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“The Waste Hierarchy. A goal-oriented assessment and a discourse analysis of a globalized waste management strategy”

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List of Abbreviations and Acronyms

3R	Reduce, Re-use, Recycle
AMPL	Working Group for Water Supply and Sanitation
ARA	Abfall Recycling Austria
AWG 2002	Abfallwirtschaftsgesetz 2002 (Waste Management Act 2002)
BAWP	Bundes Abfallwirtschaftsplan (Federal Waste Management Plan)
BGBl	Bundesgesetzblatt
BMLFUW	Bundesministerium für Landwirtschaft, Forstwirtschaft, Umwelt und Wasserwirtschaft (Federal Ministry for Agriculture, Forestry, Environment and Water Resources Management)
BPS	Badan Pusat Statistik (National Department for Statistics)
c	Capita
CBO	Community Based Organisation
DKP	Dinas Kebersihan dan Pertamanan (Sanitary and Park Department)
EC	European Community
FWMP	Federal Waste Management Plan
GHG	Greenhouse Gases
GNI	Gross National Income
GWP	Global Warming Potential
HIC	High Income Countries
IPCS	International Program on Chemical Safety
ISWM	Integrated Solid Waste Management
LGBl	Landesgesetzblatt
LMY	Low and Middle Income Countries
LIC	Low Income Countries
MA 48	Magistratsabteilung 48
MBT	Mechanical Biological Treatment

MFA	Material Flow Analysis
MIC	Middle Income Countries
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MVA	Müllverbrennungsanalge (Waste Incineration Plant)
RU	Reference Unit
SD	Elementary School
SMP	Junior High School
SMA	Senior High School
SW	Solid Waste
SWM	Solid Waste Management
TEQ	Toxic equivalent
UNCED	United Nations Conference on Environment and Development
UNDESA	Department of Economical and Social Affairs
UNEP	United Nations Environment Programme
UNSYIAH	Universitas Syiah Kuala, Banda Aceh
VNG	Association of Netherlands Municipalities
VO	Verordnung (Ordinance)
WM	Waste Management
WMA 2002	Waste Management Act 2002
Wr. AWG 1994	Wiener Abfallwirtschaftsgesetz 1994 (Vienna Waste Management Act 1994)
yr	Year

Part I - Introduction

1 Introduction

1.1 General

Contemporary societies face the occurrence of growth in consumption and production of goods. Beside this quantitative growth, the number of substances to produce the goods we consume increases, leading to a qualitative growth in material flows.

Along with products, the quality and quantity of wastes also changes. This is particularly through for municipal solid wastes (MSW). Regarding these shifts in quality and quantity, all actors and decision makers in municipal solid waste management (MSWM) are challenged to find solutions to cope with the problems around solid wastes.

Now, solid waste implies some dualism. On one hand, it is a potential threat to human health and the environment. On the other hand, it is also a potential source to provide materials for production, in order to substitute primary raw materials. According to this dualism, policy makers and governments have fixed objectives of solid waste management.

Stated after Brunner and Rechberger, the common objectives of waste management are

- "the protection of human beings and the environment
- the conservation of resources
- pre-treatment of wastes in order to reduce aftercare after final storage to zero" (Brunner and Rechberger 2004:17)

These objectives should be achieved in a way that future generations are not impaired through present generations' activities (cp. WCED 1987:54).

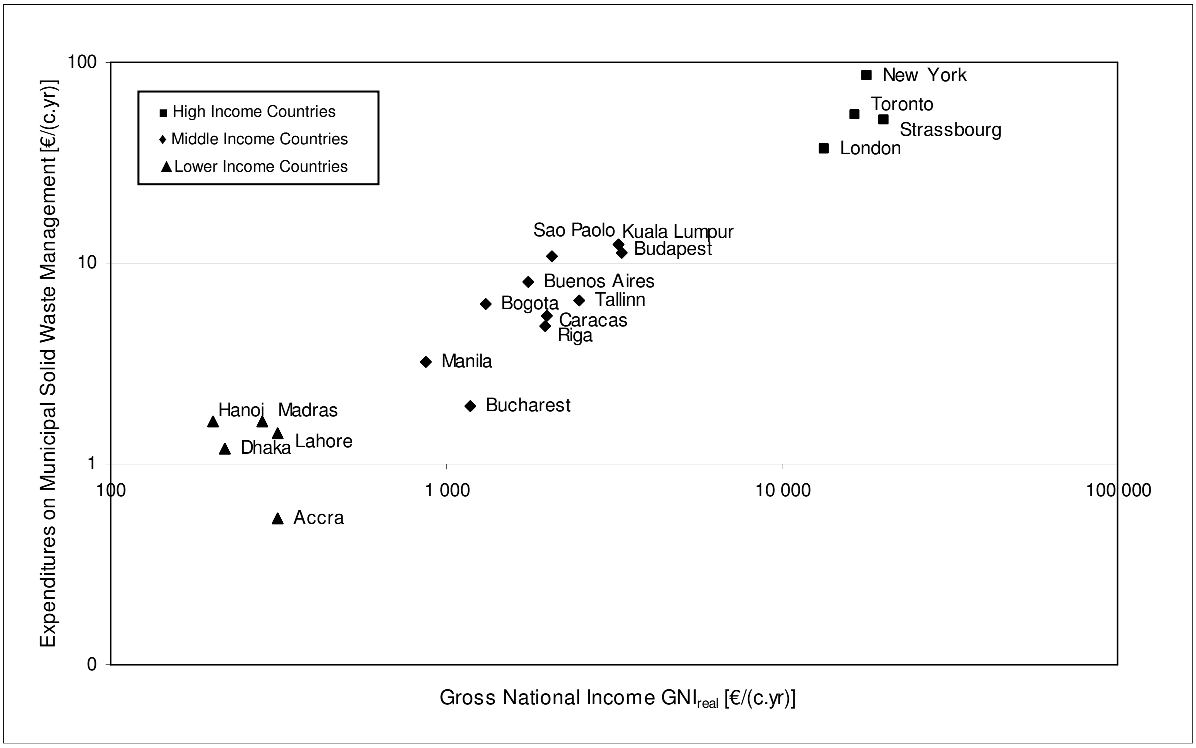
Beside objectives, principles and strategies for solid waste management have been developed. One common used waste management strategy is the so called *waste hierarchy*, which claims that

- waste reduction is better than
- waste recovery and recycling, which is again better than
- safe final disposal

This waste hierarchy is sometimes also termed as waste management hierarchy or, more radically, as *3 R principle*. Therein, *3 R* stands for *reduce – reuse – recycle*.

In coping with the challenges regarding waste management, developed or high income countries (HIC) have intended high sophisticated waste management systems, based on expensive technology and complex regulations, in order to achieve the waste management objectives. Contrary, developing or low and middle income countries (LMY) do find it more difficult to implement sophisticated waste management systems in order to achieve the objectives of waste management, for reasons as struggling with limited financial sources or lack of capacities.

Figure 1-1 Expenditures on SWM versus GNI of selected urban regions between 1991 and 1995



(Lederer 2008; data from Hoornweg et al. 1999:20; classification according to Worldbank 2007)

In middle and lower income countries, waste management practises considered as unsafe are still existing, such as illegal dumping, burning of solid wastes in neighbourhoods, waste handling without safety equipment and so on. These practises are a threat to public and occupational health, particularly for poorer and thus more vulnerable citizens.

Simultaneously, dissatisfaction about improper solid waste management among lower income countries' citizens increases, resulting in higher pressure towards policy makers and authorities. Many examples can be given, for instance the protests in Coté d'Ivoire's economic capital Abidijan after a Dutch company has disposed half a kiloton of hazardous chemical waste at a municipal dumping site, with the result of eight dead an thousands of injured victims (Radio France International 2006).

According to the obstacles on waste management and environmental issues in general, waste management policies and strategies emerged or have been developed, like the *producer pays principle*, the *precautionary principle* or the *waste hierarchy*. The latter, which is theoretically based on the concepts of dematerialization and has first been stated by OECD and European Community policy strategy approaches, have become very popular, not only in the high income countries of origin, but worldwide, thus also in lower income countries. According to many experts, scientists, national and international development organisations, politicians and NGOs in both, the *Global North* and the *South*, the waste hierarchy is one of the most important waste policy strategy approaches in order to

solve the challenges in waste management in every country, thus also improving the situation and living conditions for citizens in lower income countries.
Whether this is really the case, meaning that a concept like the waste hierarchy which is originating from high income countries, can be successfully applied in lower income countries too, is discussed in this work. Furthermore, how the waste hierarchy has impede the discourse on waste management, meaning how a strategy like this became popular, is asked in this work. Thus, a work focusing on both, technical and socio-political aspects is designed. Consequently, following research questions have been developed.

1.2 Research questions

1.2.1 Technical research questions

1. "How do existing MSWM systems look like in countries with different Gross National Income (GNI) and different expenditures on MSWM?
2. How do these systems fulfil the objectives of waste management?
3. If systems can't fulfil these objectives, which solutions could be applied?
4. How do solutions that follow the waste hierarchy reach the objectives of waste management?" (Lederer 2008:3)

1.2.2 Socio-political research questions

1. How is the discourse on waste management and environmental issues in developed and developing countries hold?
2. What is therein the function of the waste hierarchy?
3. Which actors are shaping this discourse?
4. Regarding the discourse, which conclusion can be drawn on the applicability of the waste hierarchy in lower income developing countries?

1.3 Objectives

The thesis aims to assess and discuss popular environmental strategies by the example of the *waste hierarchy*. The assessment and discussion should be combine two views, first the technical-scientific identification, description and assessment of a problem and hypothetical solutions and second, the political dimension on the delivery of waste management strategies.

1.4 General Outline

The thesis contains four parts. After Part I, the introduction, Part II follows, which aims to provide a socio-economic and technical description, but also an impact assessment of waste management systems in higher and lower income countries. The whole Part II refers to my own Master Thesis at Vienna University of Technology with the title "A goal-oriented assessment of solid waste

management strategies in high and lower income countries", conducted at the Institute of Water Quality, Resource and Waste Management (Lederer 2008).
At first, in Chapter 2, two research areas for case studies are selected, one in a high and one in a lower income country. The case studies refer to the cities of Vienna, Austria and Band Aceh, Indonesia. Then, theories important for municipal solid waste management are presented, as well as a set of methods, in order to investigate both waste management systems, containing material flow analysis and qualitative and quantitative social research methods. Furthermore, a framework for the goal-oriented assessment of waste management options, based on problem oriented sanitation, life cycle and economic indicators. Finally, scenarios for extended municipal solid waste management for the case study of Banda Aceh are designed. The scenarios refer to the waste hierarchy, thus distinguishing between two recycling scenarios and one waste collection and final disposal scenario. In assessing these scenarios by using the same indicators as for the current waste management system of Banda Aceh, a statement on the applicability of waste hierarchy based options should be given.
Chapter 3 provides the results of the investigation of municipal solid waste management systems of the two case studies, the scenarios for extended waste management in Banda Aceh and the goal-oriented assessment. In Chapter 4, the results are discussed, leading to the conclusions of the goal-oriented assessment in Chapter 5.

Part III deals with the discursive dimension of the waste hierarchy as a strategy for solid waste management in developing countries. It builds up on the key findings of Part II. Chapter 6 contains the theoretical base for discourse analysis regarding environmental policies and strategies, as well as the theoretical-scientific background of the waste hierarchy. Chapter 7 gives an overview on how discourse analysis is applied, thus presenting the methodology for Part III. Chapter 8 reviews first the primary literature sources for the textual discourse analysis for different actors in waste management, which is then analysed and discussed, leading to the conclusion of Part III (Chapter 9).

Part IV summarizes and contextualizes the key-findings of Part II and III, leading to the final conclusion (Chapter 10).

Part II - Goal-oriented assessment of solid waste management strategies

Foreword:

Part II refers fully to my Master Thesis titled “A goal-oriented assessment of solid waste management strategies in high and lower income countries” (Lederer 2008), conducted at Vienna University of Technology, Faculty of Civil Engineering, Institute for Water Quality, Resource and Waste Management and supervised by o. Univ. Prof. Dr. Dipl. Natw. Paul Hans Brunner and Dr. Dipl. Ing. Johann Fellner (Lederer 2008:5-8;14-149). The annex herein refers to Lederer (2008:157-179).

2 Theory and methodology goal-oriented assessment

2.1 Selection of Research Area

Two urban regions in the world were chosen, one with high and one with low GNI and low MSWM expenditures. Urban population grows faster and generates more waste than rural (Medina 1999:4; The World Bank 1999:1). Thus the challenges regarding waste management arising in urban regions are bigger than in rural regions. Both regions then underwent an investigation and subsequently a comparative analysis.

There are numerous regions fitting to this presetting, which would be interesting to investigate, and a broader study containing more urban regions in the world would be desirable. However, as time and resources are limited, especially in the scope of this master thesis, practical considerations leaded to the selection of the city of Vienna, the capital of Austria, and Banda Aceh, the capital of the Aceh Region in Indonesia.

Vienna constitutes a representative case. As the capital of Austria, it is located in a high-income economy, among of the highest in the World (The World Bank 2007). Vienna has about 1 650 000 inhabitants and is an over-regional administrative and economic centre. The per capita expenditures on MSWM are among the highest in the World too. The MSWM system is representative for large parts of Western Europe, with a fully covering municipal waste collection, separate collection and extensive waste treatment and processing. The system is well described and data is easily available due to detailed annual reports, published by MA 48, the municipal office in charge for waste collection and disposal in Vienna. As Vienna is also the home town of Vienna University of Technology, the host university of this thesis, the outtake of the study was easy feasible.

The selection of Banda Aceh might surprise somewhat. Even though it fits in the requirements and reflects some of the most occasional problems of MSWM for low and middle income countries, like partial municipal waste collection cover and unsafe collection, processing and disposal practises (Munawar 2006), other challenges due to feasibility of the research exist.

As widely known, Banda Aceh was hit by both, a civil war over decades and the Tsunami event in late 2004. The Tsunami wave killed 60 000 of Banda Acehs former 260 000 inhabitants, more than one fifth of the population. Many people lost their homes, as their houses were burst through the wave, and a high number of displaced people have moved to the city. Nowadays, Banda Aceh has about 220 000 inhabitants.

The main reason to consider Banda Aceh derives from the fact that the existing research cooperation between Syiah Kuala University and Vienna University of Technology should be deepen.

Banda Aceh is located in Sumatra, Indonesia, which is, according to its GNI of 1 024 € (2 976 € PPP) (The World Bank 2007), a lower-middle income country. However, income distribution within Indonesia varies widely.

The expenditures on MSWM in Banda Aceh are not known yet, but as an initial assumption it can be expected that they are not higher than in Jakarta, for instance.

Table 2-1 Comparison of available key data of Vienna and Banda Aceh

Region	Inhabitants[1]	GNI 2005[2] [€/(c.yr)]		MSW generation[3] [kg/(c.yr)]	Expenditures on MSWM [€/(c.yr)][4]
		Real	PPP		
Banda Aceh	219 657	1 024	2 976	0.76	Less than 5
Vienna	1.651 437	29 584	26 512	1.5	106

[1] Municipality of Vienna 2007; BPS 2007
[2] World Bank 2007
[3] The World Bank 1999:7; Brunner and Fellner 2006:6
[4] Brunner and Fellner 2006:6. The expenditures on MSWM for Banda Aceh are not available yet, thus an assumption was done, based on data from the Indonesian cities of Jakarta (2.26) and Surabaya (3.52) in ($/capita/a) in 1993 (ISWA 2002:35)

2.2 Selection of methodology

2.2.1 Material flows and quantification

Material Flow Analysis (MFA) shows the flow or flux of materials through a spatial-temporal defined system and the processes these materials undergoes. This methodology was, among other things, chosen due to its ability to

- make a complex system easier understandable
- offer a clearly defined methodology and its application possibilities
- using cost-effective and basic material balance calculations
- be the base for decisions in waste and resource management
- help to calculate and identify stocks of hazardous materials, e.g. in soils or aquifers

(derived from Brunner and Rechberger 2004, chapter 1.4 “Application of MFA”). Declaredly, no other methodology for the quantification of the MSWM system was considered, as the author believes that MFA is the only applicable methodology approach. See Van Beukering (1999) for a similar, though not as mature approach as MFA. The methodology itself is explained later in chapter 2.4, page 26.

2.2.2 Data and background research

While a literature review (chapter 2.3, page 13) is of course part of a thesis, different methodologies must be applied, because of lack of data, particularly for Banda Aceh (Munawar 2006). Thus, the decision was made to make a field visit to Banda Aceh. Clear from the beginning, the subsequent methodologies evolved during the research processes, and were not designed in advance.

In Banda Aceh, various types of interviews were made. The interview technique differed according to the interview situation, interview partners and the desired information.

Also, a questionnaire survey about disposal practises and socio-economic properties of households was undertaken. As survey methodology, a non-random approach was utilized, as a diploma student does not have the capacity for a random sampling.

2.2.3 Waste data

Waste data was either gathered through literature or, in case of Banda Aceh, through waste sampling at the source of waste generation, meaning households and other establishments. Waste sampling at source is easy and also affordable for this kind of student work, while sampling at, let’s say, transfer stations or at the landfill, would not be that feasible. Thus the decision fell on this method.

2.2.4 Assessment methodology

For the assessment of the MSWM systems performances, an approach similar to that in Brunner and Fellner (2007) was selected. In a first step, an assessment of the MSWM systems of Vienna and Banda Aceh by indicators which refers to the objectives of waste management (protection of human health and the environment, conservation of resources) was done. Then, scenarios were developed, which refer to the *waste hierarchy* (reduce, reuse and recycle, safe final disposal of wastes). These scenarios were also assessed in the same manner as the current MSWM systems.

Reason for choosing this methodology was that it links the within this thesis discussed waste policy principles of the waste hierarchy with their practical application. Also, the methodology is a rather basic approach compared to, for instance, a cost-benefit analysis or a life-cycle assessment.

2.3 Literature Review

2.3.1 Municipal solid waste management in Vienna

Literature in this chapter focuses on the investigated region of Vienna. Responsible for waste management within the municipality authority is the *Magistratsabteilung 48 (MA48)*. The MA48 must, according to Viennas' Waste Management Act, publish a report, called the "Waste Management Concept of the City of Vienna" (MA48 2002,1). It contains a comprehensive description of the city's MSWM system with all its processes and goods.
A somewhat newer publication is the "Umwelterklärung 2006" (MA48 2006), which contains data for the year 2005 as well, while the "Leistungsbericht 2006" (MA 48 2007) provides data for 2006. Both publications are published in German.

2.3.2 Municipal solid waste management in Banda Aceh

Different publications on MSWM in low and middle income countries in general (compare CalRecovery 2005; Zurbrugg not date; Hoornweg 1999; Achankeng 2003; Medina 1999; UNEP 2005) and in Indonesia and Banda Aceh in particular are published by several organisations and authors. Herein the author only mentions the "Solid Waste Management Master Plan – Report for Post-Tsunami Banda Aceh, Republic of Indonesia" (DKP et al. 2007), as a key publication, which provides some information on the organisational structure of the current MSWM system of Banda Aceh. Also, some information on the informal recycling sector is provided, but both are not sufficient to give a good description of the system. Thus, a field research should provide the data and information needed for analysis.

2.3.3 Methodology to investigate, illustrate and calculate the MSWM systems

Material flow analysis MFA

As shown later in chapter 2.4, page 26, MFA is selected to describe, calculate and illustrate the MSWM system, due to its advances mentioned later (ibid.). While similar approaches were used before, Bacchini and Brunner (1991) introduced MFA as a clearly defined methodology in "Metabolism of the Anthroposphere". The later published "Practical Handbook of Material Flow Analysis" of Brunner and Rechberger (2004) is the fundamental base for MFA as used within this thesis. Additionally, "German-English Terminology of the New Science 'Metabolism of the Anthroposphere' " (Brunner and Merl 2002) came to application.

Measuring waste generation rates and composition

The amounts of waste generated and its composition is the base to illustrate and investigate MSWM systems and furthermore to propose waste policies.

Two exemplified studies are illustrated here, both undertaken through sampling the waste generation at household level. The studies' objectives are the household waste generation rate and the waste composition, but also their relation to the household size and household income.

Measuring waste generation in Abu Dhabi, UAE

The first study was undertaken by Arab and British Scientists in Abu Dhabi City, United Arab Emirates, in 1996. Later on, it was published under the title "Analysis of Residential Solid Waste at Generation Sites" in Waste Management & Research (8 1997; Volume 15: pages 395 – 405).
The United Arab Emirates are classified as a high income country (The World Bank 2007), thus waste generation rates can be expected as quite high.
In the beginning, the authors explain why they were choosing their methodology of measuring waste generation at generation site. First, the extremely hot and humid climate can change the characteristics of wastes on their way to the transfer stations and second, the relation between household income and waste generation was desired to highlight, which is possible to measure by sampling at household level. Therefore, a statistically designed sampling survey was considered. By doing a preliminary sampling survey, the unknown standard deviation SD of the population was determined. The survey took two weeks to conduct and it covered 25 households and yielded 350 samples. Based on the central limit theorem, the required sample size n was calculated as 779, with a confidence interval of 99% and a standard error R of 10%.
The main sampling survey covered 40 households and took three weeks, yielded 840 samples, while 40 samples were discarded due to their inconsistence with other samples. "Stratified random sampling procedure was applied" by dividing households into high, middle and low income households. Socio-economic classification was due to the housing type, with the assumption that high income households reside in villas, middle income in flats and low income in low-cost houses. According to the distribution of the household types in Abu Dhabi, five high (13%), 28 middle (70%) and seven low (17%) income households were chose to participate in the survey.
For the sampling itself, households were supplied with scales and plastic bags to collect the waste, each fraction into a separate bag. As expressed indirectly by Table 3, page 403 later on, the fractions considered were food waste, paper, metals, glass, plastics and miscellaneous. Every day, the bags were weighted and recorded on the sampling protocol, supposedly (as not directly expressed in the text) by household members themselves.
The results of the survey were a, in international comparison, high waste generation rate of 1.76 kg/capita/day and that distribution of generated solid waste "is broader than a normal distribution" (page 400). Also, the prior classification of income groups was tested by requesting the annual rent for the property, which showed a correlation between both.
The question regarding the relation between income and waste generation shows that highest income households had an average waste generation rate of 2.33 kg/capita/day, middle income 1.85

kg/capita/day and low income 0.93 kg/capita/day. These figures, together with the correlation between waste generation rate and annual property rent, were interpreted as a relation between waste generation and income. The composition of waste fractions was different from other cities, as well as for most fractions between the different income levels, except for food waste.

Interpretation, conclusions and open questions

- Good arguments, why sampling at source makes more sense than sampling at transfer stations; another argument, specially for countries without full waste collection covering, is that also not-covered households can be investigated.
- The statistical part of the methodology is well explained.
- It is not clearly expressed in the beginning, which goods were sampled, only indirectly.
- It is not clear, which "standard deviation" was estimated through the preliminary survey. Supposedly, it is the standard deviation of the waste generation rate throughout the population.
- The practical part of the methodology leaves some open questions:
  How were the participating households trained?
  Was the methodology tested before, e.g. in a pilot survey?
  Had the households the possibility to ask questions or give a feedback?
  Is waste separation at home unusual for the households or not?
  Did all the bags had the same colour?
- In general, if no problems in such a survey occur, one should take it with caution.

<u>Measuring waste generation in Gaborone, Botswana</u>

The second study was undertaken by Botswanian Scientists in Gaborone, Botswana, in July 2001. It was published under the title "Sampling household waste at source: lessons learnt in Garborone" in Waste Management & Research, (6 2004; volume 22: pages 142 – 148).
Its main objectives were similar to those in the previously described study in Abu Dhabi, namely the determination of waste generation rates at source (on household level) and the waste composition, but also their "variability with socio-economic characteristics of households" (page 142) – meaning the relation between household income or size and the waste generation rate. The main difference in this study was that an additional objective was mentioned, which focuses on "the practical and logistical implications of sampling at source of generation" (ibid.).
The methodology itself – a statistically sampling procedure – is similar to that in the study in Abu Dhabi. First, a preliminary survey (336 samples from 48 households) gave the unknown standard deviation (0.143). With a confidence interval of 95% and a standard error of 1%, the required number of samples was calculated as 786 samples. Additionally, a "buffer" of 201 samples was chose, in case of limited co-operation or absence of the householders during the sampling, which resulted in a final

sample size of 987 (47 households over 21 days). In the end, 893 samples were obtained, as some householders forgot to place the provided waste bags or were absent.
For the sampling itself, households were provided with black bags for their daily "dry" waste and yellow or white bags for their daily "wet" waste, whereas the latter was considered as kitchen and garden wastes. It was collected every morning and weighted and analysed at the Gaborone landfill. The components distinguished were putrescible waste (including garden waste), paper, metals, glass, plastic, textile and other wastes.
The sampling was done by six research assistants from Gaborone University, who have followed introductory courses in WM in their university degree programme and an "one-day" training for the sampling survey.
To consider control for the socio-economic background, a classification into low-, middle- and high income households was done initially due to the housing type. According to this distribution, 20 low-income (43%), 14 middle-income (30%) and 13 high-income (27%) households where chosen. The classification was proved by a questionnaire which was distributed to the households and gave information about household income, size and rent for the property. The initial estimate can be confirmed.
The results were partially surprising for the authors. First, the low- and middle-income households generated 0.35 kg/capita/day, the high-income household 0.27 kg/capita/day. The weighted average waste generation rate was 0.33 kg/capita/day. The authors concludes, that low-income households consume more wet food waste, like porridge, high-income households "significant portions of packaging waste" (page144).
Second, the correlation between number of persons in a household and waste generation rate was poor. Composition was dominated by a high putrescible content of 68%, which is expected for low-income countries. By increasing income, paper and plastic content was also increasing, which is, according to the authors, due to higher likeliness to buy ready made foodstuff. (p.146)
In comparison to results from similar studies in Geneva, Switzerland and Abu Dhabi, UAE, shows a far lower waste generation rate in Gaborone and a far higher putrescible content (page 145).

Finally, the authors mentioned some lessons learnt during the sampling survey (pages146-147). First, they found, during the preliminary survey, that their initial assumption that one household occupies one plot was wrong, and that sometimes more households occupy one plot.
Second, the areas considered to be low-income also contained high cost structures. Thus other variables concerning the household income had to be found. To use the rent to determine household income showed no result, as most occupants own their houses, and in the end the direct monthly household income was used as a variable.
Third, willingness of people to participate turned out to be an obstacle. Households were expecting tangible benefits for their contribution. Particularly poorer households feared that results of the survey

would lead to (higher) waste disposal fees. Furthermore, some people felt uncomfortable if somebody browses their waste, and the presence of the households head was important during questionning. Fourth, collecting the waste bags presented some problems. The access to the bags was sometimes blocked by locked gates or guard dogs, street dogs frazzled the bags placed at the kerbside and people put the waste as usual in their waste bin rather than in the provided bags. Especially during weekends it happened that household members were absent.

Fifth, household members felt inconvenient to separate the waste into a dry and a wet fraction. Mixings occurred, even though there were improvements over the sampling period. Some households felt happy about the “good, daily” collection service provided by researchers, and sometimes they even put waste stored a long time before into the bags. Authors conclude that the usual service might be inefficient.

Interpretation, conclusions and open questions

- The methodology used was clearer expressed than in Abu Qdais et. al. (1997), same as were the objectives. Furthermore, the lessons learnt chapter gives useful information for researcher in choosing the methodology for their survey.
- 0.33 kg/capita/day is low for a middle income country like Botswana (World Bank 2007). Figures vary widely and waste generation rates from comparable studies in a similar economic environment using the same methodology are scarce. Nevertheless, Achankeng (2003:11) give figures for 24 African cities between 0.3 and 1.9 kg/capita/day with an average of 0,78 kg/capita/day for the municipal waste generation rate. All of these cities are located in countries with a significant lower GNI than Botswana.
- The second surprise is that higher income households generate more waste than lower ones.

Other papers on this issue, like Bernache-Perez et al. (2001), Parizeau et al. (2006) and Van Beukering (1999) are not described herein.

Quantitative and qualitative methods to investigate the MSWM system

If a system and its items are numerically known and reliable socio-economical data is available, such as for the city of Vienna, a simple literature study suffices to obtain the results addressed in chapter 3. However, this is not the case for Banda Aceh. Thus MFA as the natural scientific base combined with different quantitative and qualitative methods, such as questionnaire survey, interviews and participant observation is applied (see chapter 2.6, page 30).

The UNSTATS (2005) “Designing Household Survey Samples: Practical Guidelines” handbook of UN’s Department of Economical and Social Affairs (UN DESA) gives a good overview on different survey methods and design of questionnaires for household surveys. The same can be said for StatPac

Incorporated (1997-2008), which offers an internet tutorial on designing questionnaire surveys. Another source is Robsons “Real world research” (Robson 2002).

The latter is also used as a support for the quantitative and qualitative interviews and the participant observatory approach. Furthermore, Hopfs “Qualitative Interviews – ein Überblick” (Hopf 2003) was used in the design of the qualitative part of the data gathering. Qualitative, as seen there, are the semi-structured and non-structured interviews which does not follow a strict order and, unlike standardized or structured interviews, do more follow a comprehensive rather than a descriptive approach (Hopf 2003:350).

2.3.4 Health, environment and conservation of resources in waste management

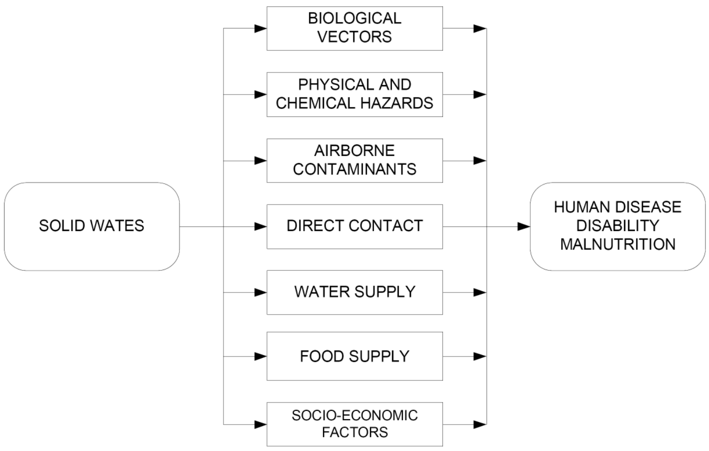
MSW and human health

The negative impacts of MSW on human health are well established and sanitation and hygiene aspects have become a so called “driver” for waste management (Wilson 2007:199). Nowadays, people particularly in lower and middle income countries suffer from diseases caused by insufficient waste management.

General

Most general MSWM literature refers, when it comes to solid waste and health aspects, to Thrift G. Hanks "Solid Waste/Disease Relationships – a literature survey" (Hanks 1967). The publication, written for the *US Department of Health, Education, and Welfare*, provides an overview of various studies about the affects of MSW activities on human health. Most of them were undertaken in the US up to the mid 1960s. Hanks notes that there are disease agents origin from MSW activities who only can cause diseases or harm to humans if there is an environmental association between those two. Therefore, he distinguishes between direct and indirect contact between the agent and the human body. An example of direct contact is the handling of waste by humans. Indirect contact is established through various vectors. The connection between the agent and the human, which Hanks terms "victim", is called the "pathway" (Hanks 1967:10-11). Figure 2-1 shows various pathways.

Figure 2-1 Pathways between solid waste and human diseases



(Hanks 1967:11)

As the report is more than 40 years old, it deals with health risks that are negligible in higher income countries, but still common in countries with lower income, like the transmission of the plague through biological hosts (rats) and biological vectors (fleas). This fact makes it a suitable publication for the posed questions. On the other hand, the information provided on chemical induced illness in this publication, is quite short (Hanks 1967:14-28).

Sandra Cointreau, a solid waste expert working since nearly 30 years in this field, has written a report for The World Banks' Urban Paper series, called "Occupational and Environmental Health Issues of Solid Waste Management – Special Emphasis on Middle- and Lower-Income Countries" (Cointreau 2006), subsuming and discussing various studies and experiences on that issue.

At first Cointreau distinguishes between occupational and environmental health risks through MSWs. While the first is limited to people handling wastes, like waste workers, pickers or scavengers, the latter affects the entire population. To identify the occupational health risks, the term relative risk was introduce, comparing the diseases of waste workers and so on with a viable control group of the population (Cointreau 2006:1-2). She divides the health affects into the groups

- "Solid waste handling and general health risks
- Birth effects and infant mortality
- Direct contact disease links
- Water contamination disease links
- Vector disease links
- Animal feeding disease links
- Injuries" (Cointreau 2006:1-2)

Then she describes different case studies on these health affects.

