. Various surfactants are added to aid the flotation process. These surfactants are made up of hydrophobic, long-chained molecules with attached hydrophilic functional groups, usually soaps. To cause the attraction of the hydrophilic soap molecules to the originally hydrophobic ink particles in the air bubbles, they must react with hard water. (primarily Ca^{+2} ions). The precipitated soaps, having reacted with the hard water, become collector agents, and carry the light flocs of ink to the surface while non-precipitated soaps stay in solution. Due to the change of the production process of paper by using new chemicals also efficiency of the waste paper recycling changes and become lower.

Density Sorting
The source of this technology was the ore industry. They developed a fluid medium for the density sorting. This technology was also tried for sorting waste components, nonferrous metals, glass, plastics and contaminants. Today density sorting is often used for sorting plastics. There are two types for the density sorting with fluid mediums:

- Float-sink method and
- Hydrocyclones

Float-sink Method
This technology can result in purity grades of over 98 % for mixed plastics. However, the soft PVC fraction can not be separated with this technology. The hydrophobic nature of plastics is easily enhanced during sorting with the aid of wetting agents. The separating liquid is adjusted to the density range of mixed plastic components from household and commercial waste by adding $CaCl_2$. Better sorting occurs when additional chemicals that increase the wettability of the plastic surfaces were added. The heavy fraction was comprised of PS and PVC. Pre-processing the waste stream through an air classifier can be used to collect most of the fines. An essential point for the success of this method is that no turbulences must occur in the separation zone that could cause the heavy fraction to become suspended. For economic reasons, only continuously operated float-sink separators should be considered in the waste management industry.

Hydrocyclones
The separation of various types of plastic form a granular mixture is accomplished in the centrifugal force field within a hydrocyclone. The geometry of a cyclone creates an upwardly spiralling inner-vortex that carries out the light fraction while an outer-vortex spirals downward and brings out the heavy fraction. The hydrocyclone is distinguished from a float-sink separator by its simpler construction, lack of complicated components and a higher feed rate. The type and quality of units used for the initial pre-processing or size reduction of the input, play an important role in the quality and concentration of the output generated by a hydrocyclone.

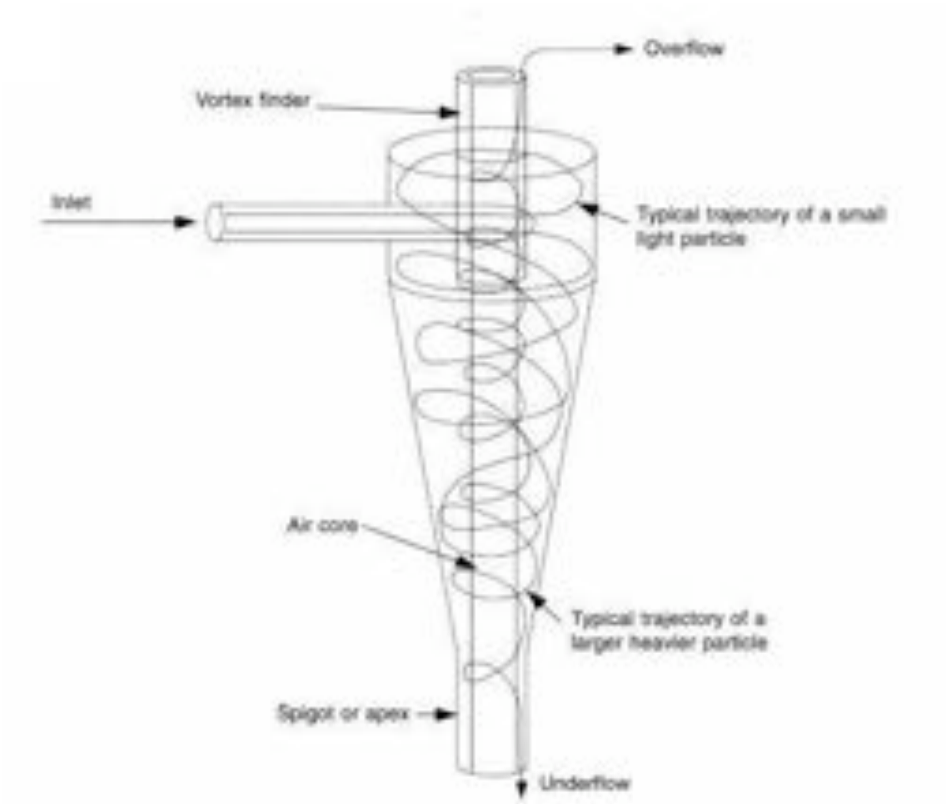


Figure 5.2-7: Principle of a hydrocyclone [Lenntech, 2007]

5.2.4 Compaction

The primary goal of compaction is to reduce the surface area and to increase bulk. Two typical methods for agglomeration are used in the field of waste treatment. At the one hand there is the build-up agglomeration which uses the influence of binding agents or added fluids after drying the material. At the other hand it is possible to use the compaction agglomeration which is produced by outside acting forces. The binding mechanisms for MSW are basically the same for both procedures and can be described as:

- Binding via adhesion and cohesion forces,
- Solids bridging,
- Capillary force attraction and
- Interlocking bridging

So the build-up agglomeration is primarily used to transform dust particles (e.g. from flue gas scrubbers) into solid granulates. However, the compaction agglomeration is often used in the waste management. It is quiet important in the logistic field of the waste management, because of the lower costs for transporting and storage of the waste. Other advantages are the raising energy density of the waste by compaction especially for the thermal recovery, the avoidance of bridging in silos and transport conveyances and the improved flow and proportioning characteristics of the waste.
The compaction methods are divided in solid resistance compaction (e.g. bale press or the compactor) and extrusion moulding (e.g. pellet press, briquette press and extruder). While the former uses the walls of the pressing chamber as a solid resistance, the latter uses formed mould plugs or briquettes for resistance. When the maximum pressure is reached, the mould plugs retract from the sides or the front and rear, the compaction process stops and the waste briquette is ejected. The process of extrusion moulding can be continuous, semi-continuous or batch. The continuous process (e.g. compactor) is used for wet, fine-grained material. The semi-continuous processes (e.g. pellet press) are pug mills where rollers rotate over slotted plates or ring matrices. In a batch process mechanical or hydraulic rollers compress the material in successive lifts into open moulding channels.

Bale Presses
Bale presses are used for various materials especially for paper, paperboards, plastic wrapping and metal cans. When using an antechamber press, the waste arrives in the containers already

compressed into bales. A bale is made by pressing against a movable wall in the antechamber, and the bale is then pushed by a compression rod into a receiving hopper. This method allows household waste to be compressed to a density of 600 kg/m³.

Figure 5.2-8: Bale press

Other compaction methods

In the following chapter the compaction technologies were primarily used for producing refused-derived-fuels (RDF). They are also used for the compaction of discards after materials recovery has occurred. The widely-used technologies are the briquette press and the pellet press.

The briquette press works principally as a piston rod with flywheel. In the first step the waste is pre-compacted in a screw press and after that the waste is fed batchwise via a conical feed chute to the compression moulding die. Another application for a briquetting plant is the brikollare-press. While tumbling under hydraulic pressure, this process produces die-formed mouldings consisting of garbage/sludge mixture with a moisture level of about 55 wt.-%.

Normally pellet presses were preferred over briquette presses in the RDF industry due to higher input rates and greater size reduction in a pug mill. The pellet presses can divide into three basic types:

- John Deere presses,
- Ring matrix presses and
- Flat matrix presses.

The John Deere press consists of a ring of vertical press channels. Material to be compacted is added onto the roller track above the press channels. The roller presses the material into the square channels. In this manner, the material is formed into strands that are subsequently cut by stationary blades. Generally the vertical press units consist of rollers circling within a ring mould. Either the ring mould or the rollers are powered. The material is radially pressed from within through the boreholes within the ring mould. The number and size of the rollers is determined by the interior size of the ring mould. The flat matrix press is constructed with a round and a flat mould with powered rollers rotating above. The material is pressed through the channels perpendicular to the axis. The distance between the rollers as well as the number of rollers is more adjustable than that of the ring matrix press. Material to be compacted is fed from above the pressing unit. Guiding plates or force feed mechanism are not necessary.

The moisture content plays an important role by using a pellet press. To avoid crumbling after pelletizing, the hot pellets must be cooled and the excess steam must be released. For long term storage of soft pellets that are produced under low pressure and without drying, chemical preservation is necessary for biological stabilization.

Figure 5.2-9: Principle of a pellet press [Kahl, 2007]

☑ Self-assessment

- Which are the main mechanical processes to treat the waste stream?
- Describe the principle of the recovery of ferrous and non-ferrous metals!
- What is the aim of the compaction process?
- What are the advantages of optical sorting processes?
- What is a zig-zag air classifier and what are the typical outputs of such a classifier?

5.3 Waste recycling

Educational objective of the chapter

- Recycling includes collection, sorting and treatment of the waste.
- For energy recovery it is possible to produce and burn RDF from the waste stream.
- Also recycling of paper/paperboard, glass and plastic are main steps of integrated waste management.

Recycling involves taking a waste item and reprocessing this material into a usable item either in the same form, as the original product, or into a different product. Recycling is widely assumed to be environmentally beneficial, although collecting, sorting and processing materials does give rise to environmental impacts and energy use. To improve resource recovery of source separated or commingled wastes in the facilities, appropriate processing equipment should be chose to separate the components into usable fractions. Recycling includes collecting, sorting, processing or converting of materials.

5.3.1 Recovery and Use of Secondary Raw Materials

In 1992 in the Old Federal States of Germany were 3.81 million tones of glass used (including imported glass packaging) and the approximately 2.46 million were recycled. This represents a recycling rate of 64.5%.

Recycling Household Waste
For the recovery of recyclables from household waste several different systems haven been employed and proved, for example:

- Drop-off system (receptacles, drop-off centers)
- Pick-up systems (multi-compartment container, mono containers, recyclables bags, bundle collections, bio bins)

On the Basis of the same system the concept of one area can be differently structured by collection frequency, marketability, quality of recyclables and quantity of contaminants, as well as expenditures for collection and processing. Most of the establishment ties the commercial and small business waste into municipal solid waste. In the surveys and analyses of waste composition the Household Waste is categorized into nine groups: paper/paperboard, ferrous/non ferrous metal, glass, plastic, textiles, vegetative matter, detrital minerals, composite materials and problematic materials.
The survey in Germany showed that in waste compositions the vegetative matter, the glass packaging and paper/paperboard make up the large percentages of waste streams and the receptacles can be the suitable system. In Germany, all light packaging materials such as plastic retail packaging, metals, and composite materials are separately collected in specific receptacles, also called yellow bins or yellow plastic bags. The materials from the receptacles are transferred in the glass manufacturing industries and they will be sorted and classified. The Part of contaminants and misplaced items such as ceramic glassware in glass container must be separated at first. For example the glass from receptacles in Germany contains ca. 0.61% contaminants. The sorting and separation are accomplished in facilities with machines .With help of manual sorting will the recycling rates be improved. The separately collected organic component of household, for example kitchen and yard waste, is called biowaste and it makes up ca. 32% (by weight) of the total waste collected. Based on collection activities, individual motivation and structure is the quantity of biowaste regional differently. As material recycling bio waste can be composted and used as fertilizer in agriculture. But the decomposition of organic waste causes harmful landfill gas emissions and contributes to the global warming. In nowadays the new fermentation technology make it possible that the Organic waste can be partially in anaerobic digester converted to renewable energy sources, e.g. biogas, and then the rest can be turned into fertilizer.

Recycling of Household-like Commercial Waste
In the commercial waste the contaminants reduce the sorting ability and resource quality. Source separation of commercial waste such as large or more recyclables containers can be easily done in a manner similar to household waste collection. At the commercial waste sorting facility the screening and classification equipments are used to separate the desired recyclable fraction from the contaminants. Other processing technologies such as screens, air classifiers, ballistic and magnetic

separator can also be applied in removing contaminants and collecting easily recoverable resource. A subsequent manual sorting aids in a high degree of efficiency. According to the desired goal of resource recovery, manual sorting must be the primary method of processing. The method varies in positive and negative hand sorting.
Recoverable material is brought to the MRF and is first weighed on a truck scale at the access. Then is it dumped onto the tipping floor or into a hopper. A wheel loader pushes the material toward the hopper's moving floor. Bulky things such as motors are pushed aside by the wheel loader and categorized by the screening and classification equipments for appropriate destination. The remaining material stream flows via an inclined conveyor to the sorting platform. On the platform the recyclable materials are manually separated from the discards. Discards are transferred to containers and taken away for landfilling.

5.3.2 Production of Refuse Derived Fuel (RDF)

The burn rate of one material is determined by the specific surface dimension and water content as well as the thermal conductivities. Comparing to ordinary fuels the MSW is inhomogeneous because the feedstock composition changes both in size and burn duration. Furthermore, the MSW is not optimal fuel, because:

- The low heating value of household waste is caused by high ash and moisture content.
- The energy content varies not only throughout the year but also in the long-term based on changes in lifestyle.
- A mount of hazardous substances such as heavy metal and halogenated compounds is comprised in household waste as well as in paper/paperboard and plastics.(Tab. 5.3- 1)

Household waste with low heating value or bed combustion behavior results in low energy yield. However, the use of refuse derived fuel hat got interesting by rising of the fuel price in the recent years and been possible by a pre-treatment process.

Tabelle 5.3-1: Hazardous substances in household and other predominant wastes [mg/kg] [Bilitewski, 2000]

Hazardous Substance	Household Waste	Waste Paper (8% Moisture Content)	Plastic (6% Moisture Content)
Cd	2.9	0.5	43.1
Cr	76.0	22.0	28.2
Cu	31.0	65.0	78.0
Ni	13.0	10.7	18.8
Pb	294	65.7	171.1
Zn	310	108	402.3
Cl	4760	1789	55012
F	71	104.0	14

Minimizing Harmful Substances during Waste Processing

The treatment process with the magnetic separation, milling and oscillating screen can not only maximize the physical and chemical characteristics of the burn material but also aid in minimizing the harmful side effects of MSW incineration. RDF can be processed so that the sorting methods remove particularly polluting materials from MSW. Table 5.3- 2 lists the contaminants present in RDF and MSW and energy content and serves to illustrate that processing waste to RDF reduce the overall hazardous substances concentration and also reduce the hazardous concentration per unit of energy. In relation to the overall mass, the levels of chlorine and sulfur do not change significantly. The energy content of RDF constitute Hu=11,6MJ (moisture content: 28.2%) and for household waste Hu=7.9MJ (moisture content: 31.3%).

Tabelle 5.3-2: RDF and household waste contaminant content [mg/kg] [Bilitewski, 2000]

Hazardous Substance	Household Waste (mg/kg)	RDF (mg/kg)
Cd	8.7	4.7
Pb	345	307
Cu	345	1.40
An	956	676
Cr	108	89
Total PAH	4.2	3.6
Cl	6800	7200
Forg	101	67
S	5100	4800

Carbo-Sed Process

The Carbo-Sed Process is a method of converting sewage sludge to burnable materials and was developed in 1981 by BASF AG. The unique characteristic of this process is:

- The use of suspended coal concentrates as a filtration aid for mechanical dewatering in filter presses. A mixture ratio of dry sludge solids/coal of 1:3 has been proved to be optimal.
- The Addition of select polyelectrolytes (anionic flocculent called Sedipur) which facilitate stable flock formation even under high pressure in the filter presses.

This combination allows for an optimal pre-dewatering. And it is followed by sludge thickening, dual blade mixing, flock stabilization in another contact mixer, and continued dewatering in chamber filter presses. The coal filter cakes and the pre-dried sludge solids are transferred from intermediate bunkers to rotary drum dryers for drying to solid content of 90 %. The alternate burning of the dry solids, coal, or oil in the dryer's combustion chamber, enables burn temperature of 800 °C to be reached. This heat can be used either for drying or pre-heating the combustion air. After the solids are removed, gases flow through the dryer and exit at temperature around 180 °C and are recirculated through the dryer. The gases are cleaned with electrostatic precipitators.

Wood Chips

Certain wood pieces, such as raw wood wastes from furniture manufacturing or housing construction, could be recovered in particle or chip board production. But other wood waste can not be recycled because of its odor or contaminant and must be disposed of with appreciate methods. The thermal recovery under special conditions has proved to be a suitable dealing method. Hammer mills are usually used to cut wood waste into chips (50 - 300 mm) or shavings (10 - 50 mm). Size reduction includes also the breakup of any metal/wood combination, and allows for the easier automated separation of ferrous and nonferrous. The shredding process can also remove potential contaminants, such as soil and cement, and possible coatings and lacquers. Contaminants and lacquer residues can be also separated by intermediate devices such as sorting.

Paper as Fuel (Paper Derived Fuel-PDF)

The paper fraction of household waste provides a special heating value of about 15,000KJ/kg. This kind of use -Paper as Fuel competes with the material recovery, which can already utilize a wide variety of paper with a wide range of quality characteristics. Furthermore The Co-firing of lower grades of waste paper with paper sludge hat two advantages:

Co-firing paper and paper sludge is possible without additional fuel because of sufficient heating value. This leads to energy servings by eliminating the need for primary fuels.
Depending on the percentage of waste paper, current technological advances would cover up to 60% of the thermal and 10 % of the electrical energy needs of the paper mill.

The burning of lower grades of paper in paper mills depends on political decision.

5.3.3 Marketing of Recycling Products

For the most efficient method a market surveys for potential buyers, for specifications, and for prices of recyclables should be conducted as well as a concept should be developed. In the framework of market surveys, it is necessary to identify the quantities of potential recyclable in a given collection area so that the existing collection and disposal methods as well as their costs can be determined. And the logistics of materials and personnel management must be considered. It is necessary to find optimal collection and transportation alternative. The marketing of products from recycling facilities represents the weakest link in the raw material cycle. Recycling facilities must produce a product and bring it to an appropriate market. A classification of recyclable products such as compost, paper, plastic, glass, and metals will be beneficial. Because of the heterogeneity of the original waste stream, it is very difficult to limit the range of acceptable quality standards. The individual end user must be able to tolerate a wide range of material quality and use the product "as-is". The marketing of recyclables can be support and promoted by manufacturing industries, the retail sector, consumers, and the public sector. They are so described:

Manufacturing Industry
By manufacturing industries it is important to promote the product marketing with following methods:

- To expand existing manufacturing operations of recycled products
- Development of recycling technologies
- The development of new products which can be made from the collected recyclables

Retail Sector
It is recommended favorable pricing for recycling products in retail sector, especially during introductory phases.

Consumer
Consumer associations can also play a critical roll in promoting and supporting these kinds of purchases. The end consume of wares is essential for the marketing and selling of the products which is made of recycled- content.

Public Entities
The public entities can promote the marketing of recycled products with following options:

- Encouraging research and development ventures
- Providing tax incentives to create greater production capacity for conversion of recyclables to goods
- Providing financial assistance to upgrade and expand existing and future specialized facilities and technologies
- Increasing use of goods and merchandise made of secondary products in public building and offices
- Creating a demand to use these products by changing national quality standards and requirements
- Enacting specific resolution and recommendations by environmental officials promoting the use of recycled products
- Conducting greater public relations outreach efforts to use and market these secondary products

Paper and paperboard
Paper and paperboard are by far the largest components of municipal solid waste. Compared to other recyclables, the recovery of paper and paperboard achieved a rather high rating. The collection method has a predominant influence on the quality of residential waste paper.

Glass
Glass has unlimited recyclability and theoretically could achieve a recovery rate of over 90%, when glass is sorted by color in recycling center. After recycled glass is crushed, it is first screened for furnace: the third party processors remove contaminants such as ferrous and nonferrous metals, plastics, ceramics, and porcelain either mechanically or manually in specialized glass processing facilities. There are maximal values necessary for avoiding damage to the melt furnace and for minimizing defects. The requirements for color combinations are based on specifications necessary for colour purity of the end-product.

Scrap Metal
Scrap metal is divided into two main categories:

- Plant scrap from blast furnaces of the steel industry and foundries. This scrap metal remains in the industry production cycle and is called cyclic-scrap.
- External scrap, specifically waste from salvaging operations or what is known as new scrap, and obsolete or unusable and manufacturing goods made of steel or cast iron, also known as old scrap.

New scrap that is generated in steel manufacturing industry is usually returned to the molten steel after processing of the semi-finished and finished product, or cast iron. Typical industrial sectors that generate new scraps are:

- Machine manufacturing
- Ship building manufacturing
- Bicycle- ,automobile manufacturing and other transportation manufacturing;
- Steel can
- Container manufacturing and
- Sheet metal manufacturing

On the other hand, old scraps come from:

- Scrap vehicles
- Obsolete machines and parts
- Demolition
- Wreckage scrap
- Railroad tracks
- Other railroad parts
- White goods, and
- Other residential scrap metal

Chemical and physical requirements for marketing/purchasing scrap metal are closely tied to the steel manufacturing industry. The general quality standard for the clean scrap is that the scrap must be free of

- All components damaging to the smelting operation, in particular, closed cylinders/tubes;
- Nonferrous metals, alloys, cast iron, all nonmetal material
- fMaterial intermingled with car bodies, motors, oily gears, shaving, sinter, and slag

Furthermore, there are also special requirements for alloy scrap, casting and foundry steel scrap as well as specific requirements regarding the physical attributes such as weight and size of the scrap. The prices for waste paper and ferrous are dependent on those respective products.

Plastics
Sorted plastics of homogeneous quality are generally marketable. It is also possible to market composite and mixed plastics which are generated in household. The quality requirement is essential for the end-product. Specification for durable, long-lasting products is based on precise technical data and uniformity. The products made of recycled materials must also demonstrate to be utilized without excessive repairs or consumer complaints. Thus, there are international and national norms and specifications which are based on authoritative rules or voluntary industry associations for recycled materials. The prices for recycled materials are dependent on the price fluctuation of new plastic on world markets.

☑ Self-assessment

- What are typical methods for recycling of waste?
- Which are the convenient fractions of household wastes for recycling processes?
- What is RDF?
- What is the advantage of producing and using RDF?

5.4 Thermal waste treatment

Educational objective of the chapter

- Thermal waste treatment is used for inertization of the waste, volume reduction, energy recovery and production of marketable secondary raw material.
- The most common way of thermal waste treatment is the combustion of the MSW with grate firing.
- The combustion process of the waste includes a pre-treatment of the waste just like cleaning processes for the exhaust gases.
- Thermal waste treatment also includes drying processes, pyrolyse and gasification of the waste.
- It exist different types of incineration methods for different types of waste.
- It is also possible to burn hazardous wastes.

Thermal treatment of segregated waste is an appropriate and important method for management of waste. Thermal waste treatment comprises waste incineration, pyrolysis (degassing), hydration and drying. The goals of thermal treatment are:

- The inertization of the waste residue or contamination concentration
- Volume reduction
- Energy recovery
- Production of marketable secondary raw material

The inertizations of the waste residue or contamination concentration and volume reduction are the primary principles of thermal treatment

5.4.1 Incineration for MSW and Commercial Waste

In modern waste management is by far most important thermal process. It is used to treat no recyclable and no reusable materials. The purposes of incineration are:

- Making inert any hazard waste residues while minimizing the emission into the air, water and soil
- Destroying organic contaminants and concentrating inorganic contaminants
- Minimizing the quantity of waste requiring disposal, especially its volume
- Recovering the waste's heat value by burning as energy resources in combination of heat recovery and power generation.(energy cycle)
- Transforming the residues into usable secondary products-slag to replace raw materials and resources.(resource cycle)

A conventional MSW incinerator consists of the following components:

- Waste receiving
- Storage, preprocessing
- Charging and incineration unit
- Slag removal, residue treatment, storage
- Boiler with steam recovery
- Air pollution control system
- Stack

The operation of a MSW incinerator is in the following figure illustrated. The following sections describe the basic components and their functions.

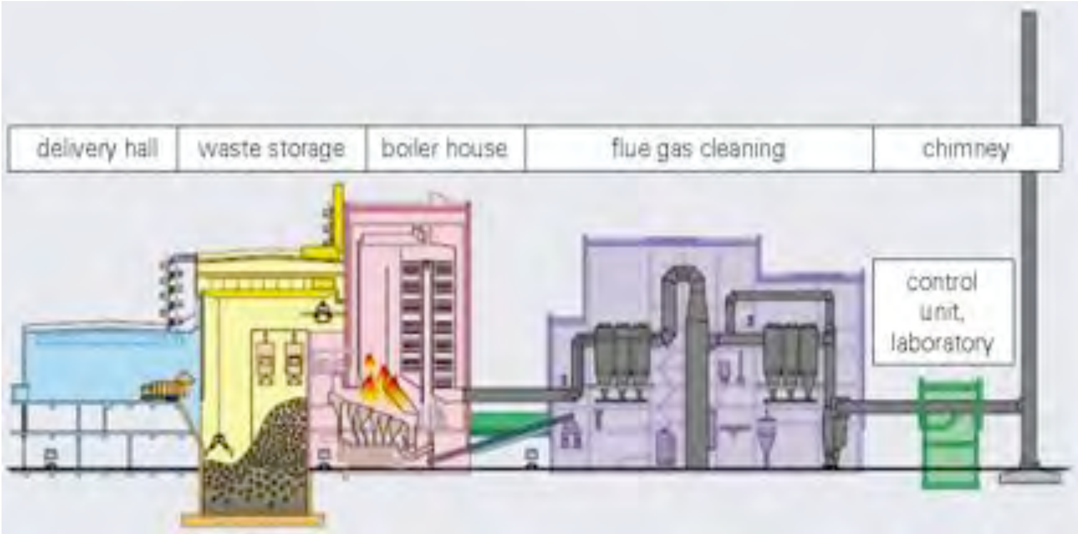


Figure 5.4-1: Principle of a combustion plant for MSW [Igelbüscher, 2005]

5.4.1.1 Waste Receiving

At the entrance the incoming waste is initially weighted and screened to determine the total quantity and quality. Sorting or screening permits the removal of noncombustible waste that may disrupt the processing or facilities. Combustible waste must be broken up or sorted out.
For weighing the electromechanical system can transmit the sensor data and can be integrated into a digital information system such as invoicing. It hat proven themselves rather well. Furthermore, the statistical data of weighing is important for estimating performance criteria.

5.4.1.2 Waste Storage, Preprocessing and Charging

Storage

Because of the delivery of waste in batch and continuous feed into the incinerator the storage is necessary. The waste bunker can serve as a buffer space and moreover it is a place, where incompatible and damaged material is to be recognized and remove or sorted out for preprocessing. In the bunker the waste homogenization occurs always with excavator and crane. There are three types of bunkers:

- Deep bunker
- Plate conveyor bunker
- Shallow bunker

If the waste long time stays in the bunker, it will generate heat and combustible gas: methane, which can lead to explosion by crane operation. Therefore it must be installed an automatic sensor and detection system, a good aerator and a fire extinguishing system.

Preprocessing

Crane can not only work as a conveyer; but also can sort out incompatible materials if necessary. The crane that is operated from an operator cabin runs on a loading bridge with trolley track and can easy reach all areas of the bunker, the tipping floor and the charging funnel. So the operator must overlook the whole area with help of a monitoring system. Bulky waste causes always clogging or a shutdown. So it must be reduced in size with the size reduction equipment such as shearing mills, impact crushers or jaw mills.

Charging

Since the incinerator works continuously, the funnel tubes are usually sized to be fed with a specified hourly input. Through the filler shaft reaches the input in the funnel tube the charging mechanism. The shaft can be closed to avoid backfiring of the flames.

5.4.1.3 Combusting Process of Grate Firing

The basic construction of the combustion chamber consists of a bottom combustion grate, the combustion chamber walls and a ceiling (or a boiler) on the top. To start up the incinerator, the combustion chamber is pre-heated and the minimum required temperature for afterburners (850°C) must be reached. To support the pre-heating the burner, which are fired by natural gas, oil or coal dust, are installed. When the afterburner chamber hat reached the minimum required temperature, the waste can be ignited by the pilot burners, which are installed in the combustion chamber. In grate firing the waste undergo the following process:

Drying

At the upper section of the grate the thermal radiation or convection heats the waste until to more than 100 °C, in which water in the waste is evaporated. Until to 250°C volatile compounds such as residual moisture and gases from low-temperature distillation disappear.

Pyrolysis

The pyrolysis takes place under reduced atmospheric pressure and under further addition of heat.

Final Combustion

At this phase the waste is completely combusted on the grate. In modern incinerator facilities ignition losses of slag are less than 0.5% by weight.

Gasification

The pyrolysis products points are oxidized with molecular oxygen. Only a fraction of gasification occurs directly at the grate, and most parts of the waste are oxidized in the upper portion of the combustion chamber at 1000°C.

Afterburning

An afterburner minimizes unburned substances and brings CO in the flue gas into final combustion section.

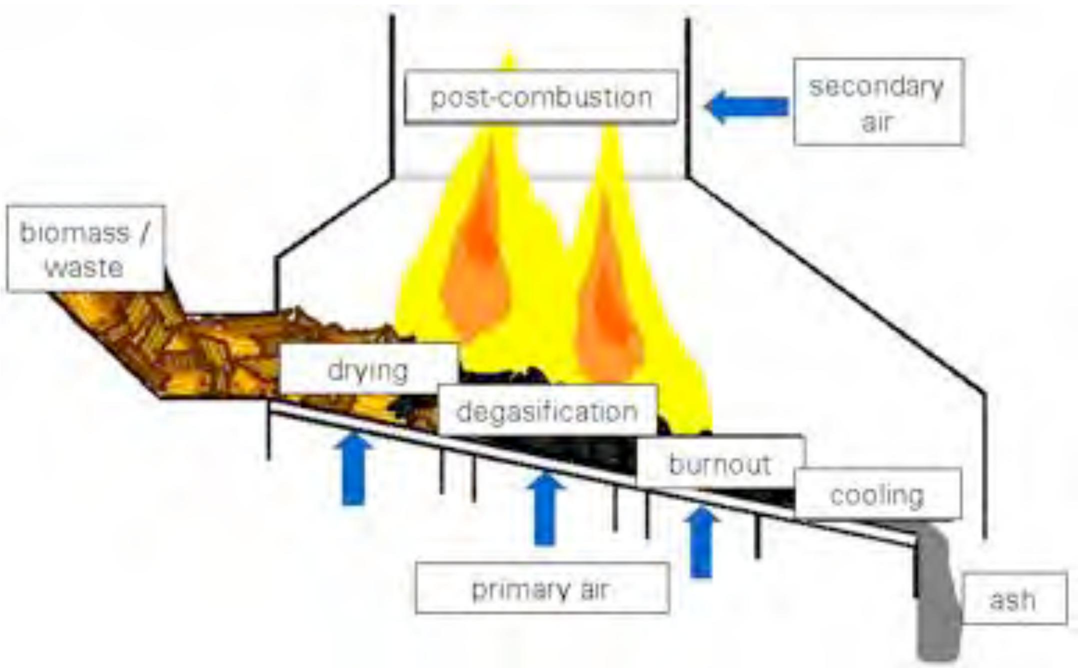


Figure 5.4-2: Principle of the combustion process

Grate Firing System

The length of time from one phase to the next depends on the composition of the waste and on its heat value.

In Germany three grate fire systems prove themselves:

- Traveling grates
- Reciprocating grates
- Rotating drum grates

Traveling grates comprise several overlapping rows of fixed and movable grates. The stroking motion of the grates transports the waste from the charging end to the outlet. The grates are installed at an incline or horizontally. The movement of the grates also supports sufficient stoking.

Reciprocating grates also consist of cross rows of fixed and movable grate bars. The grate is sloped toward the slag dumping end. The lifting motion is toward the charging mechanism and the upward motion in combination with the gravity-assisted downward motion results in excellent stoking. At the end of the grate, the combustion residue runs out with help of a roller.

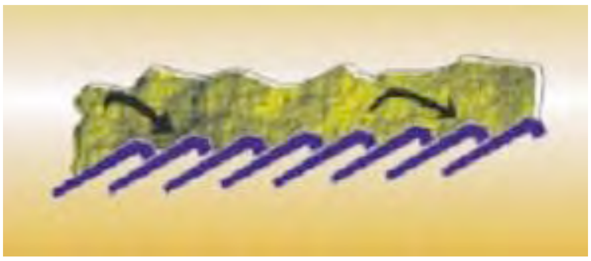


Figure 5.4-3: Principle of a reciprocating grate [Igelbüscher, 2005]

Rotating drum grates consist of six side-by-side drums with a diameter of 1, 5 m each. The grates are at 30° angle towards the discharger. The drums are individually controlled by electric motors. The pockets between the individual drums force a rolling motion of waste in which a thorough mixing and stoking result.

Figure 5.4-4: Rotary drum grate [Igelbüscher, 2005]

Volund Incineration System

The Volund System concerns a combination of a stoker with traveling grates connected to a rotary kiln furnace. The construction results in the drying and incineration of waste on the traveling grate with complete combustion in the rotary kiln furnace at temperatures of 800 to 1000°C. The rotation of the kiln also sinters the combustion residues. The grain size of the slag is therefore relatively small, uniform, and does not generate much dust.

Air Circulation and Combustion Chamber in Grate Furnaces

For optimal combustion are the combustion air and the flue gases properly under a relationship mixed in the combustion chamber. There are three types of the directing the air and gas mixture through the combustion zone and toward the stack:

- Direct flow
- Counter flow and
- Central flow

The direct flow path shows to be the best because the critical gas flow is directed through the maximum high temperature area and is thus largely incinerated. One disadvantage is that the hottest flue gases format the end of the grate and must be recirculated to the drying and ignition zones. So even damp material with low heat value can be incinerated relatively fast by pre-drying it.

The principle of the counter flow is that the hot flue gases are recirculated through the drying and ignition zones from the end of the grate to facilitate pre-drying and to allow relatively speed combustion of still damp materials and of those with low heat value.

Using central air flow, the first under air blower is installed above the main combustion area. So the flue gases must pass through the hot combustion area.

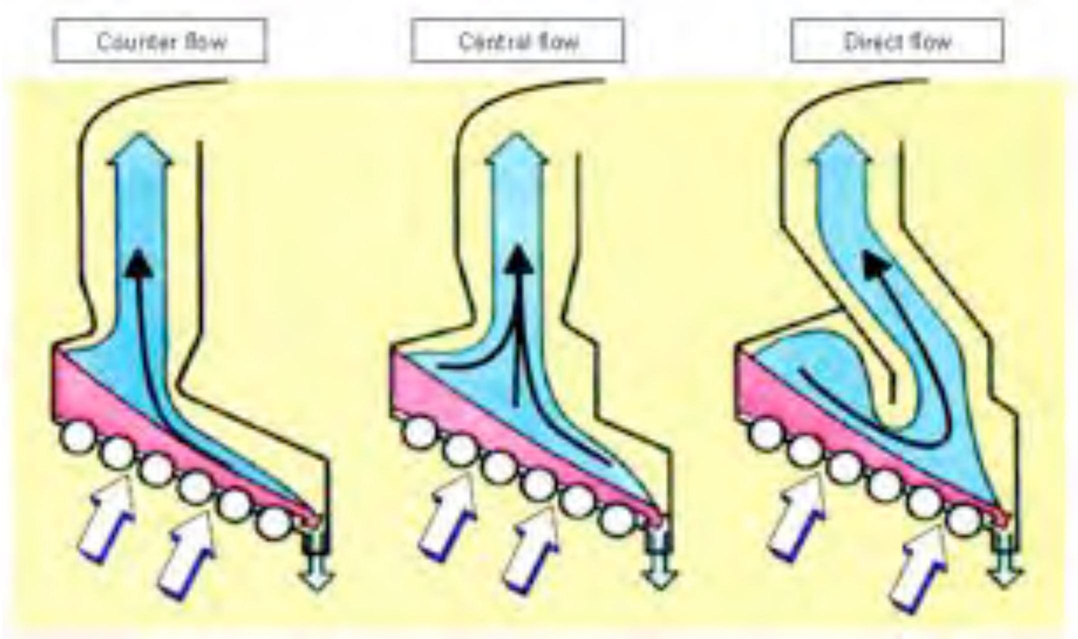


Figure 5.4-5: Principles of the air circulation in the combustion chamber [Igelbüscher, 2005]

Fluidized-Bed Incinerators

Okawara's fluidized-bed incinerator was developed based upon the experience and technical know-how acquired at circular incinerator (model ACE). The fluidized-bed incinerator has such wide application that not only the sludges but screen residues and other wastes can be incinerated. Furthermore, low air ratio combustion is possible with a fluidized-bed incinerator. Due to high thermal capacitance of sand and excellent thermal conductance of fluidized-bed, the water is instantly evaporated from the sludges or screen residues. Then, the product temperature is increased and the chemical reaction occurs, incineration process is thus completed. There is no local overheating area and a uniform temperature is kept in the incinerator furnace, and thus the fear for generation of ash clinker is reduced and energy can be saved, which are required for any types of incinerators.

Principle

In order to form a stabled fluidized-bed at a high temperature, the silica sand is filled in the incinerator furnace with optimum quantity. When the fluidizing air heated with waste heat exchanger is blown from the bottom of the furnace, the fluidized-bed is actively formed in the sand layer. The product to be incinerated is supplied on the sand fluidized-bed and mixed with the sand while the sand particles are actively moving. The water is instantly evaporated from the product and the product temperature is increased by the contact with hot air. The product is incinerated through these processes. The ash produced by incineration is crushed into small pieces and discharged out of the system accompanies with the exhaust gas. Finally, the ash is collected with dust collecting system.

Design

The fluidized-bed incinerator consists of a lined, cylindrical combustion chamber, with air distribution nozzles on the bottom. These nozzles supply the necessary air for combustion, which fluidizes the bed material and the waste which starts to behave like a viscous fluid. This results in a relatively large surface area for heat transfer and substance exchange.

The main characteristic of fluidized bed incineration is 90% inert bed which consists of either sand or other no combustible substances. Only the remaining residue consists of combustible materials. Since the bed itself possesses considerable heat capacity, it is possible to achieve a homogenous heat distribution in the fluidized bed which is independent of combustion properties of the waste. This leads to an exceptionally clean or odourless burn. To reduce concentration of pollutants in the flue gas, additives such as lime can be used to retain harmful gases.

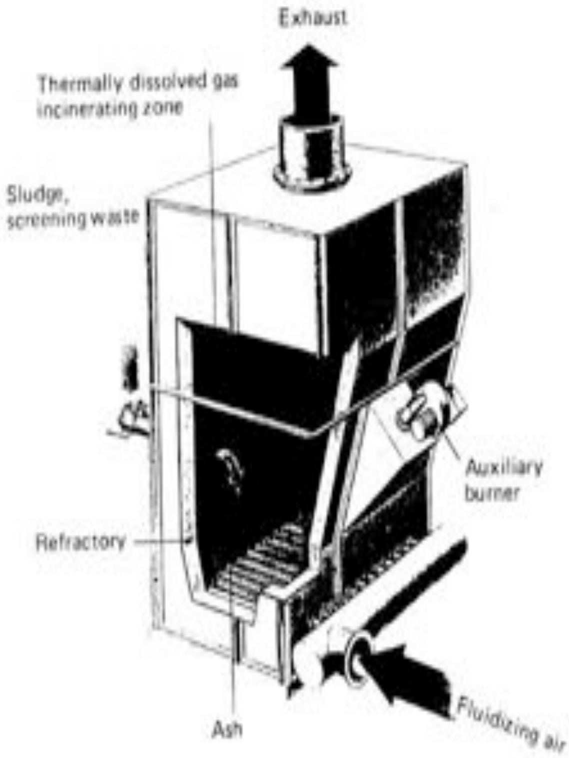


Figure 5.4-6: Principle of a fluidized-bed reactor

Figure 5.4-7 (left): Fluidized-bed reactor

Figure 5.4-8 (right): Nozzle floor of a fluidized- bed reactor [Igelbüscher, 2005]

Process

For Process with fluidized-bed incinerator, it is necessary to pre-sort the waste to remove non-combustible material as well as ferrous metals and also to perform size reduction. The ashes and solid fall through the gas distribution floor and are removed from the lower part of the incinerator.

Application

Because the bed can not exceed a certain temperatures (the bed sand would soften), only a small amount of heavy metals are retained in the ash. So fluidized-bed incinerator is only suitable for incineration of waste with low concentrations of heavy metals, for example:

- Wood, and perhaps, plastic and paper
- Human waste sludge and sewage sludge
- Industrial wastewater sludge
- Waste less from industrial processes

Modified Incinerator with Integrated Slag- and Particulate Vitrification

For an optimal incineration process for MSW waste the requirements must be fulfilled:

- Destruction of organic component
- Safe retention of heavy metals in the slag
- Simultaneously minimizing gaseous emissions

For any waste these requirements are difficultly met with conventional waste incinerators. Thus, the incinerator was modified with the goal of vitrifying slag and particulates. In such modern incinerators are following processes for slag and particulate vitrification integrated:

- A grate furnace with ancillary rotary kiln
- The low Temperature Combustion Process
- Thermo select
- A grate furnace with ancillary rotary kiln

In the method **Grate Furnace with Ancillary Rotary Kiln,** the grate is shorter as the conventional incinerator and consists of a drying zone and the main combustion area. Instead of the final burn zone, a rotary kiln is integrated to vitrify the ash, dust, and slag.

In the grate area, the waste is only under low temperature carbonized, because substoichiometric air is added continuously. At a temperature of 1000 °C, the combustion material enters the rotary kiln. Then, secondary air is added and the sudden combustion of carbonization gas leads to a rapid temperature increase. The operating condition can be so preset that the ash is either agglomerated at 1150 °C or is melted and vitrified at 1300 °C. Bottom and filter ash is returned to the rotary kiln and also agglomerated or vitrified. Because of the low extractant concentrations of heavy metal the disposal or reuse of slag and particulates are possible.

In the **low Temperature Combustion Process** the residual MSW is first put into a drum, which is indirectly lightly heated to 450°C. Under this low temperature carbonization gases with a high heat value is generated. The heat medium is air, the recirculated flue gas and particulates which itself circulate in the closed system. Residence time of the residual waste in the drum is about one hour.

After the low temperature incineration, the carbon solids run out. Less than 1% of residual particles larger than 5 mm and made of up inert materials such as glass, ceramic and stones. Over 99% of residual is fine grained carbon solid (<5 mm), which is pulverized and fed in a high temperature furnace. Because of the high combustion temperatures of at least 1300 °C the carbon solid molten in slag forms. The organic residues that are especially contained in particulates are largely destroyed. The molten and glassy slag retains the minimally leachable heavy metals. Since it was tested that the leach concentrations measured from slag at a low temperature are blow those required for Class I landfills, the vitrified slag can be easily used as a secondary raw material. This process is the preferred method for the incineration of sewage sludge.

In the **Thermoselect process** the waste is first compacted to 10% of its input volume. The compacted waste is heated up to 400 to 600 °C and is pyrolyzed in a batch furnace. The carbonization gas and the waste are incompletely burned by supplying pure oxygen. The 2000 °C molten slag that forms is extracted and the molten metals are separated from the slag. After the liquid extraction process, the remaining mineral slag gets cold and vitrified. In the process the recovery energy is lower than in the others, but lower emissions come out.

5.4.1.4 Incinerator Slag Removal

During the combustion is slag generated and it must be removed anyway, because of:

- The prevention of blockage during the continuous generation and
- The prevention of secondary air leakage

Currently there are several slag removal systems. The principle of the standards technique is that because of gravity slag falls into a chute and is led to the residue handling equipment.

The major problem in removing the slag is its high temperature (600 - 900 °C). The other problem is that the lack of excess air can result in reaching the slag melting point (between 950 and 1000 °C) and causes the combustion residue to a paste-like consistency. To quench the slag and to form an air-lock to the combustion chamber, several methods were developed. All contain the components: rams, plate, conveyors and drag chain conveyors.

5.4.1.5 Boiler and waste Heat Recovery

Boiler

For following reasons the boiler must be installed:

- Waste heat recovery from MSW incineration
- The cooling of the flue gases from temperatures of 1000 to 1200 °C to between 200 to 300 °C, since flue gas scrubbing takes place at temperatures below 350 °C

The boiler transfers the heat of the flue gas into a suitable thermal energy carrier (steam or water).The important elements of a steam boiler are the feed water treatment unit, the feed water line, an air pressure tank, safety valves, and the steam off take pipe with controls for water level, and boiler and steam pressure. There are five types of boiler:

- Warm Water Boiler
- Hot Water Boiler
- Hot Oil Boiler
- Saturated Steam Boiler and
- Superheated Steam Boiler

Incinerators use always hot water, saturated steam and superheated steam boiler. For the dynamic of steam in steam boiler there are three constructions: Circulation Boiler, Forced Circulation Boiler and Force-through-flow. The construction of a circulation boiler with three to five flues above the furnace has proven itself. The new construction of two boiler (a primary boiler and a secondary boiler) hat been used successfully.

Waste Heat Recovery

The recovery of combustion heat for the generation of stream depends on site conditions and requirements. Large facilities produce high-grade steam (40 bar, 400 °C) for electricity generation, usually combined with district heating. Smaller facilities generate steam with lower operating parameter (15 - 20 bar, 200 – 250 °C) and the steam is used for heating purposes or as process heat for industrial proposes.

5.4.1.6 Emission control

5.4.1.6.1 Flue gas Quantity and Composition

In the flue gas there are not only carbon monoxide, carbon dioxide, water steam, but also sulfur dioxide (SO_2), nitrogen oxide (NO_x), unburned particles and other hydrocarbons, polycyclic aromatic hydrocarbon, dioxins, furans, other pollutants. These pollutants occur in gaseous form or as particulates. Flue gas scrubbing removes the particulates and the gaseous pollutants.

5.4.1.6.2 Collection of particulates

In order to lighten the scrubber's load, particulates are removed before the flue gas scrubbing. The particulates range in size from 1 µm to1 mm. The following processes can be applied for the removal of particulates from the flue gas:

- Cyclones
- Fabric filters, and
- Electrostatic precipitators

Cyclones

In the Cyclone the gas flows tangentially into a symmetrically rotating centrifugal separator and swirls around an immersed tube. The particulates are carried by inertia to the cylinder wall and exit through the conical section on the bottom while the clean gas runs through the top out.