Another publication that deals with solid waste and human health is "The challenge to achieve better landfills where only dumps are achieved now: an anthology" by WHO advisor Peter Rushbrook (Rushbrook 2000). He starts by giving a brief overview on health affects of waste disposal sites. Rushbrook categorises health effects of waste management activities into

- Direct physical harm
- Bacteriological and protozoal pathogens and similar infective agents
- Chemical contaminants
- Effect of chemical and microbiological contaminants on reproduction (Rushbrook 2000:42ff)

As the provided information on relevant chemicals and chemical compounds in Cointreau (2006) and Hanks (1967) was not sufficient, the *International Program on Chemical Safety's* (IPCS) *Environmental Health Criteria Monographs (EHCs)* is additionally used to identify the hazards through exemplified relevant chemical compounds and materials emissions from MSWM activities.

<u>Examples for health effects and diseases pathways</u>

Herein, three categories of health effects are distinguished, similar to Rushbrook (2000:42). For each category a brief description is given, containing disease examples from Cointreau (2006) and Hanks (1967), but also, which processes within a MSWM system that can lead to the diseases described. Finally, possible pathways are shown, according to Hanks (1967:11ff), which also includes if the risk is more of occupational or environmental "nature" (Cointreau 2006:1-2). This last step should link the process with the affect on the human body.

<u>Direct physical harm</u>

Direct physical harm is the most obvious hazard relating to waste management activities. Cointreau (2006:30-35) names the following processes and gives examples, where a higher relative risk for, in this case, waste workers and pickers as well as scavengers, was observed:

Table 2-2 Examples for higher relative risk of waste workers, waste pickers and scavengers

Injury	Processes	Examples
Collection injuries	Collection&Transport	Accidents with the collection vehicle Laceration due to sharp materials in waste
Disposal injuries	Incineration Landfill	Accidents with the machinery Landfill gas explosions Animal bites Laceration due to sharp materials in waste
Dumpsite slides	Landfill Dump site	Workers/ scavengers entombed by waste
Lifting-induced musculoskeletal injuries	Collection&Transport Landfill/Dump site	Worker/waste pickers collecting waste Scavengers picking waste at landfill/dump site
Vibration-induced musculoskeletal injuries	Landfill Dump site	Workers operating compaction vehicles
Noise-induces injuries	Material recycling facilities	Workers working in material recycling facilities

Obviously, direct physical harm affects mostly people handling wastes, namely waste workers, waste pickers and scavengers. Thus the health risk is of occupational nature. The communication pathway is illustrated as follows:

Figure 2-2 Communication pathways for direct physical harm through MSW and MSW-related activities

However, one dimension not mentioned is the fact that, if wastes are not collected or landfills/open dumps are not fenced and controlled, the possibility of playing children getting injured through direct contact can not be ruled out.

<u>Infective transmission of microbiological agents (bacteriological and protozoal pathogens and similar infective agents)</u>

MSW contains a high quantity in biodegradable organic materials, from more or less 30% at high income countries up to nearly 60% and more for middle and low income countries (Hoornweg 1999:6-8). The organic matter origins from garden and kitchen wastes, like decayed food. Also the presence of human or animal faeces cannot be ruled out. Thus, Hanks names amoebic dysentery and other intestinal protozoal infections, cholera, coxsackie disease, infectious hepatitis, poliomyelitis, shigellosis, typhoid and paratyphoid fevers, tuberculosis, worm infections, fungus disease, anthrax, trichinosis, trypanosomiases and various diseases causes by animal faeces (Hanks 1967:50-86).

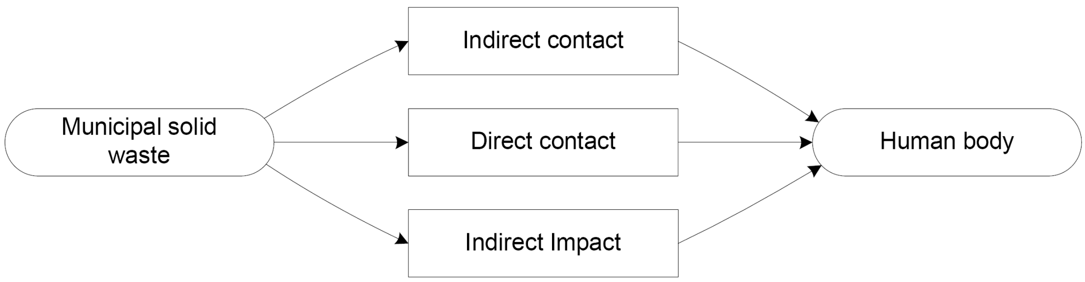
Beside the microbiological properties of wastes and their more or less direct influence on human health, waste also influence the appearance and quantity of disease "hosts" or transmitter from animal origin.

Hanks mentions diseases transmitted by the biological vectors flies, mosquitoes and rodents. These vectors can either transmit disease agents mentioned above, e.g. flies breeding in human faeces and then getting in contact with human nourishment or humans themselves. In addition, they themselves host diseases. Hanks gives examples of fly borne diseases, like sleeping sickness through tsetse flies (Hanks 1967:28-49), mosquito borne diseases like malaria or dengue fever (Hanks 1967:97-105) or rodent borne diseases like the human plague (Hanks 1967:86-96).

The relation between solid wastes and theses biological vectors is twofold. If waste is not properly disposed but dumped close to human settlements or even not collected, the distance between the waste and humans is smaller, which makes it easier for the biological vectors to reach the victim.

On the other hand, open dumped or not collected waste provides a habitat for rodents, mosquitoes and flies and thus increases their number, either directly or through blocking water drainage systems. For this reason, Hanks recommends fly, mosquito and rodent control through improved hygiene and sanitation in solid waste management (Hanks 1967:49,91,105).

Figure 2-3 Communication pathways for microbiological and other agents between MSW and humans



derived from (Hanks 1967:10ff).

Table 2-3 Examples for communication pathways for microbiological and other agents

Pathway	Examples
Indirect contact	Transmission through water, air, food, biological vectors
Direct contact	Hand to mouth contact
Indirect impact	Waste as a habitat for biological vectors

There are other biological transmitters, like cats or cockroaches, which take up microbiological agents while foraging in wastes and then transmit it to human food. Technically, somebody who works or is in direct contact with waste is also a biological transmitter.

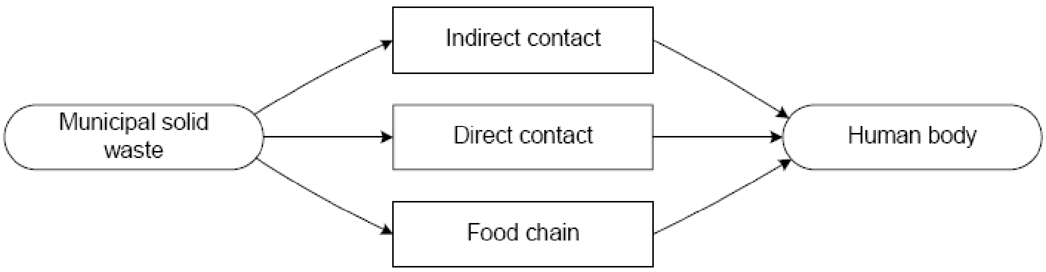
<u>Chemical induced illness</u>

Referring to their properties, chemicals and chemical compounds can affect human health in different ways, amongst others toxic, carcinogenic, mutagenic or caustic. Cointreau (2006) mentions some examples of chemicals typically related to waste management. A selection of chemicals from MSWM activities include[1]:

Polychlorinated Dibenzo- Para-dioxins and Dibenzofurans (PCDD, PCDF) (Cointreau 2006:24) are persistent organic pollutants (POPs) which do not naturally occur. Their production is not intentional, but they can be by-products, e.g. from the production of chlorophenols, and occur in PCDD/PCDF contaminated industrial waste disposal sites or off-gas and residues from fossil fuel combustion and MSW burning or incineration. Health affects reported are chloracne, a higher risk of cancer and, at high doses exposure, acutely intoxications (IPCS 1989).
As under the Stockholm Convention the production of unintentionally produced POPs should be reduced. UNEP Chemicals published a toolkit to reduce these emissions, as they might have negative impacts on human health (UNEP Chemicals 2005).

Volatilized heavy metals, such as cadmium (IPCS 1992), lead (IPCS 1977), mercury (IPCS 1976) and cadmium (IPCS 1976), can be found in MSW (Cointreau 2006:21) and if landfilled in the leachate or if burned in the off-gas and residue. From there, it can reach the human body through air, water or the food chain (Hanks 1967:16). Observed affects on human health refer to the respiratory system in case of cadmium and neurological in case of lead and mercury or carcinogenic for all of them.

Figure 2-4 Communication pathways for chemical agents between MSW and humans



derived from (Hanks 1967:10ff; 16) and (Rushbrook 2000:42)

Table 2-4 Examples for communication pathways for chemical agents

Pathway	Examples
Indirect contact	Transmission through water from landfill leachate, air from burning processes
Direct contact	Hand to mouth contact, direct exposure
Food chain	Uptake through meat and vegetables grown on contaminated sites

[1] Some of these materials and compounds have more than the mentioned affect on human health.

Municipal solid waste and environment

MSW activities release various emissions into the environment. Some literature on these emissions and affects on the environment are mentioned herein.

Paul T. Williams (2002) mentions emissions and their impact on the environment from waste landfills, incineration, composting, pyrolysis/gasification and recycling, but not uncontrolled dumping or collection and transport of wastes (Williams 2002:141-170).

Amalendu Bagchi (2004) deals in his publication "Design of landfills and Integrated solid waste management" (Bagchi 2004) also with environmental issues of incineration, composting and landfills. The UN Department of Economical and Social Affairs (UNDESA) suggest for the evaluation for environmental aspects of sustainable development a set of indicators for various human activities (UNDESA 2004). Therein, UNDESA not only names the indicators, but also describes briefly the effect of each indicator on the environment. As some indicators reflects the amount of a certain material emitted into water, air or soil, and some of these materials are also emitted through MSW activities, it is a useful tool to get an idea about their negative impacts on the environment.

Table 2-5 Examplified environmental affects through MSW and MSW-related activities

MSW process	Emissions	Environmental effect
Collection & Transport	CO_2, NO_x, SO_2 et al. from combustion	Global warming, air pollution, acid deposition
Dumping & Landfill	N, BOD, metals in leachate CH_4 in off-gas	Eutrophication, water pollution Global warming
Burning & Incineration	CO_2, NO_x, SO_2 et al. Heavy metals	Global warming, air pollution, acid deposition Air, land and water pollution
Composting	N-emissions in waste water CO_2 in off-gas	Eutrophication Global warming

Municipal solid waste and resource conservation

As mentioned in the introduction, MSW is not only an unwanted good, but also a source of materials for production. More than that, different MSW options show different demand of resources, like the demand of water for material recycling facilities or the demand of land for landfilling. Especially the latter is a reason for densely populated areas where land is scarce to favour MSW treatment options likely to reduce the volume required for landfilling of wastes.

When Paul Hans Brunner and Helmut Rechberger (2004) list some applications of MFA in their "Practical Handbook of Material Flow Analysis", they also analyse the intersection of resources- and waste management (Brunner, Rechberger 2004:16-19). The resource conservation dimension of MSW activities is also towered upon, through consideration of the growing scarcity of landfill space in densely populated areas and production of recyclable materials for subsequent processing (Brunner, Rechberger 2004:17).

UNDESA (2004) also list some indicators referring waste management and conservation of resources. For instance, they mention the materials recycling rate and the volume of waste generated or disposed and give an explanation how recycling helps to conserve resources.

Kit Strange gives, in the publication “Environmental and Health Impacts of Solid Waste Management Activities” (Strange 2002), a brief “Overview of Waste Management Options: Their Efficacy and Acceptability” (Strange 2002:1-51). In the chapter on thermal treatment and the following (Strange 2002:22ff.) he analyses pros and cons of material or thermal recycling. One argument of the proponents of the latter is that the utilization of wastes as a fuel helps to reduce the amount of other energy sources, like oil, gas or coal and thus help to conserve resources.

Table 2-6 Resource conservation aspects of MSW and MSW-related activities

Processes	Resource	Resource conservation aspect
Landfill	Land, space	Land conserved through disposal of less waste
Material recycling	Raw material	Raw materials conserved through material recycling
Thermal treatment of MSW	Energy	Energy resources conserved through energy recovery

2.3.5 Assessment of MSWM systems and indicators

As mentioned above, a goal-oriented assessment is done through indicators. The approach follows the methodology in the paper “„ Setting priorities for waste management strategies in developing countries” (Brunner and Fellner 2007). MSWM systems from different regions were assessed on the basis of how well they fulfil the objectives of MSWM. For the assessment they suggested indicators, where some refer to health and environmental aspects and some to resource conservation aspects. The indicators applied were the %age of population having direct contact with waste, greenhouse gas emissions, nitrogen emissions into the hydrosphere for short and medium term health and environmental indicators and the material recycling rate, rate of waste landfilled and required space for waste disposal as indicators for resource conservation. Furthermore, environmental sustainability was assessed through long-term emissions from landfills and economical sustainability through the ratio of expenses for MSWM to the regions GNI (Brunner and Fellner 2007:235).

For sustainability issues of MSW activities, UNDESA (2004) presented a set of indicators, as mentioned before, while the Organisation of Economic Co-operation and Development (OECD) (OECD 2004) and the European Environment Agency (EEA) (Fatta and Moll 2003) give also a range of environmental indicators.

2.4 Material flow analysis and system definition

2.4.1 Municipal solid waste management

First of all, it must be defined what is meant by municipal solid waste management, as it is the actual research object of the material flow analysis. Brunner et al. (2002) mention two alternative definitions for municipal solid waste, first that they are "…wastes which are produced by private households (residual source), small trade, working places of the tertiary sector (commercial source), open areas, and which are collected by public authorities" (Bacchini and Brunner 1991, cited in Brunner et al. 2002:A48) and second that they are "…waste(s) generated from residences, community establishments, institutions, and to a limited extend, industrial facilities" (Eblen 1994, cited in Brunner et al. 2002:A48) Municipal solid waste is a good that can be further split up into other goods, like paper and cardboard, organic waste, metal, glass, plastics and mixed waste. The splitting, as done here in this example, often refers to the properties of these goods and their economical value.

From the citation above, one can see that MSW is not only defined by were it is produced (households, small trade, etc.), but also who is responsible for it: public authorities. Hence public authorities are the ones who should manage the waste. In fact they do, but not everywhere to a full extend. In many countries public authorities or their private contractors do not collect 100% of MSW. There are other, informal our uncontrolled methods of waste collection, treatment and disposal. Even if not controlled and managed by authorities, the municipal solid wastes from this fraction are part of municipal solid waste management and must be considered.

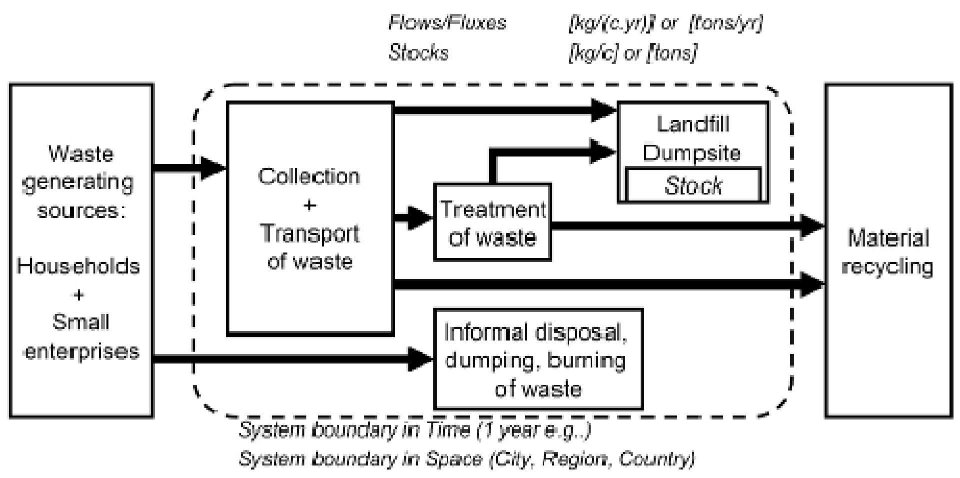
According to that, municipal solid waste management is every activity that deals with municipal solid waste from its generation to transport, transformation and storage

2.4.2 Material flow analysis (MFA)

In the devolution of MFA from the idea to the result, first the system and its borders must be defined. Then the relevant goods (materials) and processes are listed and after that the processes are linked with each other by the flow of goods.

System definition

Figure 2-5 General system definition municipal solid waste management



derived from (Brunner and Fellner 2006)[1]

System and system boundary

The system covers any goods referring to *municipal solid waste management*, meaning wastes from households and small enterprises.

The boundaries of the system are twofold, one in time and one in space. The first refers to the chosen observation time, the latter usually to geographical or administrative boundaries. A temporal boundary can be one day or one year and so on.

Processes

In general, the relevant processes in any MFA-system are *transport, transformation* and *storage* of goods.

The processes within this system are *collection and transport, treatment and landfill/ disposal/dumping*. The processes outside the system are *households and small enterprises* and *material recycling*. Even though they are outside of the considered system and thus technically not considered in MFA, they are mentioned, as the output of *households and small enterprises* makes the import flow into the system and the input of *material recycling* makes one export flow out of the system.

[1] Water and off-gas, which are also relevant output-flows, are not mentioned in this figure.

Substances, goods and materials

In MFA, *substance* is a chemical element or compound and *goods* are build up substances, but have a positive or negative economic value, while material is used as an *generic term for both, substances or goods*. Hence, the term material is used for *MSW* and its fractions. The import material, which enters the system, is *MSW* and the export materials are *recycling materials* or *recyclables* from the processes *treatment and collection* and *transport*, but also *off-gas* and *wastewater*. The materials inside the system are *MSW* and its transformation products, transformed by the processes *treatment* and *collection and transport* (Brunner et al. 2002).

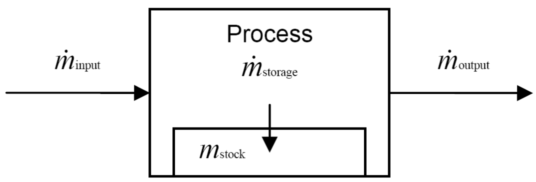
Material flow, material flux and stock

The material flow can be defined as the amount of material transported or transformed per unit of time. Usual units for *MSW* are *tons/year* or *kg/day*. Material flux is the amount of material per unit of time and area, where *per capita* stands for the area unit. Usual units for *MSW* are *g/capita/day* or *kg/capita/year*. Stock means the accumulation of a material in a process. Usual units for MSW are *kg or tons*. Unlike most goods like MSW, substances are often described with smaller units.
While the flows/fluxes crossing the system boundary are termed with the prefixes import and export, flows/fluxes just entering or leaving a process are termed with the prefixes input and output. According to the law of conservation of mass, import and export as well as input and output flows/fluxes must be equal. If not, there is a change in the stock of the system or process. Thus the stock is the difference between import and export respectively input and output (Brunner et al. 2002).

Equations

Generally, MFA base on the principle of mass conservation. That means that the total inputs into a process and the total output from a process have to be equal. Same can be said for systems and sub-systems, where total imports and total exports have to be equal as well.

Figure 2-6 Process with input flux, output flux and change of stock

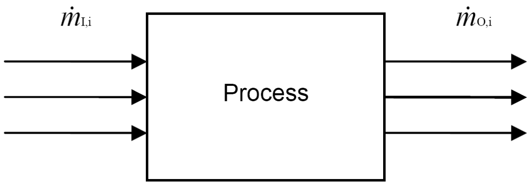


$$\sum_{k_I} \dot{m}_{input} = \sum_{k_O} \dot{m}_{\text{output}} + \dot{m}_{\text{storage}} \quad (2.1)$$

$\dot{m}_{\text{input}}$	input flux	$\dot{m}_{\text{output}}$	ouput flux
$\dot{m}_{\text{storage}}$	change of stock	m_{stock}	stock
k_I	number of input fluxes	k_O	number of output fluxes (Brunner and Rechberger 2004:59)

Another important term used in MFA is transfer coefficient. Usually it describes how a substance partition in a process. Herein, transfer coefficient was used to describe how a good partition in a process. Thus the term good transfer coefficient is more appropriate.

Figure 2-7 Schematic process with one input and two output fluxes



$$TC_i = \frac{\dot{m}_{O,i}}{\sum_{i=1}^{k} \dot{m}_{I,i}} \qquad (2.2)$$

TC_i transfer coefficient for flux *i* derived from Brunner and Rechberger (2004:40ff)

Calculations with STAN

STAN is an open source program to calculate material flows. It was developed by the Institute of Water Quality, Resources and Waste Management of Vienna University of Technology. The MFA calculations were partially carried out using this program. The software could be downloaded from the homepage of the university institute mentioned above (IWA 2008)

2.5 Data collection and calculations for Vienna

Processes, quantities and flows of goods in MSW-management system of Vienna are well documented by MA48.

For the indicators to assess the MSWM system, data from Brunner and Fellner (2007) was used. Even though the insert data for calculating and the methodology might differ slightly from each other, these differences were assumed as negligible.

2.6 Data collection and calculations for Banda Aceh

The field research in Banda Aceh was conducted by the author, Mr. Fakhrial and Mr. Hidayat Syaf, students of UNSYIAH and Mr. Edi Munawar, lecturer at UNSYIAH.

2.6.1 Background research on MSWM in Banda Aceh

To describe the MSWM system, but also to gather pre-information for the later conducted surveys, several qualitative research methods (semi-structured and unstructured interviews, field visit and participant observation) were undertaken. They are described in the following chapter. Note that the interpretation of all results from the interviews was undertaken quantitatively.

Semi-structured interviews with authorities and international organisations

Intrinsically information about MSWM in Banda Aceh was gathered by contacting and interviewing local authorities and international organisations, which work together with local authorities in Banda Aceh since the Tsunami of 2004. The contacts were established by Mr. Edi Munawar, lecturer at Chemical Engineering Department of Syiah Kuala Universitas Banda Aceh.
First interviews were held in beginning of September 2007 with associates of the United Nations Development Program (UNDP) in Aceh and municipal authorities of the Sanitation and Park Department (Departemen Kelautan dan Perikanan – DKP) of Banda Aceh Municipality. Both gave a brief overview about the existing MSWM system. During the field research, more questions emerged and DKP, who provided the deepest insight into the MSWM system of Banda Aceh, was visited frequently. In the end, German Technical Assistance (GTZ) associates were interviewed, not only to get another view on the issue, but also because they are involved in the extension plans of the MSWM system.
All interviews were semi-structured with pre-determined questions due to general information from literature and previous interviews. Wording and order was more or less open.

Unstructured interviews with waste producers, recycling agents, waste pickers, scavengers

During the field visits in residential areas, shopping streets and other commercial areas and the landfill, numerous unstructured interviews with different stakeholders and other parties involved were held. Questions were related to the specific research object, for instance asking households about their waste disposal practise and recycling agents about their business.
What made the interviews unstructured was the fact that the questions were not phrased beforehand, but evolved from a specific situation observed by the researchers. For instance, when researchers saw a waste picker while walking through the town, they stopped and started a conversation with him, ending in an interview that provided some useful information.

Field visits and participant observation

Several field visits and participant observations were done during the field research. *Field* in this context stands for the MSWM system, as well as the by definition outside of the system's border located waste generating sources. The difference between the field visits and the participant observation was primarily the way how researchers appeared in the field. While in the prior the researchers introduce themselves as researchers to the stakeholders, they do not so in latter.
Objects of the field visits and the participant observation were activities of the waste producers in residential and commercial areas, the formal waste collection service, the informal recycling sector and people working at the landfill.

2.6.2 Data for estimating material flows

General

As the relevant processes that can be expected were identified based on the background research described in chapter 2.6 just above, the next step was estimating the material flows into and within the system. To calculate the flows of relevant goods, data about MSW quantities and composition had to be collected and analysed. Unfortunately, the existing secondary data did not meet the desired requirements of the researchers, thus primary data through sampling was needed.
A determination of the MSW quantity and composition only at collection stations or at the landfill do not seem to be applicable, as waste quantities there are generally too voluminous. Furthermore, there is no scale at the landfill. The MSW quantity transferred to the land fill can only be estimated by its volume, density and the number of waste vehicles, which leads to some uncertainties. This does not mean that this data should not be used, but a crosscheck with data obtained using a different method increases the reliability of the results. Another point is that municipal collection does not cover 100% of all households, as practises like burning of waste and illegal dumping are, due to the background research, common. MSW treated in this manner will not be included in the statistics, if only landfill quantities are considered.
All these uncertainties can be overcome by sampling the MSW quantity at its source, meaning at household level. Carried out as a sampling survey, more reliable results regarding waste quantities were collected.

For this estimation, a three step approach was applied. First, a questionnaire survey with waste producers was implemented, to provide base information for the waste sampling survey and to identify the distribution of waste streams from the source. Second, waste sampling should give information about quantities and composition of waste. As a third step, data gathered from recycling agents and authorities completed the picture.

It should be noted that the decision on method was not made completely in advance. Rather it was a process based on the experiences accumulated during each stage of the research study.

Questionnaire survey

As mentioned earlier, data to outtake the material flow analysis in Banda Aceh was rare. Thus some data had to be gathered by contacting authorities and organisations. The non-available data needed was the objective of the questionnaire survey.

The questionnaire survey deals with socio-economic aspects, waste disposal practises, consumption behaviour for household and disposal practises and business properties of restaurants and small enterprises

Subjects of this survey were households and small enterprises of the tertiary sector, like restaurants, shops and grocery stores.

The questionnaire survey itself was designed as a non-random sampling survey.

<u>Households</u>

The information desired from households were 1) the location and address of the household, 2) the number of household members, 3) the average household income per month, 4) the waste disposal practise and 5) the meals consumed in restaurants per week (see Annex 12.1.1, page 209). The purpose and desired delivery of each question can be subsumed as follow.

2) Household size as number of household members

The number of household members is an important socio-economic factor, but within this research also important for the statistics. As described later, an average of 4.5 capita per household (DKP 2007) was assumed to receive the number of households in Banda Aceh based on the number of inhabitants and thus the number of questionnaires distributed.

The result from this survey can later not only compared with the assumed figure of 4.5 capita. Furthermore, household size can possibly have an affect on the household income and on the waste generation rate, as mentioned on comparable studies (cp. Bolaane et. al. 2004; Abu Qdais et. al. 1997; Parizeau et. al. 2006).

3) Average household income

Economic wealth of a household is considered as an important factor in the amount and composition of waste generated. The basic rationale behind is the assumption that wealthier households have, due to their financial abilities, a different consumption pattern and thus a different waste generation rate with different waste composition. However, various similar research studies have not shown unique results whether there is a correlation between economic wealth and waste generation or composition (Abu Qdais et al. 1997; Bernache-Perez et al. 2001; Boolane et al. 2004; Parizeau et al. 2006).

Economic wealth is mostly expressed either by household income or by household expenditures. The data is usually collected by national statistics departments, in Indonesia the BPS (Badan Pusat Statistik). As the data about household consumption and expenditures from the Indonesian national socio-economic survey SUSENAS (survei nasional sosial ekonomi nasional) was not available at the time of research, the household expenditure or income distribution of Banda Aceh had to be determined through the questionnaire survey.

Therefore the surveyed household were only asked about their monthly household income, meaning the totalled income of all household members per month.

For the questionnaire, five income groups were formed (see Table 2-7). The formation of these groups follows the average household income in Banda Aceh, which was about 2 562 525 (IDR/household/month) in 2005[1] and the basic assumption, that a family with one employed member earning the regional minimum wage of 850 000 (IDR/month)[2].

Table 2-7 Banda Aceh – household income groups

Income group	1	2	3	4	5
Household income in (Mio. IDR/household/month)	< 1.5	1.5 – 3.0	3.0 – 4.5	4.5 – 6.0	> 6.0
Per capita household income (Mio. IDR/household/month)	< 0.3	0.3 – 0.7	0.7 – 1.0	1.0 – 1.3	> 1.3
Per capita household income (€/capita/month)	< 27	27 – 53	53 – 80	80 – 106	> 106

4) Waste disposal practices

During the background research, a range of waste disposal practises were observed. The most occasional were taken out for the questionnaire design. The results should show the %age of households per disposal practise. With this data combined with the later described waste generation sampling per household, the total amount of waste from households which is collected or burned or informal dumped /disposed was estimated.

5) Consumption of food in restaurants and takeaways

As observed during the background research, the consumption of food in restaurants and takeaways is quite popular in Banda Aceh, but the number of restaurants and their size has not yet been recorded (DKP 2007)[3]. As an alternative, the average number of meals consumed per capita and day – as delivery of this question – could have been multiplied with the amount of waste generated by meal produced, as described in chapter 3. The result is the amount of waste generated by restaurants and takeaways per day in Banda Aceh.

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[1] Figure from BRR (2006:107); The original data comes from the Indonesian national socio-economic survey SUSENAS 2005 of the national statistics department of Indonesia BPS.

[2] Figure from Serambi Indonesia 5 December, 2006, cited in Rice, R. (2007): Planning for the end of the construction boom in tsunami-stricken Aceh and transition to a rapidly growing sustainable economy. Economic papers – Economic society of Australia. Download from http://www.encyclopedia.com/doc/1G1-169070044.html, download on 5.November 2007

[3] DKP has prepared a register about small enterprises in town. At the time of research, the register were not finished.

The survey including the pre-settings was undertaken the 1st to 9th of October 2007. First, a sample size of about 500 households was desired, which is about 1% of the total number of households in Banda Aceh. The total number of households were estimated by the population of 219 657 in 2007[1] (BPS 2007) and an average household size of 4.5 inhabitants per household (DKP 2007), given 48 823 households in Banda Aceh.

DKP has divided Banda Aceh into five operational zones (zone A – zone E). Each zone was seen as a cluster for the sampling. The number of questionnaires distributed per zone was calculated based on the number of inhabitants per zone.

For this calculation, another adjustment had to be done, as for the villages in the zones only the population figure from the census of 2005 was available (see Table 2-8, second line). As the figures from the projection for 2007 seem more likely[2], the difference between the figure of 2007 (219 657 inhabitants) and 2005 (177 881 inhabitants) was calculated (41.776 inhabitants) and equally distributed on each of the 86 villages of Banda Aceh. The resulting number of inhabitants per zone is shown in Table 2-8, third line. According to the number of inhabitants per zone, the approximate sample size per zone was calculated (Table 2-8, fourth line).

Then, 28 villages were selected where the questionnaires were distributed (Table 2-8, fifth line). Note that the number of villages selected per zone refers to the total number of villages per zone. After allocating the number of questionnaire to each village, according roughly to the inhabitants per village, the total sample size and thus number of questionnaires or households per zone is shown in Table 2-8, sixth line.

Table 2-8 Banda Aceh - population figure per operational zone of DKP[3]

1	Collection Zone	Zone A	Zone B	Zone C	Zone D	Zone E	Total
2	Inhabitants 2005	55 907	59 003	27 821	6 227	27 312	177 881
3	Inhabitants 2007	64 651	70 407	39 937	12 979	31 684	219 657
4	Estimated sample size - households per zone	147	160	91	30	72	496
5	Chosen villages per zone	7	7	6	4	4	28
6	Surveyed households per zone	152	150	91	33	82	508
7	Surveyed restaurants / enterprises (each) per zone	9	9	5	2	2	30

[1] The last census from 2005 gave a figure of 177 611 inhabitants. The figure of 219 657 is an extrapolation of BPS.
[2] Population figures in Banda Aceh are a difficult issue. Many people died during the Tsunami of 2004, leaving some villages with only some hundreds of inhabitants, were thousands of people were living before. On the other hand, new houses were built in this areas.
[3] Population figures according to the population census of 2005, the projection for 2007 and the number of surveyed households, restaurants and small enterprises per zone (BPS 2007, own estimations)

As later found the estimated population per village differs from other figures shown in the "Solid waste management master plan – report for post-tsunami Banda Aceh Republic of Indonesia" (DKP et al. 2007). However, these figures have not been obtained at the time of conduction of questionnaire survey.
The distribution of the questionnaires was carried out by research assistants (six students of Syiah Kuala Universitas) from 1st to 4th October 2007. Before research assistants were informed about the objective of the study and the questionnaire. Then they went to the selected villages and there from house to house, while the starting point was choose by the research assistants themselves.

Restaurants and small enterprises

The information desired from restaurants was 1) the location and address, 2) the size expressed in square meters, 3) the capacity expressed in number of available seats and 4) the waste disposal practise and (see Annex 12.1.2, page 210). The purpose and desired delivery of each question can be subsumed as follows.