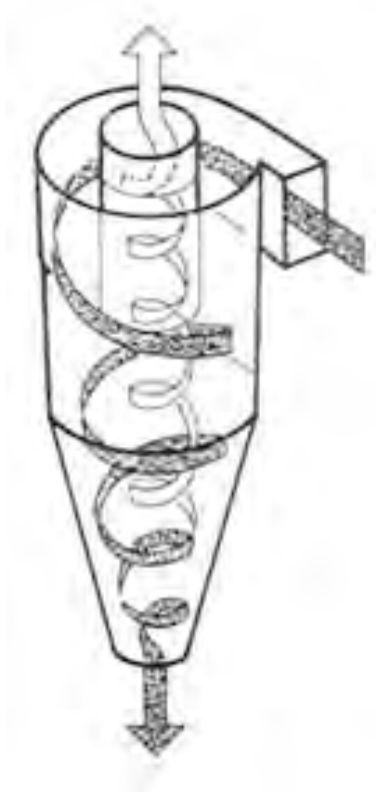


Figure 5.4-9: Principle of a cyclone

Fabric filters

The dust-laden gas is introduced through a porous layer of fabric and it retains the particulates on the surface. So the gas is cleaned.

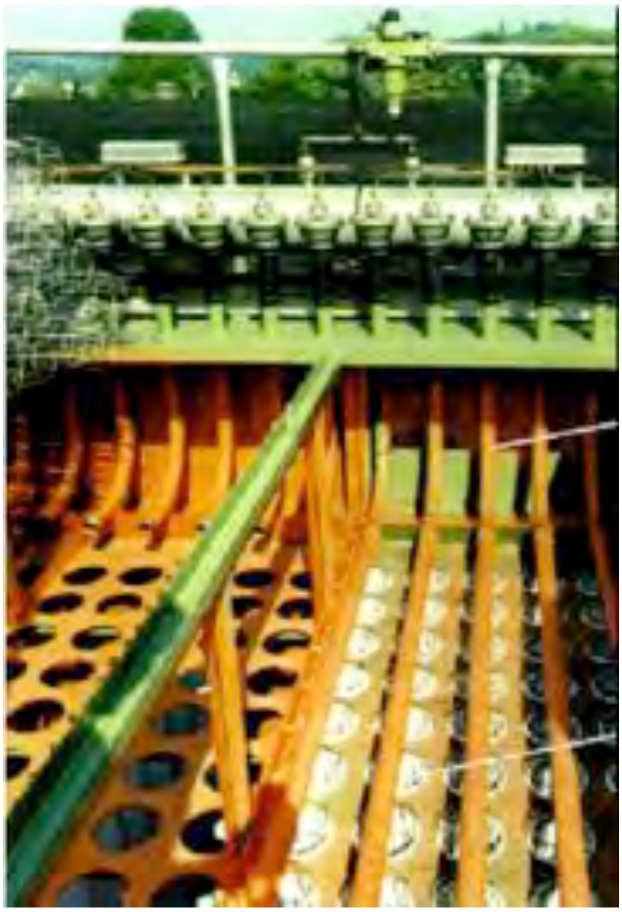


Figure 5.4-10: Fabric filter [Igelbüscher, 2005]

Electrostatic Precipitator

The principle of the Electrostatic Precipitator is that the particulates move onto the wall surface by the force of a high-voltage field and are separated.

Physical and Chemical Principles for the Removal of Gaseous Pollutants

Physical and Chemical Principles for the Removal of Gaseous Pollutants are based on either absorption or adsorption.

5.4.1.6.3 Removal of Acidic Pollutants

For removal of Acidic Pollutants there are three methods to remove the acidic pollutants: wet, wet-dry and dry-scrubbing.

The method **wet scrubbers** is based upon the absorption of acidic gases in an alkaline liquid phase, whereby, depending on the alkaline solid used, calcium, magnesium or sodium gypsum slag is generated.

A **wet-dry system** uses a spray absorption process. A neutralizing solution or suspension is sprayed into the hot flue gas to simultaneously cool and neutralize it.

Absorption processes are also utilized for **dry scrubber** method. The flue gases pass through a fine powder alkaline mist such as $Ca(OH)_2$ powder and the reaction products are removed from the flue gas stream by a filter.

5.4.1.6.4 Denitrification

During the incineration at high temperatures, nitrogen oxides form. Because of the hazard and the legitimate limit for nitrogen oxides the denitrification is always achieved by using a primary and secondary process. Primary denitrification prevents the formation of nitrogen oxides in the combustion chamber. Secondary denitrification is divided into processes: **catalytic reduction** and **non-catalytic reduction**. In the non-catalytic reduction ammonia, urea, liquid manure, or similar substances are used as reducing agents and are injected into the combustion/catalytic chamber. At temperatures of about 1000 °C, the reducing agent reacts with the NO_x and forms oxygen and nitrogen (N_2). And catalytic reduction can achieve a high denitrification rate of up to 85 %.

5.4.1.6.5 Removal of Dioxins and Furans

Residual MSW contains certain significant dioxin and furan concentrations. In spite of combustion with minimum temperatures, enough retention time, enough air supply and complete incineration the concentrations lies much over the legitimate limits. To reduce dioxin and furan emission, the method of primary and secondary minimization measures is used as standard technique. Primary minimization means reducing CO and unburned residues by improving combustion, reducing the concentration of particulates in the flue gas, improving the combustion configuration and elimination the use of electrostatic precipitators. The secondary measures include two processes, which remove dioxins from flue gas: Dioxin catalytic converter and Removal with activated carbon or coke. With the help of modern pollution control technology, it is possible to stay well blow the required emission limits.

5.4.1.6.6 Treatment of Slag, Ashes and Incineration Residues

During MSW incineration, a mass of solid and liquid residual materials is generated, whose quantity and composition depend on the fuel composition and the firing technique.

Incineration slag

As **Incineration slag** is defined slag, screenings and bottom ash, which are produced in the combustion process. According to the tests the incineration slag consist primary non-combustible material such as insoluble silicates, aluminum and iron oxides. A great fraction of it can be recovered as frost protection in road construction, as fill for dams and noise protection walls or as foundation stabilizer.

Because of the potential leaching of heavy metals, several processes have been developed to increase the leaching properties during treatment and to improve the acceptability. Despite all that, slag may not be used in groundwater recharge areas and in protected watershed areas.

Aside from the method of removing the heavy metal content as technically possible there are other processes such as Ash Residue Aging, Separation of Fine Fraction and Vitrification.

Ry Ash and Filter Dust

Filter dust and fly ash has higher concentration of organics, including dioxins and furans, heavy metals, chlorides and sulfates. Fly ash is usually not recovered and must be deposit subsurface. To improve the disposal properties of fly ash several process can be applied such as hardening with cement, 3-R-Process, solidifying fly ash with neutralization sludge from wet scrubbers, with treated slugs and salt residues from wet-dry scrubbers or with cement. By hardening with cement contaminants are chemically and physically fixed in the cement matrix, which effectively reduces leaching.

Liquid Residues
The modern incinerators work wastewater-free whereby wastewater generated in wet scrubbers is evaporated. The solid products are removed with a fabric filter and must be disposed of.

Reaction Products from Dry and Spray Absorbers

Currently, the recovery of the reaction products from spray dryers is not possible and as standard technique Reaction Products from Dry- and Spray Absorbers are together with incineration slag disposed of. This co-disposal aims at reducing the pH to a value between 9 and 10 to prevent the leaching of heavy metals.

Salts and Acids from Wastewater-free Pollution Control Systems

By the gas scrubbing the following salts are generated in varying mixture ratios: NaCl, NO_2SO_4, $CaCl_2$ and $CaSO_4$. They can be used in industrial process and be sold in the marketplace in competition in salts from natural deposits or manufactured.

Iron Scrap

About 100 - 150 kg of scrap iron are recovered from each tone of raw incinerator slag. Depending on the quality and price iron scrap can replace the raw material.

5.4.1.7 Control and Monitoring

A motoring system provides information about the status of individual processes to the automated control system in a control room. It has many sensors at different locations, including a gas analysis at the boiler outlet (raw gas) and another after the gas cleaning process. Sensors for temperatures, pressure, throughput and charging gauges and switches supply information on the operating conditions. CO and O_2 measurement help to control the combustion process. Particulates emissions are constantly measured for operating the electrostatic precipitator while the contaminant concentrations in the clean gas are constantly monitored and recorded. The conductivity and pH value of the boiler water as well as pH value of the scrubber wastewater are normally analyzed.

For combustion process control is at most important. With help of the precise control reduction of emissions such as CO, NO_x and unburned material can be achieved. Heavy metals and inorganic halides can be controlled by combustion only to a limited degree. To reduce the temperature in the firebox, the steam temperatures are under control recirculated. For denitrification flue gases are also recirculated in the area of primary denitrification.

5.4.2 Pyrolyzation and Gasification of Waste

Comparing to the other processes, Pyrolyzation and Gasification have following advantages:

- Uncomplicated and cost effective processes
- A potential for energy and resource recovery
- The recoverable product (energy) is easily stored
- Flexibility with respect to various wastes and changing waste compositions,
- Almost complete prevention of environmental pollution

By Pyrolyzation and Gasification waste materials are significantly reduced in volume and are converted to a Physical state whose storage has no serious effects on the environment. The relationship between various thermal processes of drying, pyrolysis, gasification, and incineration are showed in following Table.

Table 5.4-1: Classification of various treatment methods

Potenzial Process Steps	Treatment Method			
	Drying	Pyrolysis	Gasification	Combustion
Step 1	Drying	Drying	Drying	Drying
Step 2		Pyrolysis	Pyrolysis	Pyrolysis
Step 3			Pyrolysis	Pyrolysis
Step 4				Combustion

5.4.2.1 Pyrolysis

During pyrolysis, some of these incomplete processes can be operated in separate reactors, which makes pyrolysis and gasification separate waste treatment processes.

Pyrolysis means the thermal decomposition of organic materials without gasification aids such as oxygen, air, CO_2, steam, etc. In the temperature ranges between 150 and 900 °C, volatile compounds are expelled, and complex carbohydrates are converted into simpler ones. Depending on the operating parameters, the products are pyrolysis gas, pyrolsis coke, oil, and tar. The main product is normally pyrolysis gas. The recovery of oil fractions by distillation is only economical if the inputs are plastics, discarded tired in large quantities. The solid residue consists of pyrolysis coke which contains varying amounts of residual carbon that is not converted to gas in the process.

Input Materials and Pyrolysis Products

Determined by the input material, the heating parameters, the pyrolysis temperature and the reaction time, a variety of products can be outputted. And the composition of the products is determined by the composition of the input material, the conditions during heating to the degasification temperature, and by the duration of the reaction. The following products are possible:

- Fuels, i.e., raw material in the form of tars, oils or combustible gases;
- Condensate with dissolved contaminants
- Residues such as waste coke, metals, glass, sand, etc.
- Marketability of Pyrolysis Products

The oils extracted during scrap tire pyrolysis and pyrolysis gases are usable as raw material in chemical or petroleum feedstock. Pyrolysis coke has not found stable or reliable markets. Pyrolysis can not compete with incineration because of many problems and its insufficient availability.

5.4.2.2 Gasification

Gasification means that the carbon-containing materials are converted at high temperatures into gaseous fuels, whereby reactive gases are added to oxidize the residual carbon from the glowing embers of the pyrolysis coke at temperatures above 800 °C with sub-stoichiometric oxygen and further convert carbonized residues into additional gaseous products. Steam, carbon dioxide, oxygen or air are often used as gasification agents. Gasification is an independent process and the continuation of the pyrolysis process but still a part of combustion process. The quantity and composition of products are determined by the type of agent, lean gas, water, gas, etc. The following chemical reactions take place in the gasification of carbon-containing materials, and depend on the gasification agents (oxygen, air, steam, hydrogen, carbon dioxide).

$$C+\tfrac{1}{2}\,O_2 \rightarrow CO \qquad \text{(reaction 1)}$$

$$C+O_2 \rightarrow CO_2 \qquad \text{(reaction 2)}$$

$$C+2\,H_2O \rightarrow CO_2+2\,H_2 \qquad \text{(reaction 3)}$$

$$C+H_2O \rightarrow CO+H_2 \qquad \text{(reaction 4)}$$

At higher temperatures in the fuel bed more carbon monoxide is produced. From the partial combustion of the carbon in reaction (1) and (2) the fuel bed becomes red hot and reacts with the generated carbon dioxide according to the heterogeneous Boudouard reaction:

$$C+CO_2 \rightarrow 2CO \qquad \text{(reaction 5)}$$

The relationship of $CO/\,CO_2$ is present by the Boudouard equilibrium.

There are others processes so-called water gas reaction. The addition of steam to the air in the chamber leads to the production of CO_2 and hydrogen at high temperatures. The Boudouard and the water gas reaction are endothermal reactions, while the oxidation of carbon proceeds exothermally.

The immediate use of these gases in a secondary combustion chamber is desirable and efficient at most, since this is how the existing heat can also be recovered. The gas had a lower heat value than pyrolysis gas. But after cracking, the gas can be readily burned. The solid residues from the gasification process are similar to those from incineration and have a high percentage of ash and a low percentage of carbon. In contrast to pyrolysis, gasification slag is so vitreous that it does not leach contaminants into the environment. Therefore, this material is suitable for use in trail and road construction or as sanding material for winter road service.

5.4.2.3 Environmental Considerations of Gasification and Pyrolysis

With respect to environmental effects from pyrolsis, a distinction can be made between contaminants inherent to the medium and those specific to the process. Elements such as sulphur, fluoride, chlorine, heavy metals, and mercury and from compounds of these elements are medium-inherent contaminants. Process-specific contaminants emerge from thermal process. The type of contaminants depends on the operating conditions and the type of pyrolysis facility.

Pyrolysis Gas

During pyrolysis, organic compounds are reduced into simple, low molecular compounds such as hydrogen (H_2), carbon monoxide (CO) and carbon dioxide (CO_2). In addition to these predominant components, pyrolysis gas also contains hydrogen compounds such as ammonia (NH_3), hydrogen sulphide (H_2S), and hydrogen chloride (HCl)

If pyrolysis takes place at relatively low temperatures (around 500°C), a large amount of aromatic and phenolic hydrocarbons come into being in the carbonization gas. As the gas gets cool, they condense into a tarry substance and become concentrated as contaminants in the condensate or the gas scrubbing water. To prevent further contamination of wastewater, the pyrolysis gas must be incinerated immediately. The resulting flue gases must be treated to meet air quality standards. During pyrolysis, the elements sulfur, chlorine and nitrogen exist as hydrogen compounds. At a pyrolysis temperature of more than 750 °C the total nitrogen concentration increase steeply and then is burned.

Heavy metals

By the concentration of heavy metals in the pyrolysis gas (by adsorption of volatile metals to fly ash) the process temperatures play an important part. At temperature around 500 °C only a small percentage of heavy metals can turn into the gaseous phase.

Organic contaminants

Organic contaminants can be reduced by their destruction during the pyrolysis process, whereby the gases is directed through the hottest zone of reactor and the temperature is required between 1000 and 1300 °C.

Sulphur

By the pyrolysis process the extracted sulfur concentration rises between 700 - 750 °C, plateaus at about 850 °C and the steeply increases to about 80 % of the input sulphur. The largest content of chlorine in the mixture of waste comes from PVC and the content in the pyrolysis gas is not impacted by pyrolysis temperature.

Pyrolysis Wastewater

Pyrolysis wastewater consists of moisture from waste, decomposition water and the water from combustion: condensate, the liquid from scrubbing and the cooling water from the wet removal of solid residues. The contaminated wastewater contains a large amount of organics in particular: oils, tars, phenols, etc. Because the contaminants can only be partially decomposed in biological sewage treatment plants, a chemical/physical pre-treatment is recommend.

The water from wet removal of solid residues can extract soluble compounds (water-soluble calcium, chlorides, sulfates and organic compounds) to a limited degree.

Solid Residues

Studies of pyrolysis coke have showed that rising temperatures are associated with an increase in the water retention capacity resulting in delayed leaching of contaminants. The heavy metal leachate concentration rises as the treatment temperatures of the pyrolysis residues increases. Still, the low temperature pyrolysis (at 400 - 500 °C) can help to retain the heavy metals in the pyrolysis residue.

Organic Contaminants

By pyrolysis process of organic materials several hundred different polycyclic aromatic hydrocarbons (PAHs) come into existence. The PAH concentration in the solid residues of the Destrugas Process is several times higher than that of the Kiener Pyrolysis Process. This is caused by varying process temperatures and the effects of different pyrolysis reactors (vertical blast furnace without material turnover for the Destrugas process, and horizontal rotary kiln furnace for the Kiener Process). Studies prove that the PAH concentrations in MSW are much higher than in the solid residues of pyrolysis, i.e., pyrolysis reduces PAHs in the solid phase. Pyrolysis generates only small quantities of PCDD and PCDF as compared to incineration.

5.4.3 Hydrogenation and Hydrolysis

Hydrogenation is the reaction of certain substances with hydrogen under pressure and rising temperature. Hydrogenation is operated at temperature of 440 - 480 °C and at a pressure of about 300 bar and in presence of hydrogen. The input materials are carbon-containing waste such as coal, distillation residues from crude oil processing, waste oil, waste oil containing PCBs, spent activated carbon (containing solvent), spent paint thinner, and scrap plastics. Macromolecules are split into smaller molecules and are saturated with hydrogen. For example, polyolefines, polyamids, and aliphatic polymethanes are converted to gaseous and liquid hydrocarbon. The hydrogenation products then become raw materials for oil refineries. The heteroatom in the input material, such as oxygen, nitrogen, chlorine, and sulfur are separated and form water, ammonia, hydrochloric acid and hydrogen sulfides.

For example plastics will be first depolymerized in the proposed pretreatment facility. The waste plastic is melted and dissolved at a temperature of 400 °C. Under these conditions, the macromolecules are partially split. Vaccum reside oils from oil processing are used for slurry oil. The plastic and residual oil slurry along with additives and hydrogen is pumped by a high pressure pump or a compressor into the hydrogenation reactor. In a hot separator, the products of the first hydrogenation phase (liquid phase hydrogenation) are separated into a gaseous and a solid-liquid phase.

The solid-liquid phase is processed by vacuum distillation. The resulting vacuum gas oil flows back to the process and the still bottoms are added as a bonding agent to the coking coal for use in the coke oven.

The gas phase of the semi-solid phase hydrogenation is subjected to a second hydrogenation (gas phase hydrogenation). After a cold separation and a wash phase, the hydrogen is returned to the process. Hydrochloric acid is removed with the residue in the form of calcium and sodium chloride. The hydrocarbons and hydrogen sulfide are used in a refinery.

After the hydrogenation of scrap plastic a number of products are generated which have boiling points in the same range as gasoline components, and which are intermediate products for the synthesis of new plastics. This process hat proved for mixed plastics which are collected in Germany. On the other hand, Hydrolysis is a process which water reacts with a chemical compound to form two or more new substances whereby the original monomer materials from the scrap plastic are recovered. It is possible to crack all plastics such as polyamide, polyester, polycarbonate, and polyurethane which are produced by poly-condensation or poly-addition (polymerization). The breakdown of the plastics can be accomplished with water by the removal if possible cracking products from the batch reactor. After appropriate processing, the liquid or gaseous cleavage products can be made into high-grade plastics.

5.4.4 Drying Methods

Drying Methods are suitable for sludge drying. There are two main processes for drying: convection drying and contact drying.

In **convection drying**, the drying media (flue gases, superheated steam or vapor, or air) are in direct contact with the sludge and absorb water evaporating from sludge. In closed system operating with heated vapors a condenser the excess vapors. In open systems, the hot flue gases exit the dryer with the steam.

In **contact drying**, the heat energy is directly piped to the material that is to be dried. The sludge and the heat medium are separated by a pressurized water wall. The sludge is kept in direct contact with the wall by mechanical means, and the water in the sludge evaporates.

The choice of drying process is determined by the odor of sludge. For malodorous sludge, an indirect drying process such as fluidized bed drying with vapor circulation is to be recommendable. Odorless sludge can also be treated by convection in an open system. The gas emission must be cleaned in a wet or a dry scrubber.

Sewage Sludge Drying Processes

Drying processes can convert the fresh sludge into a storable and spreadable product. Drying processes demand on energy source: heating oil, natural gas, or biogas. The following types of Dryer are available for sewage sludge drying treatment:

1. Contact Dryer

- Thin film dryer
- Disc dryer
- Fluidized bed dryer

2. Convection drying

- Rotary cylinder dryer
- Suspension dryer
- Multi-floor dryer
- Belt dryer

The surfaces of contact dryer are heated by steam, hot water, or thermo-oil and transmit heat to the sludge, while the sludge is frequently turned. In comparison to Contact Dryer Convection Dryer are designed for high feed rates.

Film and Disc Dryer

The thin film dryer is arranged horizontally and takes advantage of the large surface area of a thinly spread layer. The thin film is made by a centrally mounted motor, which generates centrifugal force that overcomes gravity. The thin film is uniformly spread, with a thickness of a few millimeters to a few centimeters, along a pipe heated with saturated steam. The intensive contact with the heat wall evaporates the water, and the vapor leaves the dryer in the opposite direction of the material flow. In the different zones of the dryer the dryer's sludge consistency is changed and dry solid increase:

Zone A: The sludge is still able to flow, is pulpy, and can be spread on the heated wall.

Zone B: The sludge becomes doughy and viscous, and the rotor blade breaks up the moist layers into smaller pieces.

Zone C: The sludge dries on the surfaces and become crumbly, and the rotor blades turn the sludge and ensure an intensive contact with the heated wall.

Fluidized-bed dryer

Fluidized-bed drying permits the drying of the sewage sludge in one step to 95 % dry solids content. The Fluidized bed drying process can be modified depending on the sludge's origin and the required final use specifications.

Rotary Cylinder Dryer

Rotary Cylinder Dryers are often used in sewage sludge drying. The slightly inclines cylindrical steel drum rotates slowly, and a trickling device turn over the sludge constantly. The hot gases flow at end of the cylinder and the drying occurs in the direction of flow which prevents the ignition of the sludge. For the rotary cylinder dryer, the resulting dry solids content can reach 80-90 %.

Suspension Dryer

The input material must be dewatered to 25 - 30 % dry solids content. Sludge of pulpy and flowable consistency is pumped by an eccentric screw pump into the fluidized sand bed of the dryer. In this fluidized bed, the sludge is reduced in size, dispersed and dried at a temperature of 150 °C. The dry solids can be used alternatively as fuel in a solid fuel burner or are recovered for external use.

Multi-Floor Dryer

The multi-floor dryers are always used in combination with multi-hearth incinerator for the incineration o f sewage sludge.

Belt Dryer

For small quantities of sewage sludge, a belt dryer is recommended. This drying processes one step process. Pre-dewatered sewage sludge is heaped on the perforated belt and hot gases pass through the belt from below. The drying takes place at temperatures between 80 and 150°C and can operate with little or no generation of exhaust.

Example of Sludge Drying Process

The decomposed sludge is first dewatered on a screen belt press whereby the dry solids content can reach 25 - 37 %. The gas which is produced in the decomposition process is used to generate hot gas for the drying process and to generate electricity. So the sludge is dried by burning the biogas. The water in sludge is vaporized and the granulated material with a dry solid content of 90-95% forms in a cyclone. Before the granulated sludge is combusted in a dual fuel burner, it is reduced in size in hammer mill to a particle size of 70 - 90 mm. The resulting sewage sludge ach can be mixed other material and used as construction material for example in road construction.

5.4.5 Hazardous Waste Incinerators

The hazardous waste treatment facility normally consists of:

- An inspection area
- Temporary storage
- Treatment plant
- Processing of waste for recovery, and a
- Thermal plant

The inspection area includes scalehouse, registration, data collection, and a laboratory. For temporary storage a staging area is available, as are tanks, barrels, and solid waste storage facilities.

5.4.5.1 Storage, Pretreatment, and Charging

Hazardous wastes are delivered and stored in containers and barrels of varying shapes and sizes. Hazardous waste that can not be incinerated because of its physical, chemical, or toxicological properties must be pre-treated before it is fed into the incinerator. (e.g.: chemical/physical treatment for detoxification, neutralization, sludge treatment, emulsion separation, solidification, or evaporation). For the trouble-free incineration, it is also important to avoid large fluctuations in heat values.

5.4.5.2 Incinerator Furnaces

Hazardous waste should be incinerated in grateless systems. The major types of grateless incineration systems are:

- Rotary kiln furnace
- Multi-hearth furnace
- Fluidized bed furnace, and
- Combustion chamber

Rotary kiln furnace

Because of high operating temperatures, the long residence time, and the universal firing system, the Rotary kiln furnace is the predominant type of furnace for the incineration of hazardous waste. The following industrial wastes can be treated in Rotary kiln furnace equipped with after-burners:

- Liquid substances, such as solvents
- Pumpable material, such as sludge
- Pasty material, and
- Solid and compound materials that melt below their flash points

Liquid waste is injected above a water-cooled burner at the front end of the rotary kiln, using the pipe pressure. Doughy and pasty wastes are directly injected through water-cooled nozzles from the storage container into a rotary kiln using a double piston pump. The waste is fed first into an antechamber that is secured by a gate, and then into the feed hopper. Solid waste is fed in the hopper by crane. The feed hopper then feeds the material into the rotary kiln.

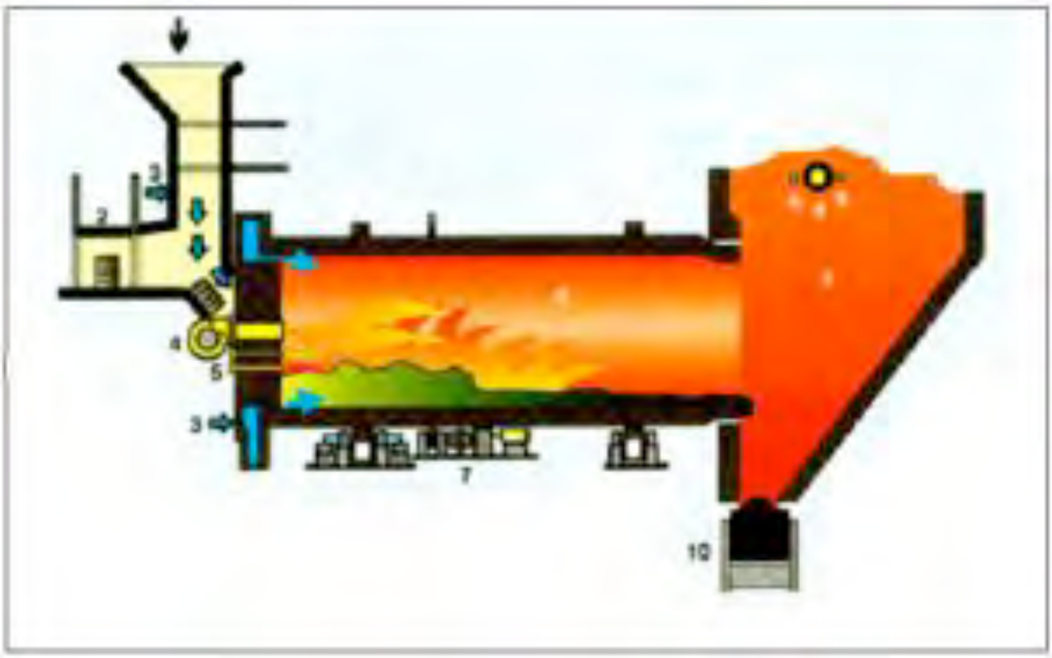


Figure 5.4-11: Principle of a rotary kiln

Figure 5.4-12 (left): Inside the rotary kiln

Figure 5.4-13 (right): Rotary Kiln

Multi-hearth Furnace

Industrial waste with very high water content is also incinerated in this type of furnace. However, this incinerator is rarely used for treatment of hazardous waste.

Fluidized bed furnace

Fluidized bed furnace is used to incinerate homogenous liquid, pasty, and gaseous wastes. On the bottom, is the fluidized bed above a grate (air inflow surface). The high heat transfer and material conversion results in the same specific combustion efficiency as in a thrust chamber.

Combustion chamber

This type is the preferred type for the incineration of gaseous and liquid industrial wastes because the combustion chamber is a cylinder into which the waste and the combustion air are injected. Liquid and gaseous industrial residues are co-incinerated with auxiliary fuel in the reaction chamber. Almost the entire energy is released in this part. Depending on the requirements, the combustion can work with excess oxygen or in an oxygen deficient environment. The hot flue gases from the reaction chamber can be mixed with additional oxygen in the reaction chamber through a nozzle, if necessary, and are completely incinerated.

5.4.6 Incineration of other Waste

5.4.6.1 Incineration of Sewage Sludge

Recently planned MSW incinerators often include sewage sludge incineration. Two methods are followed:

- The incineration of Sewage sludge in MSW incinerators, and
- The incineration of sewage in a separate incinerator

The co-firing of MSW and sewage sludge is recommended for following reasons:

- Using the energy content of waste combustion to dry the sewage sludge
- No requirement of preprocessing in either a multi-hearth furnace or a rotary kiln furnace

For Sewage sludge incinerations in the multi-hearth furnaces and in fluidized-bed incinerators are recommended. For incineration in a multi-hearth furnace, sewage sludge with a high water content first travels through a drying zone at temperatures blow 100 °C, before it is simply incinerated or incinerated with coal. Sewage sludge is primarily incinerated in fluidized-bed incinerators. The low heat value of sewage sludge requires the co-firing of tree bark. The ash from the fluidized-bed can be screened and returned to the fluid bed module

5.4.6.2 Incineration of Straw and Wood

Straw can be incinerated in a straw incinerator. Since straw is free of pollutants, there are hardly any harmful emissions during the process, except for incompletely oxidized gases, such as CO, from incompletely combustion. So some straw incinerators are equipped with afterburner. The associated fly ash emissions can be minimized by using more sophisticated firing system and by processing the straw into briquettes or pellets.

Incineration of wood for energy production purpose is a sensible alternative only if other form of recovery is impossible. There are two principles governing the incineration of wood:

- Completely incineration in the combustion chamber
- Pyrolyzation first and the gases are incinerated afterwards

Aside from fly ash, residues are also produced and must be disposed of according their contaminant levels.

☑ Self-assessment

- What are the advantages of thermal waste treatment?
- Which kinds of thermal waste treatment are established and for what types of waste are they used for?
- Which types of firing systems are used?
- Which processes go on during the combustion of waste with a grate-firing system?
- Is it possible to clean the exhaust gases?
- What is a fluidized-bed incinerator?
- How can hazardous wastes be treated?
- What is gasification of waste?
- When will it be useful to dry the waste?

5.5 Biological Waste Treatment

Educational objective of the chapter

- Different process parameters at composting
- Different substrates and their degradation potential
- Design of composting facilities; different processes
- Utilisation and Quality of composting products
- All relevant facts about fermentation

Biological waste treatment based on the decomposition of organic material by various microorganisms. At composting the decomposition occurs with aeration, whereas at fermentation without aeration. Both methods end in a reduction of organic substances.

5.5.1 Composting

Waste which shall be composted has to be predominantly assembled of organic material and must have minor contaminant concentrations. The most important compostable wastes include [Bilitewski et al., 1997]:

- Biowaste
- Yard and park wast
- Household-like commercial waste, kitchen waste
- Sewage sludge
- Organic waste residue of the food and non-essential foods industry

5.5.1.1 Process parameters

Lots of parameters have an influence on composting process. Their relation fixes the volume of decomposition by organic matter and the microbial activity, which is reflective of the gas exchange and the thermic activity. These factors that are also used in a controlling system of degradation should be described in the following.

Water content

Optimal water content is very important for the process of degradation. Microorganisms, which decompose the organic matter, need an aqueous solution to absorb nutrients. That is why a composting requests a sufficient amount of water. To achieve the optimum quantity of water content and the essential oxygen supply, the pore structure of the material gives information about this. Especially organic matters with a high absorbency, stability and a big air pore volume (for example paper) achieve large water content. Values from 45 % to 65 % are optimal for a biowaste composting. The microbial activity will be reduced by < 25 % or rather stopped by < 10 % water content.

Aeration

The aeration has to achieve different features on a composting:

a) to supply the microorganisms with oxygen
b) to dehydrate the degradation matter
c) to avoid a heat accumulation and thereby a deactivation of the microorganisms (depend on a substrate), in order to delimit the nitrate discharge
d) to conduct the carbon dioxide to keep up the microbial activity

Oxygen Requirements

The rate of oxygen, which is necessary to decompose the organic matter, has to be calculating in a stoichiometric way. For this you need the chemical structure of the basic material. Depend on this for the decomposition will be expected ca. 2 g oxygen per g reduced organic matter. The development from carbon dioxide und the consumption of oxygen, based of the molecular mass (coefficient of respiration), dependent on the basic material and the current situation of degradation. A rising coefficient of respiration is an indication of anaerobic process, a reduce value is a sign for an increasing aerobic development.
The requirement of oxygen depends on the temperature, the water content and the situation of nutrient (see below). For an efficient microbial activity is a concentration about 10 % of oxygen necessary. When the maximum rate of consumption will be cover by aeration then the oxygen requirements aggregates from 0,8 to 2,0 g O_2/g OS*h.

Air Pore Volume

Solid matter, water content and gas form the 3-phases-system in degradation. Water content and gas is called air pore volume because of solid matter free volume. An Air pore volume of about 30 to 50 % is ideal for degradation. Is the air pore volume higher than 70%, a reduction of biological activity as a result of missing water is the consequence, under 20% the adequate oxygen supply is not warranted. Often anerobic zones were formed.

pH-Value

The activity of microorganisms and therewith degradation intensity is influenced by pH-value of the feedstock. PH-values in an alkaline range up to 11 benefits the degradation intensity. On the other hand ph-values under 7 effect a slowdown of microbiological activity.

Type of substrate

If organic matter has to be composted, it shall be used biologically. This organic matter comprises mineral and organic fraction as well as water. The organic substances are used by aerobic microrganisms as energy source. Mineral substances are playing a secondarily role at the degradation process. Water is very important for transporting the nutrients and to supply microorganisms with oxygen. The reachable degree of degradation for different kind of substrates is shown in Table 5.5-1.

Table 5.5-1: Reachable degree of degradation for different substrates [Bidlingmaier, 2000]

Substrate	Reachable degree of degradation (%)
Natural products	
Cellulose – chemical conditioned	90
Cellulose – mechanical conditioned	50
Hemicellulose	70
Carbohydrate	70
Lignin	0
Lipid	40-50
Wax	70
Protein	50
Plants	
Scion (grassland)	60,7
Roots (grassland)	45,5
Wood (conifer)	37,5
Needle (conifer)	46,0
Wood (broad-leaves tree)	43,0
Leaves (broad-leaves tree)	51,0
Foodstuff	
Apple	65,3
Carrot	57,1
Potatoes	63,4

C/N – ratio

The C/N-rate has an influence on the degradation process. The highest degradation rates can be achieved with a C/N-rate about 1:20 up to 1:25. If the C/N-rate is not in optimal range, the degradation time will be extended and die degradation rate will be reduced. But there is no blocking of microorganisms activity.

Temperature
The temperature has an effect on the composting process, but it is also used to control it. The temperature shows the current decomposition as well, due to the fact that with increasing decomposition of organic material chemical energy will be decrease. At different temperature ranges, different microorganisms can be found (optimum value) [Bidlingmaier, 2000] (Figure 5.5-1):

- physchrophile : 15-20°C
- mesophile: 25-35 °C
- thermophile: 50-70 °C.

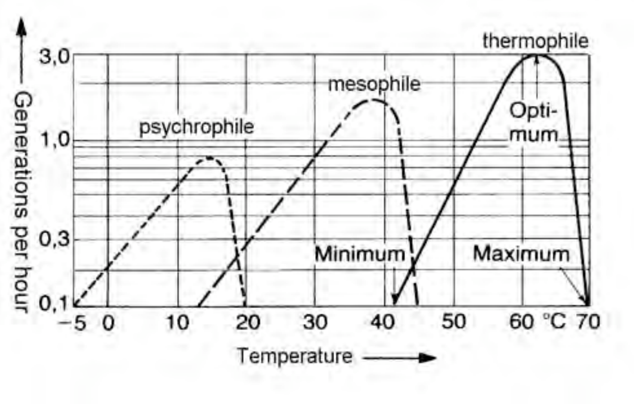


Figure 5.5-1: Temperature ranges for rate of growth and split range of microorganisms [Emberger, 1993]

During the degradation process there are three different phases inside a compost pile (Figure 5.5-2):

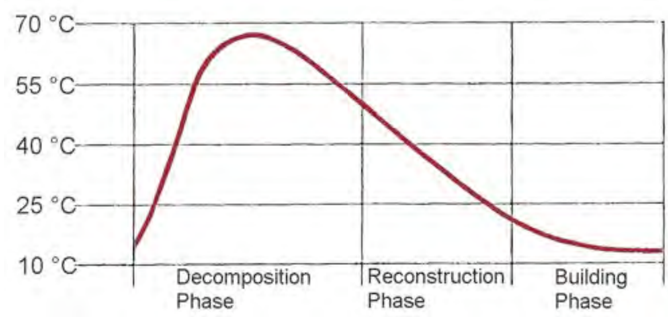


Figure 5.5-2: Curve of typical temperature inside a compost pile [nach Bidlingmaier, 2000]

- Initial and decomposition phase:
  Under optimum conditions these phase is finished after 24 hours. A strong development of the mesophile microorganisms is characteristic. There is an explicit increase in temperature concerning of high activity. If the temperature rises above 45°C, the thermophile microorganisms are overbalanced (Figure 5.5-1). From about 65-70°C there will be an deactivation of microorganisms and the temperature decrease.
- In the Reconstruction phase there is a renew increase in the number of mesophile microorganisms due to decreasing temperatures. Both, decomposition and reconstruction phase are realised in intensive degradation systems.
- Building phase
  The building phase with advanced degradation process is realized in Curing.

Emissionen

Emissions of composting facilities are leachate, dust and odour nuisance.

Liquide Emissions include the leachate from the composting matter and high contaminated rainwater. However the leachate is less than at compacted landfills. Characteristic for leachate is the high level of organic contaminant and salt concentration. It has to be treated or returned to the composting process.

All composting processes produces dust emissions. They can be minimized by collecting excess dust from the degradation bunker and buildings. An other possibility are dust-free windrow turnings.

The odour nuisance can be caused by feedstocks or transformation products. A distinction is drawn between biogenic (H_2S, organic acids, aldehydes, etc.) and abiogenic (caused by chemical transformation products during the hot decompositon) odorous substances. Emission sources are storage areas, areas of intensive decomposition and where windrows are turned. An odour abatement may be achieved by incineration of exhaust air, absorption with activated carbon or in liquid phase with following oxidation or soil filtration.

Basically the environmental impacts of composting facilities are less than other waste disposal facilities.

5.5.1.2 Design of composting facilities

The process model of composting facilities based on typical plant components (Figure 5.5-3).

<u>Conditioning of coarse input material</u>:
The material will be crushed and seperated from contraries.

<u>Degradation / Decomposition unit</u>:
Different types of process are available depending on operational capacity of the biowaste unit (see Static operations / processes and Dynamic operations / processes).

<u>Conditioning of finest output material</u>:
It is neccessary because of seperating the material from the remaining contraries.

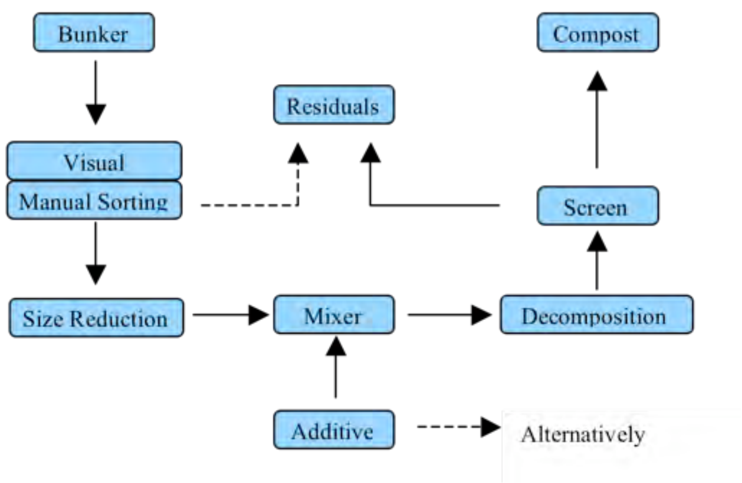


Figure 5.5-3: Process modell of the basic elements of a composting facility [according to Bilitewski et al., 1997]

At first there are waste receiving, storage (bunkers) and proportioning in the process chain of biowaste composting. After that, the main biowaste processing starts with a visual inspection. By the **visual inspection** major waste elements, which interruped the operating procedure, should be achieved to separate. Because of health contamination by odours and germs, a manual sorting is not recommended. 98% of all contraries are found in **screening** fractions with diameters of >60 mm. Screen types are round or flat screens with round, square, rectangular or diamond-shaped holes. The elimination of ferrous components can be achieved by drum magnets, overhead magnets and roller magnets with an electric or permanent magnetc field. They can be adapted to the operating conditions because of their flexibility in operation, design and configuration. **Size reduction** serves to increase the specific surface of biowaste elements. In this way the biowaste will be decomposed for microbial degradation and the absorption of water will be improved. For biowaste composting, mixers can be used for efficient mixing when bulking material is processed. By using a dynamic initial biodegradation system, the bulking material will be added to the rotary drum directly [Bilitewski et al., 1997].

5.5.1.3 Static operations / processes

in this method the organic material is unmoved, the aeration is forced or naturally. Most important static operations are windrow composting, brikollare process, in-vessel composting. The oldest operation is windrow composting.
The aerobic composting process is exothermal, so the temprature increase up to a significant point and it is used as an indicator for the composting progress (see Process parameters).
Main problem is the sufficient oxygen supply of organic material. It is only warranted if the windrow is low enough. Therefore higher windrows normally are turned or systematically aerated. The degration time depends on aeration and turning:

- with turning: 9 to 12 weeks
- without turning and with forced aeration: 12 to 16 weeks
- without turning and without forced aeration: 20 to 25 weeks

Brikollare process is a spezial form of windrow composting. It works with small briquettes of biowaste and green matter. It ist he only short process which gurantees a completely disinfection of the organic material. Therefore it can be used without curing.

5.5.1.4 Dynamic operations / processes

Dynamic degradation reactors are performed as towers (with or without floors) or drums. The feedstock is guided vertical and horizontal through the reactors (dynamic degradation) with continuously turning and aeration. By the closed system the maximum temperature will be achieved quick and the Initial Biodegradation System can be reduced onto 1-2 days. Compared to static bioinitial processes, the dynamic degradation processes are time-savers, but relating to the overall time of degradation, there is no significant time saving and the procedural effort is high.

5.5.1.5 Mass balance

The mass balance of biowaste composting plant with conditioning of coarse input material, decomposition unit and conditioning of finest output material is shown exemplarily in Figure 5.5-4.

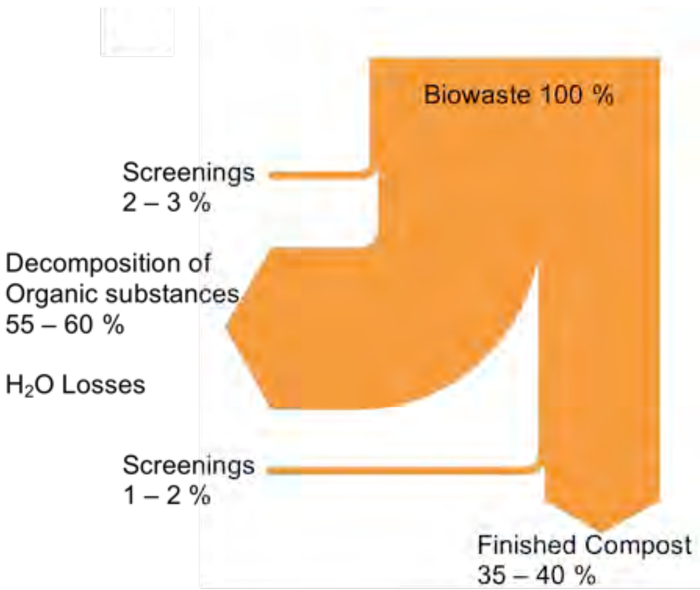


Figure 5.5-4: Mass balance of biowaste composting process [according to Bilitewski et al., 1997]

The mass balance is affected by [Bidlingmaier, 2000]:

- Input material (water content, content of organic substance and extraneous material)
- Technics at conditioning of coarse and finest material (crushing, extraction of extraneous material)
- Decomposition guidance (degradation of organic matter, water supply and discharge)

The essential mass reduction results from decomposition losses at about 60 % of the feedstock (water: 40-45%). The degradation of organic matter with 50-60% leads to mass reduction about 15% (mostly water and CO_2). Residues from the sorting, visual inspection and Fe-deposit are in a range of about 5%. Circa 10 to 15% of the feedstock can be returned as bulking material to the system. Finally remain about fourth to one third of the feedstock as finished compost for utilisation.

Utilisation and Quality
There is a wide range of application for fresh or finished compost, e.g. in the following fields [Bank, 2007]:

- Fertilizer in agriculture
- Erosion protection and land improvement in gardening and landscaping
- As a component for substrate production
- As a component for substrate for recultivation and in landscaping

A problem is substitution of compost with peat. The soil improvement properties of compost are much better. There are only little main nutrients or micronutrients and in addition using peat results in acidification of soil. Secondary the digging of peat destroys more and more of useful and worth protecting biotopes.

Compost has many beneficial qualities:

- High level of organic substances
- High level of nutrients N, P, K, Ca and Mg
- Increasing of humus content and erosion resistance
- Increasing of soil living organisms
- Improvement of soil structure, thermal, water and nutrients balance
- Increasing of ability to retain water and reduces desiccation (sandy soils)
- Enhance soil porosity → Increasing of air and water movement → Reducing surface erosion (Heavy or loamy soil)

Table 5.5-2: Quality aspects and different kinds of compost [Bilitewski, 1997]:

Aspects	Requirements
Physical	free of visible plastic, solid or glass particles (risk of injury of the compost user)
Chemical	Elimination of any potential for damage to plants. Elimination of any potentially negative effects on the consumers of farm products. (This demand can be met only by careful selection of suitable raw materials)
Biological	Sanitization and its stage of decomposition
Fresh compost	Decontaminated but not sufficiently decomposed to be compatible with plant roots (due to the presence of decomposing organisms). It contains a high level of organic substances. For fresh compost a C/N ratio of 25-30 to 1 is required. (see Process parameters)
Finished compost	Derived from fresh compost by curing up to beeing compatible with plant roots. The C/N ratio should be below 25:1 to 30:1 (about 15:1).

5.5.1.6 Benefits

The composting process as a natural waste treatment process results in al volume reduction and has a lot of other benefits. The composting product improves the soil structure, can be used as fertilizer and the process is very simple and sost efficient.. Some advantages have been listed in Table 5.5-3.

Table 5.5-3: Benefits of composting process

Area	Benefits
Waste treatment	• natural waste treatment process • reduces disposed waste volume and weight to be landfilled
Environmental	• Improvement of the soil structure • Fertilizer • Volume reduction
Other benefits	• cost-efficient • decentralised applicable • flexible process for a wide range of substrates • no / low service • simple incomplex application

5.5.2 Fermentation

The following informations have been researched and documented during the Projekt „BiWaRe - Biomass and Waste from Renewable Energy“ (ASEAN-EU University Network Programme - ASE/B7-301/1997/0178-06). The following description is extracted from the handbook.

Biogas

Biogas is a gas mixture of 50-75% methane, which is generated by anaerobic, microbial degradation of organic substrates (anaerobic digestion, fermentation). Besides the valuable component methane, other constituents are 25-45 carbon dioxide (CO_2), as well as traces of hydrogen sulfide (H_2S), Nitrogen (N_2) and carbon monoxide (CO) (Table 5.5-1).

Table 5.5-1: Average composition of biogas [Kaltschmitt, Hartmann, 2001]

Component	Concentration
Methane (CH_4)	50-75 Vol.-%
Carbon dioxide (CO_2)	25-45 Vol.-%
Water (H_20)	2-7 Vol.-% (20-40 °C)
Sulfide hydrogen (H_2S)	20-20.000 ppm
Nitrogen (N_2)	< 2 Vol.-%
Oxygen (O_2)	< 2 Vol.-%
Hydrogen (H_2)	< 1 Vol.-%

Biogas can be used for electricity and heat generation. The energy content directly depends on the methane content. One m3 methane has an energy content of ca. 10 kWh. Therefore the energy content of to typical biogas (60% methane) lies in the range of 6 kWh. The average energy content of one m3 biogas is equivalent to 0,6 l fuel oil.

The biological methane generation is a process, which occurs in nature, where wet organic material is available and free oxygen is absent, e.g. in the digestive tract of cows, wet composting plants, landfills or flooded paddy fields.

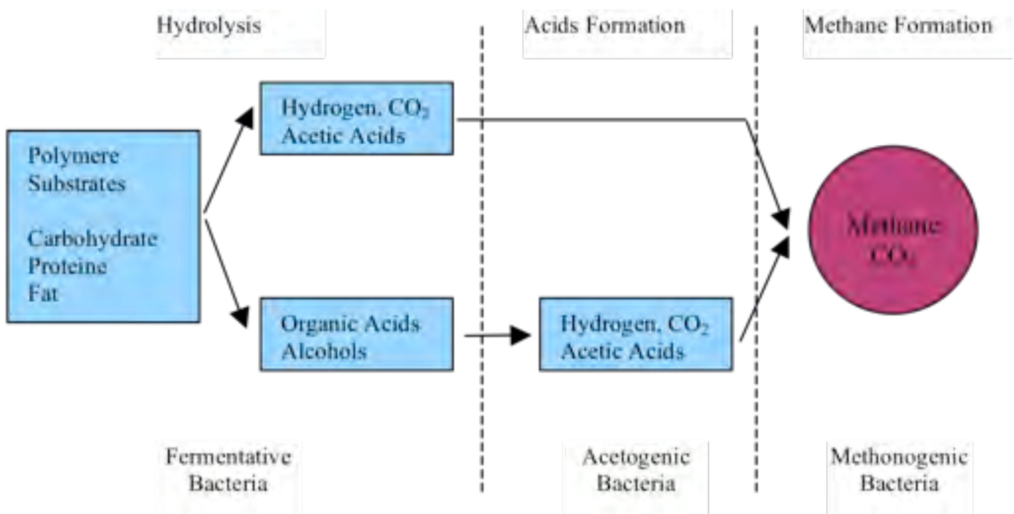


Figure 5.5-5: The phases of methane production – schematic diagram

Basic principle of anaerobic metabolism

Knowledge of the fundamental processes involved in methane fermentation is necessary for planning, building and operating biogas plants. Methane bacteria are obligate anaerobic, i.e. they are only active under oxygen free conditions. Under these conditions, the energy generation represents only 1/7 of the aerobic bacteria[39]. Therefore anaerobic bacterial have a longer growth rate, respectively. Their metabolism depends on the preparatory steps and symbiosis with other bacteria. The upper figure (Figure 5.5-5) shows the different phases of the methanogenesis, involving three different bacterial communities.

The biogas process consists of three phases:

- **1. Hydrolysis:**
  In the first phase, high molecular compounds like carbohydrates, fats and proteins are degraded into simpler compounds (monomere, like aminoacids, glucose, fatty acids) and solved in water.

- **2. Acidification:**
  Acid-producing bacteria convert the solved compounds to organic acids (butyric acid, and propionic acid), alcohol, hydrogen and carbon dioxide.

- **3. Acetogenic phase and methane formation:**
  In the acetogenic phase are the compounds converted into acetic acids. The methane formation is carried out by methane bacteria, which only can utilise C-1 and C-2 compounds.

  Methane- and acetogenic bacteria act in a symbiotical way. The latter creates and atmosphere with ideal parameters for methane producing bacteria (anaerobic conditions, compounds with a low molecular weight), the former us the intermediates of the acid-producing bacteria. Without consuming them, acid would accumulate, resulting in toxic conditions for acid-producing bacteria.

In nature as well as in biogas plants, the metabolic actions of the different bacteria act in concert.

5.5.2.1 Parameters and process optimisation

Overall, the methane yield depends on many factors, which relate to the substrate, the pre-treatment or conditions of the substrate and the fermentation process (Figure 5.5-6).

[39] Bilitewski et al., 1994

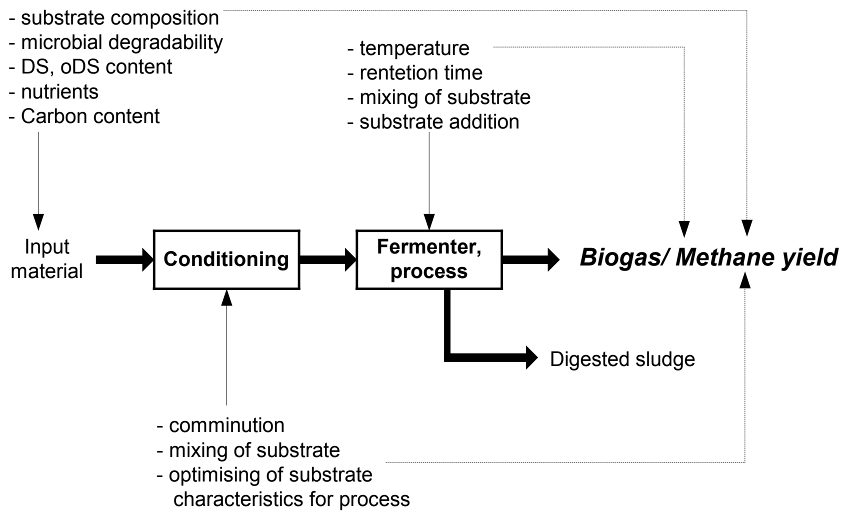


Figure 5.5-6: Factors that influence the biogas and methane yield [Weiland, 2001].

5.5.2.2 Substrate requirements

Substrates used for biogas production often are residues, by-products or residuals from agricultural, commercial and industrial activities, and also from households. See Table 5.5-2 for examples for typical substrates and possible methane yields, or tool 1 for a comprehensive list of suitable substrates and their characteristics.

Table 5.5-2: Typical substrates and biogas yield

	Methane yield [CH_4 m^3/kg o DS]
cattle manure	0,1-0,35
pig manure	0,18-0,64
Maize silage	0,22-0,5
Grass silage	0,3-0,6
Food waste	0,3-0,6
Sewage sludge	0,19-0,44

The quantity of biogas and methane produced mainly depends on the composition of the substrate. In practice it is often not possible to calculate the methane yield, as the composition not known and the degradation is not complete. Table 5.5-3 shows the theoretical, specific biogas yield. The different methane concentrations result from the differences of the relative carbon ratio.

Table 5.5-3: Specific biogas yield and methane concentration

	Biogas yield [l/kg oTS]	**Methane content [Vol.-%]**
Digestable proteine	600-700	70-75
Digestable fat	1.000-1.250	68-73
Digestable carbohydrates	700-800	50-55

Degradability
Suitable substrates for biogas production are basically all kinds of organic matters and biomass containing carbohydrates, proteins, fats, cellulose or hemicellulose. Generally, easy degradable substrates with low molecular compounds, e.g. wet organic kitchen waste, can be degraded quicker and more complete. In contrast to this, wooden substrates, containing a lot of lignin, are not suitable.

Inhibiting substances
Inhibiting substances can be toxic to the bacteria involved in anaerobic digestion, so that the processes can be reduced or stopped. Antibiotics or disinfectants in household waste can have these effects. Also, heavy metals or salts from certain concentrations act toxic.

Nutrients

The substrate must contain certain concentrations of nutrients, a certain carbon/nitrogen ratio, as well as trace elements for the bacteria to grow. The demand for nutrients can be estimated according to composition of the micro-organisms (Table 5.5-4). The optimisation of the nutrient supply must be carried out on an empirical basis, considering the mechanical, chemical and physical framework conditions.

Table 5.5-4: Typical Constitution Of Biomass (Bidlingmaier, 1985)

Component	Bacteria		Yeasts		Molds	
	Average	Range	Average	Range	Averge	Range
Organic Constituents (% dry wt)						
Carbon	48	46 - 52	48	46 - 52	48	45 - 55
Nitrogen	12,5	10 - 14	7,5	6 - 8,5	6	4 - 7
Oxygen		22 - 28				
Hydrogen		5 - 7				
Protein	55	50 - 60	40	35 - 45	32	25 - 40
Carbohydrate	9	6 - 15	38	30 - 45	49	40 - 55
Lipid	7	5 - 10	8	5 - 10	8	5 - 10
Nucleic acid	23[a]	15 - 25	8	5 - 10	5	2 - 8
Ash	6	4 - 10	6	4 - 10	6	4 - 10
	Bacteria		Fungi		Yeast	
Inorganic Constituents (g/100 g dry wt)						
Phosphorus	2.0	to 3.0	0.4	to 4.5	0.8	to 2.6
Sulfur	0.2	to 1.0	0.1	to 0.5	0.01	to 0.24
Potassium	1.0	to 4.5	0.2	to 2.5	1.0	to 4.0
Magnesium	0.1	to 0.5	0.1	to 0.3	0.1	to 0.5
Sodium	0.5	to 1.0	0.02	to 0.5	0.01	to 0.1
Calcium	0.01	to 1.1	0.1	to 1.4	0.1	to 0.3
Iron	0.02	to 0.2	0.1	to 0.2	0.01	to 0.5
Copper	0.01	to 0.02			0.002	to 0.01
Manganese	0.001	to 0.01			0.0005	to 0.007
Molybdenum					0.0001	to 0.0002
Total ash	7 to 12		2 to 8		5 to 10	

[a]Values this high are observed only with rapidly growing cells

5.5.2.3 Process parameters

A number of parameters have an influence on anaerobic digestion and can be adjusted in technical processes, to optimise the gas production, methane yield, the degradability (desintegration) of substrates, the hygienic situation, and fertilising qualities of the residual digested matter.

Temperature

The temperature is a major factor for the activity of bacterial communities. Three ranges of temperature can be distinguished:

- psychrophile : around 10°C
- mesophile: 32-50 °C
- thermophile: 50-70 °C.

Generally a thermophilic process results in an quicker metabolism and degradation. It is often preferred if the substrate contains high levels of fat, or if pathogenic micro-organisms shall be destroyed. However most biogas plants are operated under mesophilic conditions as the process is biologically more stable and less costs for energy are involved [Bilitewski, 1994]. Generally biogas plants can be operated on all temperature levels within 30-55°C.

pH-Value

The pH-value plays an important role for all microbial processes. The optimum pH-value for the methanogenesis lies in the range of 6,8- 7,5. In contrast to this, the pH-value of the previous phases (Hyrolysis and acidformation) lie in the range of 4,5-6,3 [FNR, 2004]. PH-values which are too low should be prevented as they have an inhibitory effect on the micro-organisms of the methanogenesis.

Retention time

The duration depends on the temperature, the capacity of the digestion-tank, the concentration of substrate in the reactor, the concentration of active biomass and the desired degree of degradation. The duration period can vary from a few hours (waste water clarification technology) to up to 2 months (agricultural biogas plant).

The above mentioned, slow bacteria growth creates the problem that in order to shorten the duration period the active biomass must be retained or enriched. This can be achieved by immobilising the carrying materials in a solid or whirl bed or by adding sludge or processing water. The addition of inert solid fillers or inert particles, which through adhesion can retain the bacteria, is only possible in waste water clarification. This is because by the addition of solids or sludge type waste, the solid bed can become blocked or the carrying materials in the whirl bed process also be transported out. In fermentation of clarification sludge, waste or agricultural substrates, with normal duration periods of between 15 and 60 days, continual injection or enriching of micro-organisms of the fermentation suspension is not necessary. All known continual processes do not need additional injection after the start up phase. Special types of micro-organisms are not required.

5.5.2.4 Technical application

Development of anaerobic processing technology comes traditionally from wastewater clarification. In reactors suitable for wastewater treatment, industrial organic waste, wet and bio-waste can lead to deposits, blockages and build-up of sediment and floating layers. Therefore this had lead to the development of two principle solutions which are suitable for other substrates than wastewater:

- Dry fermentation
- Wet fermentation.

With dry fermentation the substrate is fermented to a dry substance content of up to 65%, whilst with wet fermentation it is mashed with water into sludge of approx. 5% to 12 % dry substance content. In two stage wet fermentation the solid substance goes through a hydrolysing stage in which a large part of the organic substance is dissolved in water. This is then treated in a normal anaerobic reactor as is used in waste water clarification. With dry fermentation the advantages of having a lower water requirement and a higher sludge-digestion tank load can be expected. Wet fermentation promises fewer problems in the handling of a homogenous sludge, a possible separation of floating or sinking substances at the liquefying stage and sludge reduction. In two phase wet fermentation it is hoped that higher capacities can be reached by having the possibility to attain optimum conditions for the separate phases and the use of high capacity reactors as used in waste water clarification plants. The biogas generated is of higher value with higher methane content as it is mostly rejected in the carbon dioxide generated in hydrolyses. The specific biogas yield in dry and wet fermentation plants varies depending on the duration period, tank capacity etc. In principle, the same level of specific biogas yields can be reached from a substrate in both dry and wet fermentation plants. Dry fermentation plants can be made very resistant to interfering materials depending on how they are technically equipped.

Substrate handling and storage of biogas substrates is done similar to substrates used for biomass combustion (compare Chapter 3.2.1.3, 3.2.1.4). The storage and transport of liquid substrates are done using agricultural equipment and machines.

In Chapter 8, a number of existing biogas plants for different substrate characteristics, process temperature, etc. (Table 5.5-5) are presented as an example.

Table 5.5-5: Features of different types of biogas plants for solid and sludge-like substrates [Institut für Energetik gGmbH, quoted in BMU, 2003]

Criterion	Features
TS-content of substrate	• Dry fermentation (TS from 15 to 65%) • Wet fermentation (TS up to 15%) • Anaerobic wastewater treatment (for wastewater)
Type and source of substrate	• Agricultural mono-fermentation plants (manure fementatio) or Co-fermentation plants (manure plus additional substates) • Biowaste fermentation plants • wastewater
Temperature of process	• Psychrophile (below 20°C) • Mesophile (25 to 43°C) • Thermophile (below 55°C)
Charging clearance	• batch • Intermittent • Semi- or quasi continuous
Method implementation	• Single-stage - All degradation stages simultaneous • Two-stage - Separation of hydrolysis • Multi-stage - Separation of hydrolysis and formation of acid
Principle of mixture	• Mechanical - Propeller agitator • Hydraulic - Pumps • Pneumatic - Gas injection

5.5.2.5 Biogas utilisation

Biogas processing

For the utilisation of biogas in unit power stations, heating boilers etc, it must be treated to varying degrees depending on the energy utilisation system. During the anaerobic microbial transformation processes in a biogas plant, the existing various forms of sulphur (sulphate, organic sulphur compounds etc) will be converted to sulfide (S_{2-}). The sulfide will then be as hydrogen sulfide (H_2S) in the biogas. During the oxidating of biogas in a unit power station, heating boiler or other energy conversion plant, H2S is converted into SO_4^{2-}. In the form of sulfuric acid (eg. in exhaust gas heat exchanger in a unit power station) can lead to significant corrosion problems in the condensation zones. The removal of H_2S from the biogas can be achieved through biological or chemical purification.

Chemical de-sulphuring is generally carried out by precipitation of H_2S to bog iron ore (as FeS) or gas purification with sodium hydroxide.
In biological treatment, which can take place in the fermenter head itself or in a connecting reactor (gas purifier), the biogas is supplemented with oxygen (O_2). On the surfaces in the fermenter or in external reactors, micro-organisms will grow which can oxidise H_2S, S and $S_2O_3^{2-}$ to SO_4^{2-}. H_2S is

removed from the gas phase (biogas). A significant decrease in pH values on the H_2S oxidising micro-organism growing surfaces will result, and so these should be regenerated from time to time.

If silicon compounds are added (eg. those used as de-foamers in some lemonade) in the fermentation process, Silan (SiH_4) will be generated by the biological conversion. Silan is gaseous similar to methane. On burning of biogas containing silan, for example in unit power stations, silicone oxide (silica sand) will be generated. This will lead to significant damage in the internal combustion engine. It is assumed that silan causes approx. 50% of damage to unit power stations in German waste water purification plants converting biogas from sludge digestion. Silan can be removed from biogas using various different methods. A process most generally used in biogas plants is adsorption on activated carbon.

In a fermenter the relative humidity of biogas is 100%. The biogas humidity must be reduced in order to protect the e.g.unit power stations from high wear and damage. This can be brought about for example by installing a pipeline system between the fermenter and the unit power station (heating boiler etc.). On installing the pipeline it must be ensured that any condensation created in the pipeline can be drained off into condensation collectors and that no pools of condensation can result from lower points in the pipeline caused by settling for example. If the pipeline system is not long enough or the outside temperature is too high for part condensation of the water vapour in the biogas, then external cooling (air conditioning system, water cooling with ground water or cold surface water etc.) must be used to reduce the relative humidity of the biogas.

Depending on the quality of the biogas and its proposed use further specific treatment processes may be necessary. To feed biogas into the natural gas grid, its methane content must be increased. As this and other similar processes are not yet economic and are only individually applied, they do not require to be further discussed here. If required, refer to current specialist literature.

Biogas utilisation

Utilisation of biogas generally takes place in heating boilers (heat utilisation) or in unit power stations. This will briefly be discussed in the following. Other innovative processes for the conversion of biogas into energy using fuel cells, gas turbines, steam engines, organic rankine plants or stirling engines are generally not yet economic and will not be further discussed here.
In the conversion of biogas in heater power stations, depending on the type and size of the plant, electricity will be generated with an output of 30 to 40 %. In partial load areas the output is decreased. The rest of the energy is precipitated in the form of heat. Heat in the form of hot water can in be absorbed and used at a temperature of 90°C. The thermal output (usable heat) from unit power stations generally ranges from 20% and around 50% depending on the specification of the individual plant and according to the application with or without exhaust heat exchanger. When the alongside electricity also heat utilised, this is referred to as power-heat-coupling.

Unit power stations consist of an internal combustion engine and a generator for the generation of electricity. Gas-Otto engines or gas-diesel engines are used for the internal combustion engines. Whilst gas-Otto engines (Figure 5.5-7) can be run on biogas alone, with gas-diesel engines (Figure 5.5-8) require an oil-ignition part alongside the biogas (eg. diesel; approx. 10 % the combustion heat output). Gas-diesel engines are generally installed in unit power stations with an electrical output of 20 to 300 kW. Gas-Otto engines with an electrical output of between 100 kW and 2 MW. Gas-Otto engines normally have better exhaust values and a longer serviceable life.

Gas-diesel engines are suitable for operation at lower outputs and can be purchased more inexpensively. On selecting a suitable aggregate, the economic and investment costs in each individual case as well as the availability of spare parts, serviceability etc. must be taken into account.

Figure 5.5-7: Unit power station with gas-Otto engine with an electrical output of 375 kW.

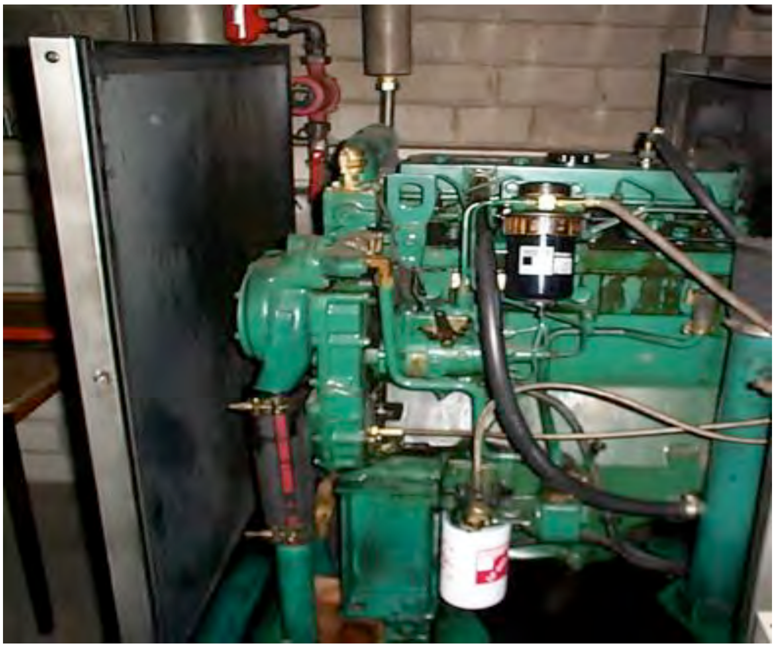


Figure 5.5-8: Unit power station with gas-diesel motor with an electrical output of 60 kW

5.5.2.6 Benefits

The development and operation of biogas plants opens up a variety of developmental perspectives, particularly also in rural areas. Alongside the reduction of GHG emission, the provision of infrastructures for the disposal of waste and substrates from waste water clarification, and agriculture in certain aspects stand here in the foreground, and relate to a generation of new added value chains in rural areas.

Biogas plants create jobs, increase economic power, and produce decentralised fertiliser and energy in the form of electricity and heat, thereby making a region less dependent on external resources.

The positive perspectives of biogas plants have been well discussed. For this reason, only a table of some of the advantages have been listed below (see Table 5.5-6).

Table 5.5-6: Benefits of biogas plants

Area	Benefits
Waste treatment	• natural waste treatment process • infrastructure for waste treatment • reduces disposed waste volume and weight to be landfilled • reduced the long term hazards of landfills • sanitation of waste and substrates from waste, waste water treatment or agriculture
Energy:	• generates biogas which can be used for the production of electricity, heat or cooling (heat exchange) • net energy producing process • proven in numerous end-use applications
Environmental	• significantly reduces carbon dioxide and methane emissions (Greenhouse effect) • eliminates odour • produces a sanitised compost and nutrient fertiliser • maximises recycling benefits, reduces resource depletion
Other benefits	• cost-efficient • decentralised applicable • flexible process for a wide range of substrates • new value creation chain for the waste management sector and agricultural sector • generates jobs, tax revenue, revenues • reduces the dependency from external energy supply

Learning outcome:

Composting and Fermentation:
Which process parameters have influence on degradation/fermantation process and why
Different Types of substrates and there reachable degree
Emissions of composting process
Design of composting/fermentation facilities
Static and dynamic processes
Mass balance and mass reduction
Utilisation and quality aspects

5.6 Physical und chemical treatment processes

Educational objective of the chapter

The chapter 5.6 gives an overview on different physical and chemical processes occurring during the waste treatment procedures. Among the methods studied, various separation technologies are presented, as well as different methods for transforming a waste in a less dangerous form by physical and chemical means.

5.6.1 Physical treatment of waste

Physical treatment involves changing the waste's physical properties such as its size, shape, density, or state (i.e., gas, liquid, solid). Physical treatment does not change a waste's chemical composition (for chemical treatment see paragraph 5.6.2). The physical treatment methods presented here can be applied for waste in various states of aggregation, with a summary given at the end of the chapter.

5.6.1.1 Filtration

Generally, filtration represents one method for the separation of solid particles from a fluid phase by using a porous medium and a pressure gradient given by gravity, centrifugal force, vacuum or higher than atmospheric pressure [Freeman, 1998]. In an integrated waste management system, filtration process represent only one step. Based on their applicability, filtration processes can be included in two categories:

- clarification (removal of suspended solid particles from acqueous media)
- dewatering of sludges (reducing the water content with about 1 to 30 percent by weight).

Based on how the suspended solids are retained and removed, one can distinguish three kinds of filtration:

- depth filtration (suspensions are retained inside a porous medium)
- cake filtration (suspensions are retained at the surface of the filter medium)
- cross-flow filtration (suspensions are flown along the filter medium).

The Figure 5.6-1 shows the three types of filtration and their respective filters (to note is that filtration is not suitable for removal of dissolved substances and it is only application to liquid waste):

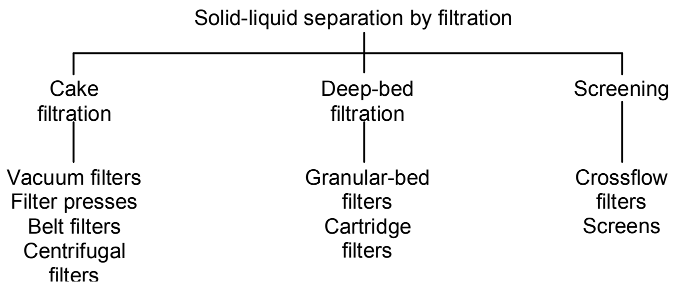


Figure 5.6-1 Solid-liquid separation by filtration [after Freeman, 1998]

The following paragraphs will present various selected filtration processes applicable to hazardous and non-hazardous waste.

Deep bed filtration
Deep bed filtration is usually used for liquids with the concentration in solid particles less than 100 ppm [Freeman, 1998]. The solid particles are retained inside the filter medium as the fluid component passes through. The filter medium can be made of granular materials (rocks, gravel, sand), specific screen filters or disposable filter materials made of inexpensive fabric. The deep bed filters can work continously of discontinously, depending on application.

Figure 5.6-2 Small scale deep bed filter with filter medium from fabric[40]

Mud cake filtration

The filtration occurs in a similar way as for deep bed filters, with solid particles being retained by the filter medium and the liquid phase flowing through. The difference is made by the retained solid particles who form a mud "cake" on the filter medium, which becomes thicker as solid particles are being retained. By time, the mud cake takes takes the role of a filter medium, growing constantly in thickness until the flow resistence increases so much, that the filtration is interrupted. In this case, the mud cake has to be removed, e.g. by back-washing.

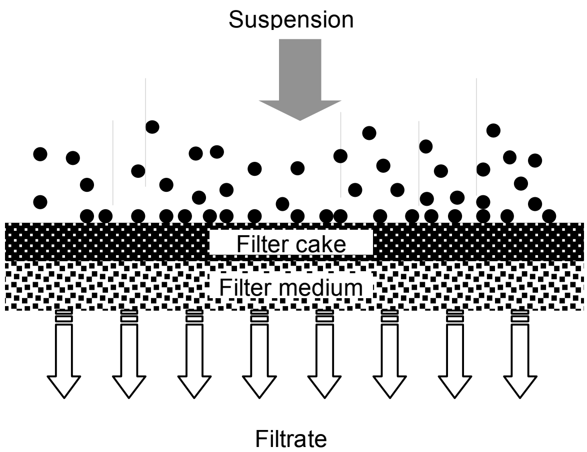


Figure 5.6-3 Filtration with a mud cake

Cross-flow filtration

In cross-flow filtration (Figure 5.6-4), the suspension flows parallel to the filter surface and the turbulencies created prevent the filter cake formation and thus the rapid clogging of the filter. The permeate is vertically absorbed and the particles become more concentrated as filtrate leaves through the filter's pores.

☞ Please note:

This method is not efficient for fluids with very high content of solid particles, an optimum in efficiency being reached with fluids with less than 0.5% suspended solids [Freeman, 1998].

[40] Source: www.indfilco.com

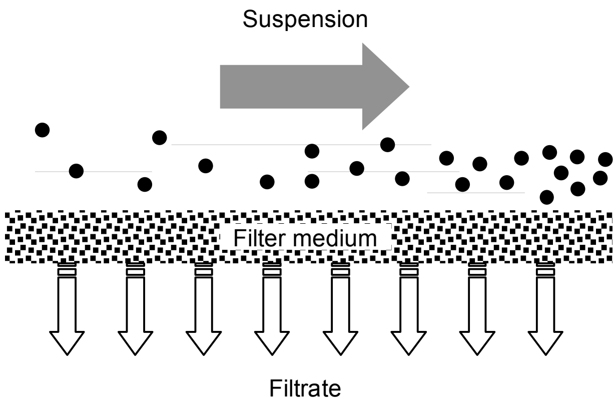


Figure 5.6-4 Cross-flow filtration

Screen filter
This type of filter (see Figure 5.6-5) is used mostly in industry for low loaded effluents and it operates after a simple scheme: the suspensions flow through the openings of the can and the particles are being retained at the pipe. Cleaning of the filter is done by rotation of the can along a fixed scrapper but it can be done also by back flushing.

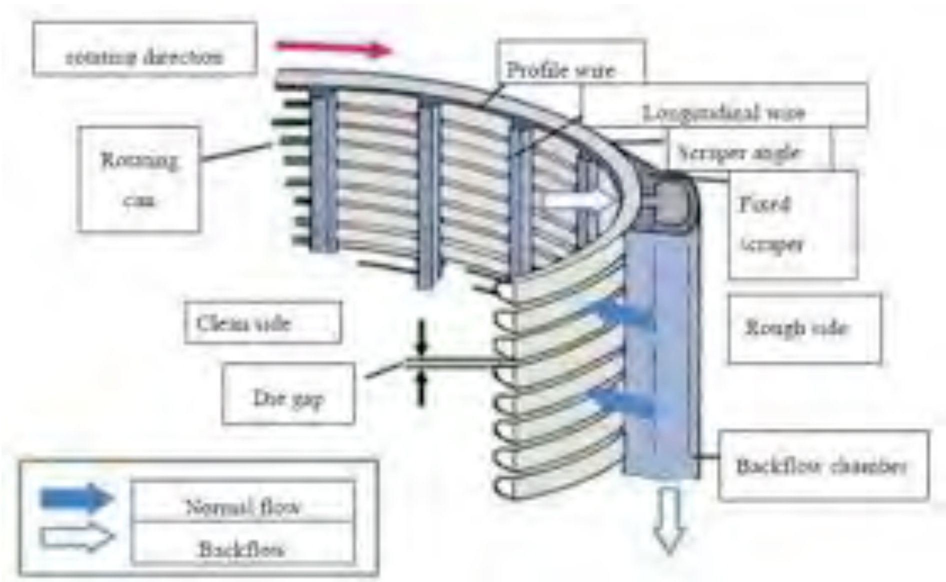


Figure 5.6-5 Screen filter [Mann+Hummel, 2002]

Vacuum drum filter
The vacuum drum filter can be used for the drainage of the industrial sludge. The filter medium is wrapped around a rotary drum and dived in the suspension (see Figure 5.6-6). Vacuum is applied inside the drum, forcing the filtrate to accumulate in the inner part. The filtrate is collected and transported by a pipe and the cake formed at the outer side is continuously removed. The big advantage of a vacuum drum filter is the possiblity of continuous operation.

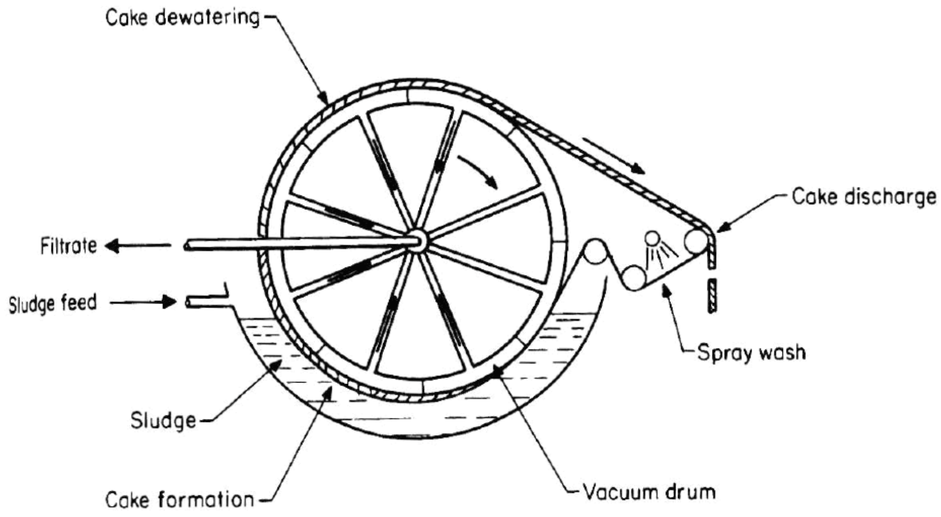


Figure 5.6-6 Vacuum drum filter [Freeman, 1998]

Filter press

A filter press (Figure 5.6-7) can be used for the drainage of the sludge. This is to be pumped inside the horizontal (or vertical) press. The special chambers will be filled with sludge and pressed by a hydraulic force. The filtrate will be released to exterior and collected, and the remaining material will take the form of a filter cake, which is to be dried and removed before using the filter press for a new load.

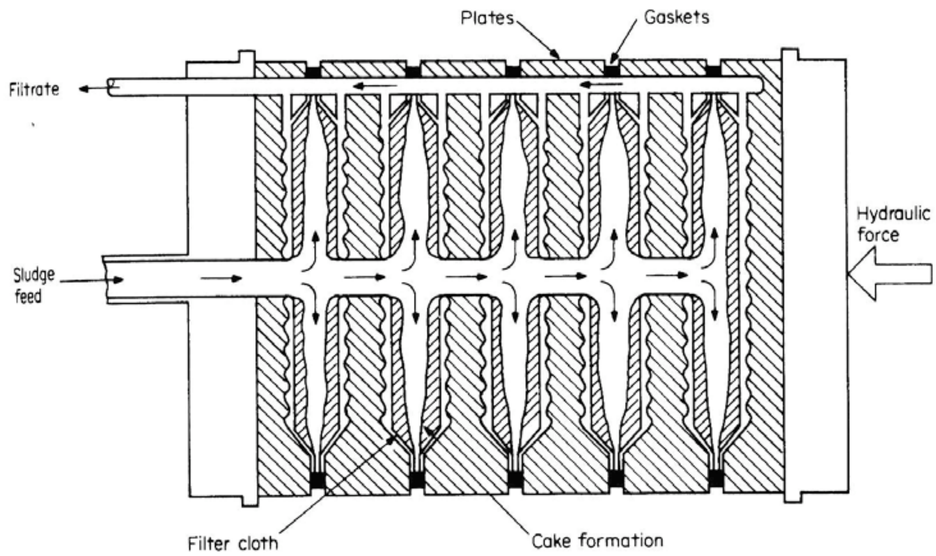


Figure 5.6-7 Filter press [Freeman, 1998]

5.6.1.2 Separation by density differences

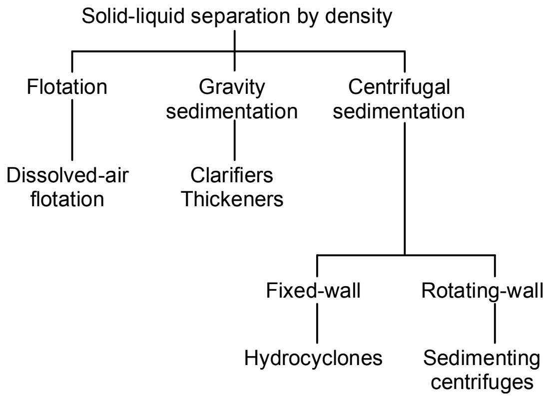


Figure 5.6-8 Solid-liquid separation by density differences [after Freeman, 1998]

<u>Flotation</u>
By flotation, the solid-liquid separation is done with the aid of up-current injection of air bubbles. Based of attraction forces between suspended solids and water particles and on the surface and pressure of the air flow, the air bubbles catch and carry with them the solid particles in suspension to the surface, where they can be removed (Figure 5.6-9).

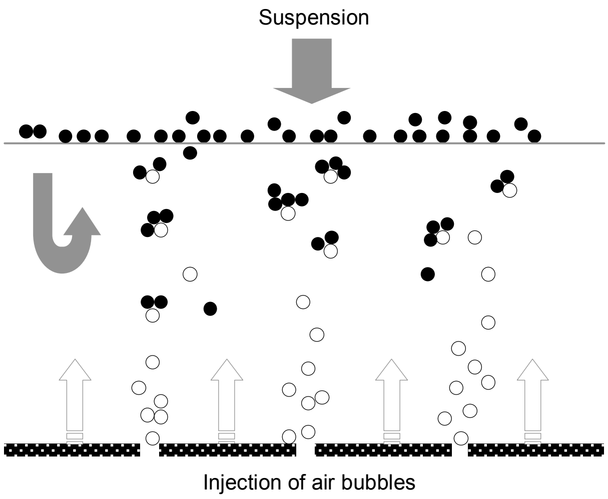


Figure 5.6-9 Solid-liquid separation by flotation

<u>Sedimentation</u>
The sedimentation is a gravity driven process where suspended solids are allowed to settle at the bottom of a tank containing resting or slowly flowing liquid (Figure 5.6-10). The accumulated solid material can be then removed.

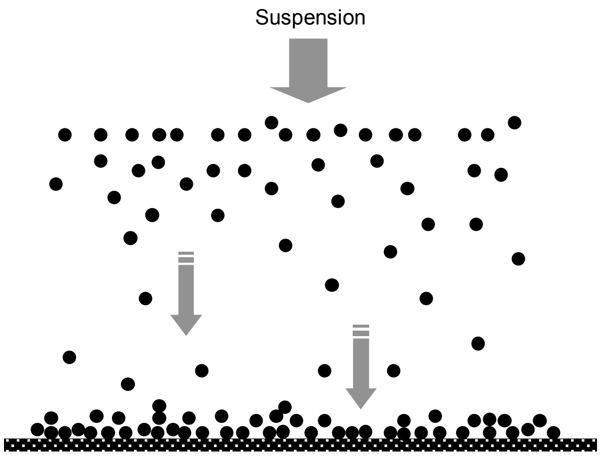


Figure 5.6-10 Solid-liquid separation by sedimentation

Centrifugation
The centrifugation process is based on the separation of lightweight and heavy particles by a centrifugal movement. The rotational movement can be done by the whole vessel (called “centrifuge”) or only by the fluid inside (“hydrocyclone”).

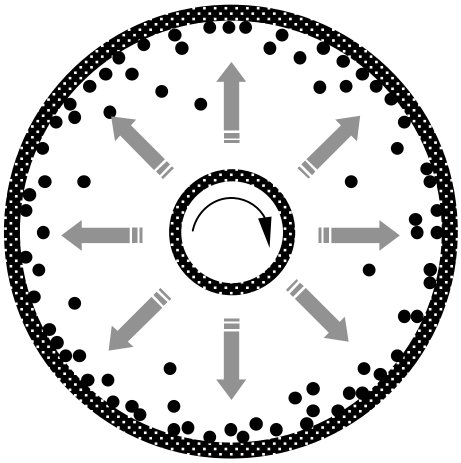


Figure 5.6-11 Solid-liquid separation by centrifugation

5.6.1.3 Immobilization

Encapsulation
Encapsulation is a method used especially for hazardous waste, which has to be solid, finely divided material. This can be encapsulated within pellets made of various materials (e.g. polymers, asphalt, etc.) having the role of preventing the waste to leak out into the environment (see Figure 5.6-12). According to the security control level of the surrounding environment, encapsulation can be primary, secondary or tertiary, and depending upon the size of agglomerate, micro and macro encapsulation can be distinguished. The granules’ size can vary from tens of micrometers to centimetres and can be used for construction applications.

Figure 5.6-12 Terra-Bond™ waste encapsulation synthetic aggregates[41]

5.6.1.4 Shredding and grinding

Shredding of waste reduces the size of the waste material and it is usually done prior to the incineration step, having the purpose to ensure that the incineration is efficient. The waste can also be shreddered for further processing in separation plants or biological treatment plants. Another application of shredding is reducing the volume of waste going to landfills, thus reducing the transport costs.

Figure 5.6-13 Solid waste shredder - Powershredder 1800 - by Powerscreen[42]

5.6.1.5 Compacting

By compacting the waste it is reduced the volume of the collected or deposited waste. Compactation can be done on mobile units, during waste collection, where portable devices (see Figure 5.6-14) are lifted and carried on trucks so that more waste can be transported at one and thus saving transport costs. Alternatively, waste can be compacted after collection by using static devices, suitable for small to medium-sized industrial units like hotels, shopping centres, food producers and others.

[41] Source: www.pildyshtech.com/technologies-encapsulation.html
[42] Source: www.powerscreen.com

Figure 5.6-14 Husmann waste compactors: portable (left) and static (right)[43]

Also with the aim of minimization of occupied space, solid waste can be more thoroughly compacted at the landfill using large landfill compactors equipped with steel wheels that have special teeth that penetrate the waste. Apart gaining valuable place by reducing the waste volume, landfill compactors also spread the waste more evenly in layers over the landfill and by compaction, they realize a stabilization of the landfill slopes.

Figure 5.6-15 Landfill compactation [image on public domain]

5.6.1.6 Chemical treatment of waste

Chemical treatment involves altering a waste's chemical composition, structure, and properties through chemical reactions. Chemical treatment can consist of mixing the waste with other materials (reagents), heating the waste to high temperatures, or a combination of both. Through chemical treatment, waste constituents can be recovered or destroyed, especially in cases where classical separation technologies cannot be applied (see above the chapter about physical treatment). As consequence, the present chapter will focus mostly on chemical treatment of hazardous waste and it is based on a previous written guidelines resulted from a similar Asia Pro Eco project in which TU Dresden was involved as project partner (for details, see http://www.tu-dresden.de/wwvwlat/sacodi).

5.6.1.7 Chemical precipitation

Chemical precipitation represents the process of transformation of soluble substances in insoluble solids by means of chemical reactions. This method is very effective for the immobilisation of toxic heavy metals from polluted waters, being usually followed by a separation step (see Figure 5.6-16).

[43] Source: www.husmann-web.com

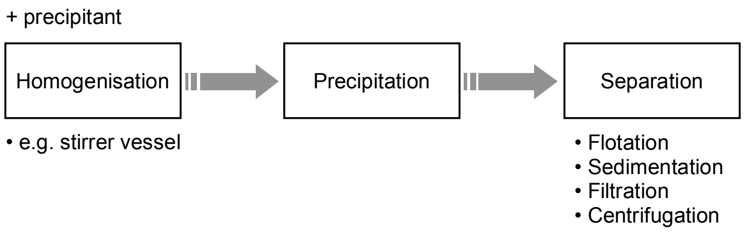


Figure 5.6-16 Treatment by chemical precipitation [SACODI, 2006]

Different precipitants can be used in the process, distinguishing three main categories of precipitations: hydroxide, sulphide and carbonate precipitations.

Hydroxide precipitation

Hydroxide precipitation is the most widely used method, involving hydroxy ions of calcium (lime) or sodium (caustic) as precipitant [Freeman, 1998]. The reactionis illustrated in the following equation:

$$M^{2+} + Ca(OH)_2 \rightarrow M(OH)_2 + Ca^{2+}$$

The method's efficiency depends upon the metal to be precipited, the conditions of reaction (especially pH) and the various substances that might interfere with the reaction.

Sulfide precipitation

The precipitation using metal sulfides has the advantage of producing lesser soluble compouns [Freeman, 1998]. The source of sulfides can be various, from sodium sulfide (Na_2S), sodium hydrosulfide (NaHS), to ferrous sulfide (FeS):

$$M^{2+} + FeS \rightarrow MS + Fe^{2+}$$

The biggest dissadvantage of sulfide precipitation is the generation of toxic hydrogen sulfide gas (H_2S), which can be prevented by maintaining the pH of the solution above 8 [Freeman, 1998].

Carbonate precipitation

The carbonate precipitation is preffered for some metals like cadmium and lead, having the advantage of a denser (easier to filtrate) sludge and operation at a lower pH value when compared with hydroxide precipitation.

$$Na_2CO_3 + M^{2+} \rightarrow MCO_3 + 2Na^+$$

However, the method is not efficient for all metals, e.g. for zinc and nickel the results are not any better in terms of operating pH value or resulting sludge compared with hydroxy ions. [Freeman, 1998].

Other precipitation processes

Apart the above mentioned methods, precipitation of metals can be also done by using sodium boronhydre ($NaBH_4$) as an effective reducing agent for removal of lead, mercury, nickel, copper, cadmium, and some precious metals. Under the name *cementation* is known the method of precipitation of a metal from a solution by a metal with a higher electromotive series, e.g. removal of copper from printed circuit etching solutions. Moreover, a selective removal of trivalent metal cations like iron, aluminium and chromium can be done by phosphate precipitation [Freeman, 1998].

5.6.1.8 Solidification and stabilization (S/S)

Solidification is a procedure meant to reduce the water content of waste by adding certain binders and additives (Figure 5.6-17). The aim is the reduction of mobility and toxicity of contaminants and it is regarded as a treatment step for the preparation of waste for disposal into landfills [Freeman, 1998]. Another important benefit is the possibility of beneficially using the resulting solid material as construction blocks, road pavements etc.