2) and 3) Restaurant size and capacity

At the time of conducting the research, it was not known whether data covering the number of restaurants and their size in Banda Aceh can be obtained. If yes, the results from this question could have been projected to the total number of restaurants.

4) Waste disposal practices

Same as with households, a range of waste disposal practises were observed. The most occasional were taken out for the questionnaire design. The results should show the %age of restaurants per disposal practise.

The information desired from small enterprises was 1) the location and address, 2) the type of the enterprise, 3) the shop size expressed in square meters and 4) the waste disposal practise and (see Annex 12.1.3, page 211). The purpose and desired delivery of each question can be subsumed as follows.

2) Type of enterprise and 3) size of the shop

At the time of conducting the research, it was not known whether data about the type of enterprises and their shop size in Banda Aceh can be obtained. If yes, the results from this question could have been projected to the total number of small enterprises.

4) Waste disposal practices

See question 4) – restaurants.

The survey was carried out simultaneous with the household survey. As a sample size, 30 restaurants and 30 small enterprises were chose. The questionnaires were distributed in the same villages chosen for the household survey, the number of questionnaires per villages was estimated based on the number of inhabitants per village (see Table 2-8, page 34).

<u>Other waste generating sources</u>

As it was not clear at the beginning of the survey, which sources of MSW can be surveyed, other generating sources, like schools, offices and markets, were not considered.

Waste sampling at source

As mentioned before, the waste sampling at source approach should complete the data from conventional methods, like sampling at transfer stations and at the landfill. It should overcome the weaknesses of these conventional methods, namely the non-consideration of MSW not transferred to the landfill and the inaccuracy of the results. Waste sources considered weree households, commercial establishments like enterprises and markets, public and alike facilities like schools and offices and gastronomy, like takeaways and restaurants. The basic assumption behind was that these producers represent the biggest MSW streams. Other, presumably important producers like the Indonesian army troops positioned in Banda Aceh or hospitals were not considered.

<u>General</u>

The equipment used contained scales, waste bags, lists and safety equipment, like gloves and masks. All items were bought in Banda Aceh, as prices there were lower and the researchers claim to use local available items. However, the scales were not the best choice in terms of accuracy, but the best available ones. Two size of kitchen scales were used, one with maximum load/ subdivision of 2 kg/ 10 g for smaller and one with maximum load/ subdivision of 15 kg/ 50 g for bigger loads.

Figure 2-8 Banda Aceh – kitchen scales for waste sampling

Each sample was first weighted total. Then it was separated into the fractions organic, plastic, paper, metal, glass and mixed waste, and each fraction was weighted separately. The decision of which fractions were relevant was made after the pilot sampling and according to the research objective, which was primarily to illustrate and calculate the material flows. A more detailed distinction, for instance between recyclable and none recyclable plastic, polypropylene, polyethylene, polyvinylchloride and other plastics or a separate fraction of textile or rubber, was not applied, as the samples' masses were generally small and the scales quite inaccurate. That does not mean that waste properties of different sources were not – though only qualitatively – recognised and noted. Other comparable studies (Abu Qdais et al. 1997, Bolaane et al. 2004, Patrizeau et al. 2006) give some examples of additional waste fractions distinguished and sampled.

<u>Households</u>

A one week pilot sampling from 10th to 16th of September 2007 made the entry point into the waste sampling survey. Five participants – one research student, three of his fellow students and one associate from the instrument laboratory – were provided with small kitchen scales, waste bags and a form to annotate the daily solid waste generation of their households. Objective was obtaining information about practical considerations for the main waste sampling, like the amount of waste per day that can be expected and its composition.

After analysing the results of the pilot sampling, the preparation for the main sampling started. Thus, the sample size, duration and period had to be fixed. Unlike Bolaane et al. (2004) and Abu Qdais et al. (1997), the sample size was not calculated but geared to their calculated required sample size of 786 (Bolaane) and 779 (Abu Qdais). With intended sample duration of 15 days and 50 households participating, a total sample size of 750 samples maximum was forecasted[1]. This number also fits with the national Indonesian standard which suggests sampling between 30 and 70 households over at least eight days for a city of Banda Acehs' size[2].

Then the researchers tried to find households who would like to participate in the sampling. After some field visits and due to background research of local research participants, three locations were considered. Basis of decision making was firstly the assumed income level of the locations population and secondly a convenient criterion. Thus, one presumable high, one middle and one low income area were selected, all not too far away from each other, in order to maximise the use of resources. The name of high income area is Lampineung, the name of the middle income area Keuramat and the name of the low income area is Lamdingin (see Annex 12.3.1, page 214). By going from door to door, explaining the households the aim and the sampling procedure, people were ask about their general willingness of participation. If willingness was assured, household were asked to fill in similar questionnaires to the ones for the questionnaire survey (see Annex 12.1.1, page 209). The most important information there was the address of the household, the number of household members and the household income. 63 households in total were interviewed, while 50 of them were selected, accordingly to the income distribution from the questionnaire survey (page 32). Then each household got a number.

Table 2-9 Banda Aceh – estimation of required sample size for household waste sampling

Income group	1	2	3	4	5
Household income in (million IDR/household/month)	< 1.5	1.5 – 3.0	3.0 – 4.5	4.5 – 6.0	> 6.0
%age each group according to the results of the questionnaire survey	43%	43%	9%	3%	2%
Number of households sampled from each group	21	20	5	1	3
%age of each income group according to the sampled households	42%	40%	10%	2%	6%

Two days before the sampling started, the selected households were visited a second time to equip them with two waste bins and sufficient marked bags, 20 for organic and 20 for inorganic waste. The bags, marked with the household number in order to identify them later, were blue and black, one for the organic and one for the inorganic fraction. Households were asked to separate their waste into these two fractions. Some households got additional bags during the sampling.

[1] The researchers were aware, that the real sampling size would be much lower.
[2] This information came from Mr. Edi Munawar, the research supervisor. Unfortunately, the author can not give a more detailed information, as the original paper with the national standard is not available at time of completing this diploma thesis.

Figure 2-9 Banda Aceh – bins and waste bags, distributed to the households for sampling

The sampling itself started on the Monday October 10th 2007, two weeks after the Idul Fitri holiday, marking the end of the fasting month of Ramadan[1], and ended on Monday November 13th 2007, making up a total of 15 days. Every day in the morning the research team, accompanied by two helpers with a motor cycle and a bicycle rickshaw, collected the waste from the household and sent it to a waste container, next to the football stadium. This location was selected due to the fact that there were no residential areas around which could have been affected by the sampling activities. To find helpers was not a big problem. The first helper was an informal waste worker, who usually collects waste from households and other establishments at the sampling area Keuramat. His knowledge on the situation helped a lot. The second helper is one of the numerous waste pickers, who usually collects recycling materials with his motor cycle rickshaw all over town.

Figure 2-10 Banda Aceh – one helper collects the waste bags for sampling at Keuramat.

Each waste bag was registered, weighted, opened and separated into the fractions organic, plastic, paper, metal and mixed waste. The fractions were then weighted separately. When there was rain or other problems, only the total weight was measured. Finally, 664 samples for the total waste weight

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[1] The Ramadan 1428 according to the Islamic calendar dated from 11. September to 13. October 2007. Source: Homepage, Department of Religious Affairs, Republic of Indonesia, http://www.depag.go.id/index.php, last access 11.01.1008

and 439 samples for the waste fractions weight were collected. From these figures, 14 respectively 6 samples were not considered, due to inconsistency of the information[1], leaving 650 respectively 433 considered samples. Reason for smaller sample number than assumed were either missing or unreadable numbers at the waste bags or people were not at home respectively forgot to place the waste bags in front of their house.

Figure 2-11 Banda Aceh – spectators together with one researcher at the sampling location

[1] One household was completely deleted from the list, as it did not provide any information about the number of people living in the household. Some other samples were deleted due to mistakes in data entry.

Table 2-10 Banda Aceh – desired versus achieved sample size for household waste sampling

	Total weight	Waste fractions weight
Number of samples assumed max.	750	750
Number of samples collected	664	439
Number of samples considered	650	433
Difference samples assumed max. – considered	100	317

Schools, Offices, Enterprises, Restaurants

The sampling of schools, offices, enterprises and restaurants started similar to the household sampling, by visiting them, explaining the study and asking about the willingness to participate. In order to maximise the use of resources, only locations close to the three sampling areas were considered. Every establishment was provided with waste bags. As it can not be quantified in advance, how much waste would be generated, some establishments got additional bags during the sampling period. A difference to the household sampling was that some establishments had helpers who usually organised the waste disposal of the establishments. These helpers were incorporated in the collection of samples.

For each establishment, samples from eight days, as proposed in the Indonesian national standard (see footnote 2, page 38), were planned for. However, this can not be obtained from every establishment.

- According to the age of students, there are basically three different types of schools in Indonesia – elementary school (SD), junior (SMP) and senior high school (SMA)[1]. From each of them, one was selected and sampled. The SD had 80, the SMP 338 and the SMA 808 students.
- Also, three offices of the governmental administration were sampled – the municipal office of education (DP), the regional office of agriculture (DP-TPH) and the regional office of youth and sport (DPO)[2]. The DP had 160, the DP-TPH 76 and the DPO 106 employees respectively.
- Four small enterprises were sampled, one grocery store (K), two copy and stationary shops (PKS) and one building shop (TB)[3].
- Three gastronomy establishments were sampled – one restaurant (WN) and two coffee shops (WK 1, WK 2)[4]. While the restaurant only sales food, one coffee shop sales food and drinks and the other coffee shop food, drinks and foodstuff.

[1] SD – Sekolah Dasar; SMP - Sekolah Menengah Pertama; SMA - Sekolah Menegah Atas
[2] DP – Dinas Pendidikan; DP-TPH – Dinas Pertanian - Tanaman Pangan dan Holtikultura; DPO – Dinas Permuda dan Olahraga
[3] K – Kelongtong; PKS – Pelengkapan Kantor dan Sekolah; TB – Toko Bangunan
[4] WN – Warung Nasi; WK – Warung Kopi

Table 2-11 Sampling – desired versus achieved sample size for waste sampling of other sources than households

	Classification	Employees /Students	Samples assumed max.	Samples collected	Samples considered	Difference samples assumed max. – considered
SD	Primary school	80	8	9	9	- 1
SMP	Junior high school	338	8	10	10	- 2
SMA	Senior high school	808	8	5	4	4
DP	Office	160	8	10	10	- 2
DP-TPH	Office	76	8	7	7	1
DPO	Office	106	8	7	7	1
K	Grocery shop		8	6	6	2
PKS 1	Copy shop		8	5	5	3
PKS 2	Copy shop		8	5	5	3
TB	Building shop		8	2	2	6
WN	Restaurant		8	8	8	0
WK 1	Coffee house		8	8	8	0
WK 2	Coffee house		8	8	8	0
Total			104	90	89	15

The total sampling period covered the period from 6^{th} to 22^{nd} November 2007, but samples were not collected throughout this time. While some establishments were sampled from November 6^{th} to 16^{th}, some started later. Reason for this methodological uncertainty was that it took longer to ensure participation of some establishments. Furthermore it was necessary to extend the sampling period in order to meet the objected number of samples – which was even then not always possible.
To collect the waste, various additional helpers were engaged, as waste quantities were too big for the two helpers mentioned before and they did not always found time to help.

Recycling survey

As in many cities in low and middle income countries, also in Banda Aceh an informal recycling system exists. Now, the size of this sector in Banda Aceh is not known, whether in terms of sales, people working in this sector or material quantities. The last in particular is the most interesting in order to draw the material flow diagram.

Various sources gave information about a rough size of the sector in terms of buyers of recycling materials and where they are located (Interviews with DKP 2007, UNDP 2007, various waste pickers and recycling agents, own observations). Then about ten of these recycling agents were interviewed respectively surveyed with a questionnaire, where information about the location of the workshop, the type of recycling materials they buy, how they get it, how much they buy and if they know other recycling agents in town (see Annex 12.1.4, page 212). Three of them were willing to give some data about the amount of material they have bought during different time periods, but also information about the price for recycling material. This data was later used for the material flow calculation.

Data from municipal authorities DKP

DKP provided a different set of secondary data, merely on expenditures on waste management and – for the material flow analysis – input data into the landfill. Furthermore, data from prior waste auditing was delivered through the Waste Management Plan 2007 for Banda Aceh.

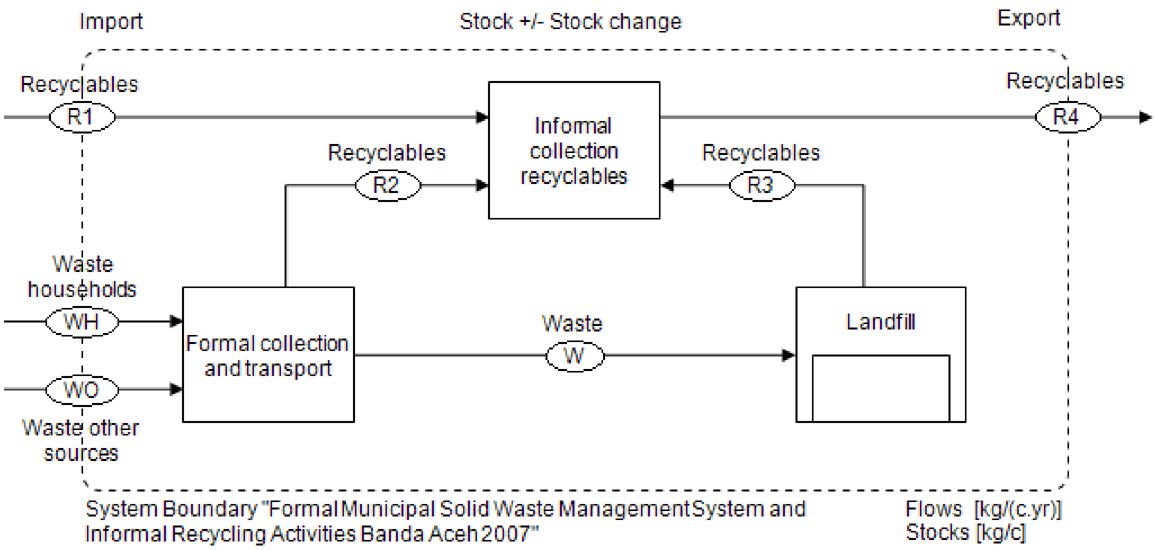
2.6.3 Calculating and estimating material fluxes of MSW total

The quantity of material fluxes of the total MSW were calculated and estimated by the primary data collected through the waste sampling and secondary data from authorities, while the questionnaire survey provides the information, how the import MSW stream partitions on different processes.
The initial idea was to incorporate the data from all sampled establishments into the import waste stream into the system. However, as first the sampling size of these establishments (school, offices et. al) was small and second the total number of establishments from each type was difficult to estimate, an extrapolation would not have made much sense. Thus a different approach was applied.

MFA-model sub-system "Formal MSWM and informal recycling Banda Aceh 2007"

To calculate the material flows, first the formal waste collection and informal recycling activities as a sub-system of the total MFA system was formed. With this model, the import stream of other sources of MSW beside households, herein termed *WO – waste from other sources,* was calculated. To simplify matters, export flows like leachate and off-gas from the landfill were disregarded.

Figure 2-12 Banda Aceh – MFA model sub-system „Formal MSWM and informal recycling activities Banda Aceh 2007"



Wastes from other sources are wastes from small enterprises, gastronomy establishments, hotels, markets, offices, schools, hospitals and other establishments where MSW is generated.

<u>Entry data for STAN</u>

WH is one of the two import fluxes into the system and the import flux into the process termed as *formal collection and transport*. Source of this flux are households. Thus the data from the households sampling was taken. Out of the 650 samples for the total amount of waste per household, the mean value and the standard deviation were calculated with Microsoft Excel spreadsheet calculation. These figures were multiplied with the data from the questionnaire survey about the fraction of households handing over their waste to DKP (see questionnaire survey for households, page 32). The resulting mean value was taken for the MFA calculation, while the calculated standard deviation formed the base for an estimated uncertainty range.

W is the input flux into the process *landfill* and the first output flux from the process *formal collection and transport*. The data from the input into the landfill was available for 11 out of 12 months between July 2006 and June 2007[1]. DKP records the type and number of vehicle entering the landfill and the filling degree of each vehicle. The resulting total volume of waste disposed, expressed as m³/day, was base for the continuing calculations.

For the calculation, the mean value of the daily volume over all months was multiplied by a filling correction factor of 0.8, which means a filling degree of 80% and by an assumed waste density of 250 kg/m³[2]. Furthermore, uncertainties were calculated through Gauss' law application, assuming an

[1] As the delivered data for October was not correct, the data for the month of Ramadan (22nd September – 22nd October 2006) was taken.
[2] Compare DKP et al. (2007:36 ff) and CalRecovery (2005:41)

uncertainty for the filling degree of ±10% and for the density of ±20% or 50 kg/m³. The uncertainties are not considered in the subsystem at this point, but later on[1].

R4 is the export flux of the process *informal collection recyclables*. By gathering data from recycling agents, this flux was calculated. Three of about 35 intermediate recycling agents gave information concerning traded recycling materials over a period of 11, 13 and 16 subsequent days in September, October and November 2007. Out of this data the mean value was calculated and extrapolated to the amount of 35 agents. The assumed uncertainty of ±25% will be considered later.

R1, R2 and *R3* are different streams of recycling materials, coming from different processes. It was not known how big these streams were, thus they were estimated.
R3 is the output flux from the process *landfill*. Recyclable materials are collected by about 40 scavengers at the landfill (Annex 12.5.1, page 220 and Annex 12.5.2, page 220).
R2 is the second output flux from the process *formal collection and transport*. During the research it was observed that waste workers separate recyclable from non-recyclable wastes while collecting. As no information about the size of this flux was gathered, the same figures as for *R1* were used.

<u>Fluxes calculated with STAN</u>

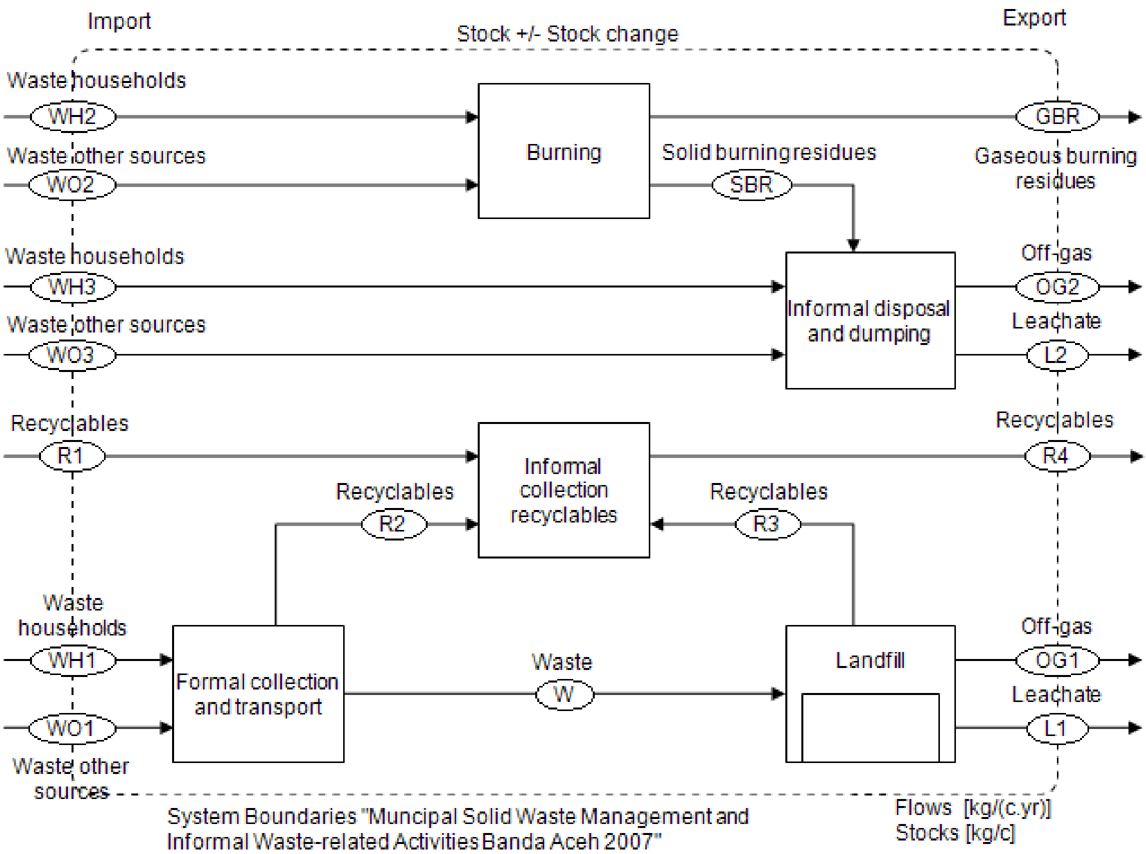
WO is the second import flux into the system and the second input flux into the process *formal collection and transport*. It represents waste from other sources than household.
R1 is the second output flux of the process *formal collection and transport* and the first input flux into the process *informal collection recyclables*.

MFA-model to calculate all waste streams

If the sub-system *Formal MSWM and informal recycling activities Banda Aceh 2007* is extended with the two process *burning* and *uncontrolled disposal and dumping*, the system *Formal MSWM and informal waste-related activities Banda Aceh 2007* is complete. Note that all following abbreviations refer to Figure 2-14.

[1]There are numerous uncertainties in this dataset, like recording errors at the landfill, uncertainties due to the filling degree of the vehicles and the waste density, data from a time were the coverage area was presumably lower was taken et al. A calculation of the uncertainty would make it far more difficult to follow the calculation of material flows.

Figure 2-13 Banda Aceh – MFA model system "Formal MSWM and informal MSW-related activities Banda Aceh 2007"



<u>Entry data for STAN</u>

The fluxes *WH1, WO2, W* and *R1 – R4* were calculated and expressed trough the sub-system *Formal MSWM and informal recycling activities* (page 43).

WH2 and *WH3*, the other import fluxes from households to the processes *burning* and *informal disposal and dumping* were estimated by the total amount of waste generated from households, combined with the data from the questionnaire survey about waste handling practises.

For *WO2* and *WO3*, the import fluxes of wastes from other sources than households to the processes *burning* and *informal disposal and dumping*, the size is unknown, thus a figure was estimated. Due to the background research and results of the questionnaire survey for enterprises and gastronomy establishments, a smaller portion of wastes are burned or uncontrolled disposed than for households. Two arguments for this assumption are:

- Market wastes, which presumably make the biggest portion of waste from other sources than households, are mostly disposed in the waste containers (DKP 2007).
- The result of the questionnaire survey on restaurants and small enterprises show a higher disposal rate to formal collection as opposed to households (see chapter 3).

Thus, it is assumed that from 100% of waste from other sources than households, 10% is burned and 5% is disposed uncontrolled, while 85% is covered by the formal collection system. Based on this estimate, the flows from other sources than households to the processes burning and informal disposal and dumping can be calculated.
The fluxes *solid burning residues* (*SBR)* and *gaseous burning residues (GBR)* are the only outcomes from the calculation. By using a *transfer co-efficient for goods* of 0.4 (40%) for *SBR* they can be calculated. This coefficient derives from a US-EPA study about barrel burning of household wastes. Figures there ranges from 31.9 to 53.4% solid residues from waste burning (Lemieux et al. 1997:18).
Two processes within the system were assumed to stock material. These processes are *landfill* and *informal disposal and dumping*. The landfill was rehabilitated after the Tsunami of 2004. As the area, height and operation time is known, the landfill stock was roughly estimated.

$$t * \sum_{i=1}^{k} \dot{m}_{\mathrm{I,i}} = m_{stock} \qquad (2.3)$$

t considered time span in years

$\dot{m}_{\mathrm{I,i}}$ input fluxes in kg/capita/year

m_{stock} stock in kg/capita/year

This value was crosschecked through using following formula:

$$\frac{A_{landfill} * h_{landfill} * \rho_{emplacement}}{P} = m_{stock} \qquad (2.4)$$

$A_{landfill}$ landfill area in m²

$h_{landfill}$ landfill height in m

$\rho_{emplacement}$ emplacement density in kg/m³

P population in capita

The landfill area, divided in three cells (Cell A, Cell B and Cell C), is about 16.500 m² (see Figure 3-9Banda Aceh 2007 – process landfill: map of landfill Gampong Jawa, the landfill height about 8 m (DKP 2007), emplacement density 1000 kg/m³ (Lechner et al. 2004:66ff; CalRecovery 2005:327ff) and the considered time span 2 years between end of 2004 and end of 2006.

To estimate the stock for the process informal disposal and dumping was somewhat more difficult, as the process itself was not as well known as the process landfill. However, considering again the Tsunami as a turning- and thus zero point, the stock was estimated through multiplying the input flux by the time span of 2 years, like in the landfill stock calculation before (see equation 2.3).

Fluxes calculated with STAN

The fluxes *SBR1* and *GBR1* are the only results from the calculation by using the *transfer co-efficient* mentioned above.

Fluxes not calculated

Due to systematic reasons, the residual fluxes like *leachates (L1, L2)* and *off-gases (OG1, OG2)* from the processes *landfill* and *informal disposal and dumping* were not calculated[1]. Even though this is inconsistent to the methodology of mass balances, it was on the other hand not necessary to calculate the indicators for assessment.

Final MFA-model as base for continuing calculations

Within this model, the results from calculating waste fluxes from the two waste generation sources households and other establishments were added together. Furthermore, uncertainties were considered within this calculation.

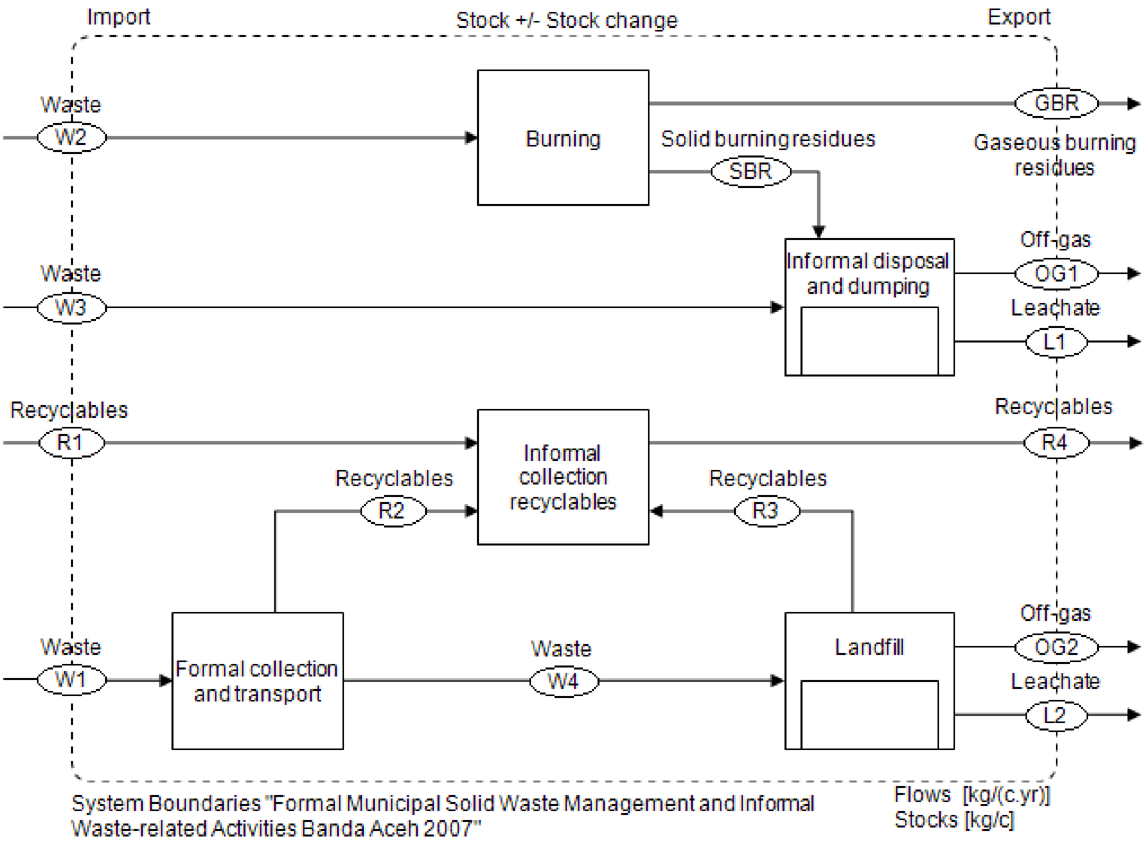
As no distinction between the different generation sources was necessary anymore, a new denomination was applied. The new streams are defined as follows:

Table 2-12 Banda Aceh – final MFA model and new denominations

Flux denomination old		Flux denomination new		
Name	Description	Name	Calculation	Description
WH1	Waste from households to formal collection	W1	W1 = WH1+WO1	Waste total to formal collection
WO1	Waste from other sources to formal collection			
WH2	Waste from households to burning	W2	W2 = WH2+WO2	Waste total to burning
WO2	Waste from other sources to burning			
WH3	Waste from households to informal disposal	W3	W2 = WH2+WO2	Waste total to informal disposal
WO3	Waste from other sources to informal disposal			
W	Waste from formal collection to landfill	W4	W4 = W	Waste formal coll. to landfill

[1] The amount of leachate is subject of estimating N-emissions to the hydrosphere, while the amount of off-gas generated is subject of the calculation of methane emissions.

Figure 2-14 Banda Aceh – final MFA-model for continuing calculations[1]



Entry data for and fluxes calculated with STAN

All fluxes were entry data or calculated before. Certainly, the uncertainties were considered within this calculation. They were all subject to assumptions and ranged from ±20% to ±30%.

Waste composition

For calculating the emissions, some important fractions of wastes had to be quantified. While sampling households and other establishments, the composition of wastes was analysed. However, this data can not be used, as sample size for other establishments than households was too small and some important generating sources, like markets, were not sampled. Hence, reasonable assumptions regarding the waste composition, based on secondary data from Banda Aceh and other Indonesian cities and on own experiences, had to be done. Furthermore, assumptions refer only to the share of fractions important for continuing calculations.

Fuel demand

Emissions from motor vehicles contribute to emissions into the air. As some emissions are subject to assessment through indicators shown later, the amount of fuel must be estimated. Motor vehicles are used for collecting waste, recyclable materials and compacting the waste at the landfill. As no data is

[1] Leachates and Off-gases from the processes *landfill* and *informal disposal and dumping* are not drawn, as they will be calculated later by estimating N-emissions into hydrosphere and methane emissions.

available for the informal collection of recyclables, but the demand of fossil fuels is presumably small compared to the collection vehicles, it was not considered.
For the formals collection service of DKP, the projected expenditures for fuel in 2007 is available, thus it was used as a base for calculating the amount of fuel consumed. The total fuel expenditures will be divided through the fuel price of 4 500 IDR[1].
To make the latter calculation of indicators easier, it is assumed that only diesel fuel is utilized.

Costs for municipal solid waste management

The Solid waste management master plan of Banda Aceh gives in its annex the cost structure (DKP et al. 2007: Annex 19) and the department's organisational structure (DKP et al. 2007: Annex 9.1-9.8). Furthermore, costs of waste management were a subject of the interviews held with DKP (DKP 2007). As DKP is not only responsible for solid waste management, but also for liquid waste management, cemetery and park management and street sweeping, first a distinction between the different sub-departments had to be done. While some positions in the break down of the budget, like procurement and construction in landfill can be assigned directly, some, like total salary and insurance costs for civil servants or workers, can not. These costs were split up through the organisational structure information, where the number of civil servants/workers per each sub-department and section are shown. As for the sections a distinction between solid waste management and other duties can be done, a ratio of civil servants/workers working in solid waste management respectively non-solid waste management was calculated.
For all items in the break down of the budget where no direct assignment could have been achieved, this ratio was applied.
In the next step, the resulting costs for solid waste management were separated into costs for collection of wastes and costs for landfilling. Again, the share of personnel working with waste collection and landfill respectively was taken as a global ratio for costs of solid waste management that can not be split up directly.
As the cost information from DKP merely considers operational, but not investment costs for e.g. collection equipment, these costs were added at later stage. By using the information from the master plan covering the number of vehicles used for operating the solid waste management (DKP et al. 2007:41), price information for the vehicles from internet research/own estimations and a linear applied depreciation period of 15 years for heavy and 10 years for small vehicles respectively, the annual costs of the fleet was estimated.
Finally, the costs were expressed in IDR and Euros per capita and year respectively, per ton and as share of the GNI, for collection and landfilling separated and for solid waste management total.
Note that street sweeping was not seen as part of the collection costs.