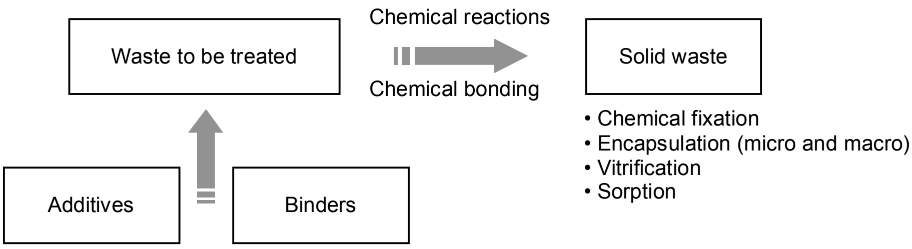


Figure 5.6-17 Solidification and stabilization processes

There are several technologies available for solidification and stabilization of waste:

- *In-drum processing* (mixing of waste with reagents takes place in a container);
- *In-plant processing* (the treatment is done in a specialized plant);
- *Mobile-plant processing* (a mobile unit is moved to the contaminated site);
- *Ex situ treatment* (the waste is removed from the contaminated site and treated or disposed elsewhere)
- *In situ treatment* (the waste is left in place and the addition and mixing of reagents is done locally, see Figure 5.6-18)

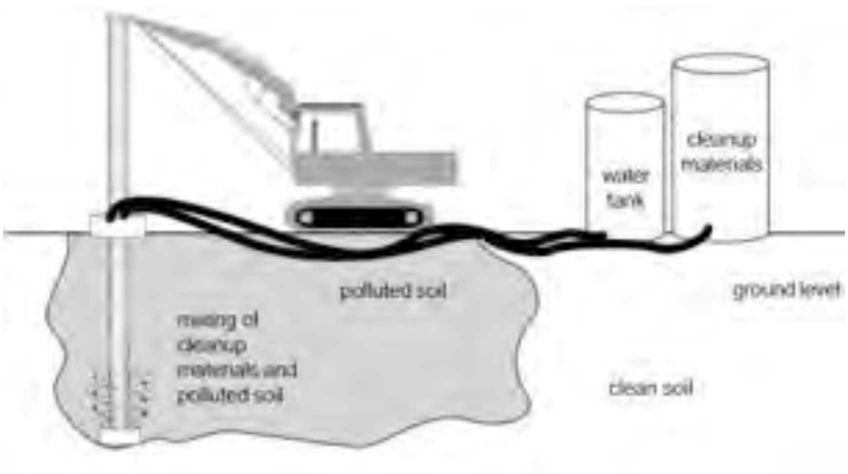


Figure 5.6-18 On-site waste treatment by stabilization [US EPA, 2001]

According to Freeman (1998), the following terms and concepts need to be defined and explained in order to better understand the meaning and concept of solidification/stabilization processes:

<u>Solidification</u>
The therm reffers strictly to the process of addition of materials to the waste in order to obtain a solid product, which can or cannot involve chemical reaction of bonding with the contaminants in the waste but it reacts with the free water present.

<u>Stabilization</u>
By stabilization process the waste is transformed to a more stable form, which does not necesserly have to be a solid. The stabilization is reached exclusively by chemical reactions between the waste and the reagents, and does not involve biological processes.

<u>Chemical fixation</u>
The term chemical fixation is used either for solidification and stabilization, or a combination of both processes, and regards to the transformation of a harmful compound to a less harmful form.

<u>Encapsulation</u>
The process has been described at section 5.6.1.3 and implies the complete coating of the waste particles with a material that will prevent the waste getting in contact with the environment. Depending on particle size, one can speak about micro- or macroencapsulation.

<u>Vitrification</u>
This process implies the application of high temperatures in order to change the form of a waste to a moltenlike state.

<u>Sorption</u>
The sorption of the liquid part of a waste by a material with sorptive characteristics represents one step in the solidification/stabilization methodology.

5.6.1.9 Chemical oxidation and reduction

Oxidation-reaction (redox) reactions have succesfuly been applied in waste and wastewater treatment if the respective technological process were carefuly designed. They apply for a wide scale of organic compounds like phenols, pesticides, benzene, toluene, chlorinated compounds, polycyclic aromatic compounds etc. and inorganic compounds (sulphides, ammoniac, cyanides or heavy metals) [Freeman, 1998]. Plenty of chemical can be used in the oxidation-reduction reactions, distinguishing following types of reactions [SACODI, 2006]:

<u>Chemical oxidation</u>
- Oxidation with chlorine (Cl^-) und hypochlorite salt (OCl^-)
- Oxidation with chlorine dioxide (ClO_2)
- Oxidation with hydrogen peroxide (H_2O_2)
- Oxidation with potassium permanganate ($KMnO_4$)
- Oxidation with oxygen (O_2)
- Oxidation with ozone (O_3)

<u>Chemical reduction</u>
- Reduction of sulphur dioxide (SO_2) and sulfites (SO_3^-)
- Reduction with metals (iron, zinc)
- Reduction with sodium dithionite ($Na_2S_2O_4$)
- Reduction with hydrazine (N_2H_4)
- Reduction with sodium borohydride (BH_4)
- Reduction with hydrogen peroxide (HO_2^-)

5.6.1.10 Pervaporation

The pervaporation is a process of separation of volatile substances from a liquid phase. A liquid stream containing the volatile compounds are forced to pass through a selective membrane by applying vacuum on the other side of the membrane (Figure 5.6-19). The components permeate through the membrane and evaporate on the other side, being condensed and handled for further treatment.

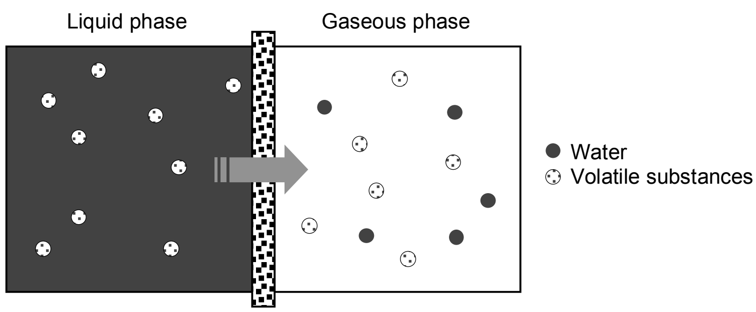


Figure 5.6-19 Pervaporation scheme

Due to continuous difference in pressure given by the application of vacuum, the membrane doesn’t get clogged by the transfered compounds, which offers the advantage of using the system continuously [Freeman, 1998].

5.6.1.11 Ozone treatment

Ozone has been used since many years in water treatment and offers a series of advantages. One of them is the generation of ozone and operation on site, without the necessity of storage and avoiding the handling problems posed by the use of similar methods. Another advantage is that the generation of ozone can be done by applying a high voltage current to an oxygen or air flow (Figure 5.6-20), the resulting gas being used immediatelly.

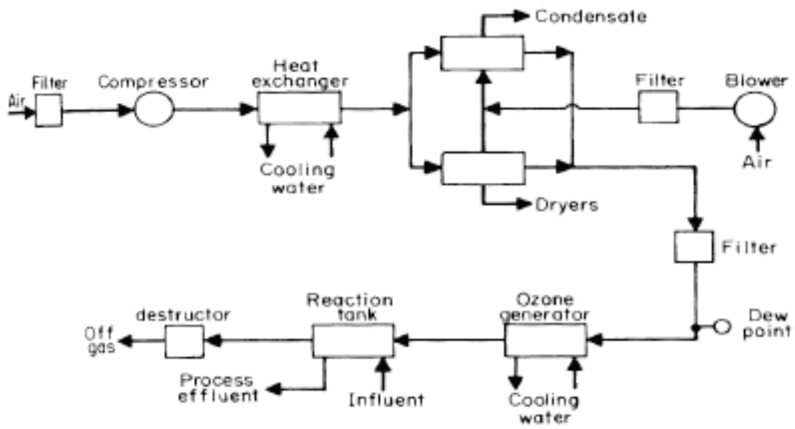


Figure 5.6-20 Flow diagram of an ozonation plant [Freeman, 1998]

However, the generation of ozone is a high energy demanding process, with high capital costs, therefore laboratory and pilot plant studies are required to determine if ozonation is suitable for a certain specific waste [Freeman, 1998].

☑ Self-assessment

5. Explain the main different between physical and chemical treatment methods.
6. Classify the separation processes by their applicability and by how the suspended particles are retained.
7. Described in a few words the deep bed filtration, mud cake filtration and the cross-flow filtration.
8. Enumerate some separation processes by density differences.
9. What it is meant with the term “chemical precipitation”?
10. How does the pervaporation work?

5.7 References

Bilitewski et al., 1994: Abfallwirtschaft- eine Einführung. Springer Verlag Berlin Heidelberg, 2. Auflage

Freeman, H. M. (editor) 1998: Standard Handbook of hazardous waste treatment and disposal, McGraw Hill

Mann+Hummel, 2002: Profluid und Spaltrohrfilter, http://www.mannhummel.com/industrialfilters/upload/doc/HBLFBhEaWA1.pdf

US EPA. 2001. A Citizen's Guide to Solidification/Stabilization. http://clu-in.org/download/citizens/s-s.pdf

Kaltschmitt, Hartmann, 2001: Energie aus Biomasse- Grundlagen, Techniken und Verfahren, Springer Verlag Berlin Heidelberg, New York

Weiland, 2001 Stand und Perspektiven der Biogasnutzung und –erzeugung. In: Gülzower Fachgespräche: „Energetische Nutzung von Biogas-Stand der Technik und Optimierungspotentiale" 2000. Hrsg.: Fachagentur Nachwachsende Rohstoffe e.V. Weimar, 26.-27. Oktober 2000. www.fnr.de

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) , 2003: Nutzung von Biomass in Kommunen, ein Leitfaden.

Bidlingmaier, Werner, 2000: Biologische Abfallverwertung, Ulmer

Emberger, Jürgen, 1993: Kompostierung und Vergärung – Bioabafall, Pflanzenabfall, organische Produktionsrückstände, Vogel Buchverlag, Würzburg

Bank, Matthias, 2007: Basiswissen Umwelttechnik – Wasser, Luft, Abfall, Lärm und Umweltrecht. Vogel Buchverlag, Würzburg, 5. Auflage

Bilitewski, 2000 Bilitewski, Härdtle, Marek, Weissbach, Boeddicker: Waste Management, Springer Verlag, 1997, Berlin, Germany

Igelbüscher, 2005: Igelbüscher: Thermal waste treatment, 2005, TU Dresden, Dresden, Germany

Kahl, 2007: Principle of a pellet press. Amandous Kahl GmbH & Co. KG, 2007, Reinbeck, Germany http://www.akahl.de/index.php?hid=10&id=63

Lenntech, 2007: Principle of a hydro cyclone. Lenntech Water- & Luchtbehandling Holding B.V., 2007, Delft, Netherlands http://www.lenntech.com

Recommendations for further reading:

EU Asia Pro Eco Programme SACODI - Segregation, collection and disposal of hazardous waste Part 1: Recommendations for environmental politics and administration, Introduction to collection and disposal systems under particular consideration of framework conditions in India and Vietnam http://www.tu-dresden.de/wwvwlat/sacodi/documents/Guidelines_part_I.pdf

Portland Cement Association – Video on how stabilization/solidification technologies work http://www.cement.org/waste/video/170mb.mpg (MGP video file, 9:35 min, 170 MB)

J. M. Vases, F. Thomas. 1999. Waste Solidification-stabilization Processes. Editions Technip, USA. ISBN 2905015322

R. D. Spence, C. Shi. 2004. Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes. CRC; 1 edition, ISBN 1566704448

Ali A. (2005): Waste management – Developing world and countries in transit. In Sardinia 2005 Tenth International Waste Management and Landfill Symposium, Editors Raffaello Cossu, Rainer Stegmann

Asian Institute of Technology (2004): Municipal Solid Waste Management in Asia. Asian Regional Research Program on Environmental Technology (ARRPET)

Bilitewski B., Schirmer M. (2005): Thermal treatment of waste – State of the art. In: Sardinia 2005 Tenth International Waste Management and Landfill Symposium, Editors Raffaello Cossu, Rainer Stegmann

Hosoda, Hiroyuki (2000): Development of Fluidised bed Pyrolysis and Melting System for Municipal Solid Waste, Proc. Int. Conf. Combustion, Incineration/Pyrolysis and Emission Controls (ICIPEC), Seoul, Korea

IEM/ICE (1994): Conference on Solid Waste Management System, Kuala Lumpur

UNEP (2001): State of the Environment South Asia 2001. United Nations Environment Programme, ISBN: 92-807-2137-2

UNEP (2001b): State of the Environment Vietnam 2001. United Nations Environment Programme, ISBN: 92-807-2013-9

6 Waste disposal

6.1 Background

Waste management term has been widely accepted as a sum of measures and solutions for waste avoidance, treatment, recovery, reuse and least but not last, final disposal with consideration to ecological and economical aspects.[44] However, waste disposal to controlled landfills should only be a final option, adopted when further treatment of waste is neither economically nor technically possible [Bilitewski et al., 1994]. Unfortunately, uncontrolled waste dumping on the land is the first option for many regions in Asian continent due to very low costs. Over years, this was leading to two main problems: 1) dumped waste has generated liquid and gaseous emissions making the area out of use, and 2) dump sites rapidly became a breeding and hosting place for large amounts of disease-bearing organisms, posing a high threat to humans' health and safety living nearby the respective areas, and as well for the surrounding environment. Nevertheless, carefully managed sanitary landfills should replace the open dumps to significantly reduce the contact between the waste and the environment by concentrating the waste in a well defined and managed area [UNEP, 2005].

📖 Educational objective of the chapter

The present chapter will offer information on construction and managing of landfills such as basic principles, site requirements, as well as technical construction and operation advices.

6.2 Basic principles

6.2.1 Definitions and planning

6.2.1.1 Definitions

An overall definition of a "sanitary landfill" is not simple since this depends a lot on the level of development of the regarded country. Nevertheless, the differences mostly lie on the degree of isolation the respective disposal site offers for the separation of the disposed waste and the surrounding environment. Since this is a very sensitive issue also in many developed countries, not the same requirements are feasible for a developing country.

In order to qualify as a sanitary landfill, a disposal site must meet the following three basic conditions [UNEP, 2005]:

- Disposed waste must be properly compacted;
- The waste has to be properly covered for a good separation from the surroundings;
- High control and prevention of the negative impact given by odours, contaminated waters etc. resulted from the construction and operation of the landfill

The level of accomplishment of these three requirements is different for developing countries compared with developed ones. While the long-term goal must be the filling all three conditions, the last one should be the most important with disregard to the level of development.

<u>Classifications</u>
In addition to the above mentioned criteria, the landfills can be classified by the technical level accomplished, by the type of waste deposited and by processes occurring during the exploitation.

By technical level achieved, in landfill classification system in Germany comprises four levels (see also Table 6.2-1), ordered as following [TETRAWAMA, 2002]:

- Level 1 - Controlled tipping
- Level 2 - Sanitary landfill with a bund and daily cover soil
- Level 3 - Sanitary landfill with leachate circulation
- Level 4 - Sanitary landfill with leachate treatment

[44] Chapter based mostly on two following sources: Bilitewski et al., 1994; UNEP, 2005 – Vol. I + II and TETRAWAMA, 2002

Table 6.2-1 Levels of sanitary landfills [TETRAWAMA, 2002]

Item	Level 1	Level 2	Level 3	Level 4
Soil cover	✓	✓✓	✓✓	✓✓
Embankment	-	✓✓	✓✓	✓✓
Drain facility	-	✓✓	✓✓	✓✓
Gas venting	-	✓✓	✓✓	✓✓
Leachate collection	-	-	✓✓	✓✓
Leachate re-circulation	-	-	✓✓	✓✓
Leachate treatment	-	-	-	✓✓
Liner	-	-	-	✓✓

By the type of deposited waste, the federal waste disposal regulation [BMU, 2002] defines the following landfill classes:

- Class 0 - Inert waste
- Class I - Quite inert municipal waste
- Class II - Municipal waste
- Class III - Hazardous waste
- Class IV - Underground disposal site

By type of processes occurring, the waste decomposition due to biological processes plays a major role in landfills' classification and indicates a different approach for aerobic and anaerobic operating landfills (see also chapter 6.2.1.5). Because the biological content of municipal waste is expected to generally be higher in Asia than in Europe, the biological processes are considered of an extreme importance, suggesting the following types for Asian landfills [TETRAWAMA, 2002]:

- Anaerobic landfill
- Anaerobic landfill with daily cover
- Improved anaerobic sanitary landfill with buried leachate collection pipes
- Semi-anaerobic landfill with natural ventilation and leachate collection
- Aerobic landfill with forced aeration

6.2.1.2 Planning

Planning of a sanitary landfill should always be done starting from the assumption that reduction and recycling of waste designated to be disposed have a higher priority. If further handling of waste is not possible anymore, only then the interested party should start collecting following types of information [UNEP, 2005]:

- Type of waste to be disposed
- Amounts generated
- Waste generation rates
- Characteristics of the waste

Besides the above mentioned information, important criteria have to be evaluated regarding the requirements for the site proposed to host a sanitary landfill (this will be further discussed in the paragraph 6.2.3). The Figure 6.2-1 offers a preliminary overview on the basic aspects of a sanitary landfill layout and its components:

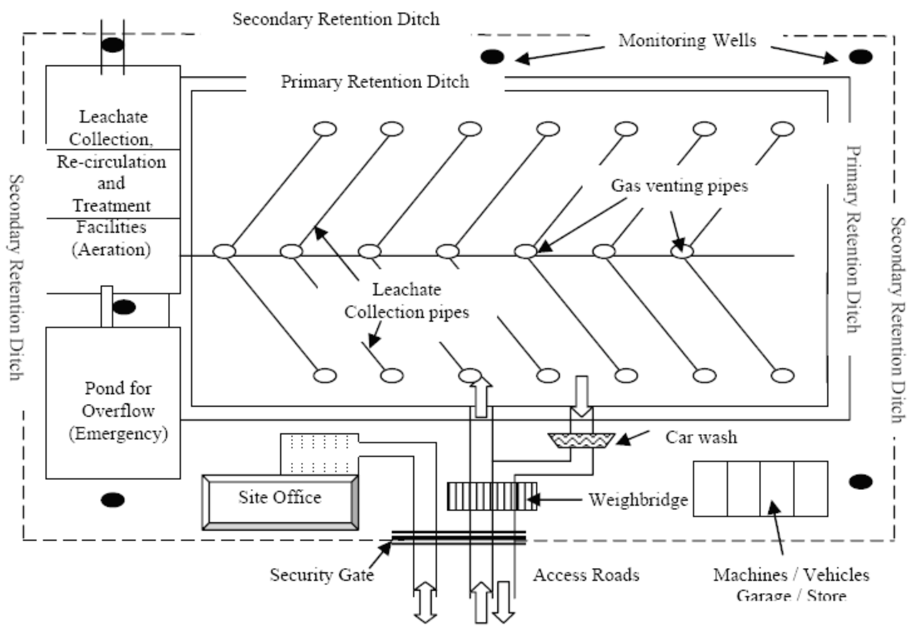


Figure 6.2-1 Schematic diagram of basic aspects of a sanitary landfill layout [TETRAWAMA, 2006]

Processes occurring in a sanitary landfill

When decision to start constructing a sanitary landfill is taken, one has to keep in mind that the waste disposed is not an inert material but it is exposed to a mixture of physical, chemical and biological processes [UNEP, 2005]. Depending on type of waste disposed, amounts and generation rates, and also waste characteristics, the involved processes can largely vary but they can be summarized as follows:

6.2.1.3 Physical processes

Basically, the waste disposed in a sanitary landfill is exposed to a broad form of mechanical-physical processes during the regular operation time of the landfill:

Compaction
The physical compression of the waste has the purpose of reduction the volume of waste deposited, as well as a better stabilisation of landfill slopes (see also chapter 5.6.1.7). This can be achieved with special designed landfill compacting machinery, as seen in Figure 6.2-2:

Figure 6.2-2 Various types of landfill compactors[45]

Dissolution
The amount of water present in the disposed waste represents the key factor for the dissolution of soluble substances and their transport.

Sorption
One important aim of a sanitary landfill is the immobilization of substances that could pose a risk to the environment. This can be achieved also with the aid of sorption processes occurring in the body of the landfill, which is directly dependent on the composition of the disposed waste.

[45] Sources: www.cityofglasgow.org (image left) and www.letsrecycle.com (image right)

6.2.1.4 Chemical processes

Reactions with oxygen

Although limited, oxidation processes still occur in a sanitary landfill, being linked with the presence of trapped oxygen (for more information about oxidation-reduction reactions, see also chapter 5.6.2.4).

Reactions with organic acids and carbon dioxide

This is the second major class of reactions occurring, involving the organic acids and CO_2 resulted from the biological processes.

6.2.1.5 Biological processes

The biological processes can be regarded as most important processes in a landfill management due to the following reasons [UNEP, 2005]:

- The organic fraction of the deposited waste is biologically rendered inert and thus does not pose further problems;
- Transformation of an important part of the organic fraction into gaseous form with the aid of microorganisms leads to an important reduction in the overall volume occupied by the organic waste.

Another important aspect regarding the biodegradable organic fraction of the deposited waste is the assumption that lies at the base of the landfill management: on the landfill should be brought only waste whose further treatment cannot be economically or technically feasible. Since the organic fraction represents a key issue in the biological treatment of waste, final disposal to the landfill should be chosen only after carefully studying the respective alternatives (see more details on the process of biological treatment of waste see also the chapter 5.5).

☞ Please note:

Biological processes governing the decomposition of the organic fraction of waste play an important role especially in tropical regions, where they form a high percentage of the dumped waste. Since the activity of most microorganisms improves with the increase of the temperature, it is expected a shorter operational time until the waste in a sanitary landfill become biologically inert, e.g. the landfill becomes “completed”. This conducts to a faster rehabilitation of the site occupied by the landfill and allows the allocation of a further use (recreational, agriculture, construction etc.)

Decomposition of the biodegradable organic fraction in a landfill can be done either aerobic or anaerobic, depending on the oxygen trapped inside the landfill and the time the microorganisms need to break down the organic compounds by using this ready available oxygen.

Aerobic decomposition

This decomposition occurs very fast, mostly at the beginning of the landfill operation and has a relatively short duration, until all the trapped oxygen has been consumed by the demanding microorganisms. The effect of the aerobic decomposition on the overall environmental impact is minimal since most of the ultimate end products resulted is carbon dioxide and water.

Anaerobic decomposition

When all available oxygen has been depleted, the decomposition turns to an anaerobic breakdown. On a general scale, this is most important biological process because if left uncontrolled, it leads to important negative impacts to the environment. This are expressed as end products of reaction and can be found mostly in the form of volatile organic acids. In reaction with other substances, the organic acids can form more dangerous compounds, serving also as substrate for the methane producing microbes [UNEP, 2005]. The resulting gases are methane (CH_4) and CO_2, but also traces of hydrogen sulphide (H_2S), hydrogen (H_2) and nitrogen (N_2). The management of the landfill gases will be presented more in detail in chapter 6.3.1.9).

6.2.2 Waste characterization

6.2.2.1 Waste type

The type of waste accepted to the landfill should be decided by the landfill operator together to the regional or national environmental institutions and it should be based on surveys regarding the large waste generators in the respective area [UNEP, 2005]. Usually, sanitary landfills should accept for disposal waste from residential, commercial and industrial sources. Among them, the municipal solid waste will probably count for the highest percentage, while liquid waste or waste with high water content should be treated prior to disposal to a landfill (for solidification technologies, see chapter 5.6.2.3). Nevertheless, many types of industrial waste should be classified as “not acceptable” for sanitary landfills and should be disposed to special designed landfills [UNEP, 2005].

☞ Please note:

Among “not acceptable” waste, a special concern should be paid for hazardous waste (see chapter 4.6) or waste coming from hospitals and medical units (the so called “special waste”), both of them having to be specially handled.

6.2.2.2 Waste quantity and composition

For a good planning of a sanitary landfill, representative statistical data on waste quantity generated and its composition are needed. These design parameters are linked with the level of development of the local community, with the demographic predictions and also with climatic and geographic factors. Unfortunately, for most situations this is a difficult aim since the waste generation and composition varies significantly from country to country and from one area to another, thus it is not always possible to use much of the available data. Detailed and expensive studies have to be performed for a proper characterization of waste properties (see chapter 3 for more details).

6.2.3 Site requirements for landfills

Several factors linked to the selection of the “best site” have to be carefully analysed when building a sanitary landfill in order to assure a minimisation of the negative impact to the environment, especially to groundwater and surface water resources, and human life and habitation. These factors will be described on the following paragraphs.

6.2.3.1 Site selection

The selection of the best suitable site for building a sanitary landfill is a difficult matter since this will have many implications over years on the regional development of the respective area. Prognosis of various kinds have to be made, such as for demographic growth, growth of inhabited areas over time or waste generation rates and compositions. For the densely populated areas it may intervene also the problem of the ownership of the land and impacts on the surrounding environment.

One of the first calculations that have to be done when selecting the site is the duration in years of landfill operation. In general it is recommended to consider a life span of ten years [UNEP, 2005] but the decision has to take in consideration that the capital investment has to be recovered. Therefore, the useful life span of the area has to be calculated according to the local conditions and based on parameters like depth of fill, quantity of waste to be disposed, the delivery rate and it composition [UNEP, 2005]. Also the adjacent works related to the landfill have to be included, like access roads, buildings and others.

Empirical equations are available for calculation of the useful life of a sanitary landfill based on the volume of the selected site, on the quantity of waste disposed and on quantity of cover material (see UNEP, 2005, page 333). Various diagrams can further help on estimating the necessary surface area for the built land as function of the population served by the landfill and the degree of waste compaction (Figure 6.2-3) or the landfill volume required as function of waste bulk density and amounts delivered (Figure 6.2-4):

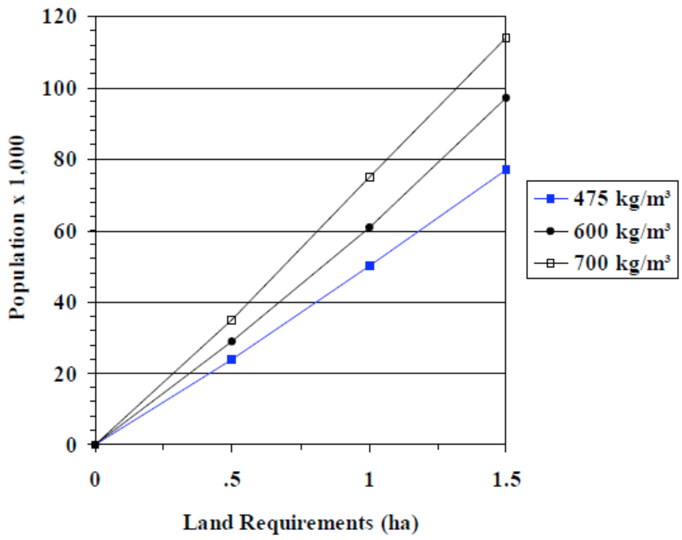


Figure 6.2-3 Land requirements for a landfill as function of compaction [UNEP, 2005]

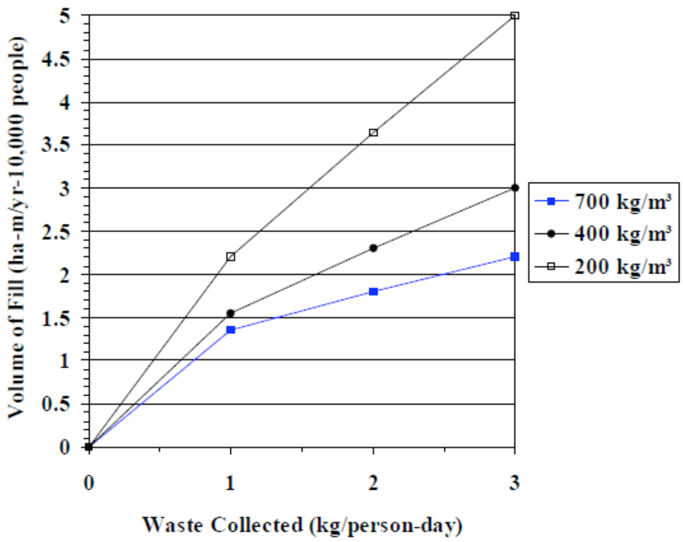


Figure 6.2-4 Relationship between bulk density of waste and landfill volume required [UNEP, 2005]

6.2.3.2 Topography

Information on topography of the selected area is extremely important in regard to the water flows to the landfill (e.g. from precipitations) and from the landfill (e.g. runoff from the waste). A completely flat area is exposed to accumulations of water during raining seasons and a very steep slope can be easily eroded. Therefore, a full set of information that is connected to the topographic maps must include the risks of flood, trajectory of surface waters, distance to nearby households, occurrence and eventual use of groundwater in the vicinity of the landfill, and the monitoring and drainage works [UNEP, 2005].

6.2.3.3 Soil

Economical and managerial reasons suggest that overall costs of the investment could be much reduced if the soil required for the bottom liners or top layers is already available on site and does not have to be imported. If the respective soil is not available, sufficient storage place has to be planned. The migration of contaminants in the subsurface can eventually be reduced or controlled if the soil characteristics are taken into consideration for the site selection.

☞ Please note:

See the UNEP report (2005), Volume I, page 335 for an overview on different soil classes and some important soil parameters.

6.2.3.4 Geology

Certain information on geology is important for proper planning of a landfill, like distance to bedrock or bedrock characteristics, especially in those cases when the bedrock is very close to the surface and it will be part of the foundation base [UNEP, 2005]. Discontinuities in the bedrock can affect the overall stability of the landfill and its facilities, and also offer convenient pathways for migration of contaminants.

6.2.3.5 Hydrogeology

Vadose zone

The vadose zone is defined as the zone between the top soil level and the groundwater table (Figure 6.2-5). Its characteristics are linked to the vertical mobility of contaminants toward the water table, and could play an important role in their attenuation or degradation. Therefore, the characterization of the site selected for building of a sanitary landfill should also include the following information about the vadose properties: mineralogy, porosity, organic matter content, particle size distribution, soils structure, as well as some information about its cation exchange capacity, temperature, soil pH value and the availability of microorganisms [UNEP, 2005].

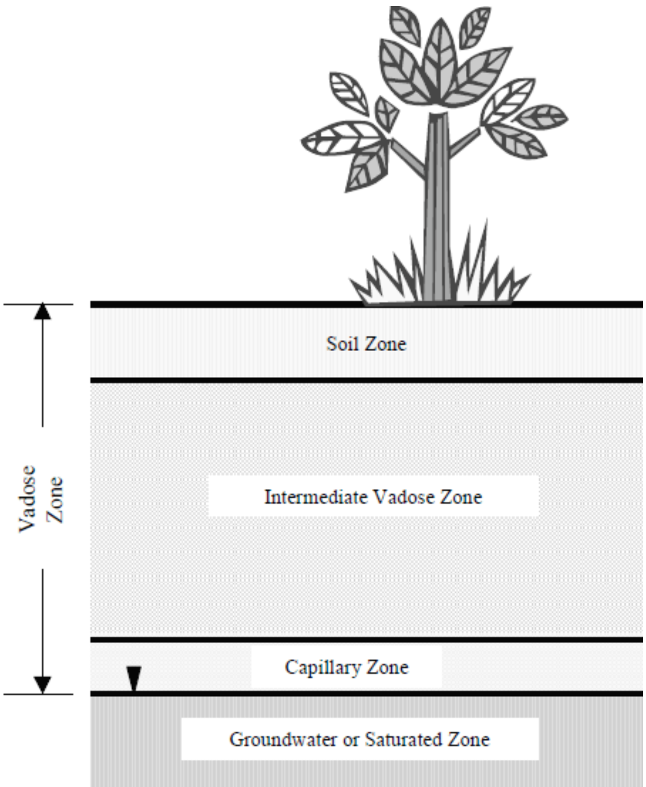


Figure 6.2-5 Schematic representation of vadose and groundwater zones [UNEP, 2005]

Groundwater

Considerations should be paid for areas with high groundwater recharge, which should normally be avoided [UNEP, 2005]. This would be the case of topographically high areas, where groundwater table would be relatively deep and any contaminant infiltration would lead to very long migrations along the aquifer. In opposite, the groundwater table is expected to be found very near to the surface in groundwater discharge areas, which may also pose a problem due to the pressure on the landfill bottom liner.

Monitoring of the groundwater quality should be performed especially for the uppermost aquifers since they are the first ones exposed to the risk of contamination by pollutants originating from the landfill runoff. The risk of contamination decreases if they or the respective vadose zone contain sorptive materials able to stop the spreading of contaminants (see also Figure 6.2-6) and could be limited by a combination of the following factors [UNEP, 2005]:

- the distance between groundwater table and the ground surface is more than 30 m;
- the net recharge rate is less than 5 cm/year;
- there are no major paths for contaminant migration;
- the topographic gradient is steeper than 18%
- the vadose zone is comprised of impervious soil (e.g. clay);
- the hydraulic conductivity of the aquifer is less than about 0.4 $m^3/day/m^2$.

In opposite, the risk of contamination rises dramatically if the following conditions are met [UNEP, 2005]:

- the distance between groundwater table and the ground surface is less than 3 m;
- the groundwater recharge rate is more than 25 cm/year;
- the vadose and/or the aquifer composition is made of fractured rocks;
- the topographic gradient is less than 2%;
- the hydraulic conductivity is higher than 80 $m^3/day/m^2$.

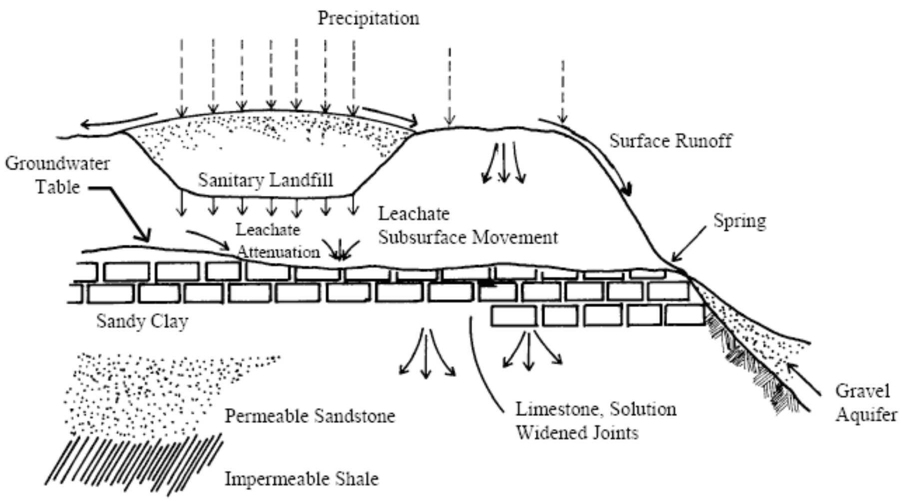


Figure 6.2-6 Interrelation between climatic, topographic, hydrologic, and geologic factors in terms of leachate travel and groundwater contamination [UNEP, 2005]

6.2.3.6 Vegetation

For a sanitary landfill, vegetation has the role of ensuring long-term stability and performance of the final landfill cover [UNEP, 2005]. Small trees, grasses and bushes can be planted to help against the erosions of the slopes and to behave like natural barriers against native climatic factors.

6.2.3.7 Access and transport

From economical perspective, the location of the landfill site should be chosen in such a way that it can allow minimum transportation times of the waste collected and this would mean the centre of the inhabited area. But as expected, this criterion gets in conflict with other socio-economical considerations and therefore a location outside of settlement has to be chosen. The access roads to the site should be in good condition, since a bad road can delay the waste delivery and deteriorate the transport vehicles, increasing the investment and maintenance costs significantly.

6.2.3.8 Economic considerations

Since most of the technical challenges expressed above can be solved by good site documentation and planning work, the decision about building a sanitary landfill faces actually the willingness of local communities to pay for their waste being properly disposed (which will implicitly improve the surrounding environment and life quality). Different economical aspects have to be well balanced in order to find the best compromise able to satisfy most of the stringent requirements. Among them, the costs for the cover materials and the costs of transportation to the site are weighting heavily in the overall balance. While the costs for the materials can be reduced by the availability of the materials on site, the transportation costs can be the main obstacle against building the landfill. On the other hand, a location far outside the settlement can offer low costs for land acquisition, which can be very important especially in densely inhabited regions, where free land is scarce and difficult to find at a convenient price. Moreover, a far off location may offer a lower adverse impact on the public health and the environment, so the final decision must be based on the evaluation of all factors involved, but in the same time not minimizing the importance of the full recovery of investment costs.

6.2.3.9 Decision-making

The decision making process for in a developing country should follow the next logical scheme in three steps [UNEP, 2005]:

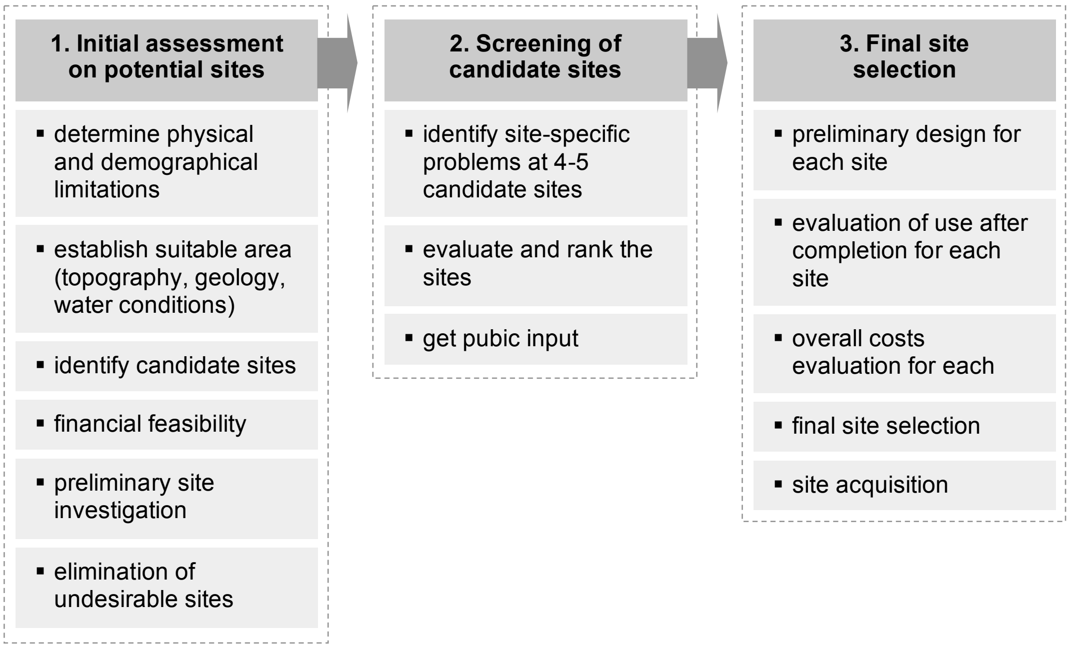


Figure 6.2-7 Decision making process for the selection of a landfill site

6.3 Landfill construction, operation and management

6.3.1 Landfill construction

According to the German waste disposal regulation [BMU, 2002], a landfill construction implies *"measures designed to create the requirements for commissioning of a landfill site, including in particular upgrading the geological barrier, landfill base sealing system, leachate and landfill gas disposal, landfill site areas, ventilation, and loading equipment".* The following chapters will present the construction of landfill's components, general landfill operation guidelines and management.

6.3.1.1 Landfill components

In order to ensure the environmental performance desired, a sanitary landfill must contain a few standard elements that are meant to reduce or even completely eliminate the negative impact to the environment and human health. The landfill components listed in Figure 6.3-1 have the main role of separation between the waste deposited in the landfill and the outside surroundings. The main problems posed by a landfill is the management of water and gases originating from the decomposition of the waste's organic fraction but also the groundwater, surface water and rainwater than might get in contact to the deposited waste.

Liner system	▪ positioned at the base and on the sides of the landfill ▪ can include clay, geotextiles for liquid leaching prevention ▪ compacted clay liner + synthetic liner
Leachate collection	▪ positioned at the top of the liner ▪ it collects the leachate and the water that passes through waste ▪ brings the leachate to the treatment unit
Cap system	▪ positioned at the top of the landfill ▪ compacted clay and synthetic material + vegetation ▪ prevents the precipitation from infiltration into the landfill
Gas collection system	▪ vertical wells + horizontal pipes installed in the landfill ▪ prevents gases escaping from the landfill (especially methane) ▪ extracts gases and pumps them to the destruction unit
Surface water control	▪ drainage channels installed on and around the landfill ▪ controls erosion of the cap and contamination of adjacent waters ▪ collects the precipitations and brings them to a retention pond
Monitoring system	▪ installed around the landfill ▪ it checks that liner and gas collection system operate properly ▪ ensures that health and environment are protected

Figure 6.3-1 Typical municipal solid waste landfill components

The systems for control and prevention (see also Figure 6.3-2) are mostly located at the landfill's boundaries (e.g. the liner system, the leachate collection system and the cap system) but also inside and around the landfill (the gas collection system, the surface water system or the monitoring system). They will be detailed in the following chapters, together with some information about the technologies used for the construction of a sanitary landfill.

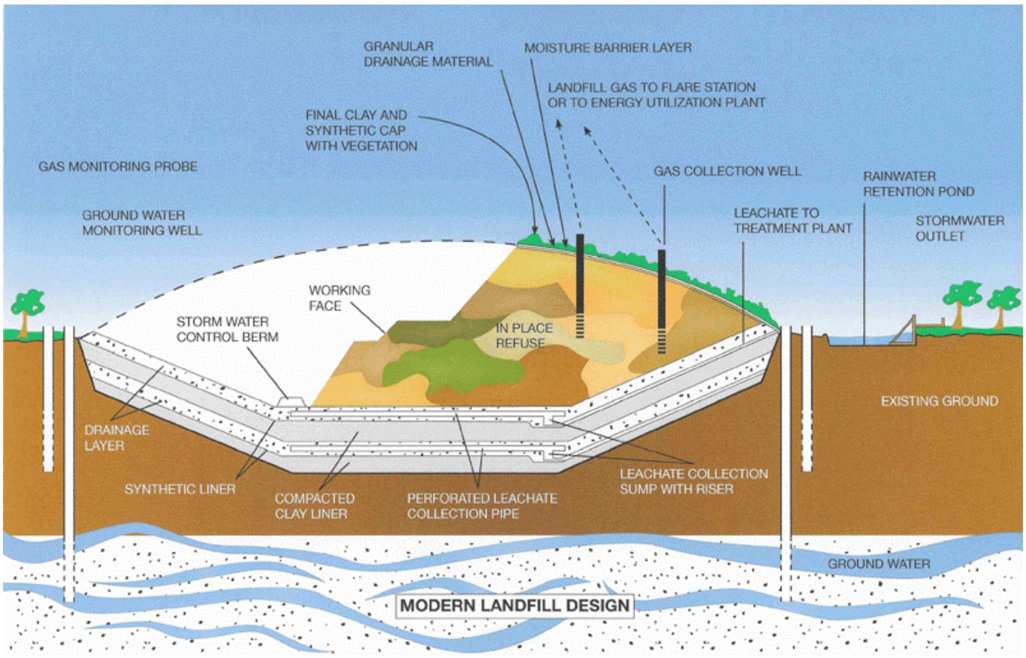


Figure 6.3-2 Landfill cross-section [www.runcoenv.com]

6.3.1.2 Cell design

A typical landfill structure is based on “cells”, which are created by spreading and compacting the deposited waste within a delimited area. At the end of each day it is recommended to cover the compacted waste with a thin layer of soil, which also has to be also compacted. The characteristics of each cell like height, length, width of the working face, slope and thickness of the cover layer) depend on the specific conditions of each particular case.

> ☞ Please note:
>
> The minimum width of the cell depends upon the equipment used and the maximum number of vehicles working simultaneous at the site. A recommended width is about 2 to 2.5 times the width of the blade building the cell [UNEP, 2005].
>
> The maximum recommended slope of the cell should be 1 to 3. A slope less than 1 to 6 implies very large areas for working face [UNEP, 2005].

6.3.1.3 Slope stability

The slope stability is an important element in the landfill design. Improperly calculated, it can lead to massive landslides of waste, destroying surrounding properties or causing serious injuries of landfill working personnel. Beside incorrect calculations, the slope’s stability depends directly on the following factors [UNEP, 2005]:

- properties of the waste deposited on the landfill
- properties and type of materials used to separate the landfill waste from the environment
- amount of moisture in the waste
- natural causes like earthquakes or heavy rains

6.3.1.4 Sealing layers

The major role of a landfill sealing layers is to act as a barrier between waste and the environment and to not allow exchanges between them. As mentioned before, they can surround the landfill (e.g. the base seal) or lay on the top of waste layers (e.g. as final cover component). The depth of the base and surface sealing layers, together with their *k* values, are presented in Table 6.2-1 and Table 6.3-1, according to landfill class:

Table 6.3-1: Standard structure of geological barrier and base sealing system [BMU, 2002]

System component	Landfill class 0	Landfill class I	Landfill class II	Landfill class III
Geological barrier	$k \leq 1 \cdot 10^{-7}$ m/s $d \geq 1.0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 1.0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 1.0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 5.0$ m
Mineral sealing layer (at least two layers)	not required	not required	$k \leq 5 \cdot 10^{-10}$ m/s $d \geq 0.5$ m	$k \leq 5 \cdot 10^{-10}$ m/s $d \geq 0.5$ m
Plastic sealing liner ($d \geq 2.5$ mm)	not required	not required	required	required
Protection layer	not required	required	required	required
Mineral drainage layer	$d \geq 0.3$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0.5$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0.5$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0.5$ m $k \geq 1 \cdot 10^{-3}$ m/s

Table 6.3-2: Standard structure of the surface sealing system [BMU, 2002]

System component	Landfill class 0	Landfill class I	Landfill class II	Landfill class III
Compensatory layer	not required	$d \geq 0.5$ m	$d \geq 0.5$ m	$d \geq 0.5$ m
Gas drainage layer	not required	not required	required in some cases	required in some cases
Mineral seal	not required	$d \geq 0.5$ m $k \leq 5 \cdot 10^{-9}$ m/s	$d \geq 0.5$ m $k \leq 1 \cdot 10^{-9}$ m/s	$d \geq 0.5$ m $k \leq 1 \cdot 10^{-3}$ m/s
Plastic sealing liner	not required	not required	$d \geq 2.5$ mm	$d \geq 2.5$ mm
Protective layer	not required	not required	required	required
Drainage layer	not required	$d \geq 0.3$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0.3$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0.3$ m $k \geq 1 \cdot 10^{-3}$ m/s
Recultivation layer ($d \geq 1.0$ m)	required	required	required	required
Vegetation	required	required	required	required

6.3.1.5 Landfill operation and management

6.3.1.6 Specific operational procedures

Depending of how the waste is deposited on the landfill site, one can differentiate two major filling methods: area method (Figure 6.3-3) and trench method (Figure 6.3-4). In the area method, the waste is deposited on a large open area (most common method), while in the second method, the waste is deposited in an excavated trench. Additionally, waste can also be deposited on the existing slopes of a site.

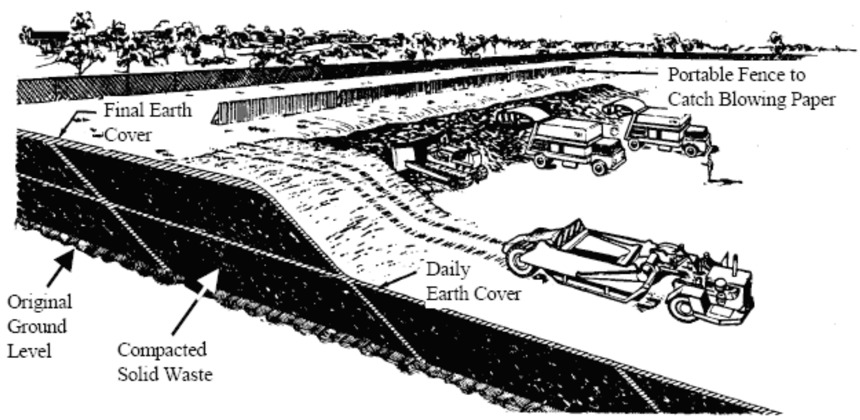


Figure 6.3-3 Area method and trench method of sanitary landfilling [UNEP, 2005]

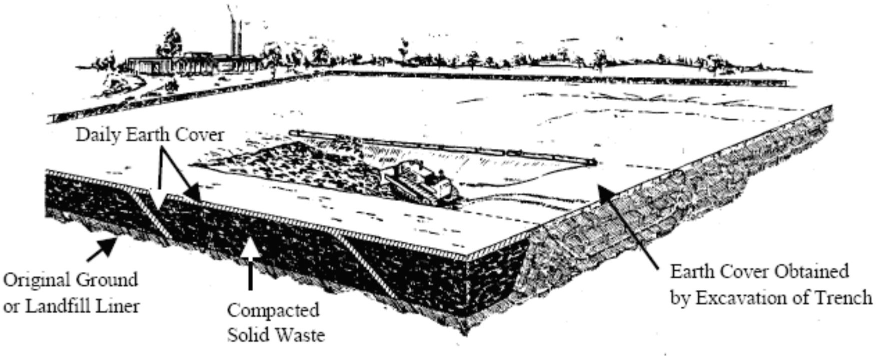


Figure 6.3-4 Trench method of sanitary landfilling [UNEP, 2005]

According to the filling method, some specific operational procedures have been summarized in Figure 6.3-5 and Figure 6.3-6. These procedures have grouped in the following basic categories:

- site preparation
- traffic flow and unloading
- compaction
- cover layers

Area method
In opposite to trench method, area method implies spreading and compaction of the waste on a flat area, usually a valley, an old mine or quarry, canyons etc. The key issues regarding the specific operational procedures are presented on short in Figure 6.3-5 (compiled from UNEP, 2005):

	AREA METHOD
Site preparation	▪ minimum disturbance of soil and vegetation from selected site ▪ eventual excavations should be effective, without stockpiling (double work avoided)
Traffic flow and unloading	▪ good compaction required if collection vehicles drive over the already deposited waste ▪ unloading should be performed at the bottom of the working face, to allow an easier compaction later
Compacting	▪ increases the landfill capacity ▪ its efficiency depends upon waste layer thickness, waste characteristics, number of passes, type of compactor
Daily, intermediate and final cover	▪ daily cover: control against odour, water infiltration, vectors ▪ intermediate cover: same function as daily cover; remains longer exposed and serves also for traffic on landfill ▪ final cover: closes the landfill and allows area rehabilitation

Figure 6.3-5 Specific operational procedures for area method

Trench method
The trench method implies placing the waste into an excavated trench, compaction, and using the excavated soil as cover material. The width and length of trenches can very according to the specific site conditions. The specific operation procedures are summarized in Figure 6.3-6:

	TRENCH METHOD
Site preparation	▪ phased fill and covering approach: soil from trench excavations should be used as cover layer either for the same trench or for the adjacent trench
Traffic flow and unloading	▪ unloading over the edge (attention at sidewall stability) or from within the trench (preferred) ▪ traffic procedures similar to area method
Compacting and cover	▪ the same like in area method

Figure 6.3-6 Specific operational procedures for trench method

Ramp method
The ramp method is very similar to area method, being mostly used for landfills built on existing slopes. The difference is represented by the cover layer, whose material is excavated right from the front of the working face. This creates a small depression for depositing the next load to waste, making the method very effective.

6.3.1.7 Water management

The contaminated water originating from the landfill is the main factor of negative impact to the environment, therefore a strict control is required for the water quantities entering and leaving the landfill. The two major water sources that have to be protected from the negative impact of a landfill are the surface waters and the groundwater.

Surface water
The contamination of the surface water flowing in the vicinity of the landfill has to be protected against the runoff from the landfill site. This can be done by constructing a series of small channels and drains around the landfill able to take over the runoff waters. It is assumed that the degree of water contamination increases with the retention time of the precipitations on the landfill, therefore grading the landfill cover could help for an efficient runoff of rainfall [UNEP, 2005].

Groundwater
The contamination of groundwater has the main origin in the passage of precipitations through the solid waste in a landfill. The rainfall can get together with the existent mixture (water from the waste decomposition) and then get in contact with the groundwater layers if the bottom liner is not able to realise a good isolation. The solution to avoid the groundwater contamination is the realisation of a system for the collection and further treatment of the landfill leachate (see chapter 6.3.1.8).

Water balance
The components of the water balance in a landfill are presented in Figure 6.3-7 and can be expressed using the following equation [UNEP, 2005]:

$$MC = W_{SW} + W_C + W_P - W_{RO} - W_{lfg} - W_V - W_{evap} + W_{leach}$$

where:

- MC = the variation of the moisture quantity stored in the landfill (kg/m^3);
- W_{SW} = quantity of water in the upcoming waste (kg/m^3);
- W_C = quantity of water in the cover material (kg/m^3);
- W_P = quantity of water from precipitations (kg/m^3);
- W_{RO} = quantity of water from precipitations diverted as runoff (kg/m^3);
- W_{lfg} = quantity of water used in the formation of landfill gas (kg/m^3 of gas);
- W_V = quantity of water lost as saturated vapours with landfill gas (kg/m^3 of gas);
- W_{evap} = quantity of water lost due to evapotranspiration (kg/m^3);
- W_{leach} = quantity of water leaving the landfill as leachate (kg/m^3).

☞ Please note:

For landfills in developing countries, the following values can be used for calculations [UNEP, 2005]:

- moisture content of waste 30 to 60%
- water used in the formation of landfill gas ~ 0.2 kg/m^3 of gas
- water lost as saturated vapours with the landfill gas ~ 0.04 kg/m^3 of gas

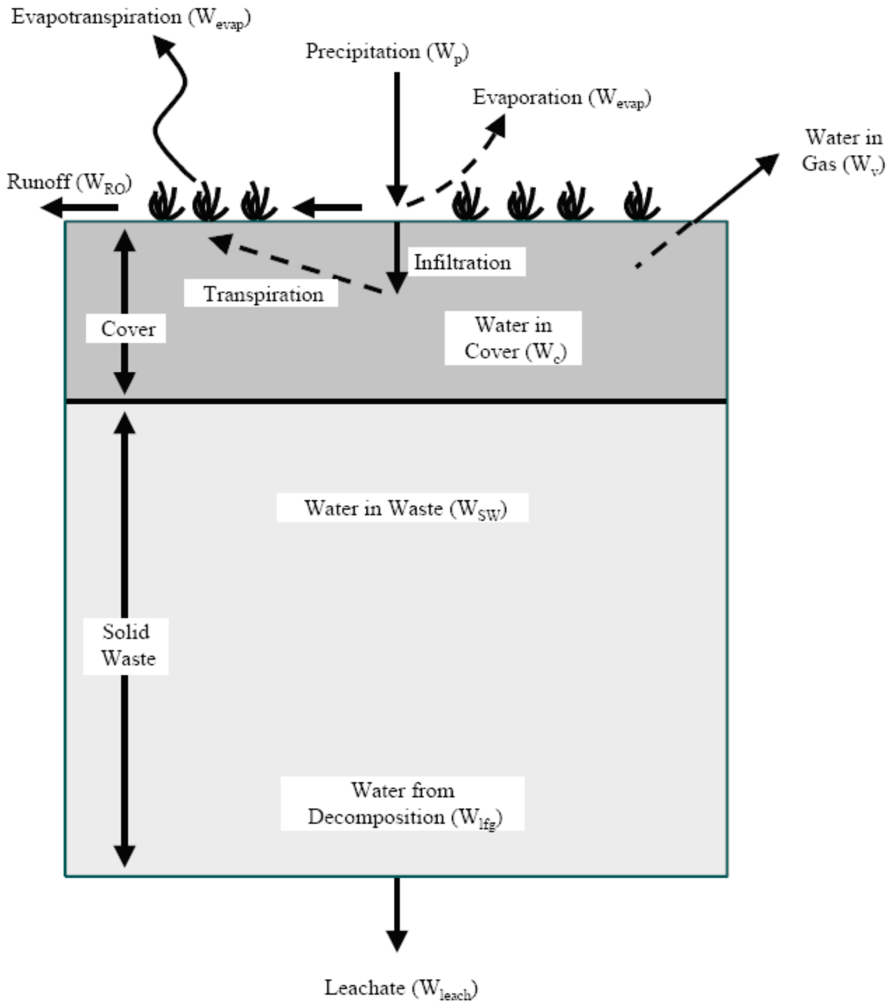


Figure 6.3-7 Components of a water balance [UNEP, 2005]

Conducting a preliminary water balance in a landfill is an important step for the correct design of a leachate collection and treatment system. The water balance should be calculated regularly and on a long time basis, as many of its components could dramatically change their values over time. Among them, the quantity of water leaving the landfill as leachate is of major importance and it will be detailed in the following chapter.

6.3.1.8 Leachate collection and treatment

The formation of leachate in a sanitary landfill is mainly caused by the percolation of water from precipitations through the waste mass. In contact with the decomposing waste, it becomes loaded with various substances and degradation products (see Table 6.3-3) and moves slowly to the base of the landfill with 10^{-2} to 10^{-4} cm/s [UNEP, 2005].

Table 6.3-3: Characteristics (Parameters) of leachate from decomposition of municipal solid waste [UNEP, 2005]

Parameter	Range of values (mg/l)
pH	4.5 to 9
Alkalinity ($CaCO_3$)	300 to 11,500
BOD (5-day)	20 to 40,000
Calcium	10 to 2,50
COD	500 to 60,000
Copper	4 to 1,400
Chloride (Cl^-)	100 to 5,000
Hardness ($CaCO_3$)	0 to 22,800
Iron – total	3 to 2,100
Lead	8 to 1,020
Magnesium	40 to 1,150
Manganese	0.03 to 65
Ammonia-NH_3	30 to 3,000
Organic N	10 to 4,250
Nitrogen – NO_2	0 to 25
Nitrogen – NO_3	0.1 to 50
Nitrogen – total	50 to 5,000
Potassium	10 to 2,500
Sodium	50 to 4,000
Sulphate (SO_4^-)	20 to 1,750
Total dissolved solids	0 to 42,300
Total suspended solids	6 to 2,700
Total phosphate	0.1 to 30
Zinc	0.03 to 120

The leachate composition can widely vary, consisting of organic and inorganic compounds that can be either dissolved or suspended. During the decomposition process, the temperature of the waste mass rises and the pH value decreases, making possible that certain metals ions, insoluble in normal conditions, to become soluble and thus dissolved in the leachate. The high amount of dissolved gases (e.g. methane, hydrogen, sulphur) and nutrients make the water resources contaminated by leachate become very quickly depleted in dissolved oxygen. Apart the contamination with heavy metals and other harmful substances, this will strongly affect the life in the respective water body making it improper for its original use.

In order to protect the respective water bodies, the landfill must be equipped with a leachate collection system consisting of a drainage layer, leachate cleanout and maintenance ports, a collection pump and a leachate storage tank [Bilitewski et al., 1994]. The extraction of leachate can be done by pipes and/or drainage layers and it has to consider all the processes occurring in a landfill. For a good review on best available techniques for landfill leachate extraction and pumping see Last et al., 2004.

Once collected, the leachate has to be discharged and, according to regulations, further managed. For this, one of the following methods can be applied:

<u>Recirculation</u>

In this method, the leachate released by a landfill is collected at the base of the landfill and reintroduced trough the landfill waste many times. This method provides a simple solution for the leachate disposal and it enhances the landfill stabilization (because the leachate helps in the production of more landfill gas by increasing the waste moisture and thus decreasing the overall waste volume). However, the recirculation does not solve the problem posed by the contaminants contained since they are only concentrated, not removed. Moreover, some landfills operators reintroduce the leachate by spraying it at the surface of the landfill, which actually increases the risk of surrounding waters contamination through stormwater runoff from the landfill area [Jones-Lee and Lee, 2000].

<u>Discharge to sewage</u>

This method might offer an alternative to recirculation but it is restricted by the local or national regulations on wastewater quality. Usually, the strength of landfill leachate is tens to thousands times higher than the accepted wastewater in a sewerage system, therefore a discharge of such high-concentrated is not indicated.

Treatment
In most developed countries, leachate generated by a municipal solid waste landfill has to be treated. Normally, any wastewater treatment methods available can be used for treating landfill waste and Table 6.3-4 provides an overview on these methods, together with their applicability and restrictions:

Table 6.3-4: Overview of leachate treatment processes [Bilitewski et al., 1994]

Method	Comments	Problems
Physical methods		
Sedimentation	Low cost	Only suitable for insoluble compounds
Evaporation	Preconcentrating constituents	Costly, corrosive, only a partial solution, COD is removed but not destroyed
Physical/Chemical methods		
Activated carbon adsorption	Suitable for hydrophobic compounds in wastewater	Only provides partial treatment, regeneration of carbon necessary
Resin adsorption	Suitable for chlorinated hydrocarbons, other hydrocarbons, aromatics	Only partial treatment, costly
Membrane Process / Reverse osmosis	Reverse osmosis, good retention	Concentrated solids may acquire additional treatment, membrane fouling possible
Ion exchange	Only specialized ions suitable	Organic solids and colloids are disruptive to process
Flocculation and precipitation	Often used, partial COD elimination, not necessarily state-of-the-art anymore	Treatment/disposal of sludges and high quantities of salts required (35 kg/m^3 leachate!)
Chemical methods		
Wet oxidation with H_2O_2	No concentrating, elimination of residual COD	No always appropriate for direct treatment, high energy demand
Wet oxidation with O_3/UV	No concentrating, elimination of residual COD	No always appropriate for direct treatment, high energy demand
Biochemical methods		
Anaerobic treatment	No energy needs for oxygenation, no surplus sludge	Retaining the biomass, sensitivity, not a total treatment
Aerobic treatment (aerated lagoons)	Most common, most cost effective method	Not effective for non-biodegradable materials, regulatory limits difficult to achieve

☞ Please note:

To some extend, the leachate can be used after treatment in agriculture, for irrigation and as fertilizer, due to its high content of nutrients (e.g. for plants suitable for biofuels production). See also www.leachate-irrigation.com.

6.3.1.9 Management of landfill gas (LFG)

Gas origin and composition
During the initial period after disposal, the waste still contains certain amounts of oxygen that is the base for the aerobic degradation processes. This phase is usually short (from few days to several weeks) and the resulted gas contains mostly CO_2 and water vapour. Soon afterwards, due to waste compaction and application of daily and intermediate cover layers, the oxygen is getting depleted and the system becomes anaerobic (phase two). This is followed by the apparition of gas emissions containing methane (CH_4) in rising concentrations (phase 3), followed by the last phase defined by constant production of methane and other gases having the following composition: 40% – 60% methane, 40% – 50% carbon dioxide, 3% - 20% nitrogen and 1% oxygen [UNEP, 2005].

Gas generation

The production of methane containing gas in a landfill is directly influenced by the waste moisture and pH value and does not depend much on the compaction level, age or density of waste deposited [UNEP, 2005]. However, due to different waste composition reported, the gas production can vary in developed countries from values of 2.33 m^3/ton*year in Denmark to 5.09 m^3/ton*year and more in countries like Portugal (see Table 6.3-5).

Table 6.3-5: Data on worldwide gas production from landfills [Willumsen, 2003]

Country	**Number of plants**	**Size of plants** (MW)	**Waste amount** (Mio. ton)	**Landfill gas** (m^3/h)	**Landfill gas** (m^3/ton*year)
USA	354	2,208	2,850	958,400	2.95
Canada	16	88	100	72,00	6.31
Australia	18	76	101	43,657	3.79
South Africa	4	4	4	1,600	3.50
Brazil	7	11	12	4,000	2.92
Austria	15	22	28	8,820	2.80
Czech Republic	6	7	8	2,700	2.96
Denmark	20	22	20	5,913	2.59
France	20	30	35	12,400	3.10
Finland	14	12	20	6,500	2.85
Germany	180	270	380	78,500	1.81
Greece	1	13	20	7,400	3.24
Netherlands	47	62	100	26,575	2.33
Italy	135	362	240	115,150	4.20
Norway	30	28	13	5,790	3.99
Switzerland	6	7	8	2,988	3.27
Spain	13	36	51	20,700	3.56
Portugal	1	2	2	900	5.09
Sweden	61	55	35	12,950	3.24
Poland	19	18	15	5,000	2.92
UK	150	320	400	180,000	3.94
Hong Kong	8	32	28	14,620	4.64
China	4	4	4	2,160	4.73
Taiwan	4	20	20	10,972	4.81
South Korea	3	16	14	7,000	4.54

In developing countries, although the organic matter content of the deposited waste is very high, the landfill cover is usually not adequately applied and this leads to free escape of the landfill gas.

Gas collection and utilisation

The first step in gas collection is providing a proper landfill sealing, with special focus on the top layers. The collection itself is done by installing a set of perforated pipes on high permeable areas and using a venting principle to pump the gas out of the landfill (Figure 6.3-10). The number and characteristics of venting pipes and their arrangement in the landfill should be designed according to the local conditions and requirements (Figure 6.3-8 shows some areal methods of connecting gas wells to the gas collection system). The collected gas can be then utilised as low heat fuel or further treated and used as a high-heat fuel. For using the landfill gas in cooking, the hydrogen sulphide (H_2S) has to be removed [UNEP, 2005].

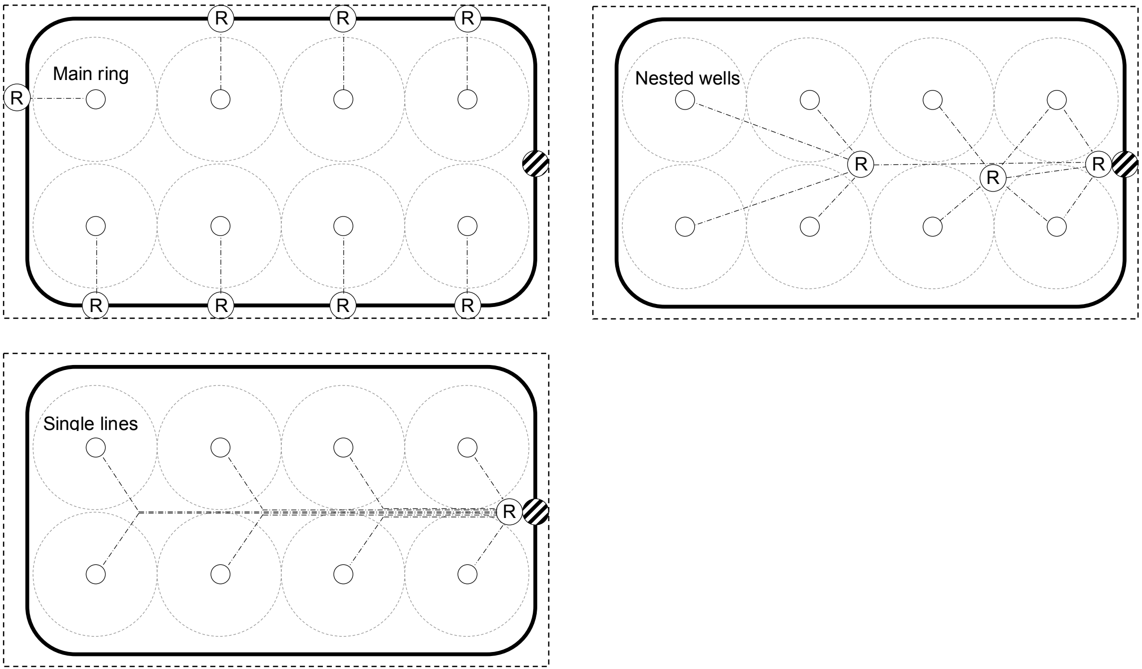


Figure 6.3-8 Methods of connecting wells to the gas collection system [Bilitewski et al., 1994]

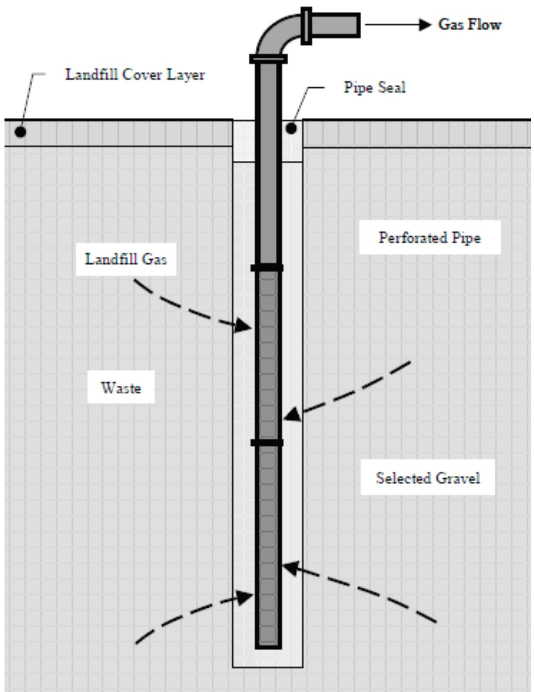


Figure 6.3-9 Schematic diagram of a gas well [UNEP, 2005]

The problem of odours from landfill sites may have important consequences on health of operating personnel, as well as important negative impacts on the socio-economical development of the area surrounding the landfill site. Taking into consideration that gas production at a landfill may take even up to several years after the applying the final cover, a careful design is required for the gas collection system. However, the reduction of odours can be realized by taking a couple of additional measures too, such as installing an onsite weather station and field monitoring or by spraying odour neutralizing chemicals along the landfill border. The Figure 6.3-10 shows an overview on different methods to reduce the odours at a landfill:

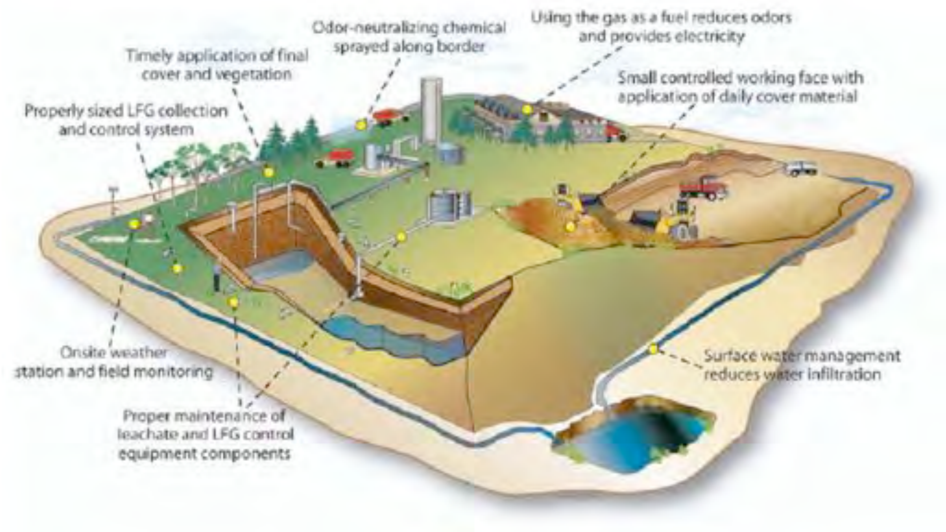


Figure 6.3-10 Methods to control odours at landfills [NAWMA, 2008]

6.3.2 Environmental monitoring

The monitoring of environmental impact of a landfill is strictly required and it has to be done by comparing the characteristics of the environmental components before building the landfill and after completion. The monitoring of the landfill vicinity should run over a long period of time and it should contain also a plan for remediation in case necessity.

6.3.2.1 Groundwater

The potential impact of a landfill on groundwater quality can be generally evaluated by a detailed analysis of the leachate composition and generation rate. This allows the identification of contaminants posing a threat to groundwater and the intensity of a potential contamination [UNEP, 2008].

Nevertheless, the groundwater quality has to be check before reaching the vicinity of the landfill and after the area potentially affected. The following parameters will offer indication of contamination by landfill leachate and should constitute the basis for an environmental monitoring program:

- pH
- specific conductance
- alkalinity
- biological oxygen demand
- chemical oxygen demand
- nitrate/nitrite nitrogen
- chloride
- iron
- sodium
- magnesium
- sulphate

The collection of water samples for the detection of the above parameters can be done using classical monitoring wells, like in Figure 6.3-11:

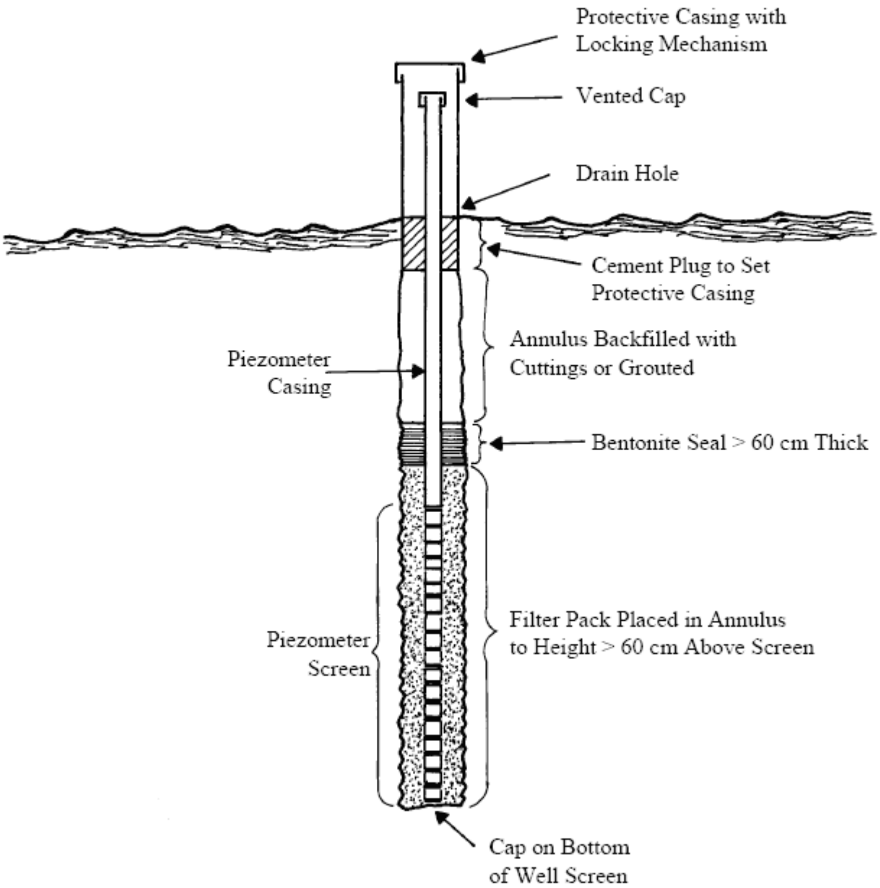


Figure 6.3-11 Groundwater monitoring well [UNEP, 2005]

6.3.2.2 Surface water

The negative impact depends mostly on the distance and also on the drainage patters between the landfill and the adjacent surface waters. A landfill situated very close to a lake or a river which is not adequately isolated can lead to massive impacts to the respective water source, as seen in Figure 6.3-12. The general approach for surface waters should be similar those adopted for the groundwater, with water samples taken upstream and downstream of the landfill and analysed for quality parameters.

Figure 6.3-12 Dumping site in the proximity of surface water in India

6.3.2.3 Landfill gas

The landfill gas escaping the landfills without a system for collecting it can also be regarded possible factor of environmental contamination. Moreover, the chemical composition of the gas (see chapter 6.3.1.9) make the gas very dangerous for the people working at the landfill and within its surroundings. If the landfill is properly top closed, the gas will find its ways out by lateral sides. This can be detected by installing sampling devices and monitoring the concentration of methane in the air samples.

6.4 Completed landfills and rehabilitation

Landfill closure starts when the planned landfill capacity is reached but the closure can also be done progressively, while still adding waste to new cells. However, a completed landfill is not going to become an abandoned place. The management of landfill gas, leachate, as well as environmental monitoring will continue for long periods of time (even 20-30 years or more) and this should be well considered at the planning stage because the costs for these activities will not be incurred on a revenue basis.

The rehabilitation of a landfill means using the site for a variety of functions, among them being:

- Residential development (houses and annexes, green spaces)
- Commercial development (storage areas, parking lots, etc)
- Active recreation areas (sport)
- Passive recreation areas and open space (parks, green areas)

The final use of a completed landfill can be decided according to criteria established by the local regulatory agencies and according to the needs the local communities. This can be influenced by the following aspects: low bearing capacity, differential settlement of the landfill site, methane which might eventually escape in the atmosphere, general public acceptance.

Figure 6.4-1 Closing works of a sanitary landfill in Germany

☑ Self-assessment

11. What are the criteria a disposal site has to meet in order to be considered a sanitary landfill?
12. Classify the landfills according to the type of waste disposed and to technical level accomplished
13. What are the processes occurring in a landfill? Which ones are the most important and why?
14. Describe the site requirements for the construction of a new landfill.
15. Enumerate the minimum necessary steps to be followed when deciding about constructing a new landfill.
16. What are the typical landfill components?
17. What are the main methods of depositing the waste to a landfill?
18. What is a water balance and what are its components?
19. What are the advantages and disadvantages between different methods for the management of landfill leachate?
20. What is the composition of the landfill gas?
21. What measures can be taken to reduce the negative environmental impact posed by a landfill?

6.5 References

Bilitewski, B., Härdtle, G., Marek, K., Weissbach, A., Boeddicker, H. 1994: Waste Management. Springer-Verlag Berlin Heidelberg. ISBN 3-540-59210-5

United Nations Environment Programme (UNEP) 2005: Solid Waste Management. Volume I. ISBN: 92-807-2676-5

United Nations Environment Programme (UNEP) 2005: Solid Waste Management. Volume II – Regional Overviews and Information Sources. ISBN: 92-807-2676-5

TETRAWAMA 2006: Teaching and training modules for higher education in the waste management sector. Module 1 – "Solid waste management in Asia". e-Book, version 1.0

NSWMA 2008: Managing Soild Waste Facilities to Prevent Odor – http://wastec.isproductions.net/webmodules/webarticles/articlefiles/438-OdorReport.pdf

Willumsen, H. 2003: Landfill gas plants worldwide: number and types. Proceedings Sardinia 2003, 9th International Waste Management and Landfill Symposium, CISA, University of Cagliari, Sardinia, Italy

Jones-Lee, A. Lee, G. 2000: Appropriate Use of MSW Leachate Recycling in Municipal Solid Waste Landfilling. Proceedings Air and Waste Management Association 93rd national annual meeting, CD-ROM paper, 00-455 Pittsburgh, PA June 2000 http://www.gfredlee.com/leachatepapsli.pdf

Last, S., Corden, K., Harris G. 2004: Best available techniques for landfill leachate extraction and pumping. Proceedings of Waste 2004 Conference, Stratford-upon-Avon, UK. http://www.leachate.co.uk/Waste2004-BAT-for-Leachate-Extraction-and-Pumping.pdf

Recommendations for further reading:

Diaz, L.F., Savage, G.M., Golueke, C.G., Martone, C., Ham, R.K. 1998: Guidance for Landfilling Waste in Economically Developing Countries. CalRecovery Inc. Report

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2002: Ordinance on Landfills and Long-Term Storage Facilities and Amending the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (unofficial text as of February 1st, 2007) http://www.bmu.de/files/pdfs/allgemein/application/pdf/deponievo_engl.pdf

Springer, C., Kraft, E., Bidlingmaier, W. 2005: Development of alternative concepts for construction and operation of landfills under the conditions of tropical climate. Proceedings Sardinia 2005, 10th International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy; 3-7 October 2005

Heyer, K.-U., Hupe, K., Stegmann, R. 2005: Landfill aftercare – scope for actions, duration, costs and quantitative criteria for the completion. Proceedings Sardinia 2005, 10th International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy; 3-7 October 2005

Streese, J., Stegmann, R. 2005: Design of biofilters for methane oxidation. Proceedings Sardinia 2005, 10th International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy; 3-7 October 2005

Further acts and ordinances related to waste management in Germany issued by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety http://www.bmu.de/english/waste_management/acts_and_ordinances/acts_and_ordinances_in_germany/doc/20203.php

Randy, M. 1987: Solid Waste Landfill Design Manual http://www.ecy.wa.gov/pubs/87013.pdf

G. le Roux – Guidelines for leachate control http://www.dwaf.gov.za/Documents/Policies/WDD/LeachateControl.pdf

Stegmann, R., Heyer, H.-U., Cossu, R. 2005: Leachate treatment. Proceedings Sardinia 2005, 10th International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy; 3-7 October 2005
http://www.image.unipd.it/tetrawama/S2005/leachate_treatment.pdf

Aquious – Leachate treatment using membrane technology. Multistage treatment of landfill leachate
http://www.pci-memtech.com/images/Tp128_5(Web)%20Leachate%20Treatment.pdf

Dwyer, S.F. 2003: Water balance measurements and computer simulations of landfill covers. PhD thesis, The University of New Mexico, Albuquerque, New Mexico, May 2003
http://www.sandia.gov/caps/ALCD_report.pdf

Ecoaccess – Guideline on landfill sitting, design, operation and rehabilitation: Waste disposal
http://www.epa.qld.gov.au/publications/p01312aa.pdf/Landfill_siting_design_operation_and_rehabilitation_Waste_disposal__ERA_75.pdf

7 Economic and Socio-economic aspects of waste management

Background

Understanding the socio-economic impact of waste management systems and renewable energy solutions becomes necessary for setting up the necessary framework conditions and for having the impacts integrated into the political, social and economic system of a country.

Educational objective of the chapter

To throw some light on the significance of environmental economics towards understanding the impact potentials of promoting an appropriate economic instrument to reap the right benefit.

7.1 Factors to be considered in waste management system

7.1.1 Justifications for initiatives to augmenting renewable energy solutions:

The government polices of recent years face a strong critique from social activists stating that bio fuel are to blame for the shortage of grains and the inflation forthwith. To counter this argument and to find an efficient alternative to corn ethanol, a few firms (GeneSyst International, Netherlands and Blue Fire Ethanol USA) have begun to build and develop ethanol plants that use household wastes to produce the fuel. This brings a double dividend cutting down on wastes volume going to landfills thereby, reducing the negative impact on environment; bringing economic benefits to individuals and the economy. Household waste is inherently putrescible and it can be decomposed with the help of methane bacteria. It may ferment naturally in a landfill, which even when lined is at comparatively low cost. But, the landfills cause considerable safety and environmental hazards. The technologies that help to produce energy out of wastes prevent the release of green house gases in the form of carbon dioxide, methane, nitrogen oxides along the volatile organic compounds from entering the atmosphere. They avoid the release of methane that otherwise would be emitted when the waste decomposes, and the release of CO2 that would be emitted from generating electricity from fossil fuels. Hill et al (2006) evaluate whether the bio fuel from corn grain or bio diesel from soybeans can replace much petroleum without impacting food supplies. They find dedicating all US corn and soybean production to bio fuel can meet only 12% of the gasoline demand and 6% of the diesel demand. Biomass from wastes, whereas, can provide much greater supplies thereby reaping two goals of containing the problem of managing wastes and meeting the growing energy demands.

If the demand for food grew with the growing middle class population of Asian countries along the rising depletion of world stocks, the resultant effect would be rising food prices. Therefore, the best solution under the present circumstances is to switch to renewable energy solutions. The project, INVENT, therefore, offers a breakthrough in its contribution suggesting proper use of the by product of consumption and production activities to use as input fully knowing the ‘economic value’ of the commodity. Secondly, it does not suggest for anything like food withdrawal from the stock thereby leaving it for the purpose it is meant for.

7.1.2 Cost-effectiveness and sustainability issues

The government polices in Europe seem to pace faster in the renewable energy sector. Europe’s renewable energy sector represents around 50% of the world market for renewable energy. And the sector of industry employs more than 300,000 people. European Union’s Energy Efficiency Action Plan has set a goal of 20% energy consumption reduction of non-renewable energy sources by 2020. The target will reduce emission equivalent to 780 Mt of GHG each year and this will also reduce energy cost of 100 billion Euros every year. This action plan of European Union will be complemented by 21% of switch- over to renewable sources. According to the Directive 2003, in 2010 5.75% of all transport fuels in Europe has to originate from biomass. Biomass trade will involve sustainability aspect whether the biomass has been produced from renewable and sustainable sources identified by the EU. According to the EU Directive on power from renewable sources (2001/77) bio degradable fraction of industrial and municipal waste has been identified as the sustainable and renewable source of energy production. Europe will also be the first region to grasp the environmental contribution from Green Heat technologies and also likely to benefit from early mover advantage, the most in economic terms.

Renewable energy accounted for 13.3% of the world's total primary energy supply in 2003. And, almost 80% of the renewable energy supply was from biomass. An increase in the use of renewable energy should significantly reduce the burden on conventional sources of energy. The economic feasibility of renewable sources can be reaped when their production is extended to a large scale and cost effective sources of renewable energy should be supported irrespective of their size of operation.

Out of the total world electricity production renewable energy sources account only for 17.6% share with hydroelectric power providing almost 90% of it. But, as the renewable energy technologies become even more cost competitive in the future they will be able to replace a major fraction of fossil fuels for electricity generation. In the near future, home generated electricity from micro generation may also become the norm, with the surplus sold to the grid.

7.1.3 Economic evaluation and viability of waste management systems

7.1.3.1 Economic viability of integrated waste management:

The question of implementing a concept of Integrated Waste Management should therefore assign priority to appropriate reduction and reuse strategies, complemented by recycling activities. Of course, all these strategies and activities have to be technically and economically viable or "reasonable", given the framework conditions of a particular country.

What do we understand by economic viability of certain strategies and actions in the context of waste management? The Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (Germany, September 1994) addresses this issue in Article 5: Basic Obligations of Closed Substance Cycle Waste Management. Paragraph 4 states: "The obligation to recover waste is to be met, to the extent this is technically possible and economically reasonable, especially when a market exists, or can be created, for an extracted substance or for extracted energy…. Waste recovery is economically reasonable if the costs it entails are not disproportionate in comparison with the costs waste disposal would entail."

This last statement is difficult to verify in practical situations. This can be judged from the experiences with the Renewable Energy Sources Act in Germany. Nevertheless, it is a consequence of the optimality criterion introduced and explained earlier. For the practical implementation one would have to conduct a Benefit-Cost-Analysis on the basis of the available information to single out the best strategy or the best alternative.

7.1.3.2 Economic viability of an investment on waste treatment facility:

The financial analysis of a project revolves around the monetary aspects of the project and the return on the investment to the investors. It includes the payment transfer of taxes, duties and subsidies in this regard. The economic analysis, on the other hand, evaluates whether the project brings benefits to the whole economy apart from the region it serves. It takes into account the socio economic aspects of the benefit that emanates from the project. It takes, also, into account the prices of the traded goods as well as the shadow prices of the non traded good and services.

The economic viability of a project can be calculated on the basis of the net benefit the project produce. The payback period is the length of time between the initial investment and recovery of the investment from the annual cash flow into the project. The shorter the payback period the more attractive it is for investors to choose the option. The financial analysts usually begin with estimating the capital cost of the project along projected power output, annual revenues, expenses, and deductions to arrive at the net benefit. A simple payback period is calculated without regard to the time value of money.

The pay back period of an investment on a project can be calculated as follows:

Pay back period is = $$\frac{Totalinvestment\cos t - subsidyamount}{annualrevenue - annual\exp enditure}$$

<u>Net Present Value</u>:

Net Present Value (NPV) is the most common method of calculating the net benefit of a project. It is the sum of all years' discounted after-tax cash flows. The net present value method is a valuable

indicator to identify the economic viability of a project because it recognizes the time value of money. Projects whose returns show positive net present value are considered to be attractive.
Net Present Value can be calculated as follows:

$$\text{NPV} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+k)^t}$$

This is one of the dynamic approaches to calculating the present value of the money invested in the past or expected to be invested in the future. This method compares the benefit and cost of the project. This can be done by compounding the amount invested in the past or discounting from the expected investment of the future with the help of a factor which depends on the interest rate and the length of time between the payment period and the present period.

Depending on the results if the Net Present Value is positive, then the project can be counted as an economically viable option. Investing in such project can fetch a higher return to the investor than an investment on capital market. This method however is ideal for evaluating the relative economic viability between a few projects.

7.1.4 Optimality of waste treatment strategy

An optimal strategy of waste treatment is the one that will either maximise the fossil primary energy savings or minimise the costs per unit of fossil primary energy savings achieved by the utilisation of available biomass residues and wastes (Dornburg and Faaji, 2006). According to general understanding, the concept of integrated waste management is based on the strategy of the three "R": Reduce, Reuse, and Recycle. Material production, cost and energy could be saved by using less and reusing or recycling more. The problem is then to identify the "optimal" level of the three R with optimality respecting the individual situation of each group of relevant stakeholders.

The stakeholders are

- Individual households, who as consumers benefit from a clean environment and "green" energy, but also from a sufficient supply of packaging material;
- Individuals, who profit directly from collecting discarded materials for reuse or recycling purposes;
- Companies, which profit from recycling activities, but also from the production or usage of packaging material

The optimality concept should – in agreement with the Pareto-Principle – ideally be based on the well-being of individuals; companies are as usual considered to be "owned" by either individuals (in the case of private companies) or the general public (in the case of public companies), and profits of the companies are valuable for their owners. According to the Pareto Principle, optimal levels of the three R are then given, if there is no other allocation with different levels of the three R, which increases the well-being of some individuals without hurting any other.

Given this definition it is clear that the optimality concept itself depends on the concrete situation in a country, in particular on the current state of the environment, the economic growth process, the innovative potential of the industry, and the relations to international partners. It therefore leaves some room for the implementation.

7.1.5 Practicability considerations

The practical implementation of the concept of Integrated Waste Management is not an easy thing to do. It is the missing information on preferences of households, on markets for recycled material, on possible technological innovations, which matters the most.

Therefore, the question of a practical concept for Integrated Waste Management is essential and should be handled with great care. As environmental commodities with characteristics of public commodities play a substantial role in this context the market mechanism alone cannot be expected to provide an optimal solution. Modifications to the framework conditions are necessary; in addition to that we could use some plausibility considerations to approximate an optimal solution.

Not only in Germany, the three R "Reduce", "Reuse", "Recycle" are interpreted to give priority to the reduction of waste. Waste which cannot be avoided should – if feasible – be reused and the rest should be recycled, which includes combustion to generate energy from renewable sources. In addition to that, the depositing of untreated biodegradable material and of municipal solid waste containing organics ceased in Germany in June 2005.

If one agrees that source reduction strategies have many favourable environmental impacts, including reducing greenhouse gas production, saving energy, and conserving resources, in addition to reducing the volume of the waste stream, and that biodegradable material should be – if technically and economically feasible – used to generate energy from renewable sources, this approach is probably in agreement with the optimality principle.

7.1.6 Free market – a prerequisite

Renewable energy options may have to be supplemented by reserve capacity, storage or increased trade with the neighbouring areas. The electricity markets of the future need to provide consumers with a highly reliable, accessible and flexible power supply. Most of the Asian countries have electricity markets dominated by large state owned or private monopoly enterprises. With their political clout these enterprises almost prevent the new ventures from entering the market and this discourages investment in this area of economic sector. To make the system work, there needs to be fully liberalised market available for access to budding enterprises. The networks may have to be separated from the supply of power giving new traders impartial access to the market and facilitate cross border energy trade within the Asian countries. Transparency, accountability and accessibility should be the three important features of liberalising energy sector.

Like the European Union, the Asian countries may have to give priority to generating installations using renewable energy sources or waste or producing combined heat and power, provided the safety and reliability regulations of the grids are not compromised

7.1.7 Benefit considerations

7.1.7.1 Energy empowerment – a sure way to poverty eradication

The quality of life is represented as being proportionally related to the per capita energy use of a particular country (Suganthi & Samuel, 2000). The awareness, literacy level, information dissemination and a change in the life style contributing to the shift from non-commercial to commercial energy source option in many Asian countries rural and semi-urban areas can, if well propagated, be used for the shift from non-renewable to renewable sources of energy, as well. Therefore, the South East Asian countries like Cambodia may have to plan for grid infrastructures which can accommodate diverse generators ranging from micro power systems to massive grid connected renewable complex. In some other Asian countries like India the grids require substantial investment in updating, with the replacement and interconnection of networks. Whereas in countries like Cambodia and Sri Lanka where only a very small fraction of the population have access to grid electricity (for example in Sri Lanka it is only 10%) the infrastructure can be designed so as to accommodate a mix of power which may solve the issue of the cities of Asia plunging into darkness part or most of the day. A low carbon renewable energy future can also be made possible

7.1.7.2 Employment benefits

Biogas and the renewable energy production are labour intensive and they can provide employment to people. The additional employment will, however, vary with trends in the labour markets of the countries. The jobs created thereby, may be low value jobs but in periods of high unemployment the positive job creation will be viewed with less scepticism. These options suit the developing countries as most of them have younger population and a large work force. On the other hand, if the community is involved in the production then the workers can be drawn from the community where the project serves. This can improve the income distribution among the rural population and different income brackets. A significant population shifting to urban centres one of the typical issues the developing countries have to tackle in the past few years, can be reduced. This removes the additional burden on the resources at the urban centres. In the case of biogas, the conventional fuels not utilised are conserved and this improves their value.

The employment effects of renewable energy projects can be such as the direct employment in construction, operation and maintenance; indirect employment of job creation in the supply chain supporting the projects; induced employment created because of the wages earned through direct and indirect employment spent in goods and services thus creating jobs. But, the renewable energy projects may create job losses too in the non renewable energy sector. Job losses may also be due to support-mechanisms which result in lower spending elsewhere in the economy.

7.1.7.3 Macro level effects

The regional and the national economy where an economic activity of producing energy from renewable sources operates may have to take into account the cost and benefit of the operation of that project.

Any project whether it produces biogas or energy from renewable resources is expected to produce some economic effects. Such projects create external economies where the outcome influences the utility function of the consumers and the social welfare function in the economy thereby creating better living conditions and improved quality of life along less spending on health aspects. On the whole, only the energy needs of the regions or nations can not justify the cause of the move from non renewable to renewable sources of energy. Such projects should ensure for an improved living conditions of the community apart from their environmentally benign move.