[1] 4.500,- IDR[1] (= 0,36 € - mean value 2007) was the during the research stay observed price for fuel at gas stations in September 2007.

2.6.4 Scenarios for extended waste management

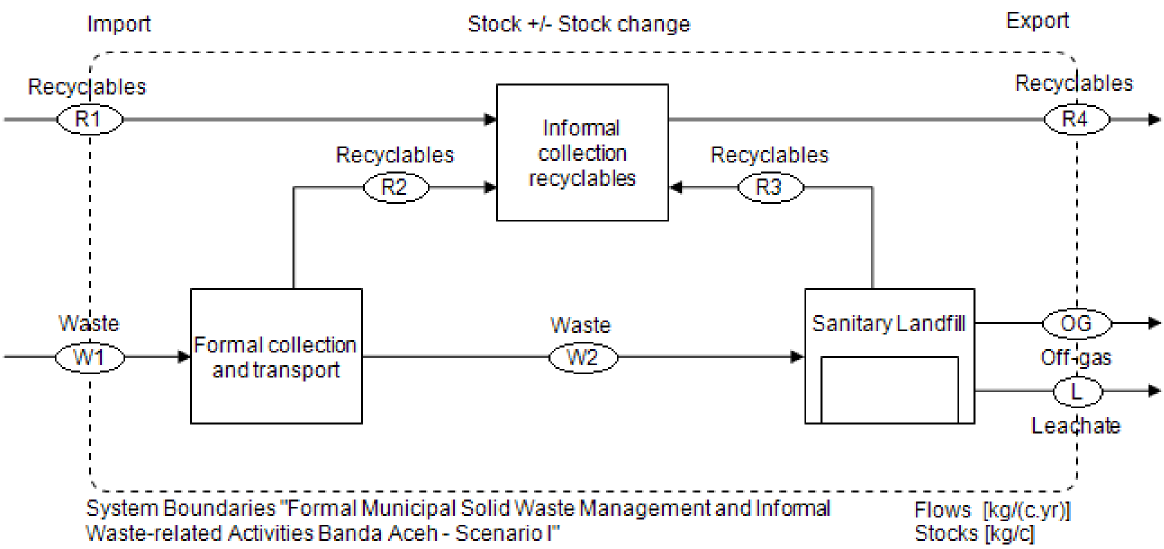
Within this thesis, a scenario is the addition or subtraction of one or more processes in the MSWM system and its affect on the waste streams. Two main influences lead to the decision, how the scenarios should look like.
First, the scenarios should represent the *waste hierarchy*, meaning that there should be one scenario representing each step in the hierarchy. Thus, one reduction/ re-use scenario, one recycling scenario and one safe final disposal scenario should be considered.
Second, the scenarios should represent actual projects or waste management plans for extensions in MSWM systems in low and middle income countries.
As it is quite difficult to design, estimate and discuss a reduction/ re-use scenario, the decision was made to show two recycle and one safe final disposal scenario. According to actual projects discussed and planed in Banda Aceh or Indonesia, the detailed design of the scenarios was chosen.

First scenario is a safe final disposal scenario with full waste collection service coverage and construction of a new sanitary landfill. Both is planed and desired by Banda Aceh municipality (DKP 2007; UNDP 2007; GTZ 2007).
Second scenario is a material recycling scenario, introducing waste separation of organic materials and a large scale composting unit beside the new landfill. This is also planned by Banda Aceh Municipality (GTZ 2007).
Third scenario is a thermal recycling scenario, including the construction and operation of a state-of-the-art waste incineration plant. Even though not planned by Banda Aceh Municipality, it is discussed in other, larger cities in Indonesia, like Bandung Municipality (The Jakarta Post, January 09, 2008).
For all scenarios, the waste amounts and compositions were assumed remain constant.

Scenario I: 100% collection and sanitary landfilling

Scenario I represents a MSWM system with a full collection service coverage and sanitary landfilling. Thus it can be seen as a *final disposal scenario*, representing the third preferential step within the *waste hierarchy*. Furthermore, both extensions are projected by DKP and the municipality (DKP et al. 2007:86), which makes it a reasonable scenario. At actual state of affairs, a sanitary landfill construction located outside the municipal boundaries in Aceh Besar region is projected (GTZ 2007).
Under the assumption that waste fluxes into the process *burning* and *informal disposal and dumping* were negligible, they can be set aside, unlike fluxes into the process *informal collection of recyclables*, which were assumed to be constant.
Due to the extension of collection service, an additional demand of fuel for the collection vehicles had to be considered, which will have an affect on *CO2* and *PCDD/PCDF* emissions and on the *Energy input-output* from the process *formal collection and transport.*

Figure 2-15 Banda Aceh scenario I "100% collection and sanitary landfill" – MFA model



Scenario II: Large scale composting and a waste separation unit

As found out through interviews (GTZ 2007), Banda Aceh Municipality plan to build a waste separation and a composting unit at the area of the new landfill in Aceh Besar. Through the separation unit, compostable organic wastes should be separated from all non-compostable wastes, followed by a large scale composting plant to process the organic wastes into compost. The idea arises first from the generally high organic content in waste and second from using the compost as a fertilizer. Thus one can call it a *material recycling scenario*, which would be ranked on second place according to the *waste hierarchy*. At current state, a feasibility study should show whether this project brings the desired outcomes referring to its investment and operation costs.

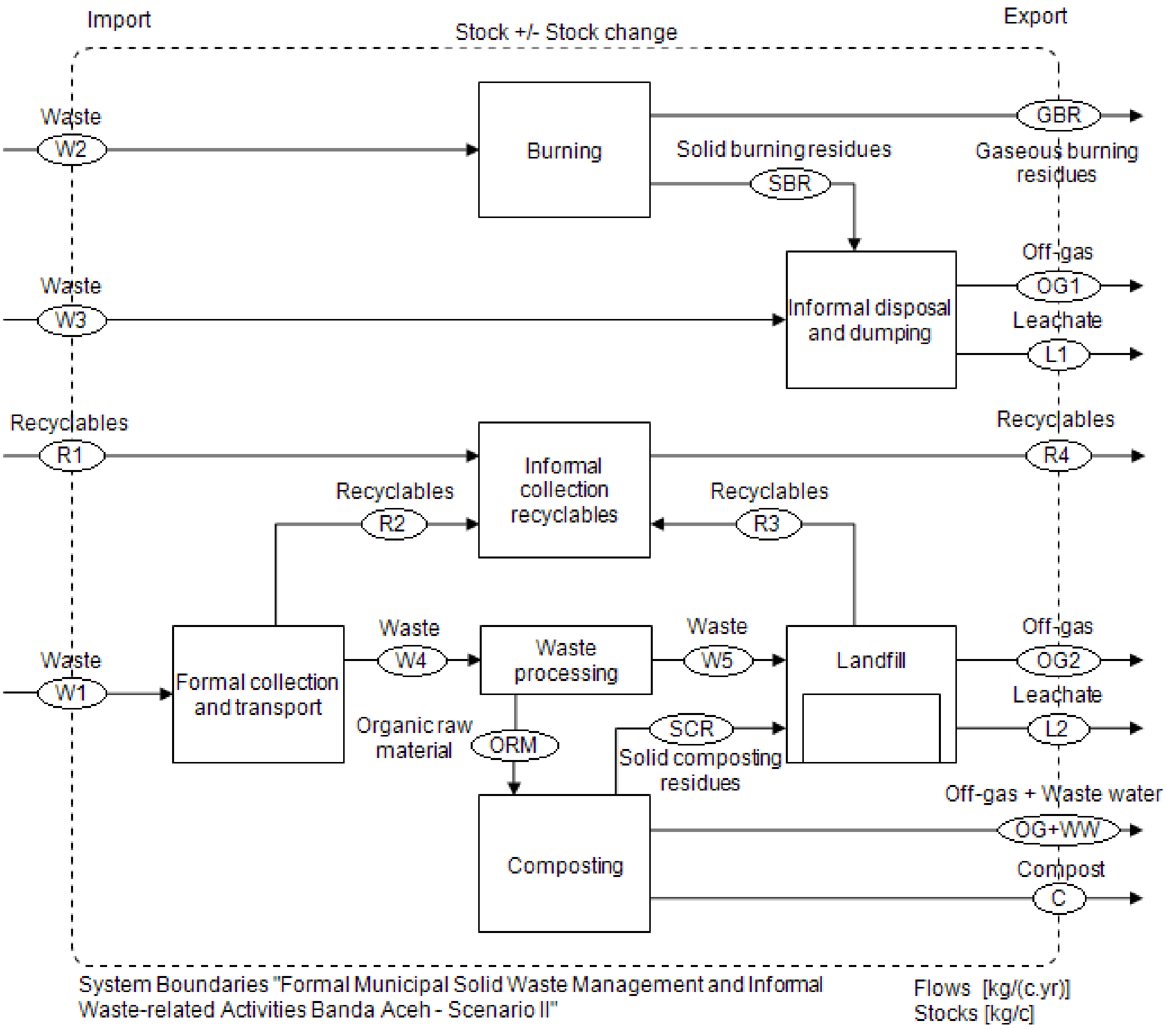
As shown in the MFA model below, two new processes were introduced, *waste processing*, which means separation of wastes into compostable and non-compostable, and *composting*. The same amounts of wastes were assumed to reach the formal waste system, while the informal part, meaning *informal collection recyclables, burning* and *informal disposal and dumping*, remain constant.
For the input composition into the process, a distribution had to be assumed. Furthermore, not all organic wastes might be separated. Market wastes, for instance, are more suitable for large scale composting than household wastes, as the latter are more often mixed. Assuming an efficiency of 50% of all organic wastes collected, this value is incorporated as transfer coefficient for the process *waste processing*.
The outputs from composting are usually a mass loss due to decomposing, solid composting residues, which usually are sent to the landfill[1] and compost as the desired product. According to Amlinger et al. (2005:8), the composting process is characterized through a composting mass loss of about 55 – 65% and compost output of about 30 – 35%. Thus, transfer coefficients for the process composting of 60%

[1] The projected composting plant is assumed to be close to the landfill.

(0.6) composting mass loss (off-gas and waste water), 30% (0.3) compost output and 10% (0.1) of solid residues were assumed.

The introduction of these processes change not only the amount of waste sent to the landfill, but also the composition of waste at the landfill. This had to be considered.

Figure 2-16 Banda Aceh scenario II "Composting" – MFA model



Scenario III: Waste incineration

While extension of collection service, sanitary landfill and composting are options more or less recommended for and applied in low and medium income countries, waste incineration makes far more waves when waste processing and disposal options are discussed, not only in developing countries[1]. Various arguments for and far more against the application of this technology exist in different solid waste management publications. The main arguments against incineration in low and middle income countries are the high costs of an appropriate treatment, emissions if treatment does not

[1]Examples in Europe are the provinces of Naples in Italy or Tyrol in Austria. In the latter local newspapers do not even use the term incinerator, but *waste oven* in order to further emotionalise the discussion (Tiroler Tageszeitung, February 10, 2008).

meet state-of-the-art standards and simply the low heating value of wastes (The World Bank 1999:9 and 13). This and the fact that in the special case of Banda Aceh the amount of wastes for incineration is too small, makes it a technology where one hardly finds experts support[1]. However, waste incineration with an energy recovery unit stands for the third scenario.

A state-of-the-art waste incinerator is operated through different firing systems, like fluidized bed or grate firing. Energy from the wastes is utilized directly as heat or converted into electrical energy. The off-gas and waste water requires special attention due to air and water pollution. Thus, an air pollution control system (APC) and waste water treatment (WWT) is incorporated. Beside that, waste incineration requires certain ranges of waste heating values. MSW in developing countries often do not meet this required heating value (The World Bank 1999:28).

For the calculation of the scenario, it was assumed that all collected wastes are incinerated. From the incineration, one flux of *solid incineration residues (SIR)* goes to the landfill. As transfer coefficient for this flux a value of 30% (0.3) was chosen[2]. *Waste water and off-gas* were calculated as one stream. All other sources remain stable compared to the current state.

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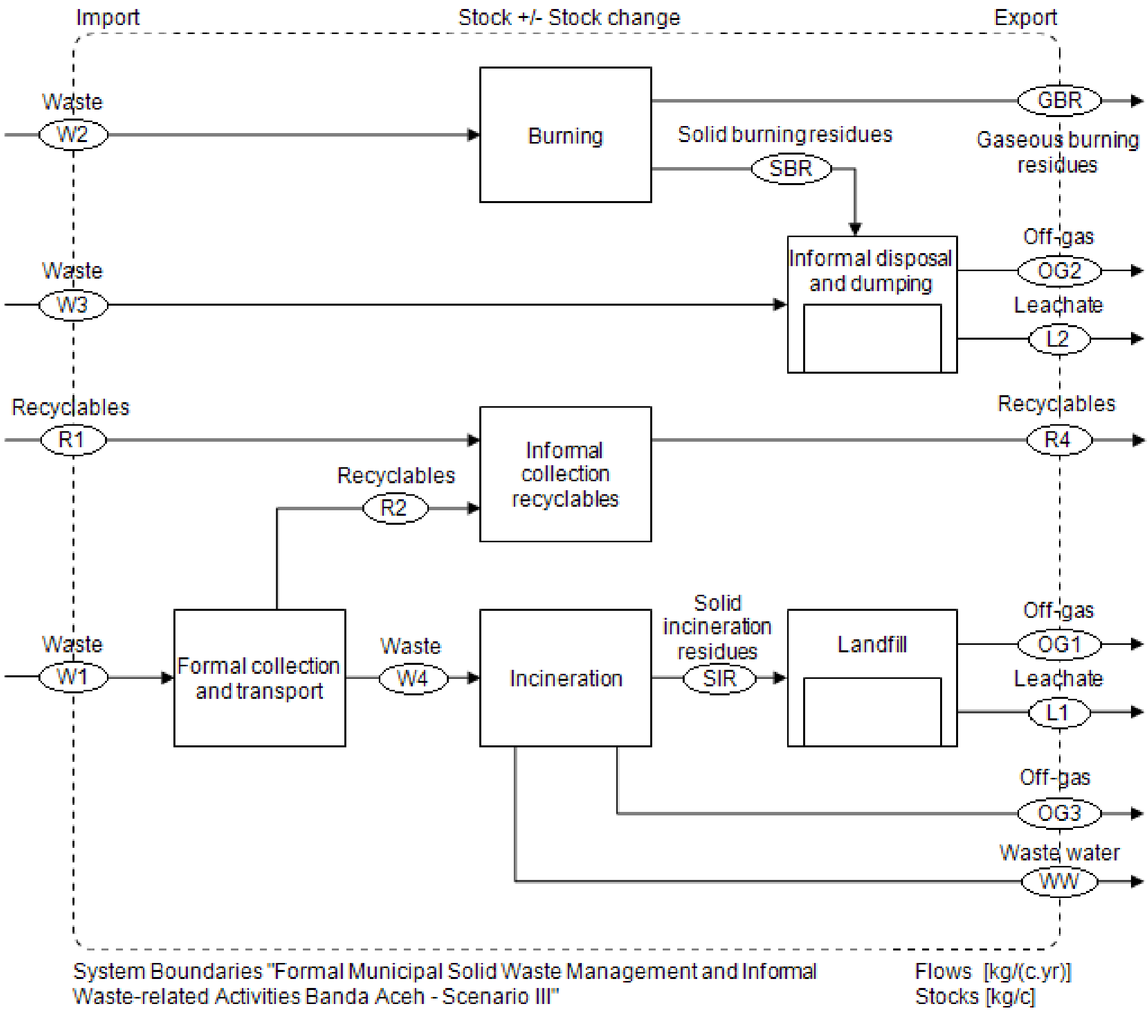
[1]The annual waste generation must be at least 50 000 tons/year (World Bank 1999:52). According to the scenario, only about 40 800 tons/year are incinerated, which would be too low.

[2]According to Stubenvoll et al. (2002:63,71,78), three austrian incinerators with grate firing have ranges of 25 to 33 % solid residues, while CalRecovery (2005:304) give ranges of 20 – 40 %.

Figure 2-17 Banda Aceh scenario III "Incineration" – MFA model



For the calculation of the *energy input - output*, also information about the heating value of the waste and the energy efficiency η had to be obtained. As incineration is only recommended for wastes with a lower heating value of at least 6 000 kJ/kg waste, this heating value was used, even though it is likely and must be strictly pointed out that wastes in Banda Aceh might not meet this value. For the efficiency η, a default value of 0.58 MWh/ton waste for power production is used (The World Bank 1999:28). By applying the conversion factor of 1 Wh = 3 600 J, the energy recovery $E_{recovered}$ can be calculated.

2.6.5 Assessment of status quo and scenarios

Indirect indicators for health and environment

Share of MSW informally disposed, dumped or burned in %

The *Share of MSW which is informally disposed, dumped or burned* is an indirect indicator representing negative effects through wastes on human health and the environment.
While waste burning contributes to urban air pollution affecting the human respiratory system, informal disposal affects in different ways, through direct contact or indirect harm. See chapter 2.3 (page 18ff) for a more detailed discussion.
Unlike the indicator *Share of households without access to waste collection*, it only considers how much waste is informally disposed or burned, but not where.
The indicator is simply the share of MSW informally disposed, dumped or burned, expressed as % of the MSW import total. The output stream from the process *burning* to *informal disposal and dumping* was not considered, as a consideration would mean double counting.
Note that the higher the collection service coverage the lower the indicator and thus the negative impacts on human health and environment are.

Share of households without access to waste collection in %

People not having or using access to waste collection have to dispose, dump or burn their waste informally, most likely in their neighbourhood. Similar to the indicator *Share of MSW informally disposed, dumped or burned*, it is an indirect one, but unlike the former it should show that disposed or burned wastes in peoples' neighbourhood increase the negative effects on human health and environment. To emphasize this point, imagine a poor neighbourhood which is not served by municipal waste collection. Assuming that poorer people generate less waste and business activities are small in the neighbourhood, the share of waste informally disposed or burned might be small compared to the total amount of waste generated, still many people are affected through these negative impacts.
The indicator is expressed in *Share of households without access to waste collection* in % of all households. To simplify, the results from the questionnaire survey were used for all scenarios (see page 32 and 86), except for scenario I, where 100% collection service coverage was assumed.
The higher the coverage the lower the indicator and thus the negative impacts on human health and environment are.

Direct indicators for health and environment

Dioxin (PCDD) and furan (PCDF) emissions into the air in µgTEQ/capita/year

As described in the literature study, dioxin and furan contributes to air, water and soil pollution and affects human health (see page 22). For many years, the context between waste management and dioxin and furan emissions has been investigated, leading to strict regulations, especially for off-gas treatment for formal waste incineration processes. Due to their impact on human health and environment, they are considered.

To calculate the dioxin and furan emissions, UNEPs "Standardized toolkit for identification and quantification of dioxin and furan releases" (UNEP Chemicals 2005) was applied, using one basic formula (UNEP Chemicals 2005:21):

$$\textit{Source Strength} = \textit{Emission Factor} * \text{“}\textit{Activity Rate}\text{”} \quad (2.5)$$

While the *activity rate* is a flux of *feed material processed or product produced* in tons or litres per year, the emission factor is expressed in mass TEQ per unit of feed material or product produced. TEQ means toxic equivalent. The toolkit gives default emission factors for various sources of dioxins and furans. The result is the source strength, expressed in mass TEQ per year.

It must be mentioned beforehand that the emission factors were default values taken out from literature. Thus it might be possible to find different values for the emission factors in literature. However, the toolkit makes calculations easy and comparable with results from other relating studies. See Annex 12.7.1 (page 228) for emission factors used.

For the interpretation it means that the higher the indicator the higher are the negative impacts on human health and environment.

Nitrogen emissions to hydrosphere in gN/capita/year

Nitrogen emissions to the hydrosphere have various affects on human health and the environment. While for example high nitrate (NO_3) concentrations in tap water can lead to methemoglobinemia or blue disease, which can be dangerous especially for infants, nitrogen emissions also contribute to eutrophication, meaning enhanced algae growth in water bodies. Numerous other affects can be named herein, thus nitrogen emissions from MSW activities are considered.

For the current state and the scenarios, nitrogen emissions from the processes landfill and sanitary landfill, informal dumping and disposal and composting can be considered, as their share is presumably dominating. Nitrogen releases from other processes are assumed to be negligible.

Landfill, informal dumping and sanitary landfill

To calculate the emissions, first the amount of nitrogen in biodegradable organic wastes ($N_{biogenic}$) must be detected. Calrecovery (2005:46) gives values between 0.24% and 0.9% nitrogen or 2.4 – 9 gN/kg MSW, Belevi and Bacchini (1989:51) 4 gN/kg MSW and Brunner and Fellner (2007:236) 4 – 7 gN/kg

MSW. Thus a concentration of 5 $gN_{biogenic}$/kg wet MSW for MSW total and 8 $gN_{biogenic}$/kg wet $MSW_{organic}$ for organic waste was used.
For scenario II the MSW at landfill had a lower concentration of 2.5 $gN_{biogenic}$ / kg wet MSW, as half of the organic waste is composted, while the amount of nitrogen from landfilled incineration residues are assumed to be negligible.
For the landfill, sanitary landfill and the informal dumping, about 20% of the $N_{biogenic}$ are middle-term emitted (Belevi and Bacchini 1989). While there is no leachate treatment for informal dumping and the current state[1], a non aerated lagoon system is considered for the sanitary landfill, removing 75% of the nitrogen released (Frascari et al. 2004:339). With following formula, the release of nitrogen for the landfill and the informal disposal and dumping was calculated:

$$N_{hydrosphere} = MSW_{disposed} * c_N * 0.2 \qquad (2.6)$$

$N_{hydrosphere}$	amount of nitrogen released to the hydrosphere in g/capita/year
$MSW_{disposed}$	amount of waste landfilled, dumped or sanitary landfilled in kg/capita/year
c_N	concentration of $N_{biogenic}$ in the waste in $gN_{biogenic}$/kg wet waste
0.2	stands for the 20% of $N_{biogenic}$ which is emitted

For the sanitary landfill, the formula was extended:

$$N_{hydrosphere} = MSW_{disposed} * c_{N\_leachate} * 0.2 * 0.25 \qquad (2.7)$$

0.25	stands for the 25% of $N_{biogenic}$ which is not removed through the leachate treatment

Composting
The composting plant also releases nitrogen in the composting leachate. According to data from Hupe et al. (1997:5), a default value of 0.035 litre leachate per kilogram organic waste and a nitrogen concentration of 0.4 g per litre leachate can be assumed. Considering a leachate treatment system removing 75% of the nitrogen, the formula used for calculation can be written as follows:

$$N_{hydrosphere} = MSW_{composted} * L_{composting} * c_{N\_leachate} * 0.25 \qquad (2.8)$$

$N_{hydrosphere}$	amount of nitrogen released to the hydrosphere in g/capita/year
$MSW_{composted}$	amount of waste composted in kg/capita/year
$L_{composting}$	amount of leachate generated in l/kg organic waste
$c_{N\_leachate}$	concentration of nitrogen in the leachate in g/l
0.25	is the non-removed nitrogen after leachate treatment

Greenhouse gas emissions in kg/capita/year

[1] Even though there is a lagoon treatment of landfill leachate for the current system existing, efficiency is questionable, as there are only two ponds and now liner system to collect the leachate.

Waste management activities contribute to anthropogenic greenhouse gas (GHG) emissions and thus to the humans part on global warming. Hereby, the focus lies on solid waste disposal sites, which show a 3% to 4% contribution to anthropogenic greenhouse gas emissions (IPCC 2006, Vol.5: p.3.6). Relevant greenhouse gases in waste management are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Among them, CH_4 mainly comes from solid waste disposal sites, while CO_2 comes mainly from combustion processes. N_2O-emissions might have a minor impact.

As future projections show growing problems for human and their environment in future through global warming, greenhouse gas emissions are considered as an indicator, focusing on environmental sustainability.

For the calculation, the “2006 IPCC Guidelines for National Greenhouse Gas Inventories” from the Intergovernmental Panel on Climate Change (IPCC), was applied. “Volume 5 – Waste” provides calculation steps for all direct waste related calculations, “Volume 2 – Energy” the collection and transport of wastes.

Table 2-13 Considered greenhouse gas emissions from all processes in the MSWM system

Scenario	Current			Scenario I			Scenario II			Scenario III		
Process	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Formal MSW collection	X	X	X	X	X	X	X	X	X	x	x	X
Landfill		X		Not existing				X		Not considered[1]		
Informal recycling	Not considered[2]											
Burning	X	X	X	Not existing			X	X	X	X	X	X
Informal dumping		X		Not existing				X			X	
Sanitary landfill	Not existing				X		Not existing			Not existing		
Processing + Composting	Not existing			Not existing				X	X	Not existing		
Incineration	Not existing			Not existing			Not existing			X	X	X

(IPCC 2006, own assumptions)

For every scenario and each considered process the emissions were calculated. Then the emissions for each scenario are summed up and transferred into *Global Warming Potential (GWP)* units, in order to get one comparable unit. The GWP conversion factors are 1 for CO_2, 25 for CH_4 and 298 for N_2O, referred to a 100 year time horizon (IPCC 2007:212). Thereafter the total emissions of each scenario are compared with each other. The expression unit is in massGWP/capita/year.

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[1] Waste coming to the landfill from incineration is assumed as non-biodegradable.

[2] A quantification of consumed fuel is too difficult. On the other hand, it might be negligible compared to other GHG sources.

Formal collection of waste (IPCC 2006, Volume 2 “Energy”, Chapter 3 “Mobile Combustion”)
According to IPCC (2006) CO_2 -, CH_4 - and N_2O-emissions m considered. CO_2 was considered as it derives of fossil sources. Note that all formulas and values taken in this chapter refer to the report mentioned above.
Base for the calculations is the amount of fuel consumed per year, in this case diesel. This amount, expressed in litres/year, had to be converted into Terrajoule/year through a conversion factor of $35.3*10^{-6}$ Terrajoule/litre. Then the Tier I method was applied using the formula

$$Emission = \sum_a Fuel_a * EF_a \qquad (2.9)$$

$Emission$	emissions of CO_2 / CH4 / N2O in kg
$Fuel_a$	fuel consumed in TJ
EF_a	emission factors for each substance in kg/TJ
a	type of fuel (diesel, petrol, etc.)

to calculate CO_2 -, CH_4 - and N_2O-emissions (IPCC 2006:3.12-3.13). Default values for emission factor can be found at IPCC (2006:3.16 and 3.21).
For the interpretation it means that the higher the indicator the higher are the negative impacts on environment.

Landfill, informal disposal and dumping, sanitary landfill (IPCC 2006, Volume 5 “Waste”, Chapter 3 “Solid Waste Disposal”)
From these processes, the greenhouse gas methane from a today disposed waste generates over a long period of time. IPCC considers in its calculation tables a time span of 80 years (1950 – 2030), the same time span, but starting from 2007, is used. Taking the total amount of degradable organic waste per year 2007, the generation of methane from this annual amount over the next 80 years (2007 – 2087) was calculated. The result is expressed in mass CH_4/capita/year.
By using the excel spreadsheet from IPCC for a first order decay of organic degradable material, the IPCC Tier 1 method was applied. Within this table, the waste data from each scenario was inserted only into the first calculation row for the year 1950. For all other rows, no data was inserted. By doing so, excel calculates the amount of methane generated until 2030 from the data inserted for the year 1950, which means over a time span of 80 years.
Then the landfill or dumping data had to be inserted, meaning how the organic waste is disposed. By assuming a waste composition, the decision was made to consider the organic materials food waste and paper. For the amount of degradable dry organic carbon (DDOC) in each fraction, IPCC gives default data in the excel spreadsheet.

Burning and incineration (IPCC 2006, Volume 5 “Waste”, Chapter 5 “Incineration and open burning of wastes”)

For both processes, all mentioned GHG emissions were considered. Important for CO_2 emissions is the amount of waste burned/incinerated and its composition, particularly the plastic fraction, as it is from fossil origin. Furthermore, the efficiency of the combustion process influences the CO_2 generation. As incineration type a semi-continuous grade incinerator was assumed. IPCC gives default values for the fraction of carbon and fossil carbon in the material[1] and the oxidation factor (IPCC 2006:5.18).
To calculate CH_4 - and N_2O-emissions, the total amount of waste burned was multiplied with an emission factor. IPCC gives default values for theses emission factors (IPCC 2006:5.20-5.22).

$$CO_2\ Emission = \sum_i (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12} \qquad (2.10)$$

$CO_2\ Emission$ CO_2 emissions in inventory year in Gg/year

SW_i total amount of solid waste of type *I* (wet weight) incinerated or open-burned in Gg/year

dm_i dry matter content in the waste (wet weight) incinerated or open-burned (fraction)

CF_i fraction of carbon in the dry matter (total carbon content; fraction)

FCF_i fraction of fossil carbon in the total carbon (fraction)

OF_i oxidation factor (fraction)

$\frac{44}{12}$ conversion factor from C to CO_2

i type of waste incinerated/open-burned (herein only MSW) (IPCC 2006:5.7)

$$CH_4\ Emissions = \sum_i (IW_i * EF_i) * 10^{-6} \qquad (2.11)$$

$CH_4\ Emissions$ CH_4 emissions in inventory year in Gg/year

IW_i amount of solid waste of type *i* incinerated or open-burned in Gg/year

EF_i aggregate CH_4 emission factor in kg CH_4/Gg of waste

10^{-6} conversion factor from kilogram to gigagram

i category or type of waste incinerated/open-burned (herein only MSW) (IPCC 2006:5.12)

$$N_2O\ Emissions = \sum_i (IW_i * EF_i) * 10^{-6} \qquad (2.12)$$

$N_2O\ Emissions$ N_2O emissions in inventory year in Gg/year

IW_i amount of solid waste of type *i* incinerated or open-burned in Gg/year

[1] For default values of carbon and fossil carbon, see IPCC 2006, Volume 5 "Waste", Chapter 2 "Waste generation, composition and management data", page 2.14.

EF_i aggregate N_2O emission factor in kg N_2O/Gg of waste

10^{-6} conversion factor from kilogram to gigagram

i category or type of waste incinerated/open-burned (herein only MSW) (IPCC 2006:5.13)

Processing and Composting (IPCC 2006, Volume 5 "Waste", Chapter 4 "Biological treatment of solid waste")

Scenario II contains a large scale composting unit. Such composting units produce CO_2, which is not considered as not from fossil origin, but also CH_4 - and N_2O-emission. The latter are both considered. For the calculation according to Tier I method, the amount of organic waste composted was multiplied by emission factors (page 4.6). The formulas applied were:

$$CH_4\ Emissions = \sum_i (M_i * EF_i) * 10^{-3} - R \qquad (2.13)$$

$CH_4\ Emissions$ total CH_4 emissions in inventory year in Gg CH_4

M_i mass of organic waste treated by biological treatment type i in Gg

EF_i emission factor for treatment i in g CH_4/kg waste treated

i composting or anaerobic digestion conversion factor from gram to kilogram

10^{-3} conversion factor from gram to kilogram

R total amount of CH_4 recovered in inventory year in Gg CH4 (IPCC 2006:4.5)

$$N_2O\ Emissions = \sum_i (M_i * EF_i) * 10^{-3} \qquad (2.14)$$

$N_2O\ Emissions$ total N_2O emissions in inventory year in Gg N2O

M_i mass of organic waste treated by biological treatment type i in Gg

EF_i emission factor for treatment i in g N_2O/kg waste treated

i composting or anaerobic digestion (IPCC 2006:4.6)

Conversion of all values from Gg/year to kg/capita/year

$$perCapita\ Emissions = \frac{Emissions\ * 10^6}{Population} \qquad (2.15)$$

$perCapita\ Emissions$ emissions of CO_2, CH_4, N_2O in kg/capita/year

$Emissions$ emissions of CO_2, CH_4, N_2O in Gg/year

$Population$ population Banda Aceh 2007

10^6 conversion factor from gigagram to kilogram

Indicators for resource conservation

MSW not recycled in %

As mentioned in chapter 1.1, waste is not only a threat to human health, but also a potential source of materials. Thus valuable raw materials are collected, in higher income countries rather through formal, in lower income countries through the informal sector. By substituting primary raw materials through recycling materials, primary resources are conserved.

Usually, material recycling is expressed by the material recycling rate, which is the ratio of recycled materials from MSW to the MSW generation rate in %. However, using this indicator would be unsuitable herein. If later on all indicators are placed next to each other in a diagram and for every indicator waste management desires a decline, it would be confusing if there is one indicator where an increase is desired. This would be the case for the material recycling rate, as a higher rate is desired. Thus not the material recycling rate was used as an indicator, but the amount of MSW which is not recycled. The formula for calculation can be written as follows:

$$MSW\ not\ recycled = \frac{recycling\ materials\ collected}{total\ MSW\ generated} * 100\% \qquad (2.16)$$

While for the total waste generation the total import into the system was used, for recycling materials collected the export of recycling materials from the system was substituted. It is obvious by glancing at the formula that the sum of MSW not recycled and the material recycling rate should give the MSW generation rate.
The lower the share of MSW not recycled is, the higher is the resource conservation.

Energy input - output in MJ/capita/year

While there are inputs of external energy necessary for various processes in the MSWM system, some of the energy in the waste can be recovered.
Generally, two main applications for energy recovery in MSWM are widely used, first by using methane of organic waste produced in an anaerobic digester or landfill and second the incineration of waste. Herein, only the latter for scenario III was considered.
Unlike an usual energy balance, in the *energy input-output* indicator the energy recovered is subtracted from the energy demand. However, if calculated like this, the later illustration of all indicators is much easier.
For a basic calculation on one hand the amount of external energy demand and on the other, the amount of waste incinerated, its heating value and its energy efficiency had to be obtained. For every scenario, the external energy demand refers to the assumed fuel demand.
Energy input-output = Edemand - Erecovered

$$Energy\ input - output = E_{demand} - E_{recovered} \qquad (2.17)$$

E_{demand} Energy demand in MJ/capita/year

$E_{recovered}$ Energy recovered in MJ/capita/year

One can see that this value is the reciprocal of a normal energy balance. Then a lower energy input - output value leads to higher resource conservation.

Landfill volume required in m³/capita/year

Where space is scarce, the amount of waste landfilled matters more. This is a more urgent problem in city states like Hong Kong or Singapore or densely populated nations and islands like Japan, the Netherlands or Java. In Austria or Banda Aceh landfill space nevertheless is more available. However, as land is a resource, the landfill volume required is used as an indicator for resource conservation. For calculation, the amount of waste landfilled for each scenario was multiplied with the mean emplacement density. This requires a default value for the latter. The default value for the emplacement density used was 1 000 kg/m³ (Lechner et al. 2004:66ff; CalRecovery 2005:327ff). This value was taken for all landfilled wastes, except for incineration residues, where a default value of 1 500 kg/m³ was used. Waste which is informally disposed or dumped was not considered.

$$V_{required} = MSW_{landfilled} * \rho_{waste} \qquad (2.18)$$

$V_{required}$ is the required landfill volume, $MSW_{landfilled}$ is the amount of waste landfilled and ρ_{waste} is the emplacement density.
The lower the landfill volume, the higher is the conservation of resources.

Costs of scenarios

For each scenario, the costs of solid waste management were calculated and later compared with the current state and with each other.
While for collection and landfilling, per ton of waste costs from the current state were used, the costs for the extensions sanitary landfill, processing/composting and incineration were taken from the literature. Cointreau (2006:7ff) and CalRecovery (2005:504) give default values for different waste management processes for low, middle and high income countries (see Annex12.6.6, page 225). These default values have a certain range, depending on complexity of the system, economy of scale, labour costs or natural properties, like the geology of the landfill site. Also, the default values include owning, operation and maintenance and debt service. Note that all figures are expressed as US $ per ton of waste input into the process.

Sanitary landfill

While CalRecovery (2005:504) gives values of 5 – 30 $/ton, Cointreau (2006:8,9) states from 3 – 15 $/ton for low and middle income countries. Hereby, the restriction lies on cities over 500 000 inhabitants 250 tons of waste per day landfilled respectively. Even though Banda Aceh does not meet the required population, the required input flow of waste can be nearly achieved (see page 105).

Considering Cointreau's values and the utilization of liners, leachate collection and treatment, but no landfill gas collection, a default value of 15 $/ton or 11 €/ton seemed to be plausible.

Processing/Composting

Both, CalRecovery (2005:504) and Cointreau (2006:8,9) assume costs from 5 – 40 $/ton for composting in low and middle income countries. Assuming and indoor medium technology for screening, aeration and turning of windrows utilized, a default value of 25 $/ton or 18 €/ton input material into the processing and composting unit was taken.

Incineration

For incineration, CalRecovery (2005:504) and Cointreau (2006:8 and 9) assume costs from 30 – 80 $/ton of waste processed. The higher range of costs includes a state-of-the-art air pollution control system (APC) and appropriate waste water and solid incineration residues treatment. Following this restriction, a default value of 80 $/ton or 58 €/ton incinerated was used.

3 Results goal oriented assessment

3.1 Municipal solid waste management system Vienna

All figures refer to the *MA48 Leistungsbericht 2006* (MA48 2007) and interviews with the MA48 office (MA48 2007).

3.1.1 Relevant processes and quantities of major municipal solid waste streams

Collection and transport of wastes

Waste collection is the process that links waste generating sources with waste processing and disposal. According to Vienna's Waste Management Act (Wr. AWG 1994), § 17, every owner (generator et al.) of wastes has the right of access to a municipal waste collection, but is also obliged to do so. Even though there are some exclusions existing, it means a de-facto *obligatory connection* for waste generating sources.

In Vienna, source separation of different waste fractions takes place on waste generator level. The combined kerbside collection/ bring system collects 21 different fractions of wastes, according to the Austrian standard "ÖNORM S2100" – classification (MA48 2002,1:6; MA48 2007:23).
The collection in Vienna is primarily run by the municipal department MA48 and to a lesser extent by some entrepreneurs.
Source separation, which was introduced in the late 1970s initially to collect waste paper and glass separately, dominates the distinction between different input goods into the *collection and transport* process.
Separation is primarily determined by the desire to collect recyclable materials or, in case of bulky wastes, by the size of wastes.
Whereas waste glass and waste paper collection was primarily driven by the ability to recycle it in an economical way, the primary driver for collecting organics and packaging materials were the desire to reduce the waste streams to landfills and incinerators. For packaging materials, a system known as the "Abfall Recycling Austria (ARA) - System" was founded by the packaging industry. In response to the *Packaging Ordinance* (VerpackVO, BGBl. Nr. 645/1992), enterprises affected by this ordinance established a system to collect separately the recyclables origin from packaging.
In the descriptions and calculations, only the main waste streams will be considered. All denominations and stream sizes origins from the *MA48 Leistungsbericht 2006* (MA48 2007:23).

<u>Mixed waste</u>

What is termed as *mixed waste* describes wastes from households and commercial and industrial waste from the same category, collected mainly through the *Systemsammlung* (kerbside collection of system

wastes) and to a lesser extent by bring system, but also medical wastes from the same category as household wastes.
System waste in this regards means “the volume of waste collected in containers of 120…[to]…4400 litres size within the city’s waste collection system serviced by MA48” (MA48 2002,2).
Considering the definitions above, the total annual amount of mixed wastes in Vienna is 535 984 tons/year or 326 kg/capita/year (MA48 2007:23)

<u>Bulky waste</u>

Bulky waste, per definition, is waste that, due to its size or mass, cannot be collected through the waste collection system (FWMP 2006:34). Practically it means that waste containers of MA48s kerbside collection system are too small for these wastes. Thus, bulky waste is collected through bring collection, where producers themselves bring the waste to waste collection centres (*Mistplätze*) to hand it over. MA48 operates 19 of these centres.
The total amount of bulky wastes in Vienna is 30 933 tons/year or 19 kg/capita/year.

<u>Road waste</u>

Road waste is waste collected through road-sweeping and cleaning of large surface areas and, to a lesser extend, waste from public waste bins (BMLFUW 2006:41). Total amount in Vienna is 34 922 tons/year or 21 kg/capita/year. However, as street cleaning is not considered within the cost accounting, also this waste fraction can not be considered.

<u>Waste paper, cardboard</u>

Waste paper and cardboard are usually collected together by both, kerbside collection and bring system. The distribution density of containers is the highest among the recyclables glass, plastics and metals. Furthermore, *waste paper and cardboard* are the only considerable recyclables which are not collected by MA48, but by a private enterprise. Responsible for collection and processing are the *Altpapier Recycling Organisationsgesellschaft mbH* (ARO), part of the ARA-system.
The total amount of collected waste paper and cardboard for Vienna is 132 470 tons/year or 80 kg/capita/year.

<u>Waste glass</u>

Waste glass is collected by MA48, the responsibility for collecting and processing lies with the *Austria Glas Recycling GmbH* (AGR), part of the ARA-system. A combined kerbside collection and bring system collects clear glass and coloured glass separately. The bigger portion comes from packaging glass, the far smaller from other origin.
In total, 25 358 tons/year or 15 kg/capita/year were collected.

Plastics

Plastic recycling procedure has changed for several times since it was introduced in 1989. In the beginning, only yogurt cartons and plastic film were collected. After several schemes were applied, regulatory frameworks have changed following negotiations between packaging industry and policy makers, nowadays only plastic containers are collected.
The responsibility for collection and processing lies with the *ARGEV Verpackungsverwertungs Gesellschaft mbH* (ARGEV), part of the ARA-system, the collection is operated by MA48. Therefore a bring system with waste collection points and centres was established.
Latest figures showed an amount of 5 546 tons/year or 3 kg/capita/year plastic collected.

Metals (packaging)

The distinction between packaging and non-packaging metals can be difficult, as not all metals collected in the containers origins from the former one. This is even clearer if one considers the separate collection regulations of MA48, where, beside *packaging metals*, also cookware or metal fittings are mentioned.
Nevertheless, the ARGEV is, as for plastics, responsible for collecting and processing of *packaging metals*, the collection is undertaken by MA48. The bring system is similar to that of plastics, the main packaging goods collected (besides the ones mentioned above) are tin cans and aluminium products, which will be separated later on by magnetic separation.
Thus the total amount collected is 2 108 tons/year or 1 kg/capita/year.

Metals (non packaging)

Non packaging metals are usually collected at the MA48's waste collection centres by a bring system. The amount collected gives 18 515 tons/year or 11 kg/capita/year.

Wood

Wood is collected through MA48 at the waste collection centres. The lions share is processed wood, containing additives like protective coatings, making up more than 90 % of the wood collected. The others are packaging and unprocessed wood.
Totally, 39 519 tons/year or 24 kg/capita/year were collected.

Organic wastes

Organic wastes are, according to the *Biogene Verordnung* or *biogenic ordinance* (BGBL. Nr. 68/1992), wastes suitable for aerobic or anaerobic treatment, due to their high biodegradable content. Practically, organic kitchen and garden wastes are collected and later processed in a composting plant, except leftover food of animal origin.
The containers are placed at kerbside collection points or directly at major residential complexes.

The amount collected was 99 639 tons/year or 60 kg/capita/year.

Electrical and electronic waste

The booming electronic sector is characterized by new innovations and technologies, influencing customer behaviour enormously. New products enter the markets so fast that a consumer good *bought today will be old tomorrow*. This leads to an increase in electrical and electronic wastes. The European Commission, for instance, estimates and annually increase of 3 – 5% of the electrical and electronic waste stream (BMLFUW 2006:153). This rapid increase, together with the properties of these wastes like potentially hazardous materials content and richness in valuable materials, drive the European Union to pass legislation, namely the *Directive of the European Parliament and of the Council on Waste Electrical and Electronic Equipment* (2002/96/EU) (WEEE). It regulates the collection, recycling and disposal of all kinds of wastes subsumed under this terminology.
MA48 has established, according to the *WEEE – Directive*, a *free of charge* – bring system to its waste collection centres. From there the wastes are sent to the waste treatment plant, where they are further processed.

Other wastes

As mentioned, only main waste streams are considered within the MSWM system. That does not mean that the streams not considered here are unimportant. The main reason for this is to keep track the system easier and to simplify comparability to other regions MSWM systems.
Two of the streams which deserves special attention are the inert waste fraction and hazardous waste. The first is important due to its quantity. In 2006, Vienna's MA48 collected 101 800 tons/year or 62 kg/capita/year of inert materials, which makes around 10% of the total quantity of labelled as municipal solid waste in Vienna. The largest portions of inert wastes are construction and demolition waste from small construction sites, collected at the waste collection centres, and grit sweepings from the winter service (MA48 2007:23).
Most of these wastes are brought directly to the Rautenweg landfill.
The second important stream is hazardous wastes. The quantities of all its branch streams are marginal in comparison to the former and give in total 7 042 tons/year or 4 kg/capita/year, which is around 0.7% of the total amount of municipal solid waste (MA48 2007:23). More important is the quality of these wastes, as they are hazardous to human health or contain hazardous substances to a certain level (BMLFUW 2006:70). Some examples are leas batteries, medicine or organic pasty in liquid or solid state. The main portions, from the quantities, are visual display units, refrigerator equipment and vehicle wrecks.
The treatment depends on the goods and the content materials. Where some goods, like vehicle wrecks, are directly transferred to extern treatment, outside of Vienna municipal responsibility, others are sorted in the sorting plant and/or incinerated at the incineration plant *Simmeringer Haide* (Fernwärme Wien 2006:12-13; MA48 2007).

Table 3-1 Vienna 2006 – process collection

No.	Waste stream	Quantity [tons]	Mass flux [(kg/(c.yr)]
1	Mixed waste total	535 984	325
2	Bulky waste total	30 922	19
3	Waste paper and cardboard total	132 470	80
4	Waste glass total	25 358	15
5	Plastics packaging, total	5 546	3
6	Waste metals, packaging	2 108	1
7	Waste metals, non-packaging	18 515	11
8	Waste wood	39 519	24
9	Organic waste	99 565	11
	Total	889 951	539

(MA48 2007:23; MA48 2007)

Sorting plant

The sorting plant is part of the waste processing plant Rautenweg. Three mechanical or manual sorting procedures will be discussed.

The first refers to the sorting of packaging wastes collected separately by municipal waste collection. The wastes are delivered and sent to the manual separation by a conveyor belt. Before it reaches the separation chamber, metals are removed by magnetic separation. Recoverable plastics and metals are sent for recycling, residues directly to the landfill or incineration.

A portion of the mixed and bulky wastes are also processed at Rautenweg, making the second stream of sorting. A mechanical separation splits the waste into metals, a heavy, organic-rich fraction and a light fraction, dominated by plastics and other energy-rich fractions. Whereas the metals are recycled, the light fraction is sent directly to incineration or via temporary storage at landfill Rautenweg. The heavy fraction is either sent partially to further mechanical-biological treatment outside the defined spatial system border, or incinerated at *Simmeringer Haide* (MA48 2002,2; MA48 2007). Waste electrical equipment is dismantled manually.

Beside the processes mentioned above, the waste treatment plant contains an temporary storage for hazardous wastes, a treatment plant for incineration residues and a pre-treatment plant for organic wastes (MA48 2006:64)

Table 3-2 Vienna 2006 – process sorting

No	Waste stream	Input / Output	Source / Sub-sequent process	Quantity [tons]	Mass flux [(kg/(c.yr)]
1	Mixed waste	Input	Collection	123 092	75
2	Recyclables	Input	Collection	48 876	30
	Input total			171 968	104
3	Residues to incineration	Output	Incineration	105 881	64
4	Residues to landfill	Output	Landfill	10 965	7
5	Recyclables	Output	Export	47 950	29
6	Others	Output	Export	5 581	3
	Output total			170 377	103

(MA48 2007)

Waste pre-treatment – Incineration

Vienna has three waste incinerators in use, the *MVA Spittelau*, *MVA Flötzersteig* and *MVA Simmeringer Haide*. A fourth incinerator, *MVA Pfaffenau*, is currently under construction.
MVA Spittelau treats the largest portion of MSW in Vienna. The system processes are a waste bunker for waste storage, a reciprocating grate firing system, a combined heat and power energy utilization system and a state of the art flue gas cleaning and waste water treatment system. Part of the energy is transformed into electricity through a backpressure turbine, part is utilized for the remote district heating network through heat exchangers. The flue gas cleaning system contain an electrostatic precipitator, a three-stage wet scrubber and a catalyst for NO_x – removal and dioxin destruction (Stubenvoll et al. 2002:67-74).

MVA Flötzersteig is according to the incinerated quantity of MSW the second biggest plant in Vienna. System processes contain a waste bunker for waste storage, a combined forward and backward moving grate firing system, a heat boiler and a state of the art flue gas cleaning and waste water treatment system. All energy is transformed into heat and serves proximate bulk purchasers and the remote district heating network. The flue gas cleaning system contain an electrostatic precipitator, a three-stage wet scrubber and a catalyst for NO_x – removal and dioxin destruction (Stubenvoll et al. 2002:60-66).

The third plant, MVA Simmeringer Haide, treats predominantly sewage sludge from Viennas main waste water treatment plant, a big portion of hazardous wastes from entire Austria, but also a portion of conditioned MSW. The system contains storage and pre-treatment for the different wastes, firing is done by two fluidised bed reactors for the sewage sludge, three rotary kilns for hazardous wastes and amendments and a fourth rotary kiln to treat the conditioned MSW. Waste batteries are treated separately.

Flue gas cleaning includes an electrostatic precipitator, wet scrubbers, an active carbon filter and a catalyst for NO_x – removal. (Fernwärme Wien 2006:4-8). The energy is transformed by a combined heat and power energy utilization system to electricity and heat to the remote district heating network. Slag and bottom ash, the main non-gaseous residues, are further processed in the waste processing plant Rautenweg. There they are mixed with cement and other amendments in order to produce some kind of slag concrete, which is disposed at the landfill Rautenweg.

Table 3-3 Vienna 2006 – process incineration

No	Waste stream	Input / Output	Source / Sub-sequent process	Quantity [tons]	Mass flux [(kg/(c.yr)]
1	Mixed waste from system collection	Input	Collection	401 012	243
2	Mixed-, bulky and other wastes from landfill	Input	Landfill	14 991	9
3	Mixed and sorted wastes from sorting plant	Input	Sorting plant	109 890	67
	Input total			525 893	318
4	Slag and bottom ash	Output	Landfill	140 673	85
5	Scrap iron	Output	Export	13 409	8
6	Filter cake	Output	Export	407	0
7	Slag ASA	Output	Export	8 085	5
8	Waste water + Off-gas	Output	Export	363 319	220
	Output total			525 893	318

(MA48 2007)

Composting plants

Organic wastes from the separate collection are conditioned at the waste processing plant *Rautenweg* and further processed at the composting plants *Lobau* and *Schafflerhof*. The conditioning contains removal of contraries and mixing with shredded bulking material. Afterwards the mixture is transported to the composting plants, where it undergoes an open windrows composting process.

The input into the process *Composting plants* contains the 96 639 tons/year or 59 kg/capita/year of collected organic wastes and 19 165 tons/year or 12 kg/capita/year of bulk material, the output 38 714 tons/year or 23 kg/capita/year compost, 2 135 tons /year or 1 kg/capita/year contraries and metal, 52 856 tons/year or 32 kg/capita/year waste water and off-gas, 13 409 tons/year or 8 kg/capita/year compost residues to the sorting plant and 8 689 tons/year or 5 kg/capita/year to other waste processing agents (MA48 2007).

Table 3-4 Vienna 2006 – process composting

No	Waste stream	Input / Output	Source / Sub-sequent process	Quantity [tons]	Mass flux [(kg/(c.yr)]
1	Compost raw material	Input	Collection	96 639	59
2	Bulk material	Input	Import	19 165	12
	Input total			115 804	70
3	Contraries, metal	Output	Export	2 135	1
4	Compost residues to sorting plant	Output	Sorting plant	13 409	8
5	Compost residues	Output	Export	8 689	5
6	Compost	Output	Export	38 714	23
7	Waste water + off-gas	Output	Export	52 856	32
	Output total			115 803	70

(MA48 2007)

Landfill

Vienna has one landfill for residual wastes, called landfill *Rautenweg*. It is located close to the waste treatment plant with the same synonym. The main quantity of wastes derive from incineration residues like slag and bottom ash, followed by inert wastes, mixed wastes from waste collection and residues from processes like sorting. Incineration residues are dumped after stabilization through mixing it with cement and other amendments. Inert wastes are not considered for the calculations.

According to § 76 of the Waste Management Act 2002, the total organic carbon content of wastes dumped at a landfill is limited to five % by volume. This claim must be implemented by end of 2008, what makes it impossible afterwards to send mixed waste without pre-treatment to the landfill. Rautenweg landfill is, after some adaptions, a state of the art landfill construction, with a two diaphragm wall enclosure, reaching into the impervious layers below the aquifer. The water level inside this enclosure is lowered by a pump, in order to create a hydraulic gradient from outside to inside the enclosure. The landfill gas is collected by a pipe network system and transformed to electricity. Leachate is treated at the waste water treatment plant of Vienna.

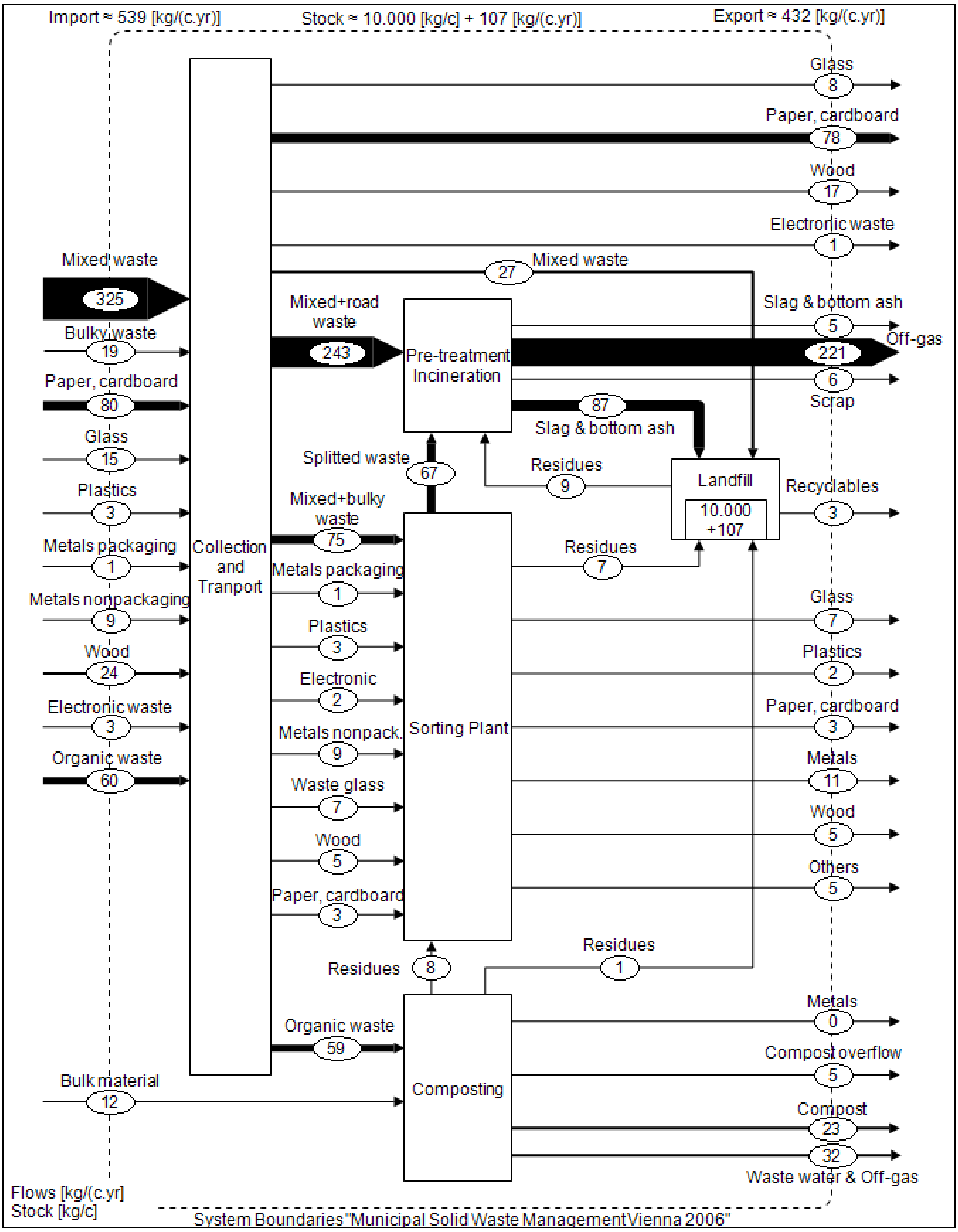
Table 3-5 Vienna 2006 – process landfill

No	Waste stream	Input / Output	Source / Sub-sequent process	Quantity [tons]	Mass flux [(kg/(c.yr)]
1	Mixed waste from collection	Input	collection	44 766	27
2	Residues sorting	Input	sorting	10 965	7
3	Slag and bottom ash		incineration	142 886	87
4	Residues composting			1 990	1
	Input total			198 617	121
5	Residues to incineration	Output	incineration		
6	Recyclables	Output	export	18 557	11
7	Miscellaneous	Output	export	4 825	3
	Output total			23 382	14
	Difference (= Stock)			175 235	107

(MA48 2007)

MSWM system of Vienna - Material Flow Chart

Figure 3-1 Vienna 2006 – resulting MFA chart



(MA48 2007:23; MA48 2007)

3.1.2 Costs of Vienna's municipal solid waste management

Finance distinguishes between different cost categories, notably operating costs and investment costs, but also costs of each process unit within an enterprise, which also counts for MSWM. To identify the *real costs* of MSWM activities is thus an important step towards transparency in order to assess the current situation and future options in MSWM planning. The objective herein was to incorporate investment and operating costs for all processes within the defined system.

Closing of Accounts 2005

Referring to the figures given in the Closing of account 2005 (MA5 2006:137-172) (see Annex 12.2, page 213), the balance sheet shows expenditures of roughly 110 €/capita/year for MSWM including depreciated investments, but without street cleaning[1]. Taking a depreciation period of 10 years and linear depreciation, the calculated investment costs are with about 1 €/capita/year less than one % of the total expenditures. However, these investments refer to the collection fleet purchased within the budget period, but not for long term investments, like the incineration plants, the landfill or the composting plant. Particularly for the older incineration plants, like the one at Spittelau, and the waste sorting unit Rinterzelt, it is difficult to give investment costs, as several modifications were carried out over the last 40 years (MA48 2007). Thus one can consider this value of 110 €/capita/year as the operating costs.

The largest portion herein are personnel costs, which are about 55 €/capita/year or 50% of total expenditures including depreciated investments. The second largest portion is expenditures for miscellaneous services, making up 35 €/capita/year or 32%.

Table 3-6 Vienna 2006 – expenditures, according to the closing of accounts 2005

	Total annual costs [€/yr]	Per capita annual costs [€/(c.yr)]
Total expenditures (including investments)	193 111 505	117
Investments	13 166 185	8
Depreciated investments	1 316 619	1
Expenditures without investments	179 945 320	109
Expenditures including depreciated investments	181 261 939	110

(MA5 2006:137-172; see details at Annex 12.2, page 213)

[1] If street cleaning would have been considered, the figure would boomed to 160 €/capita/year (Annex 12.2, page 161).

Cost structure

From the Closing of accounts 2005, a detailed distinction between investment and operating costs for every process of the MSWM system in Vienna cannot be done. Thus, alternative sources are taken. The expert report for the strategic environmental audit of Viennas SWM gives a ratio of 30 to 70 % between *waste collection and transport* and *disposal and treatment*. Brunner and Fellner (2007:238) give a more detailed distinction by a ratio of 29% to 59% to 12% between *waste collection and transport*, *treatment* and *disposal*.

When calculating the costs of future waste management, MA48 takes reference values for several processes in the system which includes both, operating and investment costs. If these values are used, the total costs can be calculated partially.

Table 3-7 Vienna 2006 – available reference costs for waste treatment processes

Process	Costs per ton [€/ton]	Waste treated [ton/(c.yr)]	Costs per capita [€/(c.yr)]
Incineration	140	0.24	34
Landfill	87	0.13	11
Composting	90	0.06	5
Total			50

(MA48 2007)

If it is assumed now that waste collection and transport is about 30 % of the calculated costs of 110 €/capita/year, 33 €/capita/year are required for this item, which would subsequently mean that the costs for MSWM excluding the sorting plant are 83 €/capita/year. For the waste separation plant, no such values are available, which makes it the unknown factor herein.

Still, the information is does not provide the answer to the question, how high the *real* costs are. If only the investment costs for the waste incineration plant are considered, an increase of 16 €/capita/year, which suggests that the *real costs* might be higher.

Table 3-8 Depreciated investments for waste incineration

Costs per unit [€]	Units	Population	Depreciation period [yrs]	Costs per capita [€/(c.yr)]
215 000 000	3	1 651 437	25	16

(MA48 2007)

3.2 Municipal solid waste management Banda Aceh

3.2.1 Background information on municipal solid waste management in Banda Aceh

According to the background research from interviews with stakeholders and parties involved, field visits and participant observation a material flow diagram scheme is drawn, as shown in Figure 2-15. (page 49).

Waste generating sources

By the definitions mentioned above under chapter 2.4 (page 26) waste generating sources are establishments producing wastes whereas municipal authorities are responsible to collect and dispose it. In Banda Aceh, the presumably most noteworthy establishments are households, educational institutions like schools and universities, public offices and governmental establishments, small enterprises, gastronomy establishments like restaurants or hotels, hospitals and markets. Waste from industries, which are sometimes also handled by municipal authorities and collected along with MSW plays a minor role in Banda Aceh[1].

Waste collection and transport

Formal municipal waste collection and transport is undertaken by DKP. Therefore DKP has divide Banda Aceh into five collection zones (zone A – zone E). The collection itself contains both, kerbside collection of waste bins at their source and a bring system, where producers can bring their wastes to central collection containers (DKP 2007). On a city map, drawn by DKP, all five zones and some of the containers are illustrated[2].

The waste from kerbside collection is collected by 26 ordinary trucks, four compactor trucks and ten pick-ups. From collection the waste is sent directly to the landfill at Gampong Jawa.

Even though there is no formal separate collection scheme, it has been observed that DKP collection staff separate the waste during collection. One reason might be that there are five recycling agents at the landfill Gampong Jawa (DKP 2007) buying recyclable materials, either from scavengers picking the materials from the waste and, as presumed, from the DKP collection staff.

Actually, between 75 and 80% of the villages are covered by the waste collection service, or in figures, 12 of 86[3] villages are not covered yet (DKP 2007).

[1] According to DKP (2007:28), only 4 % of employees work in the industry. Due to this and information through personal communication, industry does not seem to be an important source of wastes.

[2] The digital city map was copied after the Interview with DKP on the 11. September 2007. On the map there are not all the 85 containers in town inserted, but only 58.

[3] According to DKP (2007) there are 90 villages in Banda Aceh. If 12 villages are not covered, coverage is about 86.7 % of all villages. However, according to BPS (2007), there are 86 villages in Banda Aceh. The %age of villages covered does not change significantly to 86.0 %. The figure from DKP is 75 – 80 % as it contains also villages, where the collection service is not frequently.

Figure 3-2 Banda Aceh 2007 – process collection: waste bins (left) and collection vehicle (right)

Beside kerbside collection, central collection containers are part of the MSW collection service. There are about 85 containers in town, mainly at strategic places where high amounts of waste can be expected, like marketplaces. MSW producers can dispose their waste there.

Figure 3-3 Banda Aceh 2007 – process collection: two containers of DKP

Another form of waste collection was observed during the research stay in Banda Aceh. Some areas have a combined formal-informal collection scheme, were informal waste pickers collect the waste from households and other MSW producers with their own vehicle and send it to one of the central collection containers.

Informal dumping and burning of wastes

From interviews, no information was obtained about the quantities of MSWs which are disposed informally or burned. However, it is reported that these methods exist in Banda Aceh[1]. Now, it is one aim of the study to describe these methods qualitative and quantitative. When researchers were walking through the city of Banda Aceh, some of informal disposal practises were documented.

[1] Not only information from residents of Banda Aceh (students and lecturers from Syiah Kuala Universitas, other acquaintances) lead to this presumption, but also information gathered by researchers inBanda Aceh.

Figure 3-4 Banda Aceh 2007 – process informal disposal and dumping

For the burning more or less sophisticated fire places were observed. Wastes are generally piled up at these fireplaces and burned, when the pile has reached a critical size. It seems as if some people let their waste dry in order to burn it easier.

Figure 3-5 Banda Aceh 2007 – process informal burning

There are a lot of different forms of informal disposal. Some observed or mentioned by interviewees throughat the questionnaire survey are dumping the waste in the backyard or on open fields, at the beach or throwing it into the river.