The economy benefits from balance of payments as the project output substitutes imports of fossil fuel options of the country. If the country exports renewable energy to the neighbouring nations it benefits the country additionally. If the plant is fully invested by the sources from inland with the least import content of not only the investment but the materials for the plant, the nation may have to face less external diseconomies arising due to fluctuations in the exchange rates.

If the transmission network are installed afresh in the case of renewable sources of energy or biogas or if there is any incremental cost of investment in providing additional networks, they should be calculated taking into account the costs of losses occurring due to distance of the production unit and the customers. In many developing countries, under monopolistic practices, the energy suppliers sell the energy at a higher rate than under a competitive structure. If the renewable energy supply operates under competitive market conditions, it can function without creating any market distortions.

7.1.8 Impact considerations

7.1.8.1 Economic impact

The downside of generating energy from biomass has been the reason behind the shift to fermenting waste to create biogas option. It was argued that if the land is used to producing maize and grain for generating heat and energy will it not have negative impact on food production; will not more fertilisers and pesticides be needed to grow more renewable raw materials; if the raw materials are imported will it not amount to contributing to further deterioration of endangered tropical eco-systems. However, these queries will not be raised if the bio gas which is climate-neutral and energy-rich is processed by fermenting waste especially bio wastes from households

7.1.8.2 Improved health conditions and enhanced economic growth

The huge pile of wastes not segregated with hazardous components is a common sight in many developing countries of Asia. The result is a low level of sanitary and health conditions in these countries. Almost all of these countries have a large section of their population suffering from infectious and contagious diseases. The rural and urban poor of the subtropical areas of the Asian countries suffer from epidemics and gastrointestinal diseases due to the polluted water bodies and landfills. The sanitary and health conditions can be fairly improved if the issue of waste management issues are not ignored by these countries. Setting priorities in waste management through recycling the waste either via any energy recovery method or through getting treated biologically could reduce the negative impact of the wastes to a large extent. The biogas treatment for example, may improve the hygiene conditions of the community. This will have an overall positive impact on the health conditions of the community the biological treatment plant serves. A reduction of impact on such intestinal diseases can be taken as a benefit of the organised waste treatment facilities. Schistosomiasis a disease in rural China was reduced by 99% through the introduction of biogas technology. Tapeworm infections, in China, have been reduced to 13% of the pre-biogas level (GTZ). Biogas treatment of wastes can reduce the expenditure the individuals, a region and the country as a whole, spend on health care.

In countries like Thailand and Cambodia there is a huge scope for biological waste treatment through biogas. Biogas supply as a form of energy to the households can improve the nutrition and the health conditions of the community. Biogas supply can ensure the population of secured form of energy to the rural and urban poor who can boil water and use them to escape from the water borne diseases prevalent in these developing countries.

7.1.8.3 Use of by-product of biogas

The by product i.e. the fertiliser, of biogas generation can replace the commercial fertilisers. The biogas plants produce a rich organic waste which can be dried and used as a fertiliser. In the Asian countries both fertilisers and fuel wood are increasingly expensive and therefore, biogas has a potentially bright future in these countries. In most of the Asian countries, the governments support the inorganic fertiliser industry through subsidies. And, inorganic fertilizers sometimes do not replace trace mineral elements in the soil which become gradually depleted by crops grown there. The governments can help the organic fertiliser production providing subsidies and can stop the subsidies given to the inorganic fertilisers. This can also work as one of the important aspects in incentive mechanism for setting bio gas plants.

In Germany around 8.4 million tonnes of organic wastes (2006) are being composted but with the debate on climate change, increasing energy prices, governmental support (Renewable Energy Sources Act – EEG) and technological improvement in biogas technology has paved the way for fermenting the organic waste.

In the process of composting the end product i.e. the finished product is utilised but in the process of fermentation of wastes both the end product and the energy generated as by product are utilised. However, fermentation process is more expensive than the composting and an investment is advised only when the demand conditions for the power and heat generated, are certain. The subtropical climatic conditions of Asian countries also suit for setting up biogas plants

7.1.8.4 Linkage between energy security and literacy:

Many regions of the Asian countries suffer from the problem of illiteracy when the population who otherwise, should have been in the course of learning are found to be the bread winners of their families. Energy insecurity forces them to put in double the volume of work thereby depriving them of time for equipping themselves with learning. Energy security can reduce the magnitude of their hardships.
The Asian urban centres suffer from scarcity of resources due to populations migrating from their villages. As the villages can not offer the potential work force with jobs, the younger population shift to the cities thereby, leaving less polluted and cleaner villages for the more polluted urban centres. Setting biogas facilities or energy recovery facilities at less urban centres can balance the population pressure on the natural resources. This can also solve the problem of rising unemployment percentage found in the urban centres of Asian countries. This will solve another issue of the unorganised sector operating on waste collection. Under circumstances of a lenient environmental policy implementation, workers – adults, children – from the unorganised sector work under poor working conditions and unhealthy sanitary conditions and this causes a negative health impact. For example, in countries like India where the many of the waste collectors are from the unorganised sector selling some contents of the wastes, like needles and syringes to small units of manufacturers who produce medical products like syringes. This recycles the hazardous waste into the economic stream and this has been the main cause behind the rural and urban poor suffering from infectious and contagious diseases.

With the help of anaerobic digestion a renewable energy can be captured from the segregated wastes. This will not only reduce the CO2 emissions (Table 7.1-1) through a reduction in the demand for the fossil fuels but it can also capture methane which is the second most significant green house gas. The methane so captured can be used as fuel for cooking purposes in the Asian countries and this will have a strong impact in the reduction of rate of deforestation as in countries like Cambodia firewood is still, the most prevalent fuel for cooking purposes. Income level in some groups of communities of Sri Lanka has risen as the women are freed from up to two and half hours of a day of their domestic labour in fuel collection, cleaning smoke-blackened utensils and disposing of animal wastes of their cattle.

Table 7.1-1: Emissions reduction potentials [Reference: GTZ, 2007]

Type	Saving	CO2 reduction Mt/year
CH_4	13,24 Mt/year	330,9
Biogas	33,321 m3/year	-
Fossil fuels substituted	-	44,7 – 52,7
Fire wood saving	-	4,17 – 73,8
Total	-	418,5 (average)

7.1.9 Financing considerations

7.1.9.1 Requirements

For the biogas production or renewable energy generation project to be funded from lending institutions, they should fulfil certain requirements.

From the perspective of lender:

A feasibility study giving a brief description of the project; summarising history of the group, cooperative or company that is proposing the project; mentioning the findings of the feasibility study on technical, management, marketing and financial characteristics of the project proposed and the most important aspect of socio-economic implications of the proposed project, is necessary at the first instance. The feasibility study should describe the location of the project, climatic conditions of the region, the infrastructure facilities like the communication network, roads, ports, airports, banks, schools, electricity and so on. The technical aspects of the project like the size, capacity, efficiency; purpose of the project; raw material requirements; equipment and other fixed asset requirement; life expectancy of the machinery newly acquired and existing machinery, land, buildings and other movable and immovable assets should also be detailed (Arnott, 1985). The feasibility study has to give some details of marketing like supply and demand conditions for the output and the raw materials to produce the product; production costs, price policies, marketing policies and strategies for methods of the product distribution. It should elaborate the contribution of the project towards the regional, provincial and national economy. The annual volume and value of the sales expected and the net savings should also be mentioned. On the financial front, the study should project details of its expected loans, grants and investments and the sources the investor opted for. The amount and terms of selected or proposed financing including security offered schedules of repayment and interest rates. Any lending institution will find the project feasible and viable if the feasibility study offers some valid information on logistics information like the transport and storage and access to the raw material and market are taken into consideration. The lender may also be interested in knowing whether the project can be a low cost producer; whether the project will be supportive and stable under the existing regulatory framework of the region and the nation; whether it will survive technology risk factors; how the by-products have been valued and included; how it is going to make impacts, positive as well as negative, on environment; other considerations specific to the operation of the plant.

7.1.9.2 The role of the government

The human impact through energy consumption directly influences the global climate and producing and using renewable energy sources can reduce the impact to a great extent. A combination of governmental polices can improve the incentive mechanism towards an efficient use of existing non renewable resources and switching to renewable sources of energy. Renewable energy from one or two sources can also be clubbed to make a hybrid system and this can serve regions that are off-grid or those regions having limited power. The government polices can favour increased use of renewable sources by fostering collaboration, removing market barriers for renewable energy sources and developing markets for the products of renewable sources.

The political structure of many developing countries does not extend a vivid support to projects who can contribute substantially to meet their energy needs. The industrial lobby of these countries contribute a major share in meeting the election campaigns expenses and party funds and therefore, they have a major say in the political decisions of these Asian countries. There is not adequate transparency in the political decisions of these countries. The decision makers also, are apprehensive that the shift from non renewable to renewable sources of energy may hurt their countries' competitiveness in the global arena. Nevertheless, they extend their willingness, verbally, under some circumstances, for the move. The initiatives of the government allocating a certain quota of funds in their respective, national budgets can only affirm their real interest in such move. Sometimes, when the profitability of biogas plants are viewed with scepticism by the private investors the government will have to invest in such plants so as to alter the investment decisions of the private entrepreneurs. The government can also grant subsidies to the private and community owned biogas plants through grants and soft loans. If the investors fear an uncertain demand conditions for the energy produced at their plants, the government can assure them through demanding certain share of energy for use in the government offices and biogas can be used in the canteens of the government offices and in the public utilities of the municipalities.

The government can give some tax exemptions to those households who shift from the use of non renewable sources of energy and fuel use to renewable sources. The hurdles for the move are overcome, if the investors could get grants and credits from the financial institutes, from the national banks thereby assuring the project initiator of sufficient funds.

On the whole it requires both the private and public sector involvement. Technical details like the transmission grids and infrastructural improvement should also, be taken into account. Economic viability and the micro and macro level feasibility should be assessed. The financial issues like the cost, fixed and variable cost, should be estimated. Material requirements should be evaluated. The available know-how of technology at the regional and national level should also, be analysed before hand. The community should be given sufficient information so as to create public awareness. Last but not the least, the issue of sustainability should not be over looked

7.1.10 Biomass and renewable energy – points to ponder

7.1.10.1 Renewable energy sources and EU member states

The share of renewable energy sources in total energy consumption increased slowly in the EU-25 between 1990 and 2004 from 4.4% in 1990 to 6.3 % in 2004. Significant further growth will be needed to meet the indicative target of a 12 % share by 2010. All renewable sources increased in 2004. In relative terms, the strongest increased came from wind and solar energy. In absolute terms, 60% of the increase was accounted for by biomass, and about 39% split equally between hydropower and wind energy. Solar energy continues to increase very rapidly but still accounts for less than 1% of total renewable energy (EEA 2007).

7.1.10.2 Some observations on benefits of renewable energy:

Abu- Qudais and Abu- Qdais (2000) find the energy content of municipal solid waste generated in Jordan accounting for 6% of the annual imported oil consumption of the country resulting in an annual saving of USD 24 million. And converting the municipal solid waste energy content to electric supply there may be a yield of 1.77 MW/day, which may be used for desalination of 300,000 m3/day of sea water with the help of reverse osmosis process which may account for 12% of the water consumption of Jordan/day in the year 1995.

The following table lists energy density in BTU/lb, as well as the number of homes of 100 tons (200,000 lb) fuel that can power for one year

Table 7.1-2: Energy density and number of homes benefited (Resources Recovery Technologies, Minnesota)

Fuel	Heat Content (BTU/lb)	Number of homes powered by 100 of fuel *
Fuel oil	19,178	18.7
Natural Gas	24,582	24.0
Coal (Bituminous)	12,250	12.0
Wood (Dry)	8,600	8.4
Refuse Derived Fuel	5,900	5.8
Ethanol	12,741	12.4
Landfill Gas	6,517	6.4

- This assumes firstly a 30% thermodynamic efficiency and secondly a typical home using 18,000 kW-hr per year

There are 89 waste-to-energy plants operating in 27 states managing about 13 percent of America’s trash, or about 95,000 tons each day. Waste-to-energy facilities generate about 2,500 megawatts of electricity to meet the power needs of nearly 2.3 million homes, and the facilities serve the trash disposal needs of more than 36 million people. The $10 billion waste-to-energy industry employs more than 6,000 American workers with annual wages in excess of $400 million (IWSA).

If the transportation bio fuels such as the cellulose ethanol are produced from low-input biomass either grown on agriculturally marginal land or from biomass from household wastes, the environmental benefits and its supply will be much greater than if it is produced from food-based biofules (Hill et al 2006).

7.1.10.3 Potentials of biomass

Biomass ranks the fourth as an energy resource. It fulfils, approximately 14% of the world’s energy needs and 35% of the energy needs of the developing countries (Demirbas, 2004). Biomass can be divided into more specific terminology, with different terms for different end uses: heating/cooling, power (electricity) generation or transportation. The term 'bio energy' is commonly used for biomass energy systems that produce heating or cooling and/or electricity and 'bio fuels' for liquid fuels for transportation. The biomass sector could make a major contribution to the security of supplies, as biomass has become a major factor in energy, environmental and agricultural policies. Although progress has been made, this has not been enough given the potential of biomass and the available technologies.

Only a part of biomass that grows can be supplied for energy use, due to technical, ecological and economic reasons. Only a less than two thirds of the lumbar grown in Germany, is used for biomass every year. The total bio energy potential in Germany is the equivalent of 56 million tonnes of crude oil units. This would be enough to meet 50% of the total automotive fuel consumption needs of Germany, including air traffic (Scheffer 2000). There is enough biomass in the EU-25 to produce up to 115 million tonnes of synthetic automotive fuels every year (Kaltschmitt and Vogel, 2004). Expansion of bio fuels production and their use also raises some concerns, most importantly due to their diverting land away from use for food, biodiversity-preservation. Added pressure on water resources for growing bio fuel feedstock is also of concern in many areas of the world.

7.2 Environmental Economics

Environmental economics is, one of the many fields of Economics, concerning environmental issues. The objectives of the environmental economics are to provide an economic approach to the environmental problems thereby evaluating the reasons and consequences of the economic approach; to investigate the behaviour of the economic agents namely the consumers and the producers and the mechanisms leading to the environmental problems; finally, prescribing appropriate economic instruments to handle the environmental problems.

It is well known that the quality of environment affects the well being or the utility of the consumers either positively or negatively. As environment is treated in economics as a commodity the actions of economic agents bring some negative effects, say, pollution and similar problems when individuals do not bear all the costs of their actions. The costs, if, are not met at the current period will be costlier in the future while the 'quality' of environment is considered as a scarce resource in Economics. The social cost of producing any good is its cost to every individual in the society and this also, includes who do not produce or consume it. The social cost therefore, is the private cost what the producer incurs plus the cost the others incur. When the social cost of producing any good exceeds the private cost there is negative externality. Similarly, there occurs positive externality when the social benefit exceeds the private benefit. A market failure occurs when any economic activity produces an externality.

It is because of the public character of the environmental commodities like clean air and clean water for example, which makes the accountability of these commodities a difficult issue to deal with. And this public characteristic of the environmental commodities creates market failure. On a smaller scale the problem does not appear to be difficult to tackle but on a larger scale with a huge population the accountability can not be easily shared and with the inherent human nature of shifting the burden to others we, directly or indirectly, intentionally or unintentionally shift the burden on the economically challenged section of the society.

Pollution bears a financial implication when an economic activity of one person causes a negative effect, called negative externality, on others and also the extent of damage it has on others. By disposing of the effluents into the river a factory working around a water body, say a river can cause negative health impact on the community living along the river. And in the absence of governmental interference the factory may not share the accountability of its production activity. The financial implication the community bears in cleaning the river system and paying for the medical bills, owing to the economic activity of the factory owner, is the external cost outside of the purview of the calculations of the factory owner while calculating his private costs. He calculates only the cost of machinery and salary to his employees for example, into account. Whereas the local municipalities take into consideration the cost of mitigating the pollution the factory creates. Therefore, the private and external costs are clubbed together to arrive at the social cost and if it exceeds the social benefit what the community reaps out of the economic activity of the factory, it becomes an unsustainable economic activity and the factory owner therefore, should be made liable for sharing the social cost with the other members of the society. This can be done by the governmental interference of imposing some taxes on the unsustainable and polluting manufacturing activity of the factory owner (Baumol and Oates, 1998). Each society has to decide upon a solution to tackle the fundamental economic problems or the allocation problems. And the solution needs to be feasible. The solution will depend on the traditions, religion, concepts of fairness the society adopts. And this introduces the concept of optimality and a feasible or efficient allocation should fulfil some normative criteria and only then can the solution be called Pareto-Optimal or Pareto-Efficient.

This assessment explains our consumption behaviour. With each of our economic activity every one of us knowingly or unknowingly, directly or indirectly create an ecological footprint and when the consumption behaviour is made responsible we reach closer to sustainable development. Sustainable development is the ideal way of exploiting the resources say, natural resources economically in such a way to satisfy the needs of the present generation without compromising the wealth and health of the future generation (UNEP). As it avoids any irreversible damage, it inevitably assumes an economic growth function in harmony with the environment and the surrounding ecosystem. Hence, under this principle the available resources will remain the same for each generation. Any unsustainable production or consumption will inflict a cost on the future generation and any unsustainable production may restrict their available quantity to the future generation. Modifying our consumption behaviour from the consumption of energy from non renewable sources to renewable sources is an example. Future generations will have access to the renewable sources as much as the present generation as they are renewable and less polluting.

As we already know that there is external cost owing to negative externalities from unsustainable production or consumption behaviour and the external effects are not taken care of by market mechanism. This is due to missing market and therefore, we need to invest in correcting the damage. And any further delay may have a greater incidence on the future generations and on the economically less advantaged sections of the society. Higher standards of regulation might be economically advantageous. A strict environmental policy may induce innovation, reduce inefficiency and trigger industrial competitiveness (For more details: Porter hypothesis, Porter, 1998) Changing polluting machinery and improving transport mechanics are some of the ideal solutions in reducing green house gas emissions.

The optimal level of ecosystem stability and costs of pollution mitigation is reached where the social costs of economic activity are equal to the social benefits. But, it is not the case under the present conditions where the external effects are greater than the investment we make to reduce the environmental problems for example, global warming.

If the energy from non renewable sources signal entering a threshold level not sustainable for the planet and the future generations investment in that sector should be reduced and the investment on renewable sources should be augmented. This will reduce the harmful environmental effects. But, how to bring this into effect? The shift in investment from one sector to another will not take place if the patterns of consumption and production and our life styles are not changed.

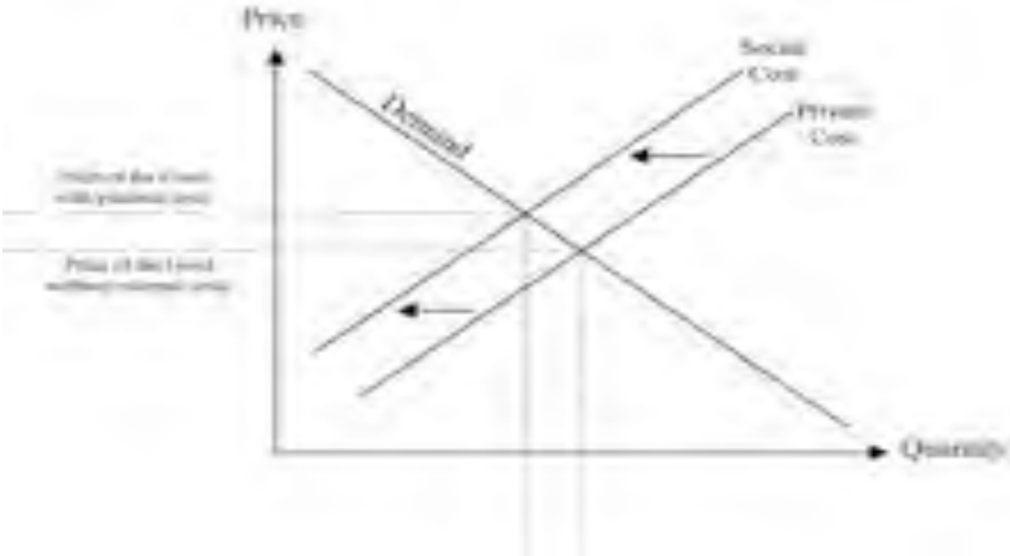


Figure 7.2-1: caption of figures

In the above figure, let us assume that it costs 10 dollars to manufacture one unit of a product. And to have a 2 dollars profit, the manufacturer should sell the product for 12 dollars. But, when we assume that a 2 dollar worth of external costs of cleaning up the environment (polluted due to the production of one unit of this particular product) is added to the private cost of 10 dollars and if the producer still wants to reap the same amount of 2 dollars profit the price rises to 14 dollars. The demand decreases due to the price increase. And this shifts the supply curve to the left. At this point of intersection the price reflects the damage the production causes to the environment. And without this, there would have been a surplus supply of the particular good.

Hence, from the angle of the society, any economic activity will be considered benign if the social benefits exceed the social costs. And, the private manufacturer may be interested in a particular economic activity only it fetches him more benefits than the private costs. We can consider this with the help of generation of energy from non renewable sources and renewable sources. Social cost of energy from conventional sources is higher than energy from renewable sources as it consists of external costs of production as well as usage. Whereas the private costs of producing energy from renewable sources is higher as the initial investment costs are high. While in the former case there is an indirect subsidy making the private costs lesser, in the latter the subsidies are absent making the private costs appear higher. And this warrants the interference of the public sector to set the frame work conditions for the private entrepreneurs to switch to generating energy from renewable sources. This the governments can do by subsidising the production of energy from non conventional sources like biomass for example by introducing micro credit facilities. If we take the example of German Renewable Energy Sources Act 2004 (BMU) the objective behind the introduction of the act was to facilitate a sustainable development of energy supply. This the German government could do by regulating the grid system operators and they were obliged to guarantee priority purchase and transmission of all electricity from renewable sources (Wiesmeth, 2008) Similarly, any economic activity generating more social costs than the social benefits can be curtailed through stringent taxes on the activity whether a tax on the input or a tax on the output depending on the circumstances (Pigou, 1928). Internalisation of the environmental effects will complete the market system. Some practical economic instruments like Pigou-Tax or the Emission certificates issued by the government can reduce the problems.

The globalisation and liberalisation and trade of the South East Asian economies have also brought certain environmental problems like deforestation, soil degradation, water pollution growing waste problems to quote a few. Growing economies with change in life styles and consumption behaviour in the absence of environmental care will widen the gap thereby, making the magnitude of the problem huge. In the energy sector for example, the governmental interference providing proper framework conditions for the investors so as to reduce the reliance on non-renewable sources of energy would be a proper move at the present circumstances.

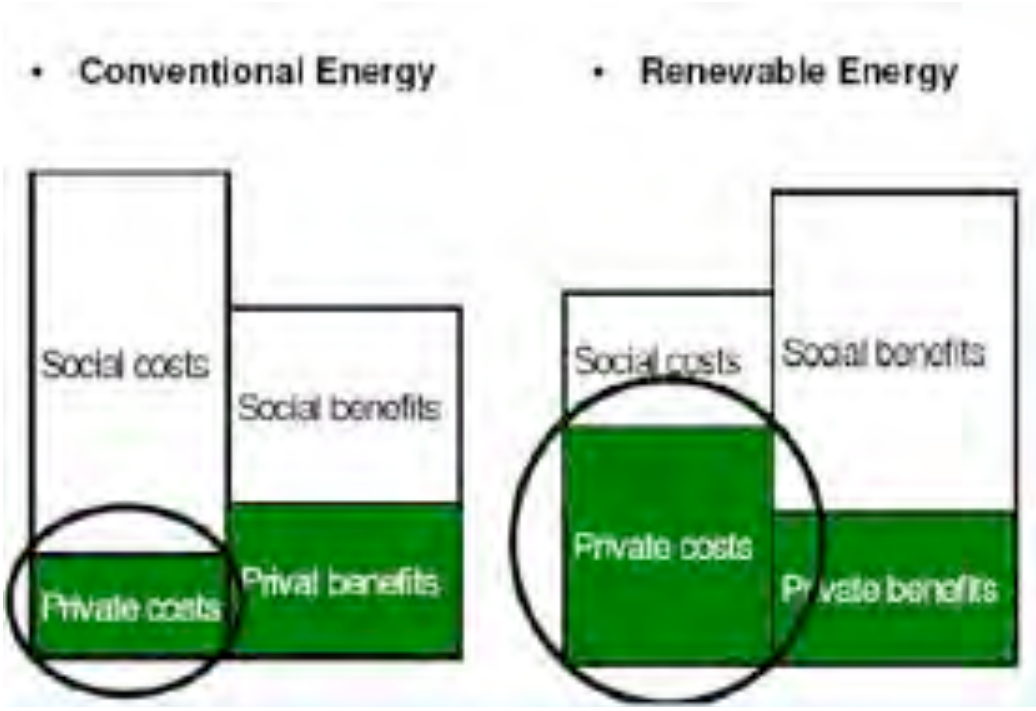


Figure 7.2-2: Private Costs

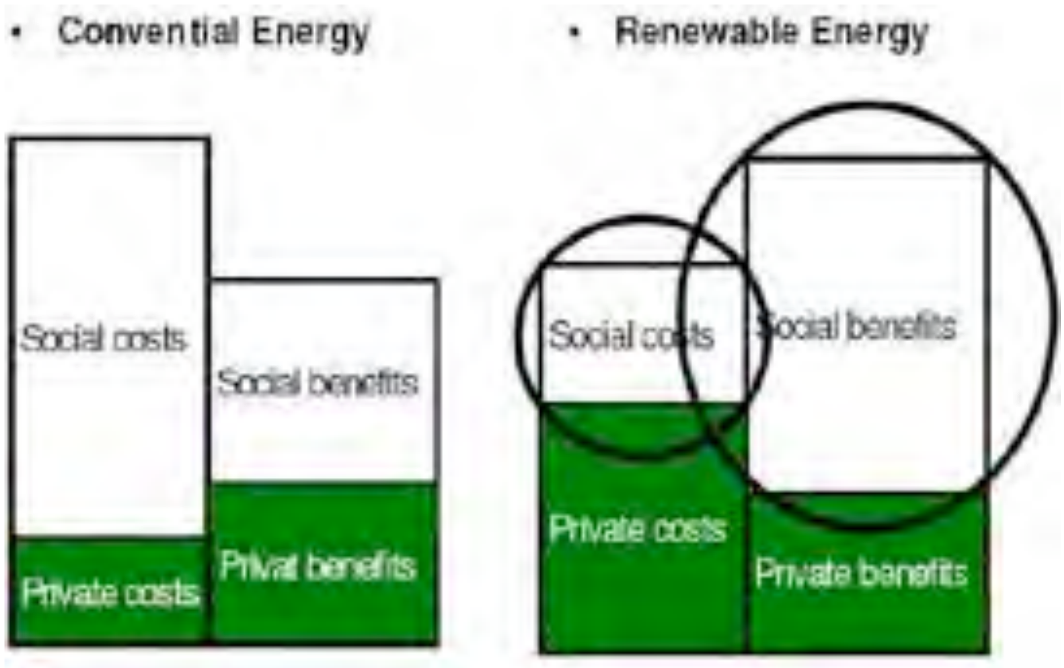


Figure 7.2-3: Social benefits

7.3 Socio-cultural aspects of waste management

7.3.1 Factors influencing waste management

There are clear differences in the attitudes towards waste recycling and managing among diverse cultural groups. These attitudes vary depending on the religious, cultural beliefs, gender and generational differences. In many developing countries the people who work in waste management have a different socio-cultural background than the rest of the population. The socio-economic status of the workers of waste management system is usually, very low. People who belong to the economically rich group believe that their littering practice is the right thing, in that it offers employment for some one (Mongkolnchaiarunya, 2005) Low education levels and unhealthy working conditions of the poor in combination with their status lead to a negative self-perception and lack of self-confidence (UNESCO, 2001). Their occupation is usually, considered to be of the lowest status in the society. Historically, outcasts and marginal groups such as slaves, gypsies and migrants have performed waste collection and recycling activities in developing countries ((Nas and Jaffe, 2004). While ascertaining the support and participation of the community for a shift in the waste management system the socio-cultural attitudes of the population towards wastes and their attitudes to gender roles relating to waste management in and outside their homes; their openness to integrated approaches involving recycling and composting; their ability and willingness to pay for an improved waste management system should be considered.

7.3.2 Factors affecting the waste composition

The physical and chemical characteristics contribute toward the composition of household waste. They are directly influenced by the food habits, cultural and socio-economic, seasonal and climatic conditions of the community generating the waste (Bhoyar et al 1996). The components of municipal solid waste may vary from urban and rural community and also from one country to another (Abu-Qudais and Abu-Qdais, 2000) and may vary within a country of vast expanse with diverse cultures, like India. In fact, the composition of wastes differs in two localities that differ considerably due to the socio-economic status of the residents in these areas (Basu, 1995). Wastes from food constitute a major component of solid waste stream generated in developing countries (Diaz and Golueke, 1987).

7.4 Waste management and South-East Asian countries

7.4.1 Objectives

Until some few decades ago, the disposal of wastes had not been a great problem, for, the population had been not much. The land available to dump wastes was sufficient too. With the rapid industrialisation and urbanisation there has been a tremendous upward swing of rural population migrating to urban centres. This has led to a significant change in the socio-economic status and a subsequent change in their consumption pattern as well. Waste management infrastructure and the institutional capacity must go hand in hand with the growth of any nation. The governmental policies aiming at development issues therefore, should address the strategic natural resource management simultaneously. The objectives of the South East Asian countries is to maximise the use of local natural resources to achieve least cost options in the power sector. This can be achieved by expanding access to electricity by the rural population through promoting renewable energy; facilitating opportunities to private entrepreneurs and help them come out with their efficient and cost-effective services; designing appropriate policy measures in setting effective tariffs; promoting technologies of renewable energy for on-grid and off-grid mode; and, increasing the standards of living of the rural poor with the help of right economic opportunities. The net societal benefits of the alternative energy can be measured only with the help of data on farm yields, commodity and fuel prices, farm energy and agro chemical inputs, plants efficiency, production of co product, green house gas emissions and other environmental effects (Hill et al 2006). The incentive regime for a decentralised renewable energy solution for south East Asian countries will be to include subsidies to reduce the start-up cost thereby promoting affordability. Further incentives can be created through providing assistance in capacity building for supporting market infrastructure.

7.4.2 Cambodia

The Royal Government of Cambodia is keen addressing issues related to adequate supply of energy throughout Cambodia at affordable prices. It explores policy avenues which encourage exploration and development of alternative energy sources to promote energy efficiency. The main sources of energy of Cambodia are biomass and conventional sources of energy. Biomass based fuels make an indirect contribution to promoting cogeneration. Cambodia is quite rich in biomass and therefore, there is a large scope for market for biomass energy. The per capita energy consumption of Cambodia from conventional energy is about 48kwh per annum and Cambodia ranks among the lowest in energy consumption in the Asian region. Only 12% of the households have access to electricity. The total installed capacity of electricity is 150 MW and out of this 100 MW are in Phnom Penh. Cambodia has no fossil fuel resources and it is a net importer of fuels. The oil import levels for Cambodia in 2002 were approximately 7,200 bbl/day.

Table 7.4-1: Economic statistics of South-East Asian countries [ADB Report)

Country	Purchasing Power Parity (PPP) $	Real GDP Growth per cent 2003	2004	Per Capita PPP $
Cambodia	18 billion	5.0	5.5	1500
Thailand	429 billion	5.2	5.5	6900
Vietnam	168 billion	6.9	7.1	2100

Around 80% of the national energy consumption is met by biomass fuels and the rest is covered by imported fossil fuels (MIME, 2001).There is no national grid for electricity transmission except a 115 kv single circuit transmission line of 120 km to Phnom Penh from Kirirom min-hydropower station. Power supply is available through small isolated systems using diesel generators. Due to lack of adequate infrastructure and regulation, rural population of Cambodia pays very high prices for electricity that is supplied by private diesel set operators. The price of power is therefore, very high. According to the data in the year 2000, the average tariff is about 14.6 US cents/kWh in Phnom Penh and 25 to 50 US cents/kWh in rural areas. The total installed capacity of Cambodia is 200 MW and out of this 65% capacity is in the Capital city Phnom Penh. The per capita consumption of power is only 48 kWh per annum which is quite low in the whole region. The annual growth rate of demand for power is 12%.

Cambodia is served by 24 small isolated power systems. There is an estimated 600 Rural Electric Enterprises (REE) in Cambodia, serving 60,000 customers (SME, 2001). The average generating capacity of the 600 REEs is about 100 kW each and about 60 MW in total. There is virtually no transmission link between load centres. Peak demand in 2003 was 120 MW in Phnom Penh and 40 MW for all other provincial centres. Power is imported across the borders of Cambodia from Vietnam, Laos, and Thailand. The Royal Government, Cambodia encourages conditions which attract private sector investment in the power industry.

Table 7.4-2: National Energy Demand of Cambodia [Adapted from COGEN3)

Type of Fuel	1994	2000	2005	2010
Wood	77,721	89,616	103,552	106,344
Other biomass	1,754	1,600	1,559	1,351
Gasoline	6,006	10,765	15,288	20,284

The Ministry of Industry, Mines and Energy (MIME) Cambodia is responsible for Concession Licensing for implementing biomass, coal and natural gas-based cogeneration plants in Cambodia. However, small projects below 125 kVA the municipal or the provincial authorities may grant the concession license.

7.4.2.1 Supply constraints of energy in Cambodia

Cambodia suffers from the following constraints:

- inefficiencies of old generating equipment
- uncompetitive market structure
- inadequate legal framework
- inadequate investment framework
- inadequate administrative capacity
- lack of access to electricity

7.4.2.2 Demand for electricity and its transmission

The forecasts are based on expected average annual consumption growth rates of 9 – 12%. The conservative estimates for growth rates are between 5 and 6% nationwide. The Royal Government of Cambodia has long term plans to establish a national electricity grid by 2016. The grid, however, may cover only the southern region and some parts of western region of Cambodia. There is a large scope to promote decentralised, cost-effective and reliable clean energy services of renewable energy technologies in Cambodia. The Royal Government of Cambodia has taken efforts towards decentralised, demand-driven, private sector initiatives in the power sector. The renewable energy device connection in the regional and national grids is expected to be facilitated.

7.4.2.3 Financial and other constraints

Cambodian banks offer short-term loans at high interest rates. The micro-finance institutions provide credit at interest rates of 40-60% per annum. The initial cost of setting renewable energy systems is high and this works as a deterrent.

There are other technical issues which deserve attention. Cambodia, like any other developing region in the world, is not devoid of problems like lack of institutional and infrastructure capacity in most of its rural areas. As the volume of operations of renewable energy systems are low there is less access to have spare parts. There is also lack of basic socio-economic and technical data on the primary resources for renewable energy technologies like biomass resources.

The low literacy level hinders dissemination of information on renewable energy technologies and also, their marketing aspects are non existent.

7.4.3 Thailand

7.4.3.1 Rudimentary information

In 2007 Thailand's total commercial energy consumption was 80,019 thousand tons of crude oil equivalent (ktoe) while peak generation of electric power system was 22,586 ktoe. During the 1990s approximately 90% Thailand's commercial primary energy consumption was imported. Despite the rapidly growing energy demand Thailand's per capita commercial energy consumption is still very low compared to other industrialised countries. As a result, the per capita emission of greenhouse gases is estimated to be about 5.5 tons of carbon dioxide.

7.4.3.2 Supply and demand conditions of power

The Electricity Generating Authority of Thailand (EGAT) is the single buyer of electricity owning half of the power generating capacity. It sells power to two distributing facilities. The economic crisis of 1998 slowed down the demand for power in Thailand. This resulted in excess generation capacity and the reserve margin rose to 35.1% in 2003(Piyasvasti Amranand, 2006). To cope with the problem, the purchase of power from cogeneration facilities under long term contracts was temporarily suspended. However, the renewable energy projects continued in Thailand.
Constraints:

- Unattractive purchase price
- Expensive interconnection requirements
- Technological risk

7.4.3.3 Renewable energy potentials

Apart from bagasse, rice husks and wood chips other sources like household wastes, biogas from pig farms and other types of agro industry and wastes from palm oil factories assure the potential to generate 1,700 MW of power additionally. The support of the government giving financial incentives with soft loans and investment subsidies for selected types of renewable energy projects is very much a need at the present circumstances. Private investments are being encouraged through Energy Service Companies (ESCO) and ESCO venture capital fund has also been established. It appears that there is right policy mix to encourage renewable energy options in Thailand.

7.4.3.4 Community's responsiveness

The incentive behind the developed countries efforts to finding a solution to fall back has been because of the increased pressure on energy supply. And they also understood that depending on corn could be an economic blunder. But, they were not the only reasons behind their success. The countries could promote the renewable energy projects through making the public aware. And as with awareness increase, the compatibility with existing land use was considered by the provinces and local municipalities to bring the Acts into force. Therefore, the challenge of the local municipalities and the scientific communities of the developing countries will be to provide information and opportunities for renewable energy facilities, including large scale operations, while ensuring that adverse effects are eliminated or minimised. Some studies (eg. Mongkolnchaiarunya, 2005) cite how a few projects could motivate the residents of a rural area, with emphasis on poorer communities, of Thailand to bring recyclables for exchange of eggs to keep their surroundings cleaner. This signifies the community empowerment through self-reliance establishing new relationships of more equality and less dependence between poor communities and local municipal administration in Asian countries Although, most of the communities of Asia react sharply to environmental issues in the recent years, Thailand paces a faster than its South East Asian counterparts.

Most of the financial resources Asian countries use is for waste collection and transportation and only a small fraction of the resources are being spent for waste disposal methods like composting and land filling and incinerating. The least resources are spent towards source reduction or for material recovery. Sometimes, there is lack of sense of acclimatising by those who move to urban centres and this leads to less social motivation in matters of waste disposal.

7.4.4 Vietnam

7.4.4.1 Vietnam – a snapshot

The purchasing power parity of Vietnam is 227USD billion with a GDP growth rate of 7.7 in 2004 (EIA, 2005). Vietnam is therefore, making a steady progress in tackling issues of rural poverty so as to include provision of reliable electricity supply. More than 87% of the households have access to electricity. Large fraction of population relies on non-commercial energy in the form of biomass resources such as wood, animal dung and rice husks. The Vietnam industry is responsible for 40% of the economy. 30% of the population of Vietnam is considered to be below the poverty line.

The rural population of Vietnam receives a low quality service from the grid like a low voltage and poor reliable supply. The per capita electricity consumption of Vietnam is among the lowest in Asia. And electricity demand of Vietnam is expected to grow between 15-16% per year until 2010. Electricity of Vietnam (EVN), the power company run by the State, plans to commission 16 hydro power plants by 2010 and increase capacity while Financial, a private company, will construct 8 additional coal-fired power plants (Vietnam Report). Despite its being a significant oil producer, Vietnam relies on imports of petroleum products as the country lacks refining capacity.

Vietnam does not import or export electricity across its borders. The Vietnamese government with its commitment to reducing rural poverty focuses on improving electricity access to a target of 90% of its population. The national grids connect the densely populated areas and the rural areas are connected by local hydroelectric power. The Electricity of Vietnam (EVN), however, plans to develop a national electricity grid connecting several regional grids. It plans to upgrade the transmission line around Hanoi (EIA, 2005). The government of Vietnam estimates that around 9,300 miles of new high voltage transmission lines and 173,600 miles of new medium and low voltage transmission lines may be necessary to accommodate the energy demands by the year 2010. The high cost grid extension and the country's geographical complexity will preclude the inclusion of around 1,100 remote mountainous communities. These communities consist of 750,000 households and around 3 million people. Some of the communities have access to commercial energy through local small grids and local power production from sources like hydro power plants of low capacity. Around 30% of the people of Vietnam live without electric power. There exists a considerable potential role for biomass and other renewable sources of electricity generation. This will include grid connection of the larger renewable energy systems and a considerable market for renewable systems for the communities and households that are likely to remain off-grid.

In Vietnam, several companies are operating in the fuel market, but as they all stem from the same mother company they are heavily influenced by the biggest market player- Petrolimex which alone accounts for a 60% market share. When the crude oil price rose to the peak of USD 147 a barrel in July, 2008 the price of A92 gasoline in Vietnam raised to VND19, 000 from VND14, 5000 per litre, a surge of more than 31%. But, after the world oil price drop to almost 50% falling below USD77 (Saigon Times, October, 2008) in the beginning of October, 2008 the price of A92 remained almost, in the same level. The companies gave a rationale that as they had to make up for the losses incurred during the last period the prices did not fall in the succeeding period. By bringing transparency into the business process through including representatives of social associations, consumers and the media, the society can benefit from reasonable fuel prices.

7.4.4.2 Renewable energy sources and Vietnam

Biomass including wood fuel and agricultural residues like rice husk, rice straw, coffee husk, and bagasse are widely used for energy production in Vietnam. Biomass fuel sources like forest wood, rubber wood, log residues, saw mill residues, sugar cane residues and coconut residues need a mention. Biogas is another not much utilised resource in Vietnam. Over 50 million tonnes of biomass is produced each year with only 30-40% is used towards energy production. The energy captured is used for cooking and only a small capacity, around 150 MW, is used for electricity generation in sugar mills. Biomass is currently, being treated as a non-commercial source of energy and it is collected and utilised locally. The use of biomass for producing energy in a commercial way has still, not received much attention of energy planners.

7.4.4.3 Barriers to implementing renewable energy projects in Vietnam

Legislative:
The current policy and regulatory framework in Vietnam is inadequate to providing necessary drivers to accelerate the development of renewable energy sector.

Technical:
- There is lack of reliable data on biomass energy sources in Vietnam
- There is shortage of high quality technology at affordable prices
- The biomass conversion technologies are imported and therefore they are expensive and thereby, making them not affordable for the many individual entrepreneurs.

Financial:
- There is lack of commercial business and infrastructure to provide renewable electricity equipment and services

- There is continuing high cost of biomass conversion technologies affecting the price of energy generated from biomass
- Access to finance is limited for consumers, business and project developers

7.4.4.4 Community reaction

The community reaction to environmental violations of Vedan, a private company discharging volumes of untreated industrial water into the river (Saigon Times, Oct. 2008) clearly affirms the awakening of Asian countries to prioritising environmental improvement. Matzuzawa an environmentalist working with the Japan International Cooperation Agency in Vietnam believes that Vietnam's economic development over the past decades has resulted in unprecedented rate of pollution. Vo Quy, a Vietnamese Zoologist, who has been honoured among 'Heroes of the Environment' by Times News magazine, fears the toll of torrid economic growth affecting the flora and fauna of Vietnam. He wants the younger generation to take an active lead in environmental issues protecting environment.

7.4.5 Laos

7.4.5.1 Basic data

Out of the least developed countries in terms of low income, human resource weakness and economic vulnerability 8 Asian countries have a number of priority issues pertaining to the country's development. And, management of municipal solid waste is one of the priority urban issues. Lao PDR is one of the Asian countries least developed suffering from poor waste management. Vientiane is the capital city of Lao PDR with a land area of 3,920 square km. The population of Vientiane was 639,326 in the year and it has been estimated to be growing at a rate of 4.7% (NORAD). Vientiane consists of nine districts but the waste management infrastructure serves the wards in four districts namely Chantabouly, Sikhottabong, Sisattanak and Xaysettha districts. Waste generation is about 200-250 t per day. There is on an average 0.75 kg of solid waste generation per capita. And more than 40% of the waste generated is biodegradable (INVENT Final Meeting). Collected waste is being dumped at the dump site 18 km from Vientiane and the site is called km18. 30% of the wastes generated are sold and recycled and this makes the composition of wastes collected by the waste pickers and which is found in the dump site different.

The agricultural residue is substantial to improve the use of biomass technologies like biogas technology and improved stove for cooking. The biogas technology will reduce the greenhouse gas emissions from the waste of animal dung. In rural areas most of the households have animals. This makes the biogas technology ideal technology for rural and livestock farm. In Lao PDR, it is estimated that there are about 4 million metric tons of animal dung per year. There can be biogas generation around 280 million cubic metres. In Laos the use of biomass as energy is about 90% of the total energy consumption. In the past few years, the government organisation and a few private organisations have developed biomass technologies and transferred to the use of the people.

There are technology and financing constraints on biomass and there is also insufficient information. At present, the Technology Research Institute (TRI), and the Science, Technology and Environment Agency (STEA) are conducting a demonstration project at the Training Centre on different sources of biomass-based energy, for example generating electricity from rice husk. There is a huge potential for various biomass technologies in Laos, but there is a shortage of data on local resources and feasibility in different areas of the country.

As Lao PDR is an oil and gas importing country, petroleum security is essentially the basis of Import policy, at present there is no restriction on imports of petroleum products. Adequate imports are allowed to meet the country's demand. In addition the importer/supplier are required to maintain a minimum 10% reserve at all times as a supply security measure

7.4.5.2 Key issues of waste management in Vientiane

- Lack of awareness among the residents
- Problems arising due to poor management of waste like bad odour
- Poor waste pickers working under unhygienic conditions affecting their health conditions
- Poor aesthetic and fear of losing tourists
- Institutional deficiencies
- Inadequate legislation
- Resource constraints

7.4.5.3 Barriers to implementing renewable energy solutions

Lao PDR like Vietnam suffers from legislative, technical and financing problems. But, above all, in the case of Lao PDR the data availability is quite limited. This could impair any analysis.

7.4.5.4 Micro credit facilities and environmental awareness

Most of the Asian countries have experienced success relating to micro credit facilities and the following economic benefits. Laos will not be an exception to the rule. The small loans provided to the poor borrowers bring positive effects in household production and consumption, the focus on women, the social capital created from community network improvement. An enhanced human and social capital can improve environmental outcome. Some studies (eg. Anderson and Locker, 2002) provide information on how micro credit facilities bring increased environmental awareness in the society. With the micro finance there is an incentive creation and this helps the message being spread across various sections of the society.

7.4.6 Barriers found common in South East Asian countries

7.4.6.1 technical and technological

The level of understanding of technology related to renewable energy solutions and biogas production among the South East Asian countries were only slightly different from one another. It is therefore, necessary to adopt any technology suitable to the existing level of knowledge in the region. In the remote areas of countries like Cambodia and Laos it may be an impediment if any technological solution is implemented without informing the community. This makes it necessary to spread knowledge and information through students who receive information at the universities or at the institutions they study. This brings more pressure on the teaching community to perceive the right information so as to pass it on to the younger generation.

7.4.6.2 institutional

The South East Asian countries suffer from institutional barriers. Renewable energy solutions and biogas generation are not well known or well understood. The authorities from the institutions do not understand the practicability of the renewable energy solutions and their benefits they may not be wiling to support a project on biogas generation or renewable energy production. An organised political framework may reduce institutional barriers to a large extent.