Informal collection of recyclable materials from MSW

As in most developing countries, the informal sector is widely encouraged in collection of recyclable materials from MSW. What is termed as *informal sector* is in fact scavengers and waste pickers who freelance, meaning that they are not organised by an employer and that they use their own equipment for collecting. Informal in this regard also means, that it is not formally organised by the municipality. Before the sector is described recyclable materials must be defined. As the sector is self-sufficient, only materials that have a certain positive market value are recycled. Recyclable materials typically found in MSW in Banda Aceh are plastic bottles and cups, aluminium and tin cans, all forms of metals, paper and cardboard and undamaged glass bottles.

Figure 3-6 Banda Aceh 2007 – process informal collection recyclables: examples for recyclable materials

Based on information obtained from DKP (2007), UNDP (2007) and interviews with households, restaurant owners, waste pickers and buyers of recycling materials, the recycling sector of Banda Aceh contain the following actors: households and other MSW generating sources, waste pickers, scavengers, DKP waste workers, intermediate buyers and buyers of recyclable materials. Herein, *buyers* will be termed *agents*, as they buy and sell recyclables.

Households and other waste generating sources themselves sell recyclable materials to an intermediate agent or agent directly.
Waste pickers collect recyclables directly from households and other MSW producers, waste bins and waste containers served by DKP, from the street and other sources, like informally disposed waste. They either work as freelancer or are employed by an intermediate agent or agent. In the latter case, they are supplied with collecting equipment by their employer. The collection equipment usually includes a vehicle, like a bicycle or motorbike with a flat board, called *becak* and bags.

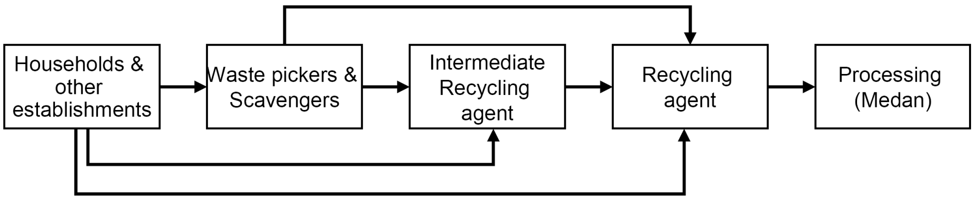
Figure 3-7 Banda Aceh 2007 – process informal collection recyclables: recycling agents

The waste workers of DKP separate the waste while collecting into recyclable and none-recyclable materials. Recyclables are sold to agents located at the landfill in Gampong Jawa.

Scavengers pick recyclables directly at the landfill Gampong Jawa and sell it to agents located at the landfill. According to DKP (2007) and UNDP (2007), there are about 40 – 50 scavengers working at the landfill. DKP provides them with safety equipment and vaccination[1].

Intermediate agents buy recyclables from the groups mentioned before and sell it to buyers. Buyers get their recyclables from both, intermediate buyers and the groups listed above. Both also employ people who collect recyclables for them. The buyers then sell the recyclables to the recyclable processing industry. Altogether, about five buyers and 30 intermediate buyers operate in Banda Aceh (DKP 2007).

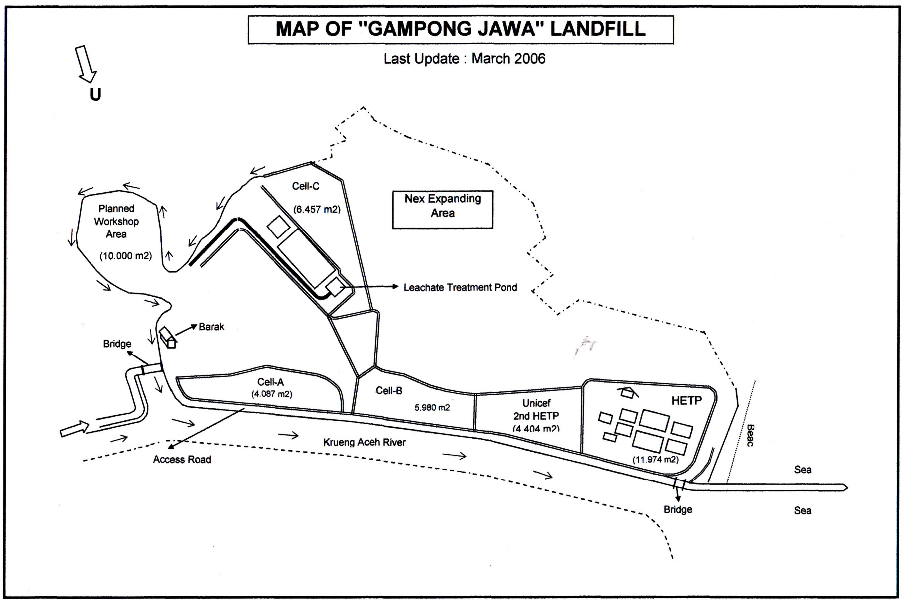
Figure 3-8 Banda Aceh 2007 – process informal collection recyclables: recycling chain



Landfill Gampong Jawa

The landfill at *Gampong Jawa* is the final destination of formal collected wastes in Banda Aceh municipality. Washed away by the Tsunami 2004, it was rebuilt to serve as a temporary solution. The close distance to the sea shore, the river *Krueng Aceh* and human settlements makes it unsuitable for a long term solution. Thus, a new sanitary landfill further inland is currently being planed (DKP 2007; UNDP 2007; GTZ 2007).

Figure 3-9 Banda Aceh 2007 – process landfill: map of landfill Gampong Jawa



(DKP et al. 2007, ANNEX 16.1.)

[1] According to UNDP (2007), many scavengers refuse to wear the safety equipment.

Gampong Jawa occupies 21 hectares of land[1]. It is situated close to the *Krueng Aceh* river and the mangrove woods, thus also close to the sea, about 5 to 10 minutes by car from the town centre. Along the access road new settlements for tsunami victims but also 5 recycling and – presumably – intermediate recycling agents can be found, as well as a small composting unit processing organic waste collected from the landfill.

Inside the fenced area there is a DKP office to control and note down the landfill input by counting the collection vehicles and checking the waste volume and a workshop processing furniture from demolition wood. Leachate is treated through a leachate treatment pond.

Behind the fenced area, two waste water treatment plants process the sludge from septic tanks.

The landfill itself has the nature of a managed dumpsite with limited leachate collection. There is neither a gas collection system, not leachate circulation. Deposition height of waste at the landfill is currently about eight meters (DKP 2007).

Figure 3-10 Banda Aceh 2007 – process landfill: access road to the landfill

Figure 3-11 Banda Aceh 2007 – process landfill: fencing landfill Gampong Jawa

At the landfill a group of 40 – 50 scavengers pick recyclable materials from the incoming waste and sell it to recycling agents and intermediate recycling agents, just outside the landfill gate. Also some

[1] The old dumpsite had 12, the extension 9 [hecaters]

people are employed to collect organic waste for the composting unit just outside the gate, but this project was not very active at the time of visiting, as not enough money for maintenance through financial assistance and sales of compost can have been gathered (interview field visit).

Figure 3-12 Banda Aceh 2007 – process landfill: scavengers and a collection vehicle

Figure 3-13 Banda Aceh 2007 – process landfill: scavengers picking recyclables

3.2.2 Data for estimating Material flows

Questionnaire Survey on Disposal Practises

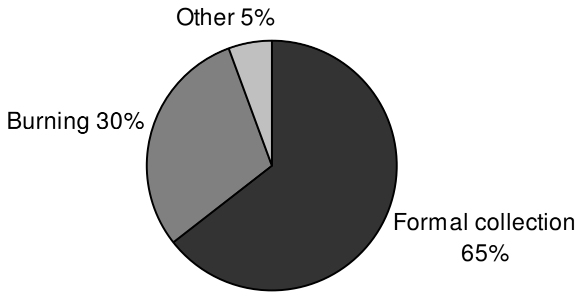
<u>Households</u>

All of the 508 questionnaires were filled-out by the participating household selected by the research assistants. According to these results, about 65% of households dispose their waste into containers and bins served by DKP, 30% burn their waste and 5% choose other handling practises, like dumping it in their backyard or throwing on the beach. Table and Figure gives an overview over the results.

Table 3-9 Banda Aceh 2007 – results questionnaire survey houesholds

	Formal collection	Burning	Other	Total
Number of households	328	153	28	508
In %	65	30	5	100

Figure 3-14 Banda Aceh 2007 – results questionnaire survey houeshold



According to DKP, 12 villages are not yet covered by the formal waste collection. As later found out, only one of the 28 selected villages for the survey is part of these uncovered villages. However, the questionnaire respondents of this village (Lamjabat) declared that their waste is collected by the formal collection service of DKP. Either the helpers who distributed the questionnaires made a mistake or the respondents did not understand the question or were not willing to give a correct answer. On the other hand, DKP possibly extends its collection service between the time when the information was gathered and the questionnaire survey.

Nevertheless, it would mean that the figures shown above count for villages already served by DKP. If the households of villages not covered by waste collection are taken into account, the effective coverage of waste collection from households is 63% and thus somewhat lower than the 65%.

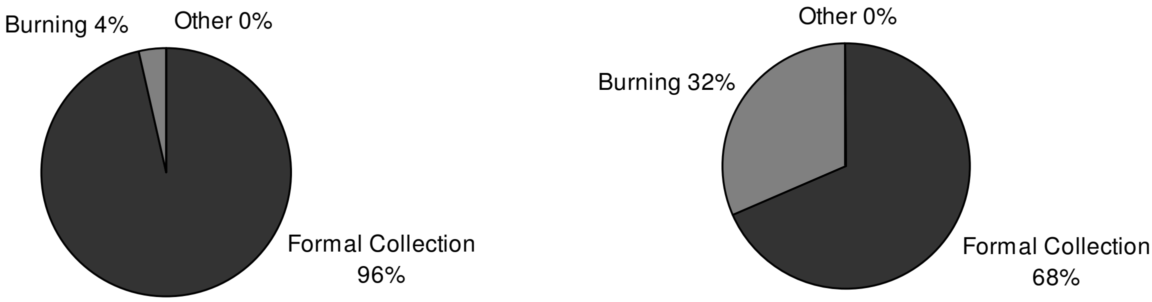
Gastronomy establishments and Small enterprises

In total, 28 gastronomy establishments and 30 small enterprises participated in the survey. The results show that in restaurants formal collection dominates with 96% far more than in enterprises (68%). The residual share is burned in both cases.

Table 3-10Banda Aceh 2007 – results questionnaire survey enterprises and restaurants

	Formal collection	Burning	Other	Total
Number of restaurants	27	1	0	28
In %	96%	4%	0%	100%
Number of enterprises	20	10	0	30
In %	68%	32%	0%	100%

Figure 3-15 Banda Aceh 2007 - results questionnaire survey for restaurants (left) and small enterprises (right)



Waste sampling

Households

The calculated daily mean value of waste generation gave a result of 322 g/capita/day and a standard deviation of 46 g/capita/day or, transferred in the unit which will be used later in the material flux calculation, 117 respectively 17 kg/capita/year, giving a calculated standard deviation of 14%.
The minimum value of all samples was 10 and the maximum 2 005 g/capita/day, while the minimum daily average over all households was 251 and the maximum 411 g/capita/day. The smallest measured value was 58 and the highest value had 986 g/capita/day (Table 3-11)

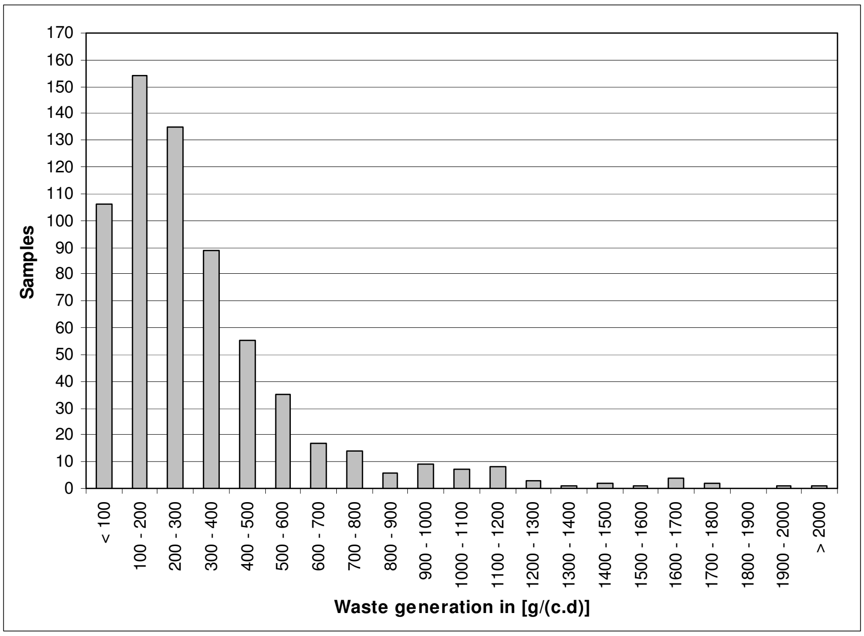
Table 3-11 Banda Aceh 2007 – results waste sampling households

	Minimum value	Mean value	Maximum value	Median value
All samples	10	323	2005	249
Daily average over all households	251	322	411	320
Household average over all days	58	330	986	272

in g/capita/day

Figure 3-16 shows the distribution of the taken samples, which figuratively resembles a logarithmic normal distribution.

Figure 3-16 Banda Aceh 2007 – distribution of household waste sampling results



Waste Generation Groups	Number of Samples per Group
[g/c.d]	
< 100	106
100 - 200	154
200 - 300	135
300 - 400	89
400 - 500	55
500 - 600	35
600 - 700	17
700 - 800	14
800 - 900	6
900 - 1000	9
1000 - 1100	7
1100 - 1200	8
1200 - 1300	3
1300 - 1400	1
1400 - 1500	2
1500 - 1600	1
1600 - 1700	4
1700 - 1800	2
1800 - 1900	0
1900 - 2000	1
> 2000	1

The household sampling survey was stratified due to the household income. Furthermore, the attempt was made to include households with different household sizes. Figure 3-17 and Figure 3-18 show the results.

Figure 3-17 Banda Aceh 2007 – household waste generation versus household income

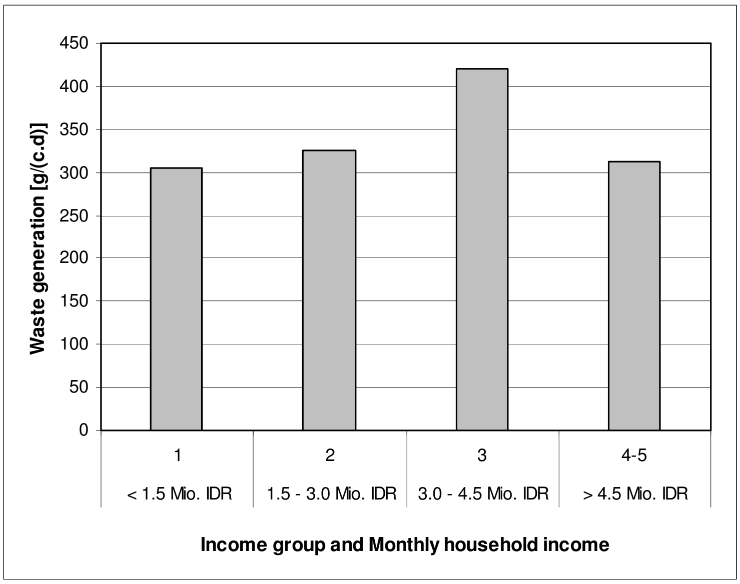
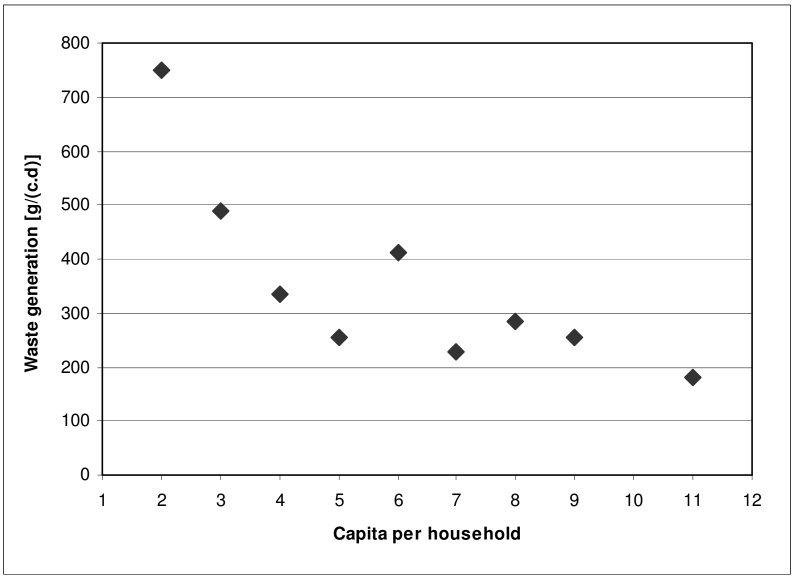


Figure 3-18 Banda Aceh 2007 – household waste generation versus household size

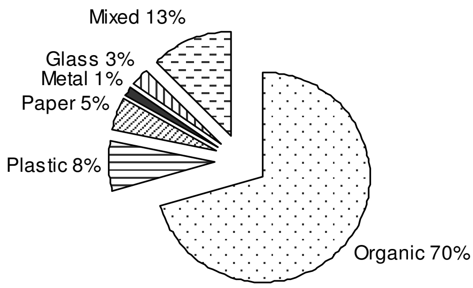


According to the waste composition sampling results (Figure 3-21), organic wastes dominate the waste stream with over 70 %, followed by mixed waste, plastic, paper and cardboard, glass and metal. Organic waste is dominated by food waste, plastic by plastic bags and small packing materials and paper by packing paper for take away food. Grain size for both is relatively small. Both, plastic and paper, were mixed with other waste, thus the observed water content in this fractions was quite high. While metal usually origins from small tin cans, glass comes from small bottles (smaller than 200 ml) or broken items. Mixed waste is dominated by baby napkins or stones, but also contains compound materials.

Table 3-12 Banda Aceh 2007 – waste composition of household waste samples

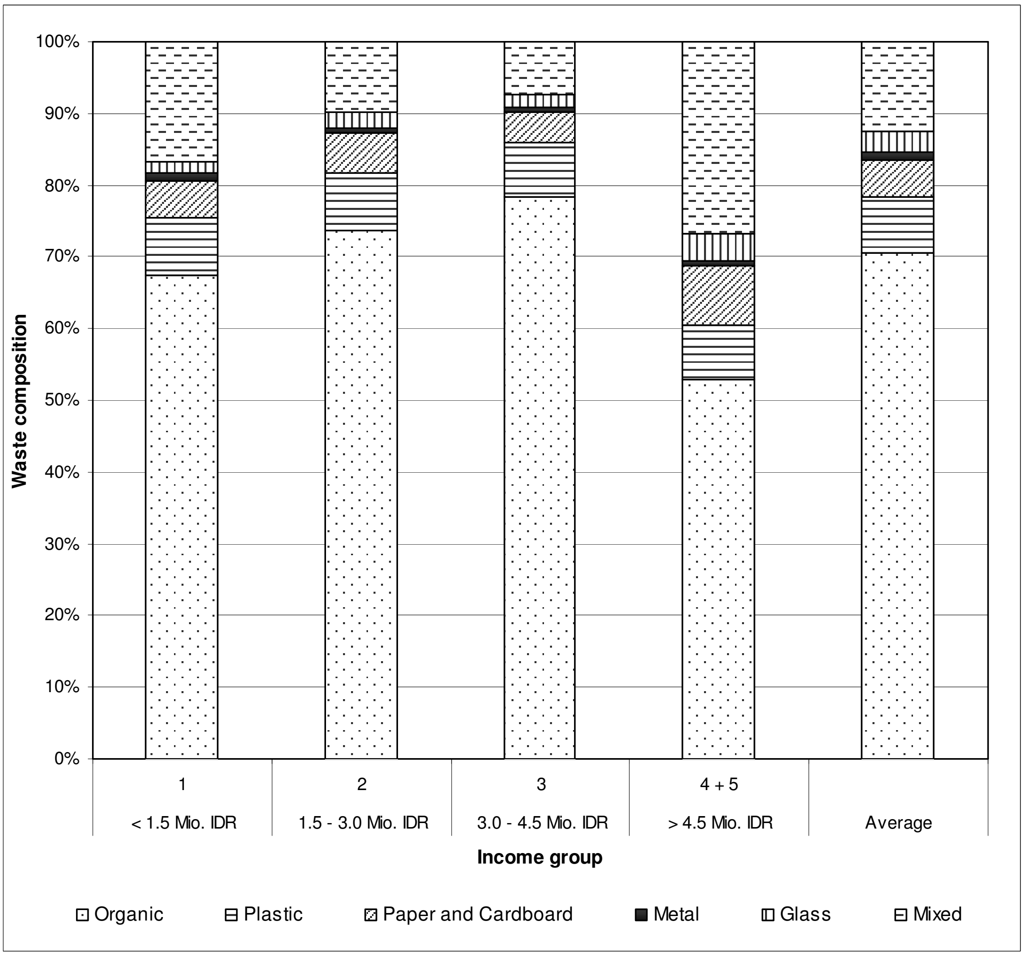
Unit	Organic waste	Plastic waste	Paper & Cardboard	Metal waste	Glass waste	Mixed waste	Total waste
[g/(c.d)]	235	26	17	4	10	42	329
mass%	70	8	5	1	3	13	100

Figure 3-19 Banda Aceh 2007 – waste composition of household waste samples



Referring to the income groups, the organic waste fraction increases from income group 1 to 3. Therefore, the mixed waste fraction decreases. Income groups 4 and 5 have a far lower organic waste fraction. Therefore the mixed waste and the paper fraction are higher.

Figure 3-20 Banda Aceh 2007 – waste composition of household waste samples for each income group



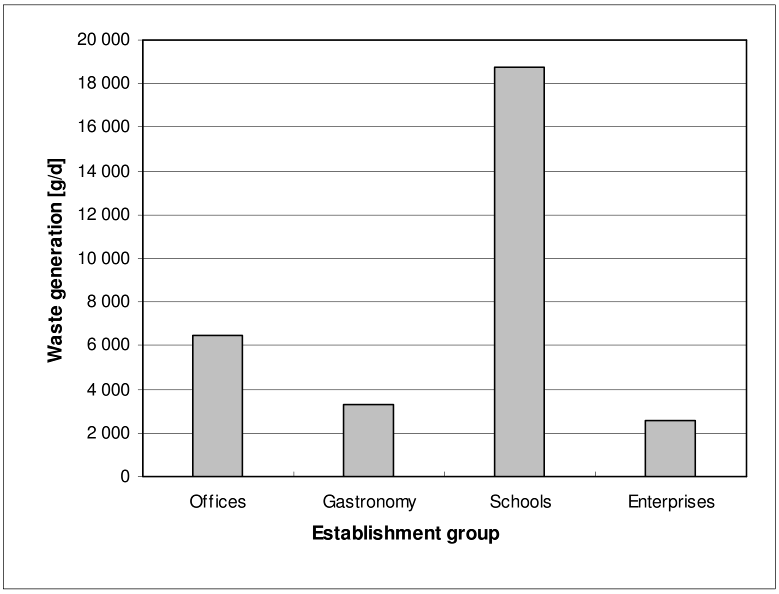
Enterprises, gastronomy establishments, offices, schools

The average waste generation of all sampled schools was about 19 kg/day, followed by offices with 7 kg/day, gastronomy establishments and restaurants with about 3 kg/day, as shown in Table 3-13 and Figure 3-21.

Table 3-13 Banda Aceh 2007 – results waste sampling other establishment s than households

	Offices	Gastronomy	Schools	Enterprises
Waste generation [g/d]	6 500	3 300	18 800	2 600

Figure 3-21 Banda Aceh 2007 – results waste sampling other establishment s than households



However, these figures can hardly be compared with each other. For schools and offices it makes sense to show the waste generated by employee or student. If done so, the result can be summarized as in Table 3-14, while Table 3-15 shows the waste generation per gastronomy and small enterprise establishment.

Table 3-14 Banda Aceh 2007 – results waste sampling offices and schools

Establishment	Government offices			Schools		
Abbreviation	K1	K2	K3	SD	SMP	SMA
Name/Type	Education	Agriculture	Sports	Elementary	Junior high	Senior high
Waste generation in [g/(ru[1].d)]	23	142	46	78	44	43

The mean value for offices is then 70 g/employee/day and for schools 50 g/student/day.

[1] ru means referent unit. Herein, the referent unit is student or employee, in order to give the waste generation per student or employee for schools respectively offices.

Figure 3-22 Banda Aceh 2007 – results waste sampling offices and schools

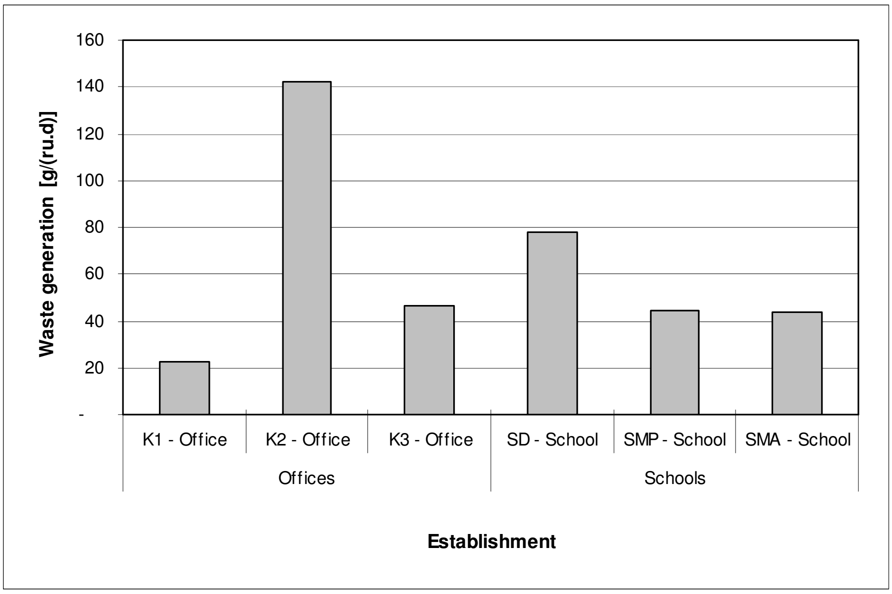
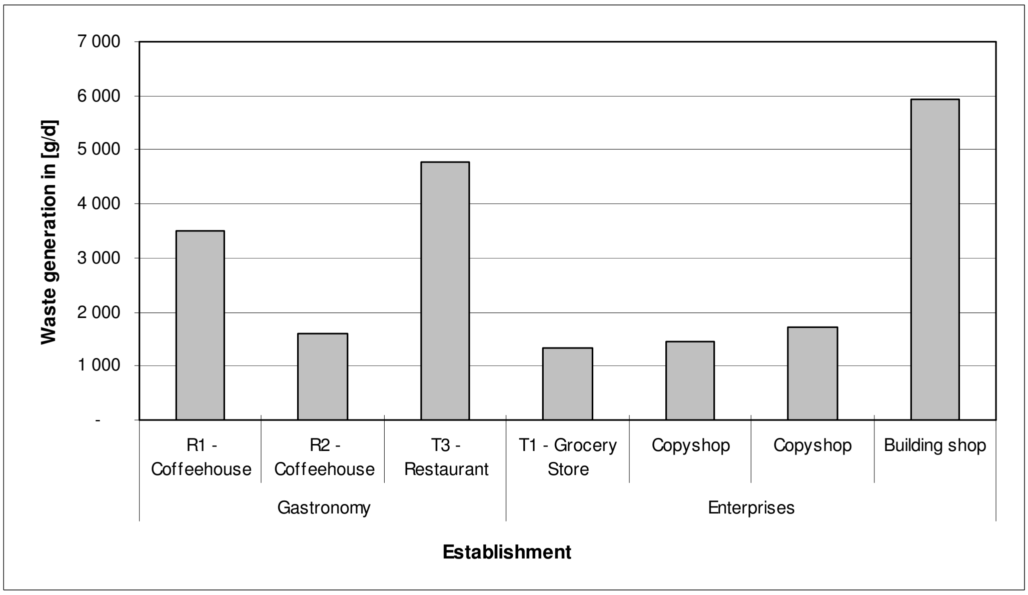


Table 3-15 Banda Aceh 2007 – results waste sampling gastronomy and small enterprises

Establishment	Gastronomy			Enterprises			
Abbreviation	R1	R2	T3	T1			
Type of business	Coffee house	Coffee house	Restaurant	Grocery store	Copy shop	Copy shop	Building shop
Waste generation in [g/d]	3 509	1 600	4 761	1 330	1 460	1 710	5 925

Figure 3-23 Banda Aceh 2007 – results waste sampling gastronomy and small enterprises

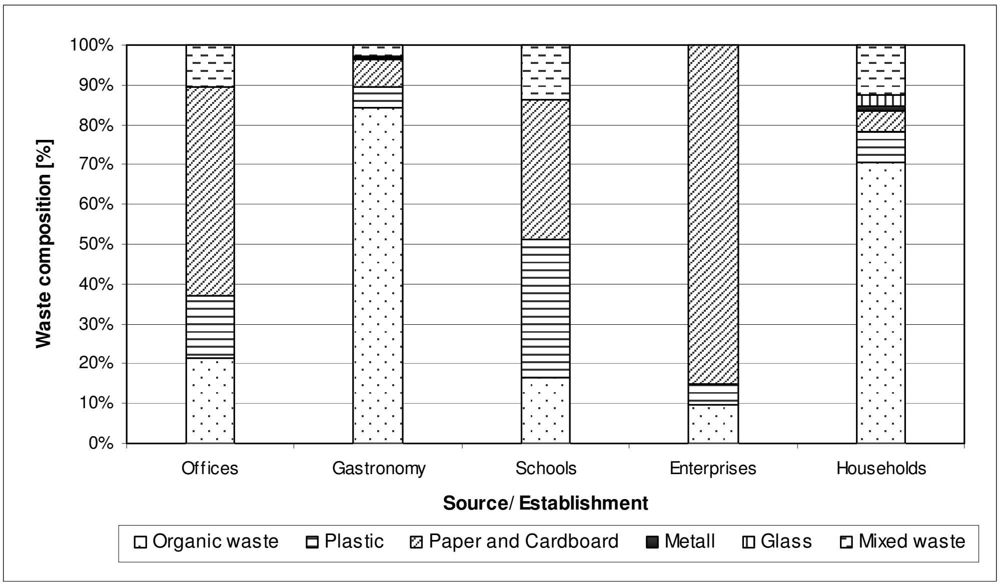


The waste composition differs from that of households. While organic waste is dominating for gastronomy establishments, offices show a far higher amount of paper and cardboard, same as the sampled enterprises. For schools, plastic and paper and cardboard are both dominating (see Table 3-16 and Figure 3-24).

Table 3-16 Banda Aceh 2007 – results waste composition of samples from other establishments than households

	Offices	Gastronomy	Schools	Enterprises
Organic waste	21%	84%	16%	10%
Plastic	16%	5%	35%	5%
Paper & Cardboard	53%	7%	35%	85%
Metal	0%	0%	0%	0%
Glass	0%	0%	0%	0%
Mixed waste	10%	3%	14%	0%

Figure 3-24 Banda Aceh 2007 – results waste composition of samples from other establishments than households



Recycling survey

Three intermediate agents were sampled, each identified by the village where operating. The mean value of recycling material collected or purchased by each agent per day ranged from 252 (agent 2) to 1 314 kg/day (agent 1). Except the agent from Keuramat, who does not collect paper and cardboard, the agents collect similar materials. It can be seen from Table 3-17 that agent 1 collects far more than agent 2 and 3.

Materials can be distinguished between MSW origin and non-MSW origin. While paper and cardboard, plastics, glass bottles and aluminium cans were counted as MSW origin, steel, copper and iron were counted as non-MSW origin. The latter group rather comes from building and construction waste e.g..

The mean value for MSW recyclables is 388 kg/day and for non-MSW recyclables 326 kg/day.

Table 3-17 Banda Aceh 2007 – all recycling materials collected per agent

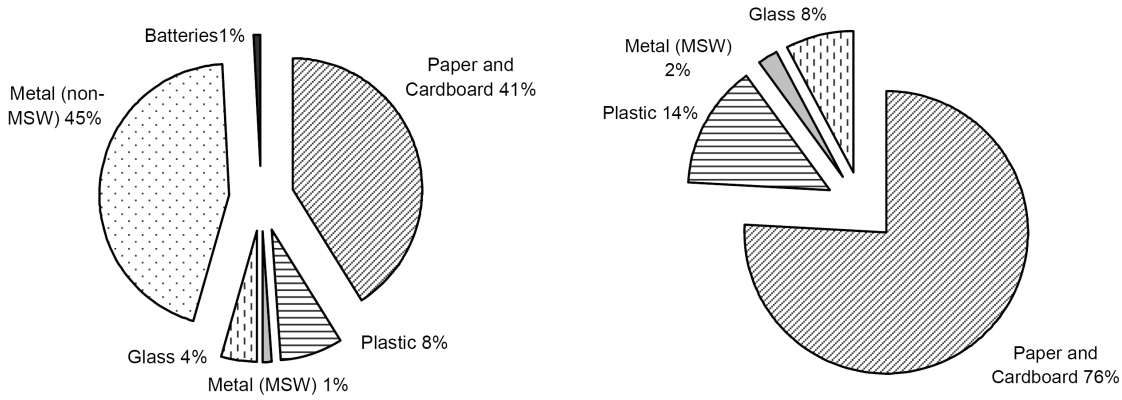
	Agent 1 Lamdingin	Agent 2 Keuramat	Agent 3 Gampung Mulia	Mean value	Share
Unit	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[mass%]
Materials MSW	640	88	436	388	54
Materials nonMSW	674	164	140	326	46
Total	1 314	252	576	714	100

The composition analysis shows that metals not origin from MSW, like iron, steel and copper, are, together with paper and cardboard, the largest fractions with 45 and 41% respectively, followed by plastics (8%), glass bottles (4%), aluminium (1%) and batteries (1%).

Table 3-18 Banda Aceh 2007 – composition of all recycling materials collected per agent

	Agent 1 Lamdingin	Agent 2 Keuramat	Agent 3 Gampung Mulia	Mean value
Paper & Cardboard	38%	0%	67%	41%
Plastic	7%	22%	3%	8%
Metal (MSW)	1%	3%	1%	1%
Glass bottles	3%	10%	5%	4%
Metal (non-MSW)	51%	61%	24%	45%
Batteries	1%	4%	0%	1%

Figure 3-25 Banda Aceh 2007 – composition of all recyclables (left) and recyclables of MSW origin (right)



The result for recyclables from MSW origin shows that paper and cardboard makes up to 76% of this group of recyclables, followed by plastic (14%), glass bottles (8%) and metals, in this case aluminium and tin cans (2%). These figures are taken for the subsequent calculations.

Table 3-19 Banda Aceh 2007 – composition of recyclables of MSW origin

	Agent 1 Lamdingin	Agent 2 Keuramat	Agent 3 Gampung Mulia	Mean value
Paper & Cardboard	78%	0%	89%	76%
Plastic	14%	63%	4%	14%
Metal (MSW)	2%	10%	1%	2%
Glass	6%	27%	6%	8%

Projection of results for MFA calculation

If assumed that the three agents are representative and that there are, altogether, 35 intermediate recycling agents in town, the material flux for recyclable materials can be calculated. Taking the mean value of the recyclable materials from MSW (388 kg/day) multiplied by the projected number of agents (35) gives the total amount of recycled material from MSW per day. The result multiplied by 365 days/year and divided by the population figure of Banda Aceh (219 657) gives the amount of recycled materials from MSW in Banda Aceh per capita and day.

$$388[kg / agent / day] * 35[agents] * 365[days / year] / 219.657 = 23[kg / capita / day] \quad (3.1)$$

An uncertainty of ±25% or 6 kg/capita/day is assumed.

Data from input landfill

The input data (DKP 2007), available for the months July 2006 until June 2007, ranged from 368 to 571 m³/day and resulted in a mean value of 480 m³/day. Highest amounts were recorded in August 2006 and during the time of Ramadan in September and October 2006.

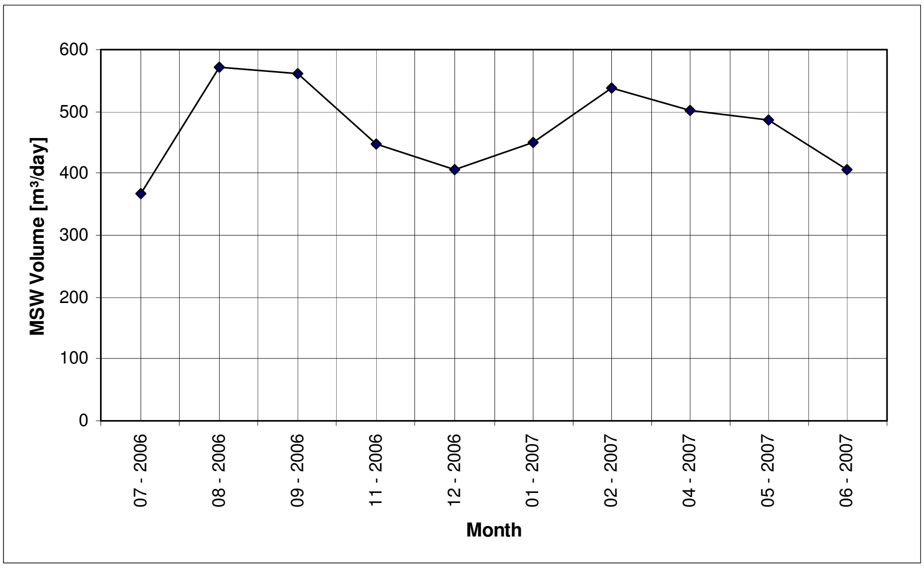
Expressed in kg/capita/year, the mean value for mass and the uncertainty over the selected period was 191 respectively 47. See Annex 12.5.3 (page 221) for details on the calculation.

Table 3-20 Banda Aceh 2007 – landfill input data

Month	Reported Volume	Mass mean value	Mass mean value	Uncertainty
	[m³/day]	[kg/day]	[kg/(c.yr)]	[kg/(c.yr)]
07 - 2006	368	88 200	147	36
08 - 2006	571	137 088	228	55
09 - 2006	563	135 000	224	55
10 - 2006	541	129 840	216	52
11 - 2006	448	107 568	179	43
12 - 2006	406	97 488	162	39
01 - 2007	451	108 216	180	44
02 - 2007	537	128 928	214	52
04 - 2007	502	120 360	200	49
05 - 2007	488	117 000	194	47
06 - 2007	407	97 584	162	39
Mean value	480	115 207	191	47

(DKP 2007)

Figure 3-26 Banda Aceh 2007 – landfill input data



(DKP 2007)

3.2.3 Calculation of material fluxes for waste total

Sub-system formal MSWM system and recycling activities

Based on the model *Formal MSWM system and recycling activities Banda Aceh 2007* (page 43), the resulting material fluxes *W2 – import waste other sources* and *R1 – import recyclables* were calculated.

Table 3-21 Banda Aceh 2007 – insert data to calculate the sub-system

Flux	Description	Mass flux [kg/(c.yr)]
WH	Import Household waste	76
W	Input Landfill	191
R2	Output Recyclables formal collection	3
R3	Output Recyclables landfill	3
R4	Export Recyclables	23

The calculated waste fluxes *R1* and *WO* are illustrated in Table 3-22, while the MFA flow chart is shown in Figure 3-27..

Figure 3-27 Banda Aceh 2007 – results sub-system

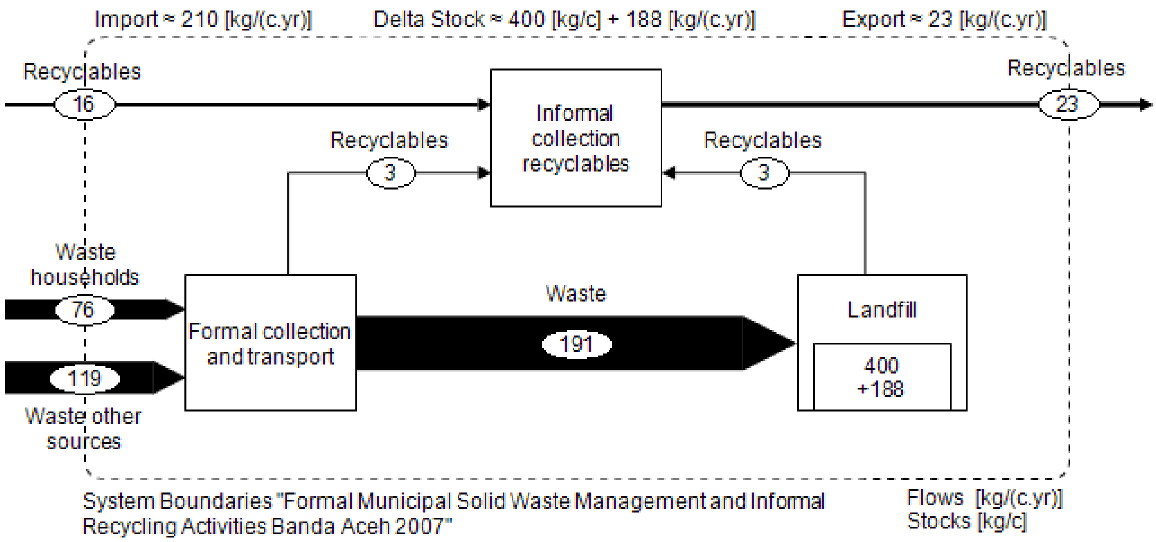


Table 3-22 Banda Aceh 2007 – results calculation sub-system

Flux	Description	Mass flux [kg/(c.yr)]
WO	Import Waste other sources	119
R1	Import Recyclables	16

MSWM system Banda Aceh 2007

Import from households

The figures from the household sampling and the questionnaire survey combined give the total import of waste from households and how this total import partition on the processes formal collection and transport, burning and uncontrolled disposal.

Table 3-23 Banda Aceh 2007 – calculation of import fluxes from households[1]

Flux	Description	Mass flux [kg/(c.yr)]	Mass flux as % of total
WH1	Import waste from households to formal collection	76	65
WH2	Import waste from households to burning	35	30
WH3	Import waste from households to informal disposal	6	5
	Import waste from households total	117	100

[1] Data for the share of each stream from "Questionnaire Survey on Disposal Practises - Households", page 50.

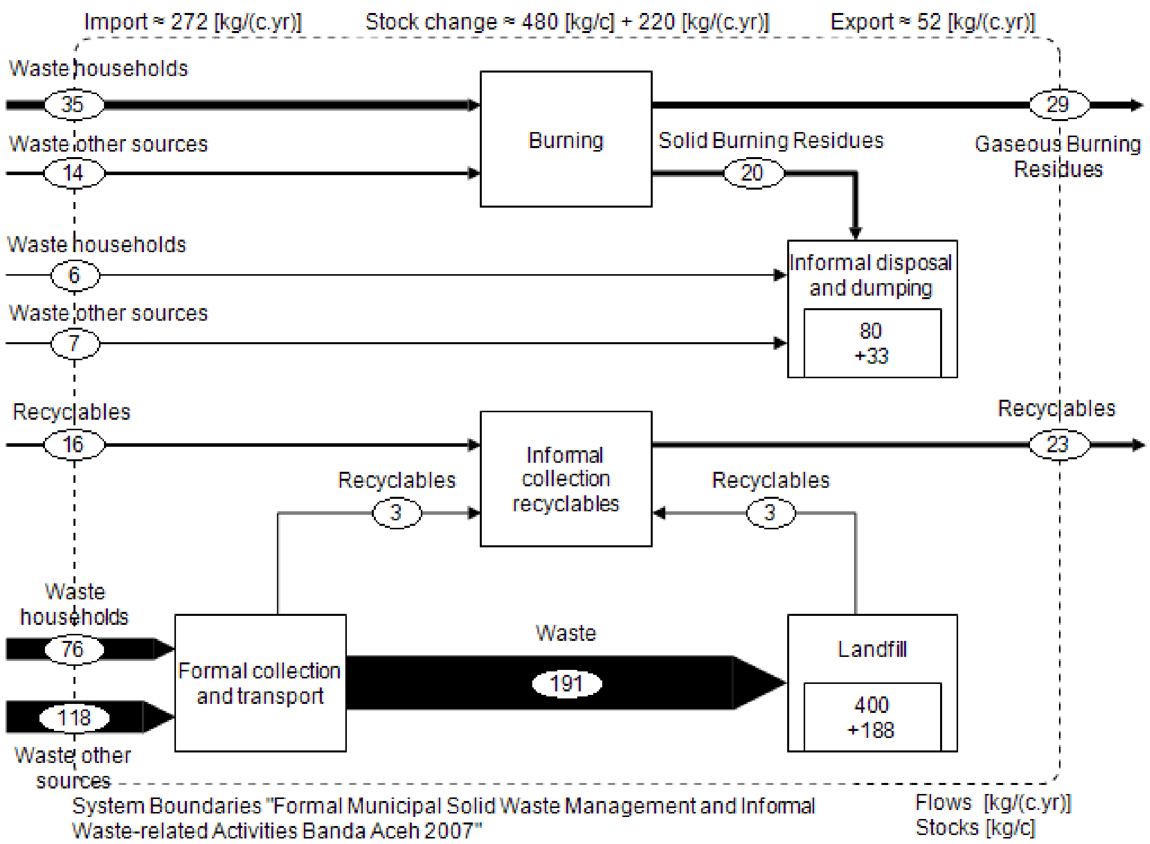
Import from other sources

For the total import from other sources, the calculated figure for the import into the process collection (see Table 3-22, page 98) was used. Under the assumption, that 85% of wastes from other sources than households are collected, 10% are burned and 5% are uncontrolled disposed, the import into theses processes can be calculated.

Table 3-24 Banda Aceh 2007 – results calculation of import fluxes from other sources than households[1]

Flux	Description	Mass flux [kg/(c.yr)]	Mass flux as % of total
WO1	Import waste from other sources to formal collection	118	85
WO2	Import waste from other sources to burning	14	10
WO3	Import waste from other sources to informal disposal	7	5
	Import waste from other sources total	140	100

Figure 3-28 Banda Aceh 2007 – current MSWM system , distinguished between different sources



Import total

[1] Data for the share of each stream estimated, see Chapter 2.3 "Calculation of Material Fluxes for Waste total - MSWM system Banda Aceh 2007", page 58.

If import fluxes from both sources are combined, the resulting total fluxes can be calculated. These import fluxes are inserted into STAN to calculate the resulting MFA system. Note that nomination changes below, as no distinction between the different import sources is made hereafter (see Figure 2-14, page 47 and Figure 2-15, page 50)

Table 3-25 Banda Aceh 2007 – results calculation of total import fluxes[1]

Flux	Description	Mass flux [kg/(c.yr)]	Mass flux as % of total
W1	Import waste to formal collection	194	71
W2	Import waste to burning	49	18
W3	Import waste to informal disposal and dumping	13	5
R1	Import recyclables	16	6
	Import waste total	272	100

Material fluxes including uncertainties

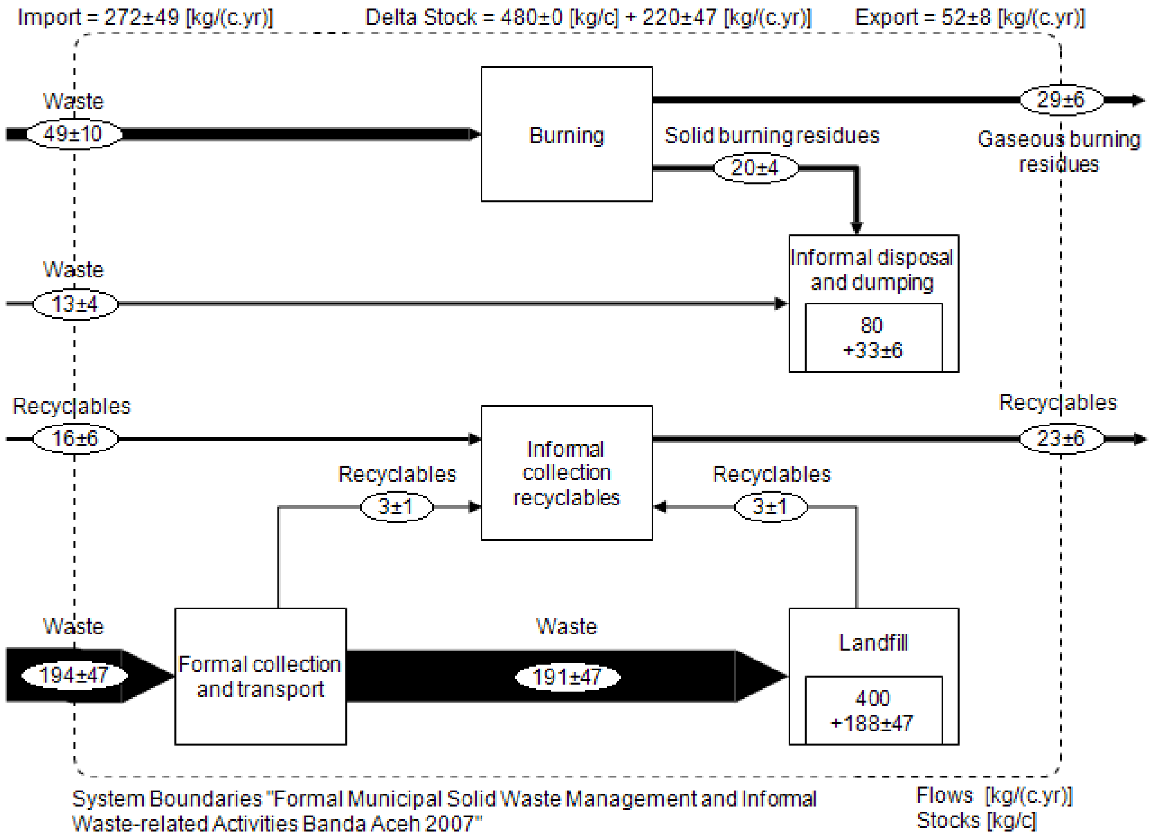
While uncertainties for the waste flux W4 – input total waste from formal collection to landfill, is calculated, others are assumed respectively a result of MFA calculation with STAN.

Table 3-26 Banda Aceh 2007 – all material fluxes for the current MSWM system

Flux	Description	Mass flux	Uncertainties		
No.		Calculated [kg/(c.yr)]	Selected [kg/(c.yr)]	Calculated [kg/(c.yr)]	%
W1	Import total waste to formal collection	194		47	24
W2	Import total waste to burning	49	10		20
W3	Import total waste to informal disposal	13	3		23
W4	Input total waste of formal collection to landfill	191	47		24
R1	Import recyclables	16		6	31
R2	Input recyclables from formal collection to informal collection recyclables	3	1		30
R3	Input recyclables from landfill to informal collection recyclables	3	1		30
R4	Export recyclables from informal collection recyclables	23	6		22
GBR	Export gaseous residues from burning	29		6	21
SBR	Output solid residues from burning	20		4	20

[1] Data for the share of each stream estimated, see Chapter 2.3 "Calculation of Material Fluxes for Waste total - MSWM system Banda Aceh 2007", page 65.

Figure 3-29 Banda Aceh 2007 – current MSWM system Banda Aceh 2007 as MFA chart



Waste composition

According to DKP et al. (2007:36ff), organic waste is the dominating fraction, of which fits the data of Indonesia and other middle and low income countries (cp. Hoornweg et al. 1999; CalRecovery 2005).

Table 3-27 Banda Aceh 2007 – waste composition from different generating sources and different areas

Waste fraction	Domestic permanent	Domestic temporary	Commercial Grocery	Commercial Copy shop	Commercial Food shop	Market	Landfill
Organics	69	38	17	9	50	58	34
Plastics	17	23	25	27	25	17	16
Paper	5	15	42	64	17	8	13
Metals	2	8	0	0	0	8	13
Textiles	7	0	0	0	0	0	8
Glass	0	0	0	0	0	0	8
Rubber	0	15	17	0	8	8	8

(DKP et al. 2007:36)

As shown in Table 3-27, the share of the organic fraction decreases along the waste chain. Reason for this might be evaporation of water. Some figures, for example for waste at the landfill, are though questionable. During the sampling, glass and textile were found in such negligible amounts that the

eight % for both do not seem accurate. On the other hand, no information was available about the source of these figures.
Hence, the share of important fractions in % is assumed as follows:

Table 3-28 Banda Aceh 2007 – waste composition selected and compared with composition figures from literature

Material	Own assumption	Household sampling	DKP Market	DKP Landfill	Indonesian cities
	All streams	Table 3-12, p.90	Table 3-27, p.101	Table 3-27, p.101	Hoornweg (5.1999:45)
Organic waste	50	71	58	34	70
Paper	15	8	17	16	11
Plastic	15	5	8	13	9
Other waste	20	16	17	37	20
Total	100	100	100	100	100

This assumed composition in column two is the base for further calculations and is applied for every waste flux.

Fuel demand in 2007 (Projection)

According to DKP, the projected expenditures for fuel by 2007 are 1 756 440 000 IDR (DKP 2007). Divided by a per litre price of 4 500 IDR, this projects a consumption 392 320 [litre/year] results. It is assumed that only diesel fuel is consumed. Taking an energy density of 35.3 [MJ/litre] and the population figure of 219 657 inhabitants, the external energy demand can be calculated as:

$$E_{demand} = 392\ 320[l / year] * 35.3[MJ / l] / 219.657 = 63[MJ / capita / year] \qquad (3.2)$$

Costs

The breakdown of the budget projections of DKP for 2007 shows total expenses of about 14 billions IDR (1.1 millions €). Most of the positions in the break-down are not assignable directly to solid waste management. The exception is item “1.08.04.15.04 – procurement/construction of landfill” (see Annex 12.6.1, page 222).
For all identifiable personnel-related expenses – salary, insurance and cloths for civil servants and workers – the fraction of civil servants and workers respectively working with solid wastes was calculate, based on the information about the organisational structure of DKP. Thus, totally 314 workers and 42 civil servants work for DKP, while 39% and 64% respectively of them work with solid waste. It does not matter for the calculation that DKP gave a figure of 343 workers during the first

interview (DKP 2007), as the share of workers/civil servants working in solid waste management is important, not the total amount. See Annex 12.6.3, page 223 for further details.
After calculating the costs for solid waste management, the share for collection and disposal was calculated, using a similar approach as above. Where direct assignment was possible, it was done, which was only the case for item "1.08.04.15.04 – procurement/construction of landfill". For the assignment of cost items for civil servants and workers salaries and cloths and the share of collection versus landfill was calculated using the data from the organisational structure (see Annex 12.6.2, page 222). For other items, a share was assumed.

The result show that 51% of the total budget of DKP is spent for solid waste management, which is about 570 000 €/year. From that, 85% are spent for MSW collection, while 15% are spent for disposal. The calculated figures for workers working in solid waste management (119 workers) differ greatly from the ones gathered from the interviews (235 workers). Reason for that is that workers working in street sweeping, riverbank cleaning and various other projects (112 workers) were not considered in the calculation. These duties are either not considered as solid waste management related or for the author simply not identifiable as solid waste related.

Table 3-29 Banda Aceh 2007 – predicted expenditures for MSWM

Unit	Collection	Landfill	MSWM total
[IDR/year]	6 068 627 400	1 092 891 400	7 161 518 800
[€/year]	484 328	87 222	571 550
%	85	15	100

(DKP et al. 2007; see Annex 12.6.4, page 224)

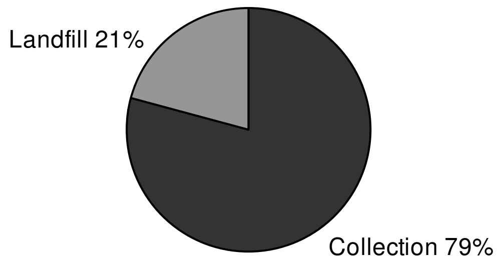
However, this cost only represents operational and maintenance costs and only partially covers investment costs. Investments for the fleet are not included. Considering them, total annual costs for waste management of about 690 000 €/year or 8.6 billion IDR/year result (Annex 12.6.5, page 224). Expressed per capita, the costs are about 3.1 €/capita/year. Based on a real national GNI per capita of 934 €/capita/year (The World Bank 2007) the expenditure for MSWM are about 0.3% of the GNI.

Table 3-30 Banda Aceh 2007 – predicted expenditures for MSWM including fleet [1]

Unit	Collection	Landfill	MSWM total
[IDR/year]	6 816 250 700	1 844 691 400	8 660 942 100
[IDR/(capita.year)]	31 000	8 400	39 400
[€/year]	543.994	142.669	686.663
[€/(capita.year)]	2,5	0,6	3,1
%	79	21	100

From the resulting costs, 79% is spent for collection, while 21% is spent for landfilling.

Figure 3-30 Banda Aceh 2007 – distribution of costs for collection and landfill for current MSWM system



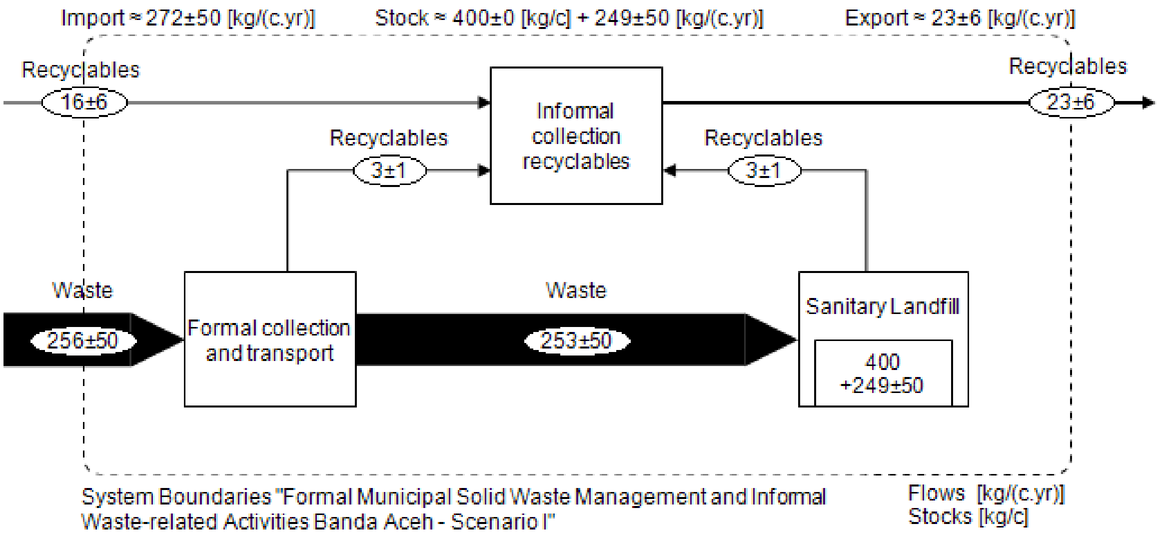
[1] *See ANNEX for the depreciation calculations.*

3.3 Scenarios for extended waste management in Banda Aceh

3.3.1 Scenario I: Full collection service coverage and sanitary landfilling

Material fluxes

Figure 3-31 Banda Aceh scenario I – results as MFA chart



If the formal collection service reaches nearly 100% of coverage, the amount of waste disposed to the landfill increases from 186 to 248 kg/capita/year, which is an increase of 33% compared to the ≈current state. Thus the processes *burning* and *informal dumping and disposal* become, within this assumption, negligible. Due to this increase the landfill size and the projected landfill size must be extended compared to the current state.

Waste composition

As waste composition on the landfill, a share of 50% organic materials, 15% plastics, 15% paper and cardboard and 20% mixed wastes will be applied.

Fuel demand

With the extension of collection service, the demand for fuel also increases. Under the assumption that

- the increase is linear to the additional connected households
- actually about 65% of all households are connected and
- about 35 % of all households should further be connected,

the increase can be estimated as follows:

$$Increased\ fuel\ demand = (35/65)*100\% \ = +54\% \qquad (3.3)$$

As the projected fuel demand for 2007 was 392 320 litre/year, the total fuel demand for scenario I can be calculated as:

$$\underline{Fuel\ demand\ Scenario\ I = 392\ 320 + (392\ 320 * 54/100) = 604\ 173\ [litre/year]} \qquad (3.4)$$

Using an energy density of 35.3 MJ/litre and population figure of 219 657 inhabitants, the external energy demand is calculated as:

$$\underline{E_{demand} = 604\ 173[l/year] * 35.3[MJ/l]/219\ 657 = 97\ [MJ/capita/year]} \qquad (3.5)$$

Costs

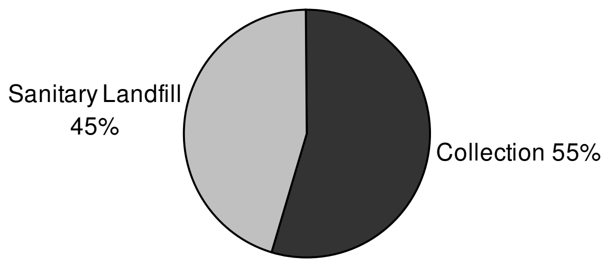
If collection is extended to a 100% coverage, the collection costs increase to about 720 000 €/year compared to the current state. The landfill costs rise twofold, first due to the increasing amount of waste landfilled and second due to higher specific costs for sanitary landfilling. Thus the landfill costs increase to 600 000 €/year, leading to total costs of 1 316 000 €/year. Per capita, the costs for MSWM are then 6 €/capita/year. Furthermore, the share between collection and sanitary landfilling changes to 55% as opposed to 45%.

Table 3-31 Banda Aceh scenario I – expenditures for MSWM

Unit	Collection	Sanitary Landfill	MSWM total
[IDR/year]	8 994 640 100	7 506 832 900	16 501 473 000
[IDR/(capita.year)]	40 950	34 180	75 130
[€/year]	717 848	598 906	1 316 000
[€/(capita.year)]	3.3	2.7	6.0
%	55	45	100

See Annex 12.6.7, page 226

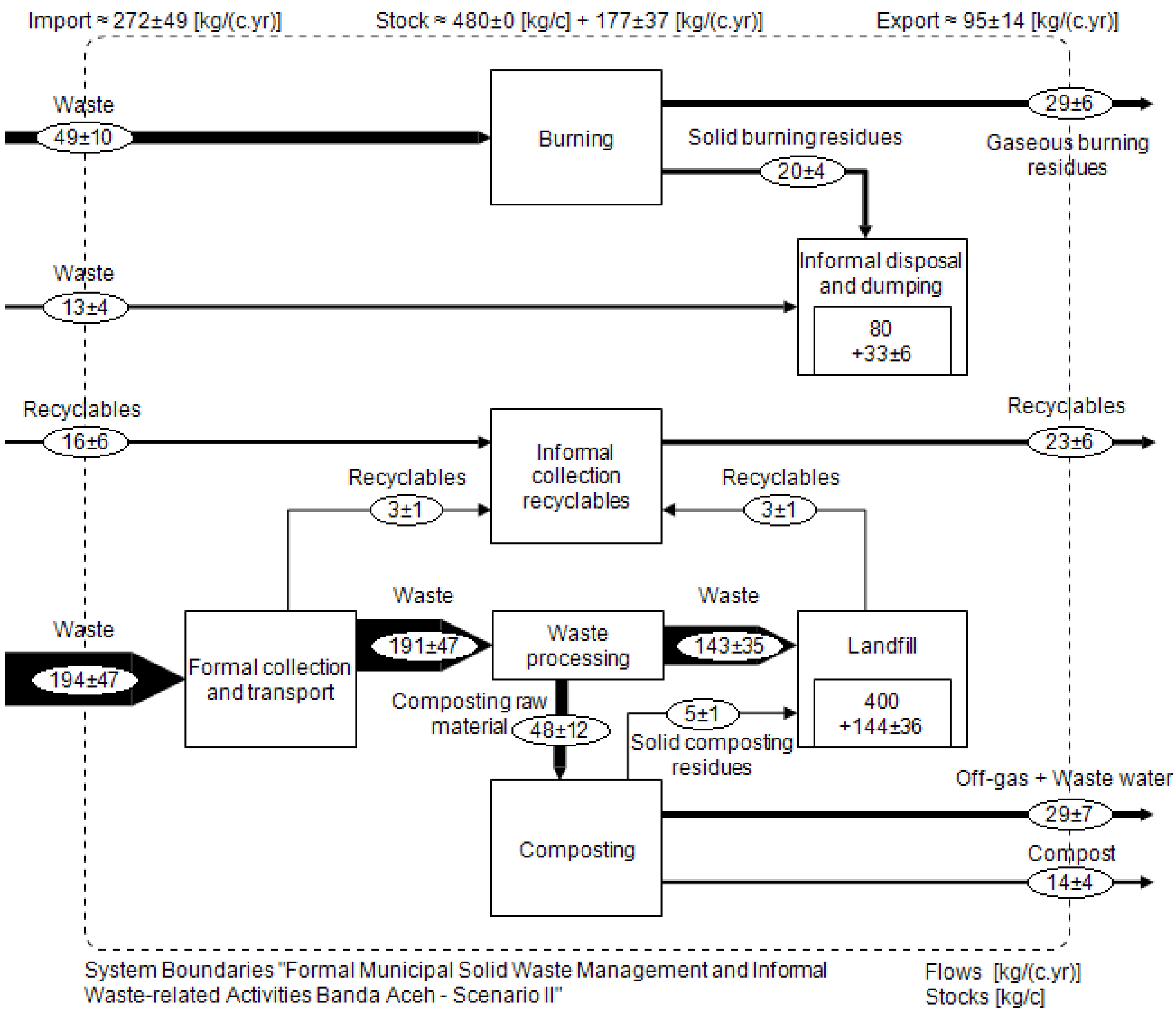
Figure 3-32 Banda Aceh scenario I – distribution of costs for collection and landfill



3.3.2 Scenario II: Large scale composting including waste separation unit

Material fluxes

Figure 3-33 Banda Aceh scenario II – results as MFA chart



If the total import into the formal collection systems remain stable, then the input into the *waste processing* process, coming from *formal collection and transport*, has the same size as the input into the process *landfill* in the current MSWM system (see Figure 3-28). In the waste processing unit, organic compostable waste is seperated from the residual waste stream. While the latter goes straight to the process *landfill*, the primary goes to the process *composting*. Under the assumptions, that organic material constituting 50% of the input stream into the waste processing and the half of this amount is sent to the composting unit, 25% from the input waste stream into the process *waste processing* continues to the composting unit, while 75% goes to the *landfill*.