7.4.6.3 informational

If the physical, chemical, technical, economic, social aspects are not known it may be a bottleneck towards creating willingness for such initiatives. And therefore, information barriers may cause acceptance problem and a following lack of support.

Learning outcome:

After reading the chapter the reader should have learnt the impact considerations of waste management systems, the benefits associated with an efficient renewable energy solution and biogas generation, the importance of economics in understanding environmental problems and the framework conditions of South East Asian countries.

☑ Self-assessment

1. *How and to what extent are the environmental problems related to and dependent on economic growth?*
2. *Describe the concept of external effects. In which sense, do external effects lead to missing markets?*

7.5 References

Abu-Qudais M and Abu-Qdais H A (2000): Energy content of municipal solid waste in Jordan and its potential utilisation Energy Conversion & Management Vol. 41 pp 983-991

Arnott, M (1985): The Biogas/Biofertilizer Business Handbook (Ed) Peace Corps 1985

Basu, S (1995): Burning at the seams The Hindu Survey of the Environment Kasturi & Sons Ltd., Chennai pp 131-134

BCSE (2005): Renewable Energy in Asia: The Cambodia Report by the Australian Business Council for Sustainable Energy

Bhide A.D (1994): Methane emissions from landfills Journal IAEM Vol. 21 pp 1-7

Bhoyar R.V., Titus S.K, Bhide A.D and Khanna P (1996): Municipal and industrial solid waste management Journal IAEM, Vol. 23 pp 53-64

Bilitewski et al., 1994: Abfallwirtschaft- eine Einführung. Springer Verlag Berlin Heidelberg, 2. Auflage

BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany)

COGEN 3 (2003): Proven, Clean & Efficient Biomass, Coal, Gas Cogeneration The EC-ASEAN Business Facilitator, National Energy Policy Review

Demirbas A (2000): Recent advances in biomass conversion technologies Energy Education Science and Technology Vol. 6 pp 19-41

Demirbas A (2004): Combustion characteristics of different biomass fuels Progress in Energy and Combustion Science Vol. 30 pp 219-230

Diaz L F and Golueke C G (1987): Solid waste management in developing countries BioCycle Vol. 28 50-52

Dornburg, V. and Faaji A.P.C (2206): Optimising waste treatment systems Part B: Analyses and scenarios for Netherlands Resources, Conservation and Recycling 48 pp 227-248

EEA (2007): How rapidly are renewable energy technologies being implemented? Indicator: Renewable Energy

EEG (2004): Erneuerbare Energien Gesetz, English Translation

GTZ Biogas Digest Vol. III

GTZ (2007): Energy Policy Framework Conditions for Electricity Markets and Renewable Energy: 23 Country Analyses

Harker J H and Backhurst J R (1981): Fuel and Energy London Academic Press 1981

Hill, J., Nelson, E., Tilman, D., Polasky, S., Tiffany, D (2006): Environmental, economic and energetic costs and benefits of bio diesel and ethanol bio fuels Proceedings of the National Academy of Sciences (PNAS) Vol. 103 (30)

MIME (2001): Report of the Ministry of Industry, Mines and Energy (MIME) Cambodia

Mongolnchaiarunya, J (2005): Promoting a community-based solid waste management initiative in local government: Yala municipality, Thailand Habitat International 29 pp 27-40

Nas, P.J.M and Jaffe, R (2004): Informal waste management: shifting the focus from problem to potential Environment, Development and Sustainability Vol. 6 pp 337-353

Pigou, A C (1928): The Economics of Welfare London: Macmillan and Co

Porter, M (1998): The Competitive Advantage of Nations (Ed) Free Press

Piyasvasti Amranand (2006): Thailand Energy Minister on alternative energy, cogeneration and distributed generation: Crucial strategy for sustainability of Thailand's energy sector

Scheffer K (2000): Biomasse-gespeicherte Sonnenenergie aus der Vielfalt der Pflanzenarten-Potentiale, Bereitstellung, Konversion in: Forschungs- Verbund Sonnenenergie Themenheft pp 34-39

SME (2001) : Report of Small and Medium Enterprise, Cambodia

Suganthi., L and Samuel A.A (2000): Exergy based supply side energy management for sustainable energy development Renewable Energy Vol. 19 (1-2) pp 285-290

The Royal Government of Cambodia (2003): "Commitments towards renewable energy-based rural electrification in Cambodia" presented at the International Conference for Renewable Energies, Bonn, Germany, June, 2004

Wiesmeth, H (2008): Presentation on Integrated Waste Management INVENT Final Meeting Cambodia, Vietnam, Laos, Thailand October,2008

Loo, S. v.; Koopejan, J.: Handbook of Biomass Combustion and Co-Firing. Twente University Press, Enschede (2003)

Internet sources:

http://www5.gtz.de/gate/publications/BiogasDigestVol1.pdf

http://www.eia.doe.gov/emeu/cabs/vietnam.html

http://www.unep.org/

http://www.recambodia.org

http://www.recambodia.org

www.re-focus.net

http://www.gtz.de/en/

http://www.openpr.com/news/42317/Biogas-at-IFAT-2008-Producing-gas-from-waste.html

http://www.bmu.de/files/pdfs/allgemein/application/pdf/eeg_en.pdf

http://www.bmu.de/english/renewable_energy/doc/6465.php

http://www.gtz.de/en

http://practicalaction.org/

8 Assessing Sustainability of Waste Management

8.1 Background

Integrated waste management contributes to sustainable development as it reduces environmental pollution by treatment of waste and waste disposal on sanitary landfills. Moreover public health and living conditions of the local community can be improved. Integrated waste management also contributes to sustainable development by economizing use of natural resources though recycling and energy recovery.

Over the past decades the waste management sector in European countries has become a complex system of different waste streams and waste treatment processes that is characterized by innovations and high-tech applications. In Germany the term *circular economy* is used to illustrate the relevance of reusing and recycling waste materials. The rapid economic growth of Asian countries makes integrated waste management an important issue as likewise complex waste management systems as in Europe are developing already.

In order to assess the contribution of a waste management system to sustainable development it is impotent to consider all factors that influence the system and its complexity (Figure 8.1-1).

Influencing factors an be classified into three main categories

- Legal framework conditions,
- Economic and socio-economic factors and
- Local framework conditions

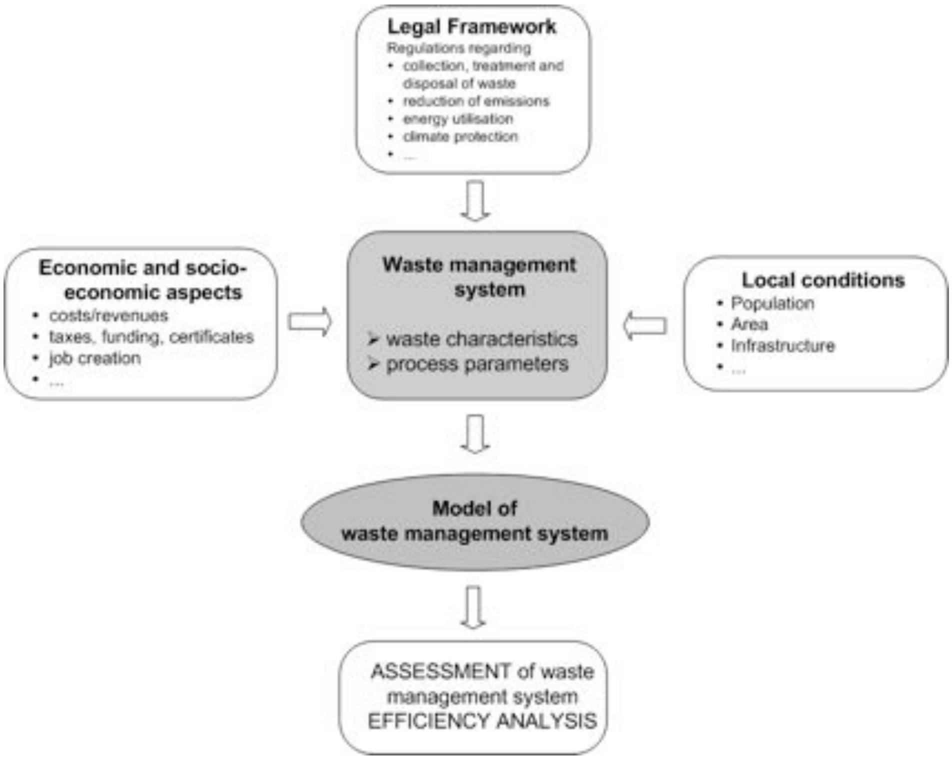


Figure 8.1-1: Factors that influence a waste management system

Modelling represents a suitable method to analyse and assess waste management systems. The real waste management system, i.e. collection, transport and treatment facilities and the way of the waste trough the different stages of the system are visualised by appropriate parameters. The above mentioned framework conditions need also consideration when developing the model. The model can support municipalities to identify the environmental and economic effects of their current waste management system. Moreover, effects that may accrue from changes to the system (e.g. redistributing the flow of identified waste material between the options of recycling, composting, energy recovery and landfill) can be assessed by examining major materials in the municipal waste stream. Thus potentials for optimised resource productivity trough energy and secondary raw material recovery can be determined.

In the following chapter the methodology of material flow analysis is introduced as tool for modelling and assessment of waste managements systems. Methods to characterise waste and to describe transformation of waste in treatment processes are explained. Finally key indicators and parameter to assess and evaluate the contribution of integrated waste management to sustainable development are presented.

Educational objective of the chapter

- *To learn how to model a waste management system and to describe waste streams and treatment processes*
- *To know important factors that influence a waste management system*
- *To learn about evaluating the modelling results*
- *To learn about indicators to assess sustainability of a waste management system*

8.2 Modelling a waste management system

The choice of appropriate surveying and treatment methods of waste is currently one of the main tasks in waste management. Due to increasing circuitry and anthropogenic accumulations into the environment material aspects are reasonable more important than ever. The material flow analyzing became one of the most reliable methods in quantitative detection and is applied as a basic utility in rating waste management systems. In a reasonable way the *material* flow analyzing can be linked to the *energy* flow analyzing to consider energetic aspects. During the last couple of years the complexity of certain disposal systems continuously rose, resulting into more dependency between the processes. Due to the link and increasing re-feeds of waste flows into certain disposal connections more complex disposal connections arise (Figure 8.2-1).

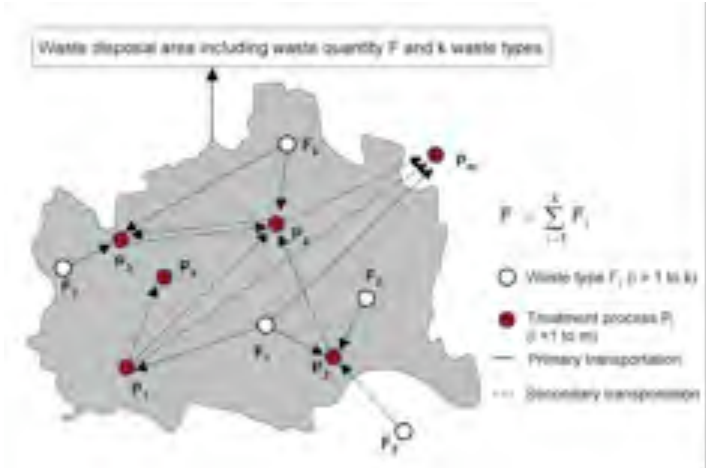


Figure 8.2-1: Complexity of a waste management system (illustration modified from LÖSCHAU, 2006)

The aim of the examination is to develop a method for material balancing of complex disposal systems. With this method deficits in current waste management systems should be identified. In addition the reasonability of managements should be assessed.

8.2.1 Methodology of Material Flow Analysis

A suitable method to model waste management systems is Material Flow Analysis (MFA) (or Substance Flow Analysis; SFA). The Organisation for Economic Co-operation and Development (OECD) defines MFA as:

☞ **Definition: Material Flow Analysis (MFA)**

„Material Flow Analysis (MFA) is the study of physical flows of materials into, through and out of a given system (usually the economy). It is generally based on methodically organised accounts in physical units. It uses the principle of mass balancing to analyse the relationships between material flows (including energy), human activities (including economic and trade developments) and environmental changes.“ (Measuring Material Flows and Resource Productivity, Synthesis report, OECD, 2008)

The method of MFA an be applied to a waste management system with the following targets:

- Illustration of material flows and processes, including different detail grades
- Considering altered frameworks
- Accounting and analyzing the regarding system in terms of the material and energy efficiency
- Supporting the material flow management by analyzing the opportunity to distribute waste flows to various constructions, considering technical, economic and ecological framework conditions
- Analysis of critical points, development of measures for optimisation,
- Definition of a base line scenario to assess future development

In the matter of modelling a material flow diagram the crucial elements are stated in terms of a simple process. Therefore it is significant to carry out reasonable assumptions. Within the system the process converts the ingoing material flow(s) (*Input*) to outgoing material flow(s) (*Output*). The *Output* of one process might represent the *Input* of the following process (Figure 8.2-2).

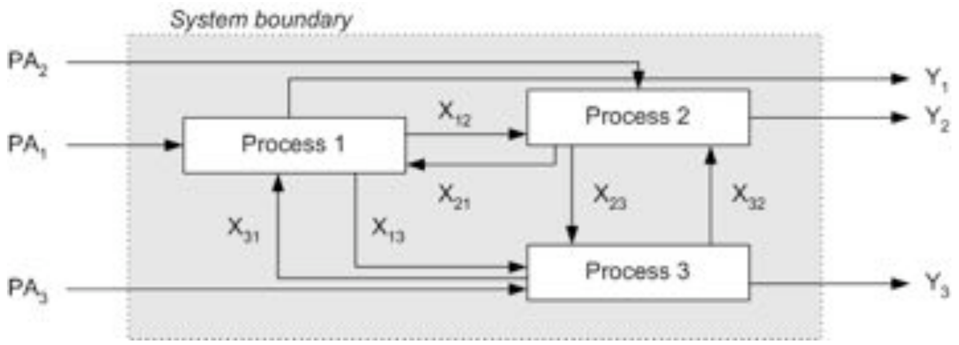


Figure 8.2-2: Elements of a MFA model (illustration modified from KYTZIA, 2003)

For the system, the principle of mass balancing, founded on the first law of thermodynamics, is applied. The principle, also called the law of conservation of matter states that matter, i.e. mass and energy, is neither created nor destroyed by any process (OECD 2008). Since Input and Output of complex waste treatment processes can differ, the term of *stock* is invented in order to describe this variation:

$$m_{Input} = \sum m_{Output} + stock$$

If material and energy flows are used to analyse the efficiency of the system, the material balance of the system will not always be balanced in total. This is because single flows are often allocated to processes or summarized in sum parameters in order to keep the system as simple as possible.

There are different levels of detail a system can have: For the description of a particular system a simple proposal considering the quantity and the quality of the waste is sufficient. The waste treatment process itself is considered a “Black Box”. The relevant in- and outgoing material flows are recorded in an Input-Output-Analysis and evaluated. For analysis of variation of material flows that are caused by the processes, these processes have to be looked at more detailed. Detailed components are described as “White Box”. Thus analyzing material flow diagrams entrapments and optimization derive.

8.2.2 Definition of system boundaries

The basics for a material flow analysis are the definition of spatial and temporary boundaries. Generally the specific period of time for a waste management material flow model is set with one year. The spatial boundary depends on the definition, for instance within a region or a catchments area of a private company.

In general the definition of local boundaries is deduced from the scope of the analysis. If, for example, the a waste management plan for a region is developed and therefore the structure of the waste management sector in this region is looked at, the system boundary will be defined by the political boundary of the region (Figure 8.2-3). If a specific waste company considered the system boundary will be orientated on the structure of the company, even if more than one region or country is involved.

For the environmental assessment of a waste management system the live-cycle-approach is used to define the system boundaries: the way of the waste defines the system boundaries (Figure 8.2-3). Thus, the life-cycle methodology qualifies to assess the environmental burdens of waste management from the point at which a material is collected to the point at which recyclable material, usable compost or recovered energy is produced.

When comparing different systems, e.g. for assessment of two different process alternatives, it is important to choose similar and well-defined system boundaries. The results of the analysis are set in relation to a reference (functional unit) for direct comparability.

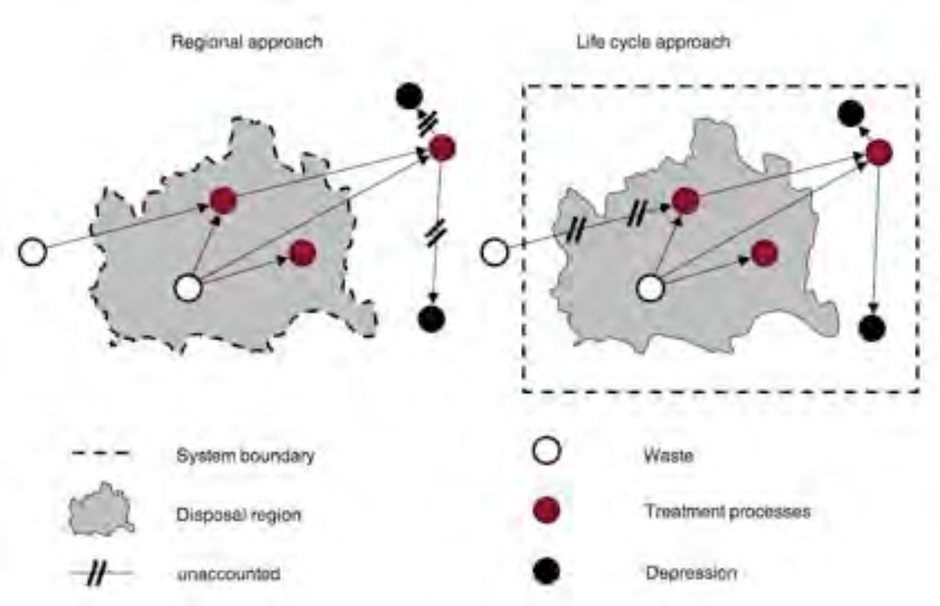


Figure 8.2-3: System boundaries: distinction between regional system boundaries and LCA-system boundaries (illustration modified from LÖSCHAU, 2006)

8.2.3 Model software

Software applications
The number of approaches in modelling is comparable to the number of methods for visualisation. Especially for graphical visualisation of models a number of software applications is available, that also facilitate the handling of complex databases, provide easy-to-handle process visualisation tools and that allows analysis and assessment of modelling results. Several types of software is available for modelling waste management systems, ranging from ready-to-use software to software that supports individual solutions (UNGER 2004).

The applicability of a software for modelling of waste management systems depends on several aspects: apart form user friendliness and well managed data bases, the possibilities to visualise the waste management system, i.e. the treatment processes and material flows, is of importance. For example a hierarchic structure of the model allows different levels of detail, i.e. the visualisation of the process as black box or a detailed view single process steps (white box).

In the following some software solutions suitable for waste management modelling are introduced (Table 8.2-1). The software solutions are partly based on EXCEL-applications. Apart form the software applications presented here there are a lot of applications that are used specifically in industries to support trade and logistic processes. WINKLER 2004 has carried out a comprehensive assessment of international modelling solutions for waste management systems.

Table 8.2-1: Examples of international software solutins for modelling of waste management systems

Software / developed by	Description
GaBi PE International in co-operation with LBP, University of Stuttgart www.pe-international.com	• Application of material flow analysis (MFA) and Life cycle analysis (LCA) • Support of environmental management systems in companies
UMBERTO Ifu Hamburg www.umberto.de	• Modelling on the basis of material flow networks • Level-based structure for visualisation of system • Variety in application, high flexibility, • Management of comprehensive data bases • Different valuation systems for impact assessment • Company-related (Process optimisation, Material efficiency) and product-related (Life-Cycle-Assessment, Life-Cycle-Costing) assessment tools
STAN Technical University of Vienna, Austria www.iwa.tuwien.ac.at	• freeware, specifically developed for application of MFA in waste management • import from/export from EXCEL data base possible • Pre-designed components to visualize processes • Presentation of results in form of Sankey Diagrams
IWM 2 (Integrated Waste Management, Version 2), Procter & Gamble IWM 2 Model guide available for download at www.scienceinthebox.com	• Minimum of data input required due to pre-designed management systems • Ready-to-use-design for application in companies • Inventory possible but no support of assessment, e.g. LCA

Software solutions suitable for waste management modelling should

- Be user friendly
- Allow handling of different data volumes and variation and adoption of parameter according to the data available
- Allow assessment of a range of factors
- Provide tools for analysis and visualisation of modelling results

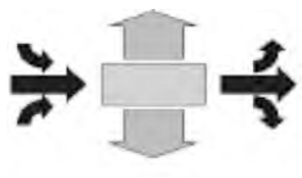
Guidance with data input and data management as well as suitable tools for visualisation of modelling results increase user friendliness of the modelling software. Well-developed graphic tools enhance the handling and visualisation of the variety of data a modelling process requires and moreover support the transparency of the modelling process and interpretation of the results. Variability and flexibility in software application increases, in comparison to EXCEL based applications, if software is especially designed for MFA. On the other hand software that is especially designed for waste management modelling (“ready-to-use-software”) requires less data input but is often limited to a set number of processes and parameters. Therefore complex systems cannot be modelled in detail. More detailed models do not always produce better results, as Input data generation is more difficult and can contain more sources of errors. Table 8.2-2 compares advantages and disadvantages of MFA software (e.g. UMBERTO, GaBi) and ready-to-use waste management modelling software.

Table 8.2-2: MFA software and ready-to-use waste management modelling software

MFA software with variety of application (e.g. GaBi; UMBERTO)	Ready-to-use-software (for waste management modelling)
Advantages	
• High flexibility and variability in modelling and visualisation of processes • Different tools to analyse and visualise modelling results • Comprehensive tools for sensitivity analysis	• Pre-defined processes and standard parameter (less data input required) • Input fields provide clear structure of model
Disadvantages	
• Technical knowledge about processes necessary • Training on how to use the software necessary • Comprehensive data input required (problem of availability of reliable data)	• Low flexibility and variability of software limits modelling and visualisation of processes • Partly insufficient analysis and visualisation tools

The applicability of model software depends on the scope of the system modelling. Ready-to-use software is suitable for indicative analysis because less work and cost intensive. If complex systems and effects of variation within the system are determined, advanced modelling software is required.

Illustration of modelling results
For illustration of modelling results the following applications are suitable:



Flow charts to illustrate material flows and process steps: The individual steps of the process are represented as boxes, the material flows between the process steps as arrows.

Sankey diagrams for scale visualization of material flows: The width of arrows is showing scale the amount per time unit.

Pie charts and **histogram** for visualization of distribution and composition: Total amount and percentages are displayed assessment and comparison o scenarios.

8.2.4 Characterisation of wastes

The distribution of waste fractions, such as plastics or metals, and hazardous substances in the waste are key questions of modelling. Therefore the characterisation of waste by appropriate parameter is a important task in waste management modelling. Data for waste characterisation can be generated from waste balances that are provided by communities (for household waste) or companies (for industrial and commercial waste). Key parameters are:

- Amount and kind of waste
- Amount of hazardous waste
- Waste utilisation paths and capacities
- Plant parameters
- Existing an planned measures to reduce, reuse, recycle and treat the waste

The characteristics of a waste are defined by its composition, i.e. the materials the waste consists of. In order to characterise the waste its different materials should be described by appropriate parameter.

Example: EASEWASTE Model of Technical University of Denmark

With the waste management model *EASEWASTE* KIKEBY (2006) has developed an approach, where waste composition can be described by 48 different materials (waste fractions) and each fraction can be characterised by 38 parameters. With this approach a waste input and its transformation in the different processes of the waste management system can be modelled very detailed. On the other hand it requires high effort for data collection.

Another approach is to define the parameter for the waste from the analysis of the treatment process. Thus the amount of data can be reduced.

Example: Scientific approach to model mechanical separation of wastes in Germany

Mechanical processes result in separation of waste fractions on the basis of their mechanical characteristics, which can be described by the parameters *grain size fraction* and *bulk density* (BEYER, 2002). Ferromagnetic properties and the infrared spectrum or surface properties for example are required parameter to model separation of metal and plastic materials.

Basically, the level of detail as well as the amount of parameter will be a compromise of required accuracy of the model and availability of data respectively the effort to generate data.

8.2.5 Determination of materials and energy flows

<u>Determination of material flows and material transformation</u>

When calculating material flows the material (or substance) freight F is the product of mass flow m and the concentration of the material (or substance) c:

$$F = m * c$$

Material (or substance) transformation in processes is expressed by the transfer factor TF as result of the ratio of mass input m_{Input} and mass output m_{Output} or freight input F_{Input} and freight output F_{Output} of a given material or substance.

$$TF = \frac{m_{Output}}{m_{Input}} \quad \text{or} \quad TF = \frac{F_{Output}}{F_{Input}}$$

The transfer function describes the distribution of process inputs n the process outputs. In order to describe the material transformation in the process as exact as possible the transfer factors should be determined specifically for the process considered. Process data are usually generated from available process data or empirically investigated material balances. The Transfer factor also depends on the composition of the input material.

Allocation of energy potentials

During analysis of the energy flows the distribution of the usable energy waste potentials on the output flows will be considered. The chemical energy bounded in the waste can be obtained by the calorific value. The energy flow E is the product of the mass m and the calorific value H_u of a given material:

$$E = m * H_u$$

Allocation of costs

A key task when developing material flow models for waste management systems is to provide the basis for economic assessment, i.e. to allocate costs to waste fractions treated. In order to assess economical aspects and involving costs in terms of waste management cost analysis has to be applied. The purpose of cost analyzing is to obtain potentials to optimize the system regarding business administration, basically a cost-benefit-analyzes.

For economic assessment material flows are linked to monetarily factors. Analogically a price is distributed to the loading account of the mass of the particular material. In order to determine the recycling costs the classification on the basis of the total waste flow has to be considered. Additionally quality depended costs will be considered, whereas a correlation to the material flow takes place.

8.3 Assessment of waste management options

The efficiency of a system can be deduced from the definition of sustainable development. The term efficiency relates to ecological and economic aspects that, together with social aspect, form the three pillars of sustainable development.

> ☞ **Definition: efficiency**
>
> The term efficiency determines the ratio of an aim of defined quality and the effort necessary to reach this aim. The term efficiency is applied in various fields, for example business or process technology.

The idea of sustainability in waste management is expressed by the terms *energy- and material efficiency* or described as *life-cycle-thinking*. Integrated waste management contributes to energy efficiency by recovering energy from waste, that substitutes fossil energy sources. Secondary raw materials generated from separation and treatment of waste can substitute raw materials and thus contribute to increased resource productivity.

> **Example: Assessment of efficiency**
>
> Efficiency analysis of energy recovery from waste can be carried out using the following indicators:
>
> - Efficiency of the process: ratio of energy input to available energy produced
> - Substitution rate for primary energy sources
> - Ratio between specific treatment costs and available energy produced
> - Ration between specific treatment costs and CO_2-emissions

The majority of methods applied for efficiency analysis are based on the LCA methodology. LCA is a standardised method to quantify and evaluate environmental burdens resulting from a product or process. Based on the definition of the system (model), an Inventory is carried out and the results are evaluated in an Impact Assessment.

8.3.1 Economic Assessment

From the economic point of view a (waste management) system operates in an economically sustainable manner if it covers all its expenses. DEN BOER and DEN BOER (2005) have defined economic sustainability criteria and indicators (Table 8.3-1):

Table 8.3-1: Example Criteria and Indicators (DEN BOER and DEN BOER, 2005)

Criterion	Possible Indicator
1. Equity	Charges (€) per capita/average income
2. Reduction of waste quantities	Tons/year over a decade
3. Quality of service	Frequency of collection
4. Citizen cost	Actual cost (€) per household or per capita Actual cost (€) per ton Municipal charges per ton
5. Municipality cost	€ per ton

Some parameters can be indictor for economic but also ecological sustainability, for example reduction of waste quantities.

The specific costs for waste treatment consist of:

- Costs for collection, transport and storage of waste
- Costs for waste treatment (investment costs/operating costs)
- Costs for the dumping the waste
- Revenue from marketing of secondary products (energy, secondary raw materials)

The Costs for collection and transport are strongly influenced by the collection system (Pick-up and Drop-off systems) and increase with the complexity of the waste management system. Surveys on collection and transport costs, that have been carried out for Germany, show that these costs can sum up to 75 % of the overall costs for waste treatment (MÖLLER; 2006). Other studies carried out for the German waste management sector (BIfA, 2004) show that treatment costs correlate to the technical standard. These results lead to the conclusion that overall waste treatment costs increase with increased standard of the waste management system.

8.2.2. Environmental Assessment

In general, environmental impacts can be subdivided in terms of their geographic extend into:

- Global impacts
- Regional impacts
- Local impacts.

Local and regional environmental impacts caused by waste management can be positive (resulting in an improvement of local/regional environmental conditions) or negative (resulting in a deterioration of the local/regional environmental conditions). The overall impact will be assessed by identification and rating of environmental impacts in several categories. Impact categories and examples for potential impacts are exemplarily compiled in Table 8.3-2.

Table 8.3-2: Impact categories for local and regional environmental impacts and examples for potential impacts

Impact category	Potential positive impacts	Potential negative impacts
Direct local impacts		
Air	- reduction of odour and local air pollution by treatment of waste (composting, fermentation, incineration) and dumping on sanitary landfills	- increase of local traffic resulting in local air pollution (transport to/from treatment facilities) - local air pollution and odour if facility is not managed properly (e.g. waste incineration without flue gas cleaning, biogas plant)
Soil	- reduction of soil pollution caused by uncontrolled disposal/handling of municipal waste (e.g. open dumping sites) - improvement of soil conditions by application of bio-fertiliser (from biological waste treatment)	
Water	- reduction of water pollution (groundwater, rivers, lakes) caused by uncontrolled disposal/handling of municipal waste (e.g. open dumping sites)	
Noise	- reduction of noise if diesel generators are replaced by energy from biogas process	- increase in noise exposure for direct neighbours of treatment facilities - increase of local traffic (transport to/from treatment facilities)
Smell	- reduction in smell from inappropriate waste handling/disposal (e.g. open dumping)	- exposure to smell for direct neighbours of biological waste treatment sites (biogas/composting plant
Regional impacts		
Deforestation	- reduction of deforestation due to provision of electricity/heat through biological waste treatment (biogas production)	

The methodology presented here uses descriptive assessment of environmental impact. In order to compare different systems, evaluation methods that are based on numerical comparison are required. When assessing material- and energy flows modelled with MFA, Inputs and Outputs are considered separately:

Inputs:

- Primary energy sources (MJ): coal, oil, gas, renewable energy
- Other raw materials: minerals, water, ...

Outputs:

- Emissions into air: carbon dioxide, SOx, NOx, methane
- Emissions into waster: CSB, BSB_5, heavy metals
- Waste: slag, process residues

For ecological assessment different environmental parameters are considered through indicators (Table 8.3-3).

Table 8.3-3: Allocation of material flows as indicators for defined impact categories

Impact category	Indicator	Parameter
Global impact		
Climate change	Green house gas emissions	Carbon dioxide (CO_2), Methane (CH_4)
Resource depletion	Energy consumption	(fossil) energy sources, power, heat
Regional/local impact		
Acid precipitation	Emissions of acid gases	Nitrogen oxides (NOx), sulphur oxides (SOx) and hydrogen chloride (HCl)
Smog formation	Emissions of smog precursors	NOx, inhalable particulates (PM-10) and non methane volatile organic compounds (VOCs)
Health risks	Air emissions	Lead, cadmium, mercury (Pb, Cd and Hg) and trace organics (dioxins)
Water quality	Water emissions	Chemical oxygen demand (CSB) and biological oxygen demand (BOD), trace organics (dioxins) and heavy metals (Pb, Cd and Hg)
Land use disruption	Residual solid waste	Amounts of waste (household waste, industrial waste, hazardous waste)

Against the background of the mechanisms on climate protection formulated in the Kyoto Protocol, that are beside others Emission Trade and Clean Development Mechanism (CDM), assessment of CO_2-emissions from waste management systems plays an important role.

Example: Assessment of CO_2-emisisons

Carbon dioxide from biomass is considered to be climate-neutral. Therefore only CO_2-emisisons from non-biogenic waste fractions are considered when assessing the global warming potential of waste incineration. For calculation of resulting CO_2-emisisons from incineration of non-biogenic waste fractions the molar mass of carbon dioxide $M(CO_2)$ is put into ration to the molar mass of carbon $M(C)$ (ECKARDT et. al, 2004):

$$m_{CO_2,fossil} = m_{C,fossil} * \frac{M(CO_2)}{M(C)}$$

Where M (CO_2) = 44 g/mol
M (C) = 12 g/mol

The emission factor is calculated from the mass of fossil carbon dioxide $m_{CO2,fossil}$ in the waste fraction in relation to the heating value of this fraction

$$emission\_factor = \frac{m_{CO_2,fossil}}{heating\_value}$$

8.3.2 Assessment of ecological and socio-cultural impact

Every economic activity causes a variety of different direct and indirect impacts. Among others, activities effect social aspects, e.g. increase or decrease of income. Waste management especially has an impact on the standard of living in a local society as it helps to increase the local health conditions. The methodology to determine the social impact of a project or single measures that is explained in the following has been described during the project BIWARE (founded under the AUNP-Programme).

The determination of the social impact of a project provides "non or indirect financial" arguments which are important to convince stakeholders like residents and the local community and administration about the project's benefit. Furthermore, positive socio-economic effects are a vital factor considered by foreign organisations or local organisations/government for granting funding.

Examples for direct local effects on employment, health conditions and poverty alleviation:

- Job creation: Number of direct created jobs, Number of indirect created jobs, e.g. through economic effects like structural changes, new business opportunities
- Income generation: Amount of direct and indirect created income
- Health: Effects of better sanitation through better water quality

A useful tool (Table 8.3-4) to determine the overall influence of a project on the regional socio-economic development has been developed by KARTHA and LARSON (2000):

Table 8.3-4: Overall influence on the regional socio-economic development (KARTHA, LARSON, 2000)

Category	**Impact**	**Quantitative indicators, based on assessment of:**
Basic needs	Improved access to basic services.	Number of families with access to waste management system (waste collection facilities; energy services, e.g. from biogas plant…), quality, reliability, accessibility, cost.
Income generating opportunities	Creation or displacement of jobs, livelihoods.	Volume of industry and small-scale enterprise promoted, jobs per $ invested, salaries, accessibility to local workers, development of markets for local products (recycled materials, energy…)
Gender	Impacts on labour, power, access to resources.	Relative access to outputs of waste management project. Decision-making responsibility both within and outside of waste management project. Changes to former division of labour.
Land use competition and land tenure	Changing patterns of land ownership. Altered access to common land resources. Emerging local and macroeconomic competition with other land uses.	Recent ownership patterns and trends (e.g., consolidation or distribution of landholdings, privatization, common enclosures, transferral of land rights/tree rights). Price effects on alternate products.

8.4 Summary

Learning outcome:

Different methodologies and applications have been developed for modelling of waste management systems; among them material flow analysis (MFA). In order to keep the model as simple as possible the definition of model parameter should be made with view to the scope of the model, i.e. the question the model should answer. This can be the comparison of different types of treatment processes (which requires a more detailed view on the treatment process and the transformation of the waste in this processes) but also distribution of waste within a region (here the model will be less detailed but comprise also collection and transport of waste and different treatment processes). If different systems are compared similar system boundaries have to be defined.

The material flow *waste* is characterised by the different types of waste, each of them with a different composition that is again characterised by the waste fractions present. The parameters for each waste fraction can be determined by laboratory analysis (which allows better description of local peculiarities) or from literature (which results in less effort in data generation). There are different methods to model the transformation of materials in a process: resulting output flows can be deduced from process data, or they are calculated from the input flows by transformation factors. The output of one process can be the input of the next process.

For efficiency analysis three key aspects are important, which are, a) were is the waste remaining, b) what are the paths of hazardous substances, and c) what are the costs of waste treatment.

Figure 8.4-1 summarizes the steps and parameter necessary to model and assess a waste management system.

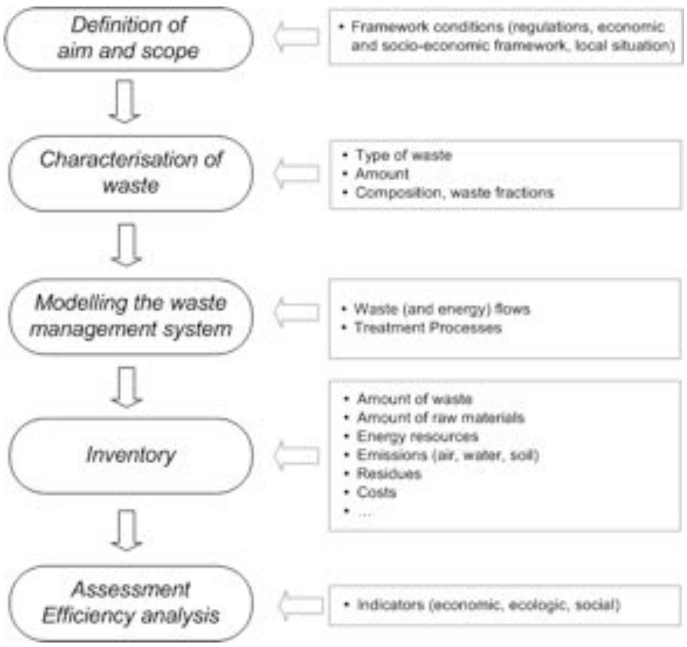


Figure 8.4-1: Steps and necessary parameter for modelling and assessing a waste management system

8.5 References and further reading

Baccini, P.; Brunner, P., 1991. Metabolism of the Anthroposphere. Springer Verlag, New York 1991

Beyer, C., 2002. Modellierung und Simulation von Abfallaufbereitungsanlagen unter besonderer Berücksichtigung der Stoffstromvektorisierung. (Modelling mechanical waste treatment processes with special consideration of material flow vectors) Dissertation, Rheinisch-Westfälische Technische Hochschule Aachen, in: Schriftenreihe zur Aufbereitung und Veredlung, Shaker Verlag, Aachen 2002

Hottenroth, S. et al., 2004. Ökoeffizienzvergleich von öffentlichen Entsorgungsstrukturen. (Eco-efficiency of municipal waste management services) Bayrisches Institut für Angewandte Umweltforschung BIfA GmbH, Augsburg, in: Müll und Abfall 9/2004, S. 420-429

Bilitewski et al. 1997. Waste Management, Springer Verlag, Berlin Heidelberg, 1997

Den Boer, J; den Boer, E. (eds), 2005. Handbook "Waste management planning and optimisation". ibidem-Verlag, Stuttgart, 2005

Eckardt, S, Schirmer, M. et al., 2004. Emissionshandelssystem – Ein wirtschaftlicher Anreiz für die Mitverbrennung von Ersatzbrennstoffen aus Restabfällen? In: Hösel, Schenkel, Bilitewski, Schnurer (Hrsg,): Müll-Handbuch, Erich Schmidt Verlag Berlin, Berlin 2004

EEA, 2003. Assessment of Information Related to Waste and Material Flows – A Catalogue of Methods and Tools. European Environment Agency, Copenhagen

Ekvall, T., 1999. Key methodical issues for life cycle inventory analysis of paper recycling. Journal of Cleaner Production 7, 281-294

Finnveden, G.; Moberg, A., 2004. Environmental system analysis tools - an overview. Journal of Cleaner Production 13 (2005) 1165-1173

Flamme, S., 2002. Energetische Verwertung von Sekundärbrennstoffen in industriellen Anlagen – Ableitung von Maßnahmen zur umweltverträglichen Verwertung. Dissertation, Bergische Universität – Gesamthochschule Wuppertal, Juli 2002

Grassinger D. et al., 1998. Methoden zur Bewertung abwallwirtschaftlicher Maßnahmen (Methods for assessing waste management measures). BOKU University, Vienna, Austria.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds)., Published: IGES, Japan.

ISO 14040:2006, 2006. Environmental Management – Life Cycle Assessment - principles and framework. International Organisation for Standardisation (ISO), Geneva

ISO 14044:2006, 2006. Environmental Management – Life Cycle Assessment – requirements and guidelines. International Organisation for Standardisation (ISO), Geneva

Kartha and Larson, 2000. Bio energy Primer: Modernised Biomass Energy for Sustainable Development

Kikeby, J. et al., 2006. Environmental assessment of solid waste systems and technologies: EASEWASTE. Waste Management and Research 24, 3-15

Kytzia, S., 2004. Stoffhaushalt III: Stoffstrommanagement. IRL-ETH Zürich, Zürich 2004

Löschau, M., 2006. Input-Output-Analyse als Methode zur stofflichen Bilanzierung komplexer Entsorgungssysteme. (Applying Input-Output-analysis to assess complex waste management systems). Dissertation, Technische Universität Berlin, Juni 2006

Morrissey, A.; Browne, J., 2003. Waste management models and their application to sustainable waste management. Waste Management 24, 297-308

Möller, K., 2003. Effizienz-Modell zur Bewertung der Transportlogistik in der Abfallwirtschaft. (Modelling efficiency of waste transports) Dissertation, technical University Dresden, in: Beiträge zu Abfallwirtschaft/Altlasten, Band 45, Dresden 2006

ÖAWV, 2003. Die Anwendung der Stoffflussanalyse in der Abfallwirtschaft (Application of material flow analysis to waste management systems). Austrian Water and Wastewater Association, Vienna

OECD, 2008. Measuring Material Flows and Resource Productivity, Synthesis report, OECD, 2008

Schmidt, M., 2002. Methodische Ansätze zur Analyse betriebliche rund produktbezogener Stoffstromsysteme. in: Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, Institut für Technikfolgenabschätzung und Systemanalyse (ITAS), Technikfolgenabschätzung – Theorie und Praxis Nr. 1, 11. Jhrg., Karlsruhe 2002

Unger, N. et al., 2004. General requirements for LCA software tools. Diploma thesis, University of Natural Resources and Applied Life Sciences, Vienna, 2004

Verfaille, H.; Bidwell, R., 2000. Measuring eco-efficiency – a guide to reporting company performance, WBCSD, 2000

Winkler J.: Comparative Evaluation of Life Cycle Assessment Models for Solid Waste Management. Dissertation, Technische Universität Dresden, in: Beiträger zu Abfallwirtschaft/Altlasten, Band 36, Dresden 2004

9 Case Studies

9.1 Vietnam

9.1.1 Waste collection and Storage

9.1.1.1 Collection system

In Vietnam at present only solid wastes are collected. Waste water and gases are not yet collected and treated before discharging in to the natural environment. Only a few industrial production establishments have waste water and waste treatment facilities. Vietnam has started to apply environmental protection fees for waste water. It is hoped that the number of production and business establishments with treating waste water treatment system will increase.

The collection of domestic solid wastes in Vietnam's urban areas has been organized systematically, mainly undertaken by State-owned urban environment companies (URENCO). All cities and towns have one or several companies of this kind, depending on their size and population. In some cities and towns, some private companies begin to be involved in waste collection and this trend is expanding in many other urban areas along with the Government's policy to attract all economic sectors to take part in municipal waste processing. In rural areas (districts, communes and villages), collection and transportation of solid waste are organized in some localities by environmental sanitation teams or commune environmental sanitation groups.

The average collection rate for municipal waste has been increased from 2000 - 2004 (Figure 9.1-1) [12]. However there is a big difference off receiving waste service in different living areas. It is improved in cities, but limited in rural and poor areas. The poor are lnot served by collection services; nine out of ten of the poorest urban households do not receive at all. New initiatives are being promoted to fill the gaps. For example, community-based and private sector organizations have organized collecting service in rural villages and also in urban areas, they did not got municipal coverage. In cities especially in the rich area, the number of people have got a waste service more than in poor area or in rural area [12] (Figure 9.1-2).

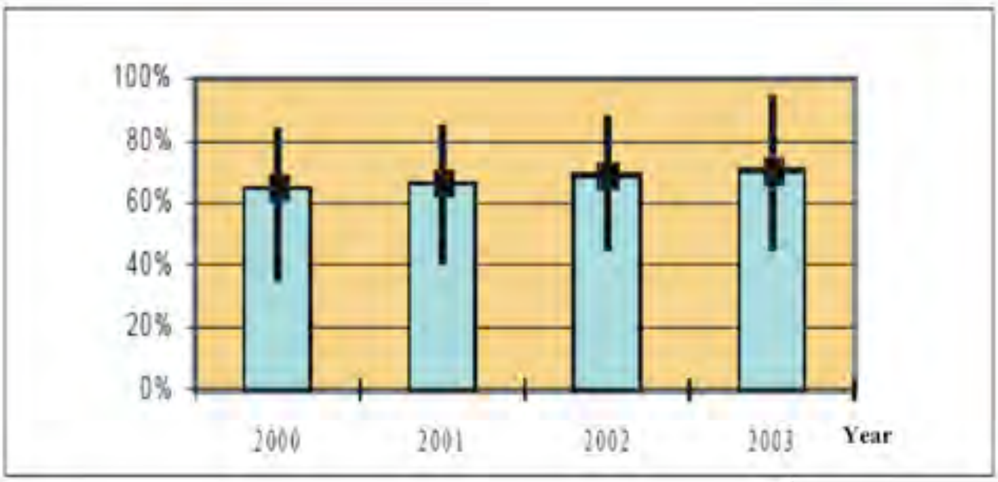


Figure 9.1-1: Average collection rate for municipal waste from 2000 – 2004

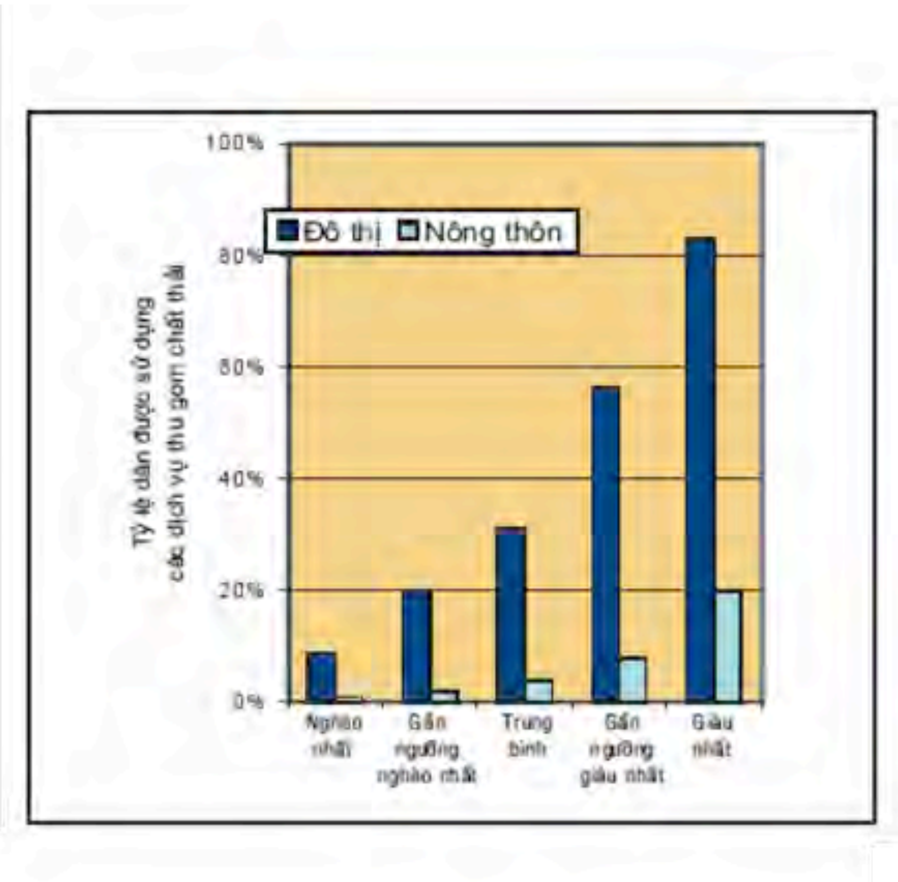


Figure 9.1-2: Rate of collection service for housholds in rich and poor urban and rural areas

In general, solid wastes have been not yet segregated at source. They have been collected together and transported to dump sites (Figure 9.1-3). The collection efficiency is 40 - 67 % of generated wastes in big cities and 20 - 40 % in small towns. Average collection rate in urban area is about 53.4%.

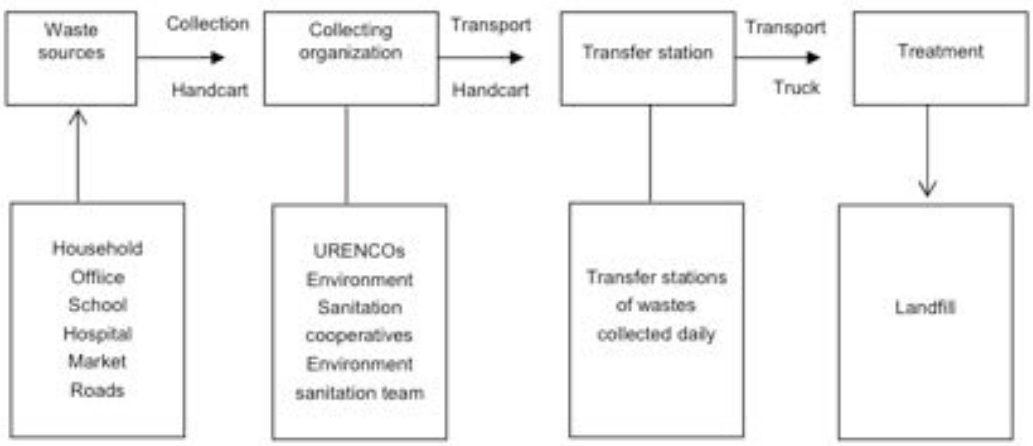


Figure 9.1-3: Municipal Solid Waste system in Vietnam

There is still inconsistency in technology of collection and transportation with different forms:

- ✓ Solid wastes from streets and public locations are collected manually, using manual sweeping and loading into handcarts for transportation into transfer stations;
- ✓ Handcarts or waste collection vehicles running through streets around living area, according to a collection planned schedule;
- ✓ Solid waste from hospitals, business, industrial centres and construction sites are collected and transported under specific contracts.

From 2000 - 2003 the waste collection rates in urban areas have been increased from 65 to 71% but in rural areas it remains less than 20%.

In many cities, URENCO contracted out by the local People's Committee for collection, transportation, and disposal of municipal waste and also industrial and healthcare wastes.

The budget for waste collection and treatment dominate from governmental sources. The waste service and waste processing therefore establish mainly by governmental institutions. Citizents and interprices contribute less on waste avoidance. The environmental fee is low, it covers only a part of collection's service. Eventhought only 20 - 70 % of fees have been collected.

In 2003 budget spent for waste collection and processing of Urencos in some cities discribed in Figure 9.1-4. In this figure there are 3 city's categories: big city (in the first column) has more than 500 000 people; medium city (in the second column) has population of 250 000 to 500 000 and the small one (in the third column) have less than 250 000 people. The payment has been calculated based on collected waste bilion VND/ton [10].

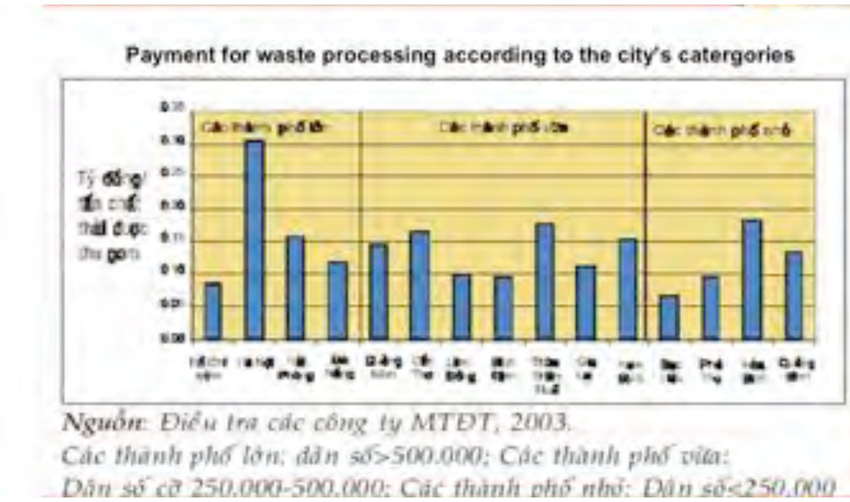


Figure 9.1-4: Payment for waste processing according to the city's catergories

Figure 9.1-5: Waste collection in Hanoi

The waste collection in Hanoi looks like in Figure 9.1-5. There are 200 collection verhicles in working condition dayly and night, 30 collection tracks, 30 sludge collection tracks and 2 medical waste collection tracks [11].

9.1.1.2 Handling of fluid waste

The handling of waste including collection, treatment and disposal, reuse and recycling is crucial to providing a cost-effective waste management system that is able to reduce public health and environmental risks. Most of the municipal waste in Vietnam is not safely disposed. However, there have been significant improvements by the public URENCOs that are responsible for municipal waste collection and disposal (Figure 9.1-6). Proper handling of hazardous waste, which is the responsibility of the industries and hospitals remains severely limited. Recycling and reuse driven by an informal network of waste pickers at landfills, informal waste collectors, and waste buyers (Figure 9.1-7).

Figure 9.1-6: The common fluid waste pre-containe

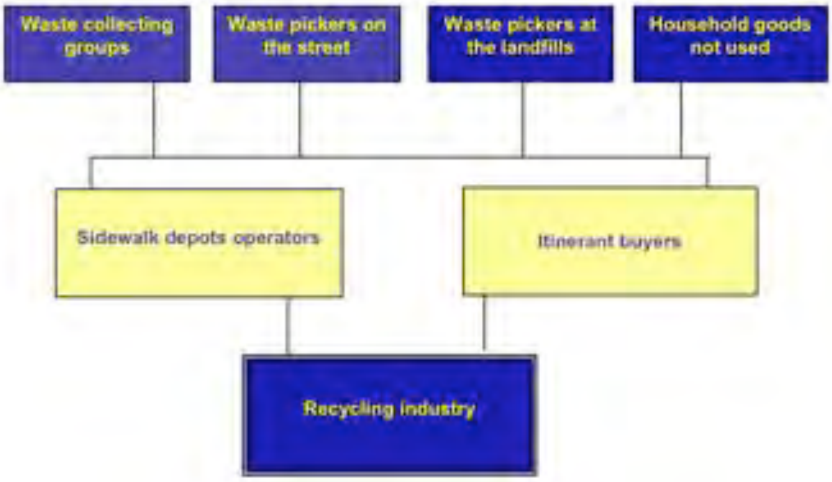


Figure 9.1-7: Channels of Municipal Waste Reuse

9.1.2 Waste processing, Treatment and Recycling

9.1.2.1 Manual separation

The 3R program (Reduce, Reuse and Recycling) has been implemented as a test over the country from the North to the South (Table 9.1-1).

The 3R program started in Hanoi in March 2007. According to 3R the people have received 02 bags for organic and unorganic waste. They put on waste to an orange bin as unorganic (plastic, glass, paper, …) and the other to green bin as organic (vegetable, food scrabes, …) (Figure 9.1-8 and Figure 9.1-9).

Table 9.1-1: List of the 3R program over the country

No.	City	Ort
1	Hanoi	Phan Chu Trinh, distric Hoàn Kiếm; Kim Liên, distric Đống Đa Trâu Quỳ, distric Gia Lâm Sài Đồng, Đức Giang, Yên Viên
2	Nam Định	
3	Ninh Bình	
4	Nghệ An	Nam Đàn
5	Huế city	
6	Hồ Chí Minh city	No.12, distric 5
7	Đồng Nai.	Phường Thanh Bình, Biên Hoà

Figure 9.1-8: Selected items for 3R program

Figure 9.1-9: Manual sorting at conveyor

9.1.2.2 Mechanical separation

Types of mechanical treatment technologies are materials recovery facilities (MRF) and feedstock preparation (size reduction for biological treatment). The different processes are size reduction, magnetic separation, screening and air classification.

There is an example about the combination between mechanical and biological municipal waste treatment system for small commune (capacity 15 ton/day), which named Compact Device for waste treatment (so-called CD-Waste System). This CD-Waste System is suitable for small town such as Dong Van town, Duy Tien distric, Ha Nam province, Vietnam (Figure 9.1-11).

In CD -Waste System the collection and transportation of solid waste are organized by environmental sanitation teams, they are also the workers in department of mechanical separation of this treatment facility (Figure 9.1-10). The workers therefore avoid unwanted items in the input flow, which may cause for damaging of machine (Table 9.1-2).

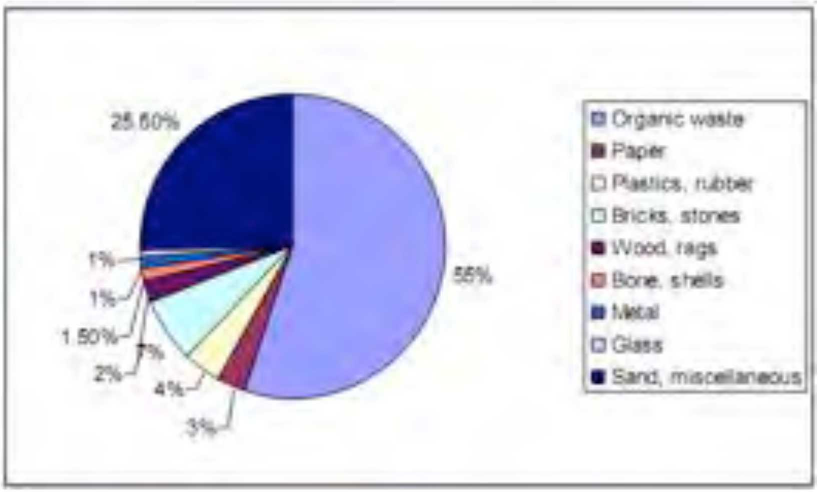


Figure 9.1-10: Composition of waste in Dong Van town, 2006

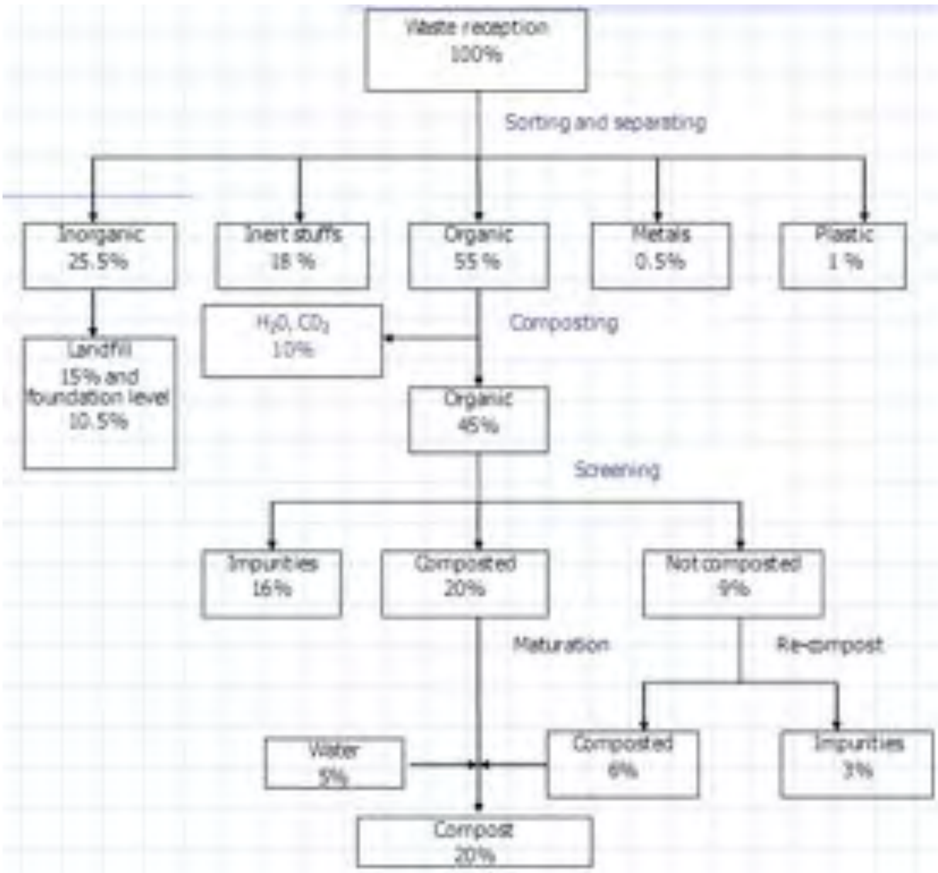


Figure 9.1-11: Sorting and separating

The CD - Waste System has main six equipment groups:

1) Group of equipments for sorting and separating (Figure 9.1-12)

2) Composting towers
3) Group of equipments for crushing and separating of organic waste after composting
4) Mature towers
5) Inorganic waste treatment system
6) Combustor

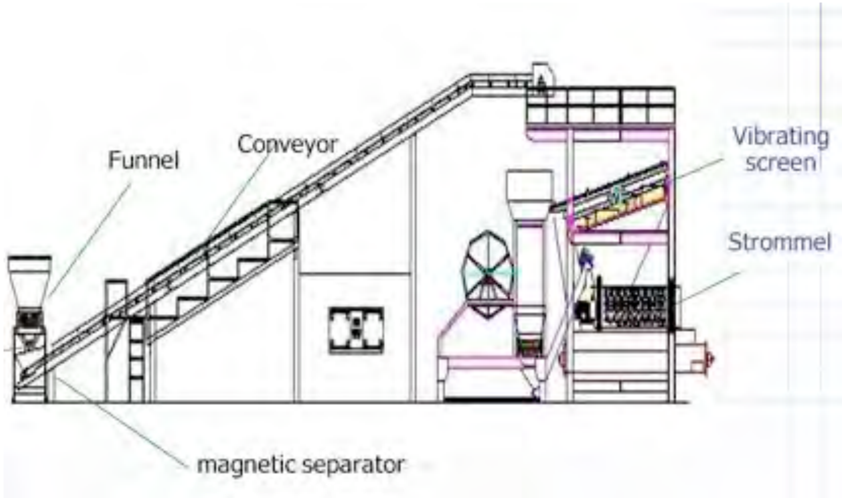


Figure 9.1-12: Equipment for Sorting and separating

Table 9.1-2: Practic data in town, 2007

Parameters	Unit
Amount of waste per day	20 tons
Organic waste content can put into composting tower	55%
Organic waste per day	11 tons/day
Amount of organic waste per year ($M_{OF/a}$)	4,015 tons
Properties of organic waste:	
Water content (WC_{OF})	70%
C/N ratio	30:1
Density (D_{OF})	0.65 ton/m^3
Retention time of composting (t_R)	10 days in composting tower 22 days for maturation Therefore total time: 32days

With this system the waste collection and treatment was completed in one day, save in waste transfer and transportation expense. Waste was transfered into products of own domestic use (Figure 9.1-13).

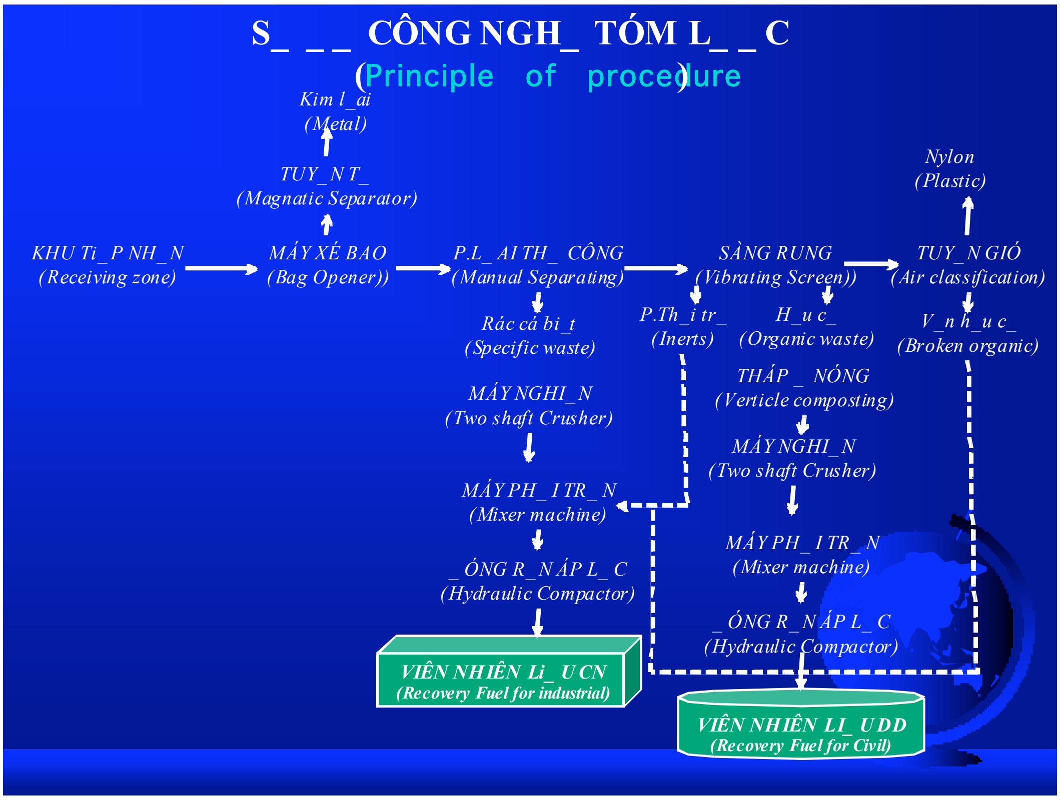


Figure 9.1-13: CD Waste System principle of procedure

9.1.2.3 Waste recycling

Recycling is common practice in Vietnam. Households routinely separate recyclable wastes such as metals and paper for sale to itinerant buyers, or sell it directly to local depots. Waste pickers are also separating reusable and recyclable wastes. This dynamic recycling market is largely led by the informal sector. In Hanoi, for example, the informal sector recycles 22% of all waste produced. In the industrial sector, several types of industries can recycle as much as 80% of their waste. Artisans and workers at many craft villages have been particularly successful in capitalizing on this opportunity, recycling over 90% of their potentially recyclable waste. Annual cost savings on disposal could be substantial. For example if each of 6 key industries could recycle 50% of its potentially recyclable wastes they would save VND 54 billion on disposal costs. Similarly, a 10% decrease in municipal waste could save VND 200 billion annually on disposal.

The market for recyclables has a large potential for expansion. Thirty-two percent of the municipal waste currently placed in disposal sites in urban areas in Vietnam, or 2.1 million tons per year, consists of commercially recyclable materials such as paper, plastic, metal, and glass. This additional recycling could result in a substantial reduction in disposal costs and allow the largely poor informal sector to capture an estimated VND 135 billion per year in additional recycling revenues in Ho Chi Minh City alone.

The composition of waste with high proportion of organic matter provides potential for composting, which can reduce disposal costs while producing a marketable soil conditioner. However, this practice is not widespread in Vietnam for many reasons, including inadequate separation of organic waste, poor product quality, and market is limitted. With the development of a strong market for composting fertilizers and successful source separation, the effectiveness of centralized composting facilities could increase considerably.

Table 9.1-3 shows the situation of some concentrated compost plants in Vietnam. Surrounding Hanoi there are some composting interprices such as: Cau Dien composting plant (Figure 9.1-14), in Kieu Ki dump site, Gialam district and Green Sun Co.Ltd, Duong Lieu, Hoai Duc, Ha Tay.

Table 9.1-3: Situation of some concentrated compost plants

Location of plants	Capacity (tones/day)	Start of operation	Organic waste source	Status
Cau Dien, Hanoi	140	1992; expanded in 2002	Waste from market, street	Operational. Selling 3 products at a price of VND 800, 1200 and 2000/kg
Nam Dinh City	250	2003	Un-separated municipal waste	RATIONAL. PROVID FREE OF CHARGE COMPOST TO FARM
Phuc Khanh, Thai Binh	75	2001	Unidentified	Operational.
Viet Tri, Phu Tho	240	1998	Unidentified	Operational. Selling 3 products at a price of VND 200, 250 and 900/kg
Hoc Mon, Ho Chi Minh	240	1982; closed 1991	Un-separated urban waste	Closed down due to difficulty in selling products
Trang Cat, Hai Phong	50	2004	Mud, matters dredged from canals and un-separated urban waste	In test run period
Ninh Thuan	100	1998	un-separated urban waste	Operational.
Thuy Phuong, Hue City	159	2004	un-separated urban waste	Operational. Selling compost at VND 1100/kg to farmers to grow coffiee and rubber trees

Figure 9.1-14: Product of composting plant in Cau Dien, Hanoi

Figure 9.1-15 shows the common sight concerning the recycling activity in Vietnam:

Figure 9.1-15: Common sight concerning the recycling activity

The recycling takes place mostly in recycling villages without properly controlled by the governmental institution. It is therefore threaten to environmental polltion. Recycling villages are the handicraft villages where process of production is operated completely by hand or by using simple tools. Waste becomes the raw materials for manufacture new products.

There are about 80 - 90 villages (of around 1500 total handicraft villages) divided into 3 main sub-groups: waste paper, waste metal and waste plastic recycling. They are located in or next to the living areas, mostly concentrated in the Northern part of the country. The development of these villages creats a network of waste, scraps and raw materials collecting (Table 9.1-4).

Table 9.1-4: Information about the recycling villages in the North of country

No.	Recycling villages	Raw material
1	Dong Mai lead-processing village	used bacteries
2	Phong Khe, Bac Ninh paper recycling village; Bai Bang, Viet Tri, Phu Tho interprise	all kinds of waste paper, , Javen solution, bleach…
3	Minh Khai plastic recycling village; Tien Tu interprise, Hanoi; Nhu Quynh Commune, Van Lam distric, Hung Yen Province	plastic waste (foils, scraps,...)
4	Vinh Loc metal-mechanical processing village (Vinh Loc hamlet, Phung Xa commune, Thach That district, Ha Tay province)	iron scraps

Table 9.1-5 discribes potential of some recycling villages such as: plastic, paper and metal in 2003.

Table 9.1-5: Potential of recycling villages for plastic, paper and metall 2003 [13

Recycling materials	Input (ton/year)	Products (ton/year)	Recycled percentage
Plastic	25,200	22,900	90.9
Paper	51,700	45,500	80.0
Metal	735,000	700,000	95.2
Total	811,900	768,400	94.6

9.1.2.4 Thermal treatment process

For incineration activity in Vietnam developed the 3 types of incinerators with two chambers, one chamber or rotary. They have been used mostly for avoiding medical waste. However only 50 % of hazardous healthecare waste have been treated by this facility.

The incinerator made in Vietnam is cheap but it has small capacity (VHI-18B, 18C,…). Waste fed into equipment mostly by hand that lighly affect homogenization. There are also import incinerators like HOVAL-MZ2, DELMONEGO,… But they have rather high price in comparason with the domestic products.

In Hanoi exist mostly the two chambers incinerator. Temperature ranges 800-1200^{0}C; capacity 0.2 - 10 tons/day, flue gases treatment is available (Figure 9.1-16).

Figure 9.1-16: Incinerator CEETIA and VHI-18B made in Vietnam

9.1.3 Waste disposal

Municipal waste disposal practices are improving but still represent a threat to health and environment. The dominant form of disposal of municipal waste remains open dumping; 49 sites have been identified on a national list as hotspots with high environmental and human health risks. Of the 91 disposal sites in the country, only 17 are sanitary landfills (in 12 of 54 provinces ov er country). However, according to the national environmental report 2005 there are 8/82 sanitary landfills over the country.
Almost amount of municipal waste is taken to open dumps (Figure 9.1-17).

Figure 9.1-17: Open dump with less care is very common

In many areas, self-disposal methods--such as burning or burying waste, or dumping in rivers, canals, and open fields is common. Poorly operated landfills and open dump sites cause contamination of ground and surface water by untreated leachate, emissions of airborne pollutants, and the spread of odors, flies, mosquitoes, rodents, dust, and noise, leading to a high incidence rate of skin, digestive, and respiratory disease.

Nam Son landfill is thr biggest sanitary site of Hanoi. It has the area of 53.4 ha. It consists of 9 disposal hole, 3 biological ponds and 1 wastewater treatment pilot module. Nam Son landfill has put into operation since 1998, and it is still in operation now. This is the final destination of 92% of household waste in Hanoi. It could be received 2,000 ton/day untill so the amount of waste will be 730,000 ton disposed in Nam Son landfill each year.

Conclussion

- Vietnam's solid waste management needs are substantial in relation to the growth of urban areas and industrial development. Without undertaking the necessary measures to establish effective handling, treatment, and disposal systems, the growing quantities of waste can have various impacts.

Therefore specific priorities need to be done:

1. Improving investments and operations for municipal waste management services. Making investments that are cost-effective, targeted to priority areas, and based on appropriate technology is a key task. The priorities are to ensure proper operation of existing landfills; expand collection to underserved areas and smaller urban centers through cost-effective investments and improved efficiency; improve SWM services available to poor households; and continue the national program of building new sanitary landfills. Improving services to the poor will require a combination of focused subsidies from the government and some cross subsidies from URENCOs, as well as expansion of community-based arrangements. Moreover, systematic consultation with and participation by poor communities is needed in the siting, impact assessment, and operation of landfills.
2. Improving cost recovery and the sustainability of investments. Improving the financial sustainability of SWM systems is a high priority. Different forms of fees--including flat rates, fees linked to provision of services such as water and electricity, and fees linked to ability to pay should be explored. Private sector participation and getting polluters to pay should be promoted and supported by policies and other economic incentives.
3. Enhancing hazardous waste management regulations and practices. There is an urgent need to establish industrial hazardous waste management systems, including both factory-based handling, treatment, and disposal systems, and centralized or shared hazardous waste treatment facilities. The first priority action should be taken in the three Focus Economic Zones (Northern, Central, and Southern). In parallel with engaging the responsibility of industries and hospitals, policy and regulatory measures and financing mechanisms need strengthening, institutional responsibilities need clarity, and sufficient resources need to be allocated for monitoring and enforcement. Special attention should be placed on State Owned Enterprise (SOE) privatization to ensure that past environmental liabilities are properly addressed, and the environmental performance of enterprises is adequately monitored and enforced.
4. Improving institutional effectiveness, monitoring, and enforcement. Complementing the development of infrastructure and strengthening institutional capacity, improving financial management, and providing incentives for cost-effective management to URENCOs are the

priorities. There is also a need to strengthen regulatory institutions for environmental oversight, monitoring, and enforcement of municipal waste management practices.

5. Creating incentives for waste minimization and recycling. Support to the informal waste sector could include expansion of micro-credit programs, development of recycling markets, integration of informal sector activities into the formal sector, assistance in the creation of waste cooperatives, and consultation on new waste management initiatives. Reducing the costs can be done through economic and other incentives for source separation and development of private sector recycling operations. Similarly, composting operations could be expanded through the development of viable composting facilities that can produce marketable quality compost from source-separated materials.

   Cleaner production technologies could be an option, since they could help minimize industrial waste and provide industrial ecology solutions.

6. Improving public information on SWM and enhancing social acceptability of waste disposal and treatment. The public must be made aware of the negative consequences of improper waste management practices, and also their accountability in paying for better waste management services. Public education programs should target not only adults, but also children in the school system. They should also aim for providing basic hygiene knowledge. Further, they could contribute practical and innovative ideas to socialization programs, which could devolve responsibility for waste management to local community groups. When siting landfills and during the operation, socioeconomic impacts need to be considered along with environmental impacts.

7. Engaging communities in waste management. There is also a need to strengthen the role of civil society in waste management. The challenge ahead will be to support initiatives that offer communities better opportunities to self-organize around community-based waste management issues. Local community groups may assume responsibility for hiring waste collectors, purchasing collection equipment, collecting fees, and overall management of the collection system. Communities should be encouraged to participate in source separation programs for composting organic waste.

8. Protecting vulnerable groups. The SWM sector has three key vulnerable groups that require protection: waste pickers, poor women, and children. Initiatives to reduce the hazardous nature of their work could include requirements for safety equipment, limiting access to dump sites to periods when there are no trucks on the site, provision of public washing facilities at the dumpsites, and separation of hazardous wastes at dump sites into segregated cells. Gender equality and provision of expanded micro-credit opportunities for women in the informal sector should be considered. Special attention should be paid to providing child pickers with educational support and alternative vocational training.

The municipalities are facing to many difficulties of waste management but find the way to solve it becomes a big question. Therefore **“Implemetation of Integrated Waste Management for Vietnam”** would be a nessessary solution. The integration of “waste” (reduction, reuse, recycling) into allocation problems need to be taken in consideration for the academics institutions and the local authorities.

9.1.4 References

1. Vietnam Environment Monitor 2004
2. Tang The Cuong, National Institute for Strategy and Policy on Science and Technology (NISTPASS), Hanoi Workshop 11/2006
3. URENCO Hanoi Report in 2005
4. Annual Environmental State Reports of DONREs 2005
5. National Environment Agency Vietnam (NEA) and University of Agriculture report, 1/2003
6. World Bank Report 2003
7. Information from practical training, 1st Master Course at HUS, 2005
8. CEETIA & Annual Environmental State Reports of DONREs 2003
9. URENCOs Report in 2003
10. Department of Transportation, Hanoi People Committee 2007
11. National Environment Agency Vietnam Report, 2004
12. Institute for Science and Environmental Technology, program KC 08-09

9.2 Cambodia

General overview

Title
Use of solid waste for small-scale biogas production for rural household energy consumption

Country
Cambodia

Strategy
To promote renewable energy and reduce deforestation

Location
Takaev Province

Keywords
Waste recovery, cooking, lighting, manure

Description of Case

Background

A large proportion of the Cambodian population live in remote rural areas, often without access to electricity or fossil fuels for cooking. This has lead to the extensive use of charcoal as a major source of energy, which, combined with rapid population growth, has lead to deforestation in many regions. Rapid population growth also leads to an increase in the amount of solid wastes. These wastes, including those from household use, commercial establishments, markets, hotels, restaurants and tourist centres, are usually dumped and burnt in areas of convenience, which in turn has an adverse effect on the environment and public health.

One of the more suitable solutions to these problems is to use biogas. Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Bacteria convert organic materials of manure and wastes into combustible biogas (methane, carbon dioxide) and fertilizer (slurry). Biogas can be used like any other combustible gas. It can be burnt, such as for cooking, used for lamps and motors, or to produce electric power or pump water. Its use thus implies a number of ecological as well as economical advantages.

As a result, the Government of Cambodia has been promoting the widespread adoption of biogas technology in areas deemed suitable and having ready access to agricultural wastes, such as animal manure. Promotion falls under the National Bio-digester Program (NBP). In order to better understand the processes involved in biogas promotion and use, a key province involved in the NBP was selected for detailed study.

Objectives

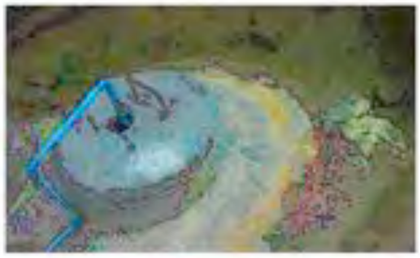
The principal objective of NBP is to disseminate domestic biodigesters as an indigenous, sustainable energy source through the development of a commercial, market oriented, biodigester sector in Cambodia.

Description of Activity

The programme covers a wide of activities, including promotion and marketing, construction, repair and maintenance, quality control, research and development, training, bio-fertiliser extension, monitoring and evaluation.

Technological Information

- Biogas digester construction
- Biogas process
- Slurry applications



Consortium

- Ministry of Agriculture, Forestry and Fisheries
- SNV- Netherlands Development Organisation
- Dutch ministry of Foreign Affairs, Directorate for Development Cooperation
- ACLEDA Bank
- Preah Kossomak Polytechnic Institute
- CEDAC- Cambodian Centre for Study and Development in Agriculture

Duration: 4 years (2005-2009)

Funding

Asia Biogas Program

Regulatory Instruments

- Environmental Protection and Natural Resource Management Law of 1999
- Sub-decree on Solid Waste Management (SWM), enacted in 1999
- National Strategic Development Plan 2006-2010

Economic Instruments

-Reduce electricity costs
-Minimize solid waste disposal

Socio-economic factors

- The cost for installation of biogas digesters is still too high, excluding many poor farmers who not afford to pay.
- The high input requirement for animal manure is another factor limiting the application of the technology. To maximize the benefits from this biogas model, each household should have at least 4 to 6 animals.
- The odor and smell of the gas is not favoured by many users.

Cooperation

National Biodigester Programme (NBP) is a joint programme between the Cambodia Ministry of Agriculture Forestry and Fisheries (MAFF) and the Netherlands Development Organisation (SNV).

Results

Impacts A significant impact of using biogas is the by-product of slurry, used to fertilize their crops. The use of slurry could not only significantly save their expenses on purchasing chemical fertilizer, but also provide more advantages over the use of compost, as their plants tended to grow faster and the growth of weeds could also be minimized. Most of the farmers interviewed found that the environments surrounding their houses were significantly improved if compared with the time when they used firewood and charcoal, since there was less waste left laying around. Use of manure as the substrate also meant that their animal housing (usually under or adjacent to the house) was significantly cleaner, resulting in less susceptibility of animals to disease or infestation. What could not be accurately measured during this survey, and what did not occur to the farmers themselves, was the reduction in deforestation through the use of an alternative to charcoal and firewood. As the study area is in a depleted area, it could also be assumed that the collection of firewood involved journeys of some distance and labour.
Lessons learned This study has shown the optimum size of digester combined with the optimum number of farm animals and this information should be helpful when considering this technology for other areas.
Potential for replication The use of farm waste for biogas production for energy consumption in the studied area appears to be an appropriate alternative, not only because of the environmentally friendly conditions, but also due to the economics of the technology. The technology should be introduced more widely to other rural communities, especially where forests become scarce

References

1. Ponlak, Tin (2000). Environment. Ministry of Environment, Phnom Penh, Cambodia (in Khmer).

2. Dasgupta, Susmita, Deichmann, Uwe, Meisner, Craig and Wheeler, David (2005). Where is the poverty-environment nexus? Evidence from Cambodia, Lao PDR and Vietnam. World Development, Vol. 33, No. 4, pp 617-638.

Case reviewer

Mr. Terry Commins, Consultant, Technical Information Services, King Mongkut's University of Technology Thonburi, Pracha Uthit Road, Ratburana, Bangkok 10140, Thailand

Case study provided by

Royal University of Agriculture
Chamkar Daung, Dangkor District, Phnom Penh, Cambodia
website: www.rua.edu.kh
Contact person: Dr. Visalsok Touch

9.3 Thailand

9.3.1 Biomass Combustion in a Food Factory

9.3.1.1 Background

Most agriculture-based economies in Asia produce large amounts of wastes (biomass) which have potential for use as an energy source. The major constraints to biomass utilization are combustion efficiency, year-round availability and transportation costs, and potentially harmful emissions. King Mongkut's University of Technology Thonburi (KMUTT) has been conducting research on fluidized bed combustion technology (FBC) for over 15 years. FBC has a wide range of applications, notably in industrial boilers and power boilers used in the generation of heat and electrical power.

Figure 9.3-1: Fluidized bed boiler for superheated steam production of 5 tonnes/hr at 30 barg, 350^{o}C

Inside a fluidized bed fuels mixed with inert solids such as ash or sand are combusted. High-velocity air is passed into the bed, creating strong turbulence inside the bed and causing the solid particles to behave like a fluid and mix uniformly. Fluidized bed reactors are capable of combusting solid fuels at 95% efficiency or higher, generating heat at a high rate which can in turn be used to produce steam and electricity for factory use. The FBC system is capable of combusting several types of fuel, such as coal, corncobs, wood scraps and precipitates from wastewater treatment at high efficiency. In addition, the technology allows for easy operation and control of toxic emissions such as sulphur dioxide and oxides of nitrogen.

The factory produces coconut milk in cartons and the company generates a large amount of waste in the form of coconut shells and coir. The company expressed interest in FBC technology to convert these wastes to generate steam and power for use in the factory.

Figure 9.3-2: 250 kW steam turbine

9.3.1.2 Impact

Although only recently completed, the initial assessment of this project indicates that the company will save 8,571 litres of imported fuel oil each day and reduce the daily consumption of electricity by 3,210 kilowatt-hours. The payback period is less than 2.5 years. The new technology is also far more environmentally friendly than burning bunker oil and there are clear environmental benefits from the company not having to dump or openly burn their wastes.

Figure 9.3-3: Boiler control panel

9.3.1.3 Lessons Learned

FBC technology has high potential for industrial applications although each system must be designed specifically for each individual application and the fuel source to be used. Close collaboration with the private sector is essential and they need to be convinced that technological support is available and that the investment costs will bring them immediate benefits. KMUTT has also found that a vital ingredient to success is “after-sales” service and training.

9.3.1.4 Critical Instrument

Regulatory:

The Royal Thai Government has an established policy on new and renewable sources of energy (NRSE) development and promotion. Under the 9th National Economic and Social Development Plan (2001-2005), the research and development, production and utilization of NRSE are promoted in the following areas:

- The production of non-conventional energy technologies that are commercially viable and would better the quality of life.
- The utilization of non-conventional energy sources such as solar energy, thermal energy and energy from agricultural and industrial residues.
- Measures that should encourage more widespread use of NRSE technologies include:
  -fiscal incentives (subsidies, grants or tax breaks),
  -guaranteed prices and markets for electric power produced by NRSE based technologies,
  -integrated planning considering NRSE research and development, information and education programs, as well as encouragement of private sector participation, and
  -in addition, rules and regulations on energy use and associated environmental standards that may favour the utilization of NRSE.

Figure 9.3-4: Fly ash removal using a cyclone

- The Energy Conservation Act of 1992 considers renewable energy under the heading of energy conservation and activities are therefore eligible for funding under the Energy Conservation Promotion Fund (ENCON). During the second phase of ENCON (2000-2004) a new project is being implemented entitled, “Promotion of Small Power Producers Using Renewable Energy”. The project is basically designed for converting the large volume of biomass waste in the country into electric power, with a target of around 300MW capacity within the next 5 years.
- The National Energy Policy Office is responsible for the Small Power Producers (SPP) Program which promotes guaranteed buy-back prices for power produced from NRSE.

These instruments created the environment necessary for the private sector collaborator in the project to be willing to invest in new technology. The regulations were also instrumental in helping to reduce risk for the investor. Also, the introduction of government regulations requiring stricter environmental controls has acted as an additional incentive when choosing appropriate energy technology.

- **Economic:**

Relatively short payback time.

Considerable savings in imported fuel costs.
Avoided cost of waste disposal.
Avoided environmental penalties through conformity with regulations.

- **Technology:**

The requirements (heat and power) and fuel source (coconut husks) were in perfect conformity with the FBC technology proposed.

9.3.1.5 Target

To utilize existing waste and produce energy, reducing the cost of waste disposal and adversely effects to the environment

9.4 Laos

General overview

Title

The participation of Villagers in Household Waste Management Work

Country

Laos

Strategy

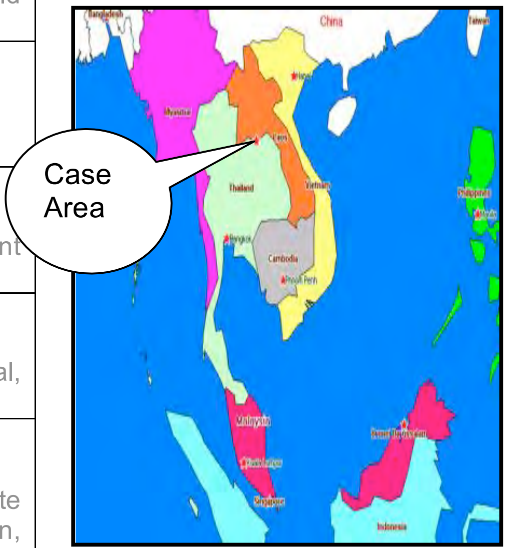
Lesson learned for better waste management at village level

Location

Chuntabouly District, Vientiane Capital, Laos

Keywords

Waste Management, Daily waste generation, Family member participation, Attitudes and Perception on Waste management



Description of Case

Background

Nongthatai village is located in Chunthabouly District, Vientiane Capital. It is one of the villages in Vientiane Capital which can be said to be crowded village with the number of 377 households living there. Apart from that there are many shops which can contribute to the amount of waste generated within the village. The village is therefore supported by Science Technology and Environment Agency (Currently it is called "Water Resources and Environment Administration") on waste management. Due to the increasing of number of villager with living life improvement activities, waste management for Nongthatai sooner or later can be a problem if there are no actions taken to response to this.

Waste Generation

It is seen that majority of the households in the village currently produce more than 0.5 kg of waste in a day. However, it seems to be true that the number of waste generated will be greater due to the fact that there are more shops and entertainment establishment and also the increasing number of people.

Waste Management and Existing Problems

It is found that there are only 26% of the households in the village have put their waste in the right place. This reflects on numbers of factors which make the villagers have inappropriate waste management systems, including inadequate of waste collecting trucks, the cost of such service and the frequency of collection, the low income of villagers causing heavily relying on burning the waste at their backyard or illegal dumping, awareness on waste management and no waste separation is required. Such activities have posted various problems. One of those is odor, air pollution mainly due to incineration and vermin

Demand

Waste management in the village is not something simple to be implemented unless the participation of everyone in the village and support from relevant organizations.

Framework conditions

Economic framework:

- Rapid economic growth
- More income to villagers and more wants causing more waste
- More shops and entertainment establishments
- High collection cost

Socio-cultural and socio-economic framework:

- The acceptance of willing to pay for waste collection fee still exist
- Lack of knowledge on the negative impacts from waste and waste burning due to fee payment avoidance
- Littering and illegal dumping at open areas are seen as common occurrence
- Waste separation and waste reusing are not widely considered necessary

Legislative, regulatory and policy framework:

According to Lao Environmental Law article 5 "natural resources, raw materials and energy must be used wisely and reduce pollution and waste for sustainable development". This is the basic policies to protect the environment. Charter 3, section 1 article 21 on pollution paragraph 3 states "pollution from waste is pollution coming from hazardous or non hazardous materials in the form of solid, liquid and gas, which are not used in the process of production but left in the environment with the amount which can be dangerous onto the environment and cause negative impacts on the health of biodiversity". In charter 3, section 3, article 22 also mention on responsibility on controlling pollution "persons and organizations have responsibilities in getting involved in pollution control. Those, industrial, service, forestry–agricultural sectors or others, must avoid causing pollution excessive the standard". Moreover, Article 23 on pollution control and prevention policies, paragraph 7 – 8 indicates that "littering is prohibited. There must have an area to keep certain waste. Before disposing, incinerate, burry or destroy in indicated area, all wastes must be separated. In addition, new technologies on waste treatment, clean production and reuse must be promoted".

According to National Assemble, 1999, "No potential hazardous waste import, transportation, and movement by any means, on land, on air or on water". Article 46 on penalties states that "if there is littering causing pollution, spoil aesthetic of an area"

Stakeholders:

There are several stakeholders involved in the village waste management such as waste collecting contractor, Vientiane Urban Development Authority, local authority and the villagers

Project concept

Observing at the participation on waste management at village level. It also so identifies the potential burdens on cleaning activities and the environment protection which includes

1. The condition of the area, location, household size related to waste management and daily waste generation.
2. The participation of family members and reducing methods
3. Qualification, attitudes and villagers' perception on waste management
4. services

Results

Recommendations

In order to make waste management system improve there are several recommendations which should be taken into account as the following.

- For sectors dealing with city cleaning and environment protection.

    1. There is a need for related sectors who deal with waste management and villager participation on waste management to campaign more widely.
    2. There should be raising activities on waste separation
    3. If possible, there should be bins on specific spots in public

- For villagers
    1. All people should separate their waste as much as possible in order to reduce waste and they can make some source of income by selling their separated waste
    2. Every household should put their waste in black plastic bag, not in baskets, in order to prevent mess before collecting and to make it convenient for waste collectors
    3. There must be a biodegradable waste system in place such as making biofertilizer, growing earth worm, bio extract fertilizer at village level.

Impacts

Participation condition on waste management and also the waste management processes used at village level are identified which can be a great source of information for the government and relevant organizations dealing with waste management to be able to use for better future waste management plans and actions. In addition, the factors and burdens causing difficulties in managing waste in small scale as rural community are analyzed for the purpose as examples or lessons learned for avoiding or improvement when waste management is implemented. Appropriate recommendation and solution to address the problems have been raised, which can be used as guides to apply to other areas. Apart from providing source of information, within the in village itself, the villagers become more aware of environment they are living in especially on waste management because the problems existing in the village have been found and it makes the people more aware of such problems and try not to cause the problems even worse or solve the problems and the many of them now know how and who they can ask for help to deal with waste.

Further Actions

Further action is to disseminate these lessons learned to other villages and communities and to include this best experiences in working with and through community in the program of study at university

References

1. Seminar on Vientiane Environment, 2- 3, 1999, p 2.
2. N. Sayamung, 2003, Waste management for community.
3. STEA, 2001, Vientiane Environment Summery.

Case study provided by

Center for Environment and Development Studies, National University of Laos
(http://ceds.noul.edu.al)