Based on value, from the 191 kg/capita/year about 48 kg/capita/year are composted and 143 kg/capita/year are send to the *landfill*.

For the output, transfer coefficients for the composting mass loss through off-gas and waste water (60%), the compost (30%) and solid compost residues (10%) were set in the methodology part (see page 52).
Subtracting the flux of recyclables from the landfill, 144 kg/capita/year waste is landfilled.
All other processes and flows are assumed not to change compared to the current situtation.

Waste composition

The waste composition at the landfill changes through these new processes. As not the total composition, but merely the amount of organic material is of interest, this amount will be calculated:

Input flux of organic material from separation to landfill: I_{1org} = 191 * 25/100 = 48 [kg/(c.yr)]
Input flux of organic material from composting to landfill: I_{2org} = 5 [kg/(c.yr)]
Input flux of organic material to landfill total: I_{org} = 53 [kg/(c.yr)]

Based on the composition set under chapter *Waste composition,* page 101, which refers to the output flux from *formal collection and transport*, the share of other fractions can be calculated:

Input flux of paper and cardboard to landfill: I_{pap} = 191 * 15/100 = 29 [kg/(c.yr)]
Input flux of plastic to landfill: I_{plas} = 191 * 15/100 = 29 [kg/(c.yr)]
Input flux of mixed waste to landfill: I_{mix} = 191 * 20/100 = 38 [kg/(c.yr)]
Input flux total to landfill: I_{total} = 53+29+29+38 = 149 [kg/(c.yr)]

Table 3-32 Banda Aceh scenario II – waste composition at landfill

Flux	[kg/(c.yr)][1]	%
Input organic	53	36
Input paper and cardboard	29	19
Input plastic	29	19
Input mixed waste	38	26
Input total	149	100

[1] To get figures in [tons/day], just multiply with the number of inhabitants divided by days per year, which gives a conversion factor of 219.657/365 = 603.

Fuel demand

The fuel demand is assumed not to change compared to the current MSWM system demand of 392 320 litre/year, same as the external energy input E_{input} with 63 MJ/capita/year. An increased energy demand for the composting process is assumed to be negligible.

Costs

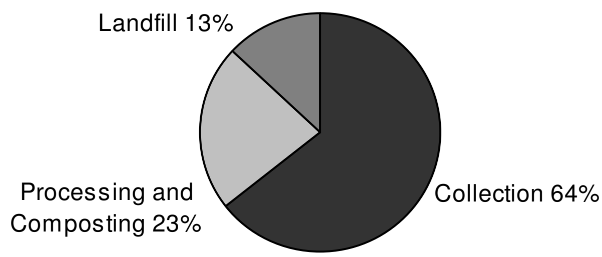
By introducing composting, another cost component is added. Collection costs remain, with 696 990 €/year, steady compared to the current state. Landfill costs decline to 115 260 €/year due to the smaller amount of waste landfilled. Processing and composting costs at approximately 153 940 €/year, lead to total costs of 966 180 €/year. Per capita, the costs for MSWM then are 4.4 €/capita/year. The share between collection, processing/composting and landfilling is then about 64 versus 23 and 13%.

Table 3-33 Banda Aceh scenario II – expenditures for MSWM

Unit	Collection	Composting	Landfill	MSWM total
[IDR/year]	6 816 250 700	2 411 833 900	1 412 955 100	10 641 039 700
[IDR/(capita.year)]	31 030	10 980	6 430	48 440
[€/year]	543 994	192 420	109 278	966 180
[€/(capita.year)]	2.5	0.9	0.5	3.9
%	64	23	13	100

See Annex 12.6.7, page 226 for calculations.

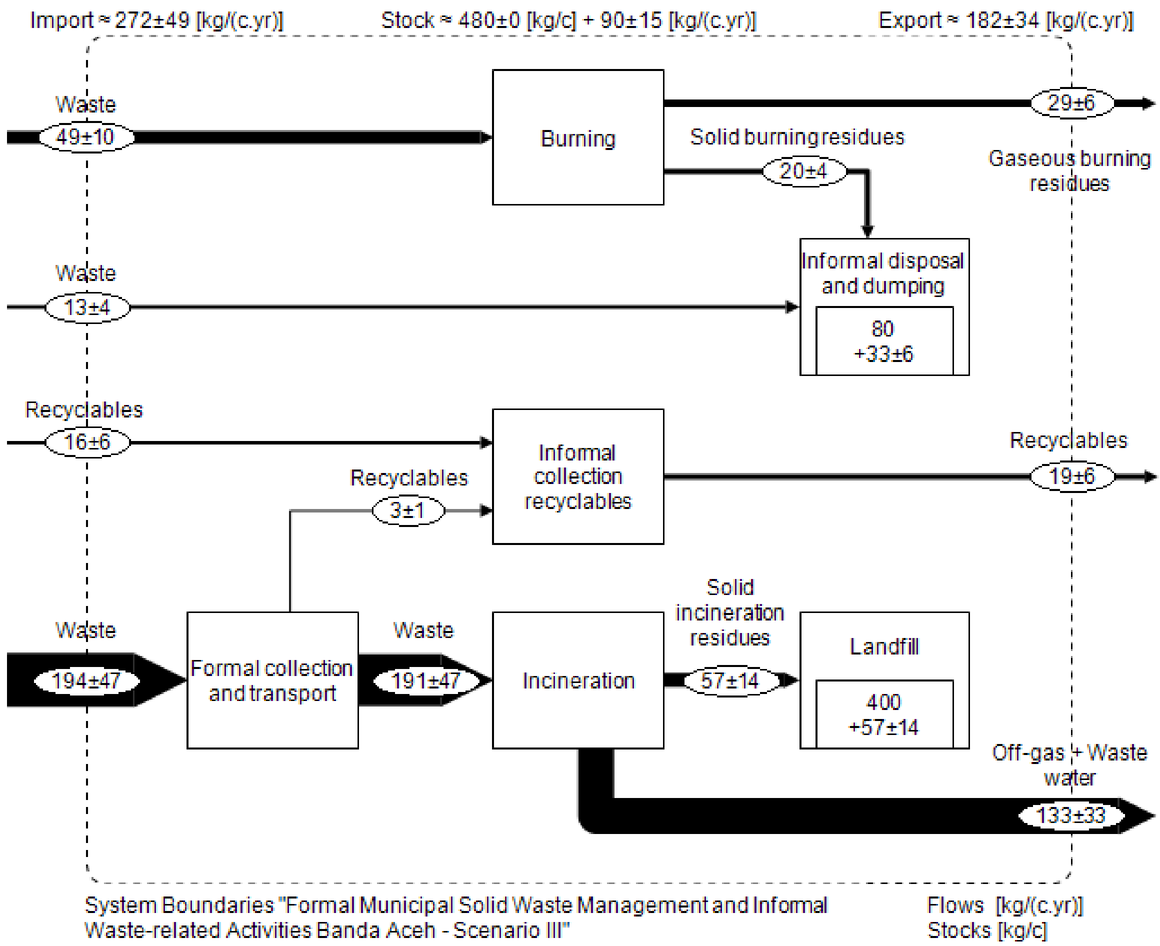
Figure 3-34 Banda Aceh scenario II – distribution of costs for collection, composting and landfill



3.3.3 Scenario III: Waste incineration

Material fluxes

Figure 3-35 Banda Aceh scenario III – results as MFA chart



Assuming that the total import into the formal collection systems remain stable, the input into the *incineration* process, coming from *formal collection and transport*, has with 191 kg/capita/year the same size as input flux into the process *landfill* in the current MSWM system (see Figure 3-29, page 101). With a transfer coefficient of 30% or 0.3 of solid incineration residues from *incineration* to the process *landfill*, about 57 kg/capita/year are landfilled, while 133 kg/capita/year gaseous and liquid residues leave the system as export.
All other processes and flows do not to change compared to the current situtation.

Waste composition

As waste composition of waste processed in the incinerator, a share of 50% organic materials, 15% plastics, 15% paper and cardboard and 20% mixed wastes is applied.

Fuel demand

The fuel demand is assumed not to change compared to the current MSWM system demand of 392 320 litre/year, the same as the external energy input E_{demand} with 63 MJ/capita/year.

Costs

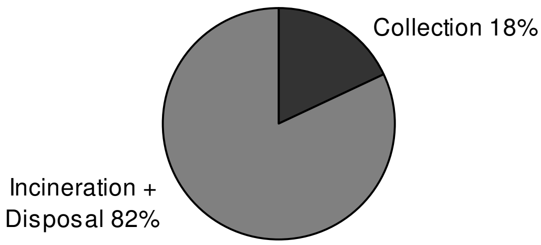
Through incineration, another cost component is added. Collection costs remain, with 544 000 €/year, steady compared to the current state. Landfill costs are incorporated within the costs for incineration and disposal of solid residual materials. Thus incineration including disposal add up to approximately 2 450 140 €/year, leading to total costs of 2 994 140 €/year. Per capita, the costs for MSWM then are 13.6 €/capita/year. The share between collection and incineration plus landfilling is then about 18 versus 82%.

Table 3-34 Banda Aceh scenario III – expenditures for MSWM

Unit	Collection	Incineration and disposal	MSWM total
[IDR/year]	6 816 250 700	30 710 684 480	37 710 684 484
[IDR/(capita.year)]	31 030	139 810	170 840
[€/year]	543 994	2 450 142	2 994 137
[€/(capita.year)]	2.5	11.2	13.6
%	18	82	100

See Annex 12.6.7, page 226 for calculations.

Figure 3-36 Banda Aceh scenario III – distribution of costs for collection, composting and landfill



Energy recovery

Using an energy yield of 0.58 MWh/ton, a conversion factor of 1 MWh = 3 600 MJ and the amount of waste burned, the energy recovery $E_{recovered}$ is calculated as follows:

$$E_{recovered} = 0.58[MWh/ton]*0.191[ton/capita/year]*\ 3\,600[MJ/MWh] = 399[MJ/capita/year] \quad (3.6)$$

3.4 Selected indicators for the current state and the scenarios

While for Vienna, the indicators from Brunner and Fellner (2007) are used, for Banda Aceh they are calculated. Thus, this chapter only refers to the current MSWM system and the scenarios of Banda Aceh.

3.4.1 Indicators for Viennas MSWM system

Most indicators used herein for Vienna were already calculated by Brunner and Fellner (2007), which makes it inevitable to use them rather than to calculate them self-contained. Indicators that can not be found there are not calculated, as the focus of this thesis lies rather on Banda Aceh, where no such thing like a strategic environmental audit was done before.

Table 3-35 Vienna 2006 – indicators for MSWM system

Indicator	Value	Unit
Share of MSW informally disposed/dumped/burned	< 1[1]	%
Share of households without access to MSW collection	< 1[2]	%
Dioxin/furan emissions	n.d[3].	[µg TEQ/(c.yr)]
Nitrogen emissions hydrosphere	7	[g N/(c.yr)]
Greenhouse gas emissions	27	[kg GWP/(c.yr)]
Waste not recycled	75	%
Energy input-ouptut	n.d.	[MJ/(c.yr)]
Required landfill volume	0.14	[m³/(c.yr)]

(Brunner and Fellner 2007:238)

3.4.2 Indicators for Banda Acehs MSWM system

Indirect indicators for health and environment

<u>Share of waste informally disposed, dumped or burned in kg/capita/year</u>

Under the defined conditions, the fraction of MSW informally disposed, dumped or burned is with 23% constant for the current state and the scenarios II and III. Only for scenario I this amount is about zero if full collection service coverage can be achieved.
23% corresponds to 62 kg/capita/year, but the figure expressed in ton per day (37 tons/day) gives a better picture of the situation.

[1] Assumption
[2] Assumption
[3] n.d. – "not determined"

Table 3-36 Banda Aceh – share of waste informally disposed, dumped or burned

	Unit	Current	Scenario I	Scenario II	Scenario III
MSW import total	[kg/(c.yr)]	272	272	272	272
MSW informally disposed/	[kg/(c.yr)]	62	0	62	62
Share MSW informally disposed/	%	23	0	23	23

<u>Share of households not having/using access to MSW collection service in %</u>

According to the questionnaire survey (see page 86 for results), about 35% do not have or use the formal waste collection service. They rather burn or dispose/dump their waste. This figure does not change for the scenarios II and III, but by extending the collection service, this indicator can be reduced, in the case of scenario I to zero.

Table 3-37 Banda Aceh – share of households without access to formal MSW collection

	Unit	Current	Scenario I	Scenario II	Scenario III
Share households not having/using access to formal MSW collection	%	35	0	35	35

Direct indicators for health and environment

<u>Dioxin (PCDD) and furan (PCDF) emissions [µg TEQ/(capiata.year)]</u>

Using the UNEP chemicals toolkit, the dioxin and furan emissions from waste management activities were calculated for every scenario. For the current system, about 45 µg TEQ/capita/year were calculated. Scenario II and scenario III (46 and 47 µg TEQ/capita/year) show a slight increase, while the annual releases are about 33 times[1] lower for scenario I with 1 µg TEQ/capita/year.

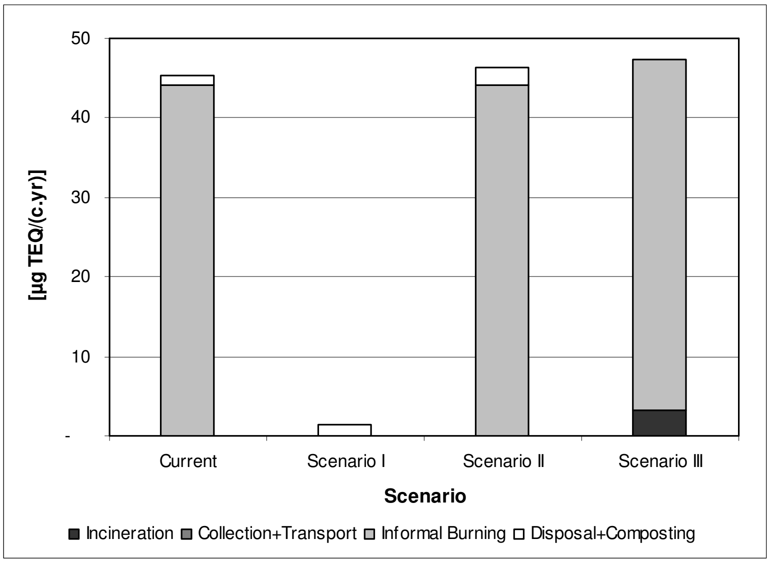
[1]The exact value is 1,47 [µg TEQ/(c.yr)] for scenario I.

Table 3-38 Banda Aceh – annual dioxin and furan emissions

Compartment	Current	Scenario I	Scenario II	Scenario III
Air	15	0	15	15
Water	0	0	0	0
Land	29	0	29	29
Product	0	0	1	0
Residue	1	1	1	3
Total	45	2	46	47

in µg TEQ/capita/year

Figure 3-37 Banda Aceh - annual dioxin and furan emissions



For the mass flow partition in each compartment from the processes were dioxin and furan are released, the fraction going to land is the highest for the current state and scenarios I and II, followed by releases into the air. Main responsible for this is the informal burning of wastes. As this process is assumed to be absent for scenario I, not only the total amount released is smaller, but also mass flow partition. Nearly all dioxins and furans are in the residue, meaning the sanitary landfill.

<u>Nitrogen emissions into the hydrosphere in g N/capita/year</u>

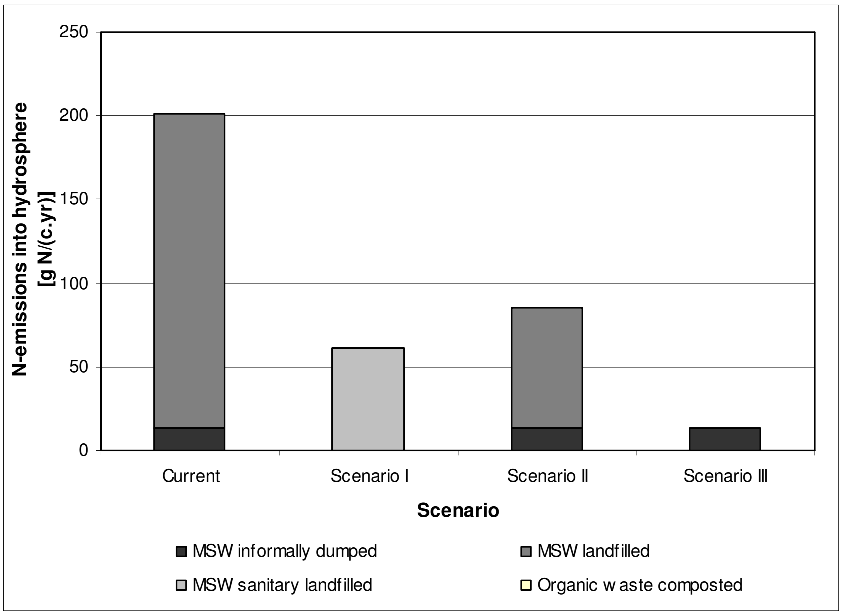
The calculation of nitrogen emissions show that the current system releases the highest amount with 201 g N/capita/year. For scenario I, the value is lower, due to the treatment of leachate (61 g N/capita/year), same as for scenario II (85 g N/capita/year), where less organic waste is disposed at landfill and nitrogen from the composting leachate is treated. Scenario II shows with 13 g N/capita/year the lowest emission, as the organic matter of the waste are incinerated.

Table 3-39 Banda Aceh – nitrogen emissions into the hydrosphere

Process	Current	Scenario I	Scenario II	Scenario III
MSW informally dumped	13	0	13	13
MSW landfilled	188	0	72	0
MSW sanitary landfilled	0	61	0	0
Organic waste composted	0	0	0,2	0
Total	201	61	85	13

in g N/capita/year

Figure 3-38 Banda Aceh – nitrogen emissions into the hydrosphere



Greenhouse gas emissions in kgGWP/capita/year

The total global warming potential of the current MSWM system was calculatedto 205 kgGWP/capita/year. While scenario I shows an increase to about 288 kgGWP/capita/year, the GWP is decreasing at scenario II and scenario III with 174 respectively 115 kgGWP/capita/year.

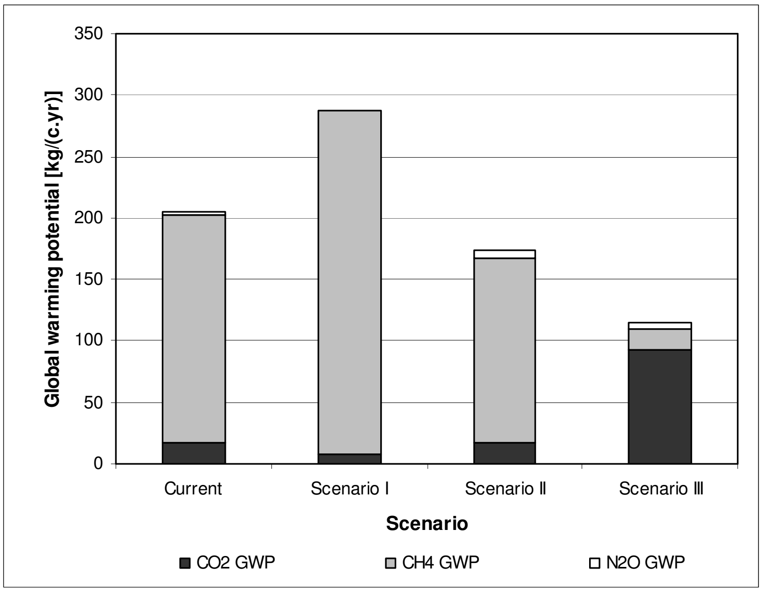
Table 3-40 Banda Aceh – global warming potential (GWP) of MSW activities

GWP	Current	Scenario I	Scenario II	Scenario III
CO2 GWP	16	7	16	93
CH4 GWP	186	280	151	17
N2O GWP	2	0	7	4
GWP Total	205	288	174	115

in kgGWP/capita/year

The largest fraction of GWP for the current state (186 kgGWP/capita/year), scenario I (280 kgGWP/capita/year) and scenario II (151 kgGWP/capita/year) are methane emissions, primarily from landfills and informal dump sites. For scenario III, the CO_2 - emissions from the incineration and open burning dominate (93 kgGWP/capita/year). Generally, N_2O has a minor impact on the GWP.

Figure 3-39 Banda Aceh – global warming potential (GWP) of MSW activities



Indicators for resource conservation

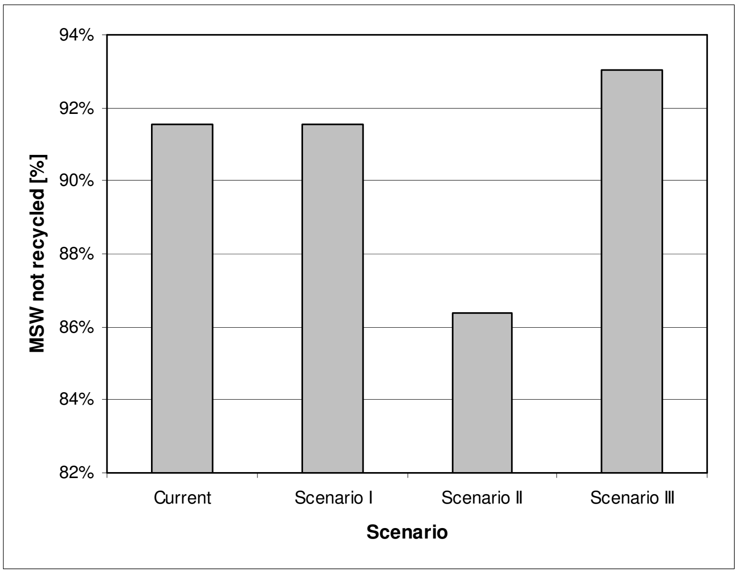
<u>MSW not recycled in %</u>

MSW not recycled, defined as the total MSW import minus recycling materials export out of the system, divided by the total MSW import into the system, is for the current system 92%. While there is no change for scenario I, scenario II shows with 86% a lower rate. Reason for this increase is the addition of compost as product from the composting unit. Scenario III shows with 93% a slight increase, compared to the current system, as it is assumed that the flux of recyclables from landfill expires. It is hardly imaginable that scavengers can pick recyclable materials in the storage bunker at the incineration plant. And metals, which could be easier removed after incineration from the slag, are simply not present in Banda Acehs MSW.

Table 3-41 Banda Aceh – MSW not recycled

	Unit	Current	Scenario I	Scenario II	Scenario III
MSW import total	[kg/(c.yr)]	272	272	272	272
Recycling materials export	[kg/(c.yr)]	23	23	37	19
MSW not recycled	[kg/(c.yr)]	249	249	235	253
MSW not recycled	%	92%	92%	86%	93%

Figure 3-40 Banda Aceh – MSW not recycled



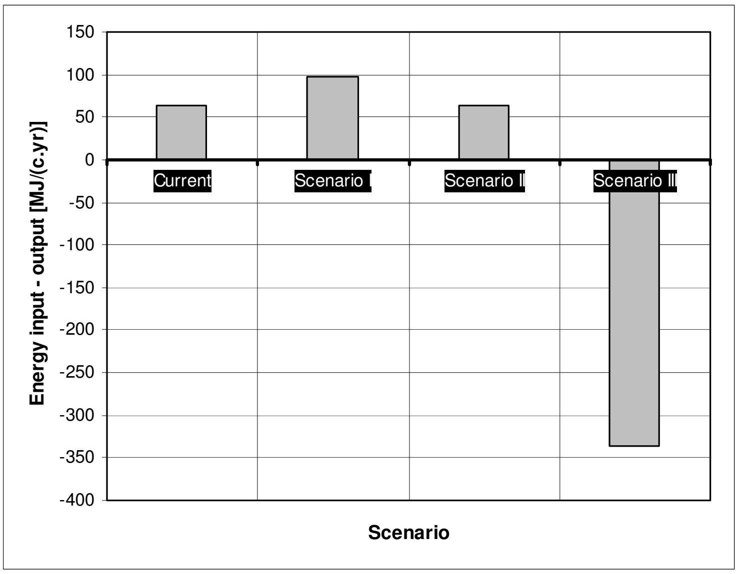
Energy input - output in MJ/capita/year

The energy input - output is stable for the current state and scenarios II and III with 63 MJ/capita/year, but higher for scenario I with 97 MJ/capita/year. Energy recovery is only for scenario III – incineration crucial with 399 MJ/capita/year, which leads to a negative value – meaning that the energy output is higher than the energy input.

Table 3-42 Banda Aceh – energy input - output

	Unit	Current	Scenario I	Scenario II	Scenario III
External energy demand	[MJ/(c.yr)]	63	97	63	63
Energy recovery	[MJ/(c.yr)]	0	0	0	399
Energy input - output	[MJ/(c.yr)]	63	97	63	-336

Figure 3-41 Banda Aceh – energy input – output



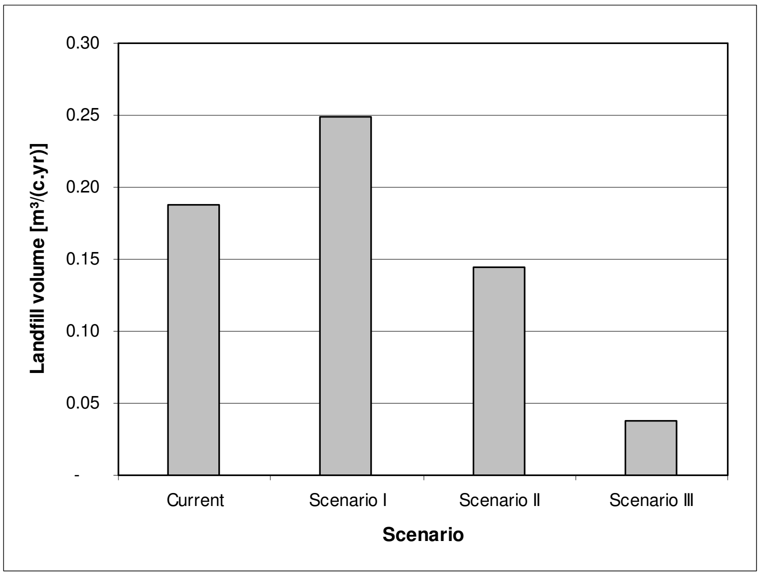
<u>Required landfill volume m³/capita/year</u>

The required landfill volume for the current system is 0.14 m³/capita/year. It increases for scenario I to 0.19 m³/capita/year which is due to the higher amount of wastes landfilled, as collection is extended. Scenario II shows a decrease to 0.11 m³/capita/year, as composting lowers the amount of waste landfilled, while scenario III shows with 0.04 m³/capita/year the lowest values. The volume reduction through incineration is far higher than, for example, through composting.

Table 3-43 Banda Aceh – required landfill volume

	Unit	Current	Scenario I	Scenario II	Scenario III
MSW landfilled	[kg/(c.yr)]	188	249	144	57
MSW default density	[kg/m³]	1 000	1 000	1 000	1 500
Landfill volume	[m³/(c.yr)]	0.19	0.25	0.14	0.04
Landfill volume	[m³/yr]	41 296	54 695	31 631	8 347

Figure 3-42 Banda Aceh – required landfill volume



4 Discussion goal oriented assessment

4.1 Discussion of results

4.1.1 Results from data collection MSWM system Vienna 2006

Viennas MSWM system is rather complex, which can be illustrated through the MFA chart (Figure 3-1, page 76). Nevertheless, it was not difficult to analyse the data, particularly for waste streams. The same can only partially be said for expenditures on MSWM. Operational costs are presented in the annual *Closing of accounts* (MA5:2006). However, it is more difficult to categorise the operational costs to the referring processes. It would be interesting to see, which process in the MSWM system would be the most or least expensive.

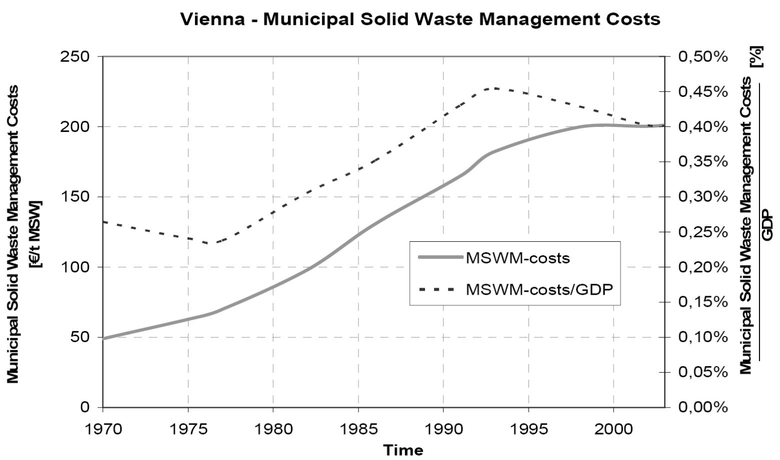
For investments, sufficient information on recently planned or implemented projects, e.g. the new MVA Pfaffenau and the biogas plant to treat organic waste, is available and also transparent illustrated. Older investments are not so easy to detect, particularly when an old facility was adapted to new standards. The sorting plant Rinterzelt, the landfill Rautenweg or the MVA Spittelau can be mentioned as examples.

Now the focus of this thesis lies on the MSWM of Banda Aceh, which makes the author not to emphasize too much on Viennas MSWM system. But there are some trends, particularly in the costs for MSWM, which are mentioned herein.

It was in 1934 when the Municipality of Vienna introduced waste collection fees. Every household had to pay 1.5 *Austrian Schillings* per bin (MA48 2007:45). This was about to finance the waste management system – which only contained collection and disposal at the time.

Nowadays, as the MSWM system has become more complex while new processes has been added and the costs for MSWM have increased.

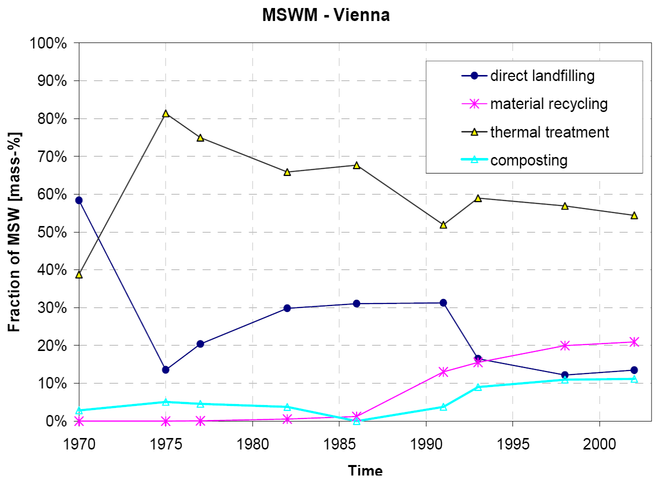
Figure 4-1 Cost trends of MSWM in Vienna from 1970 to 2002



(Brunner and Fellner 2006)

As Figure 4-1 shows, a steady increase of costs in absolute and relative terms occurred between 1975 and 1995. Now, what are the reasons for this increase? Figure 4-2 gives one answer to this question.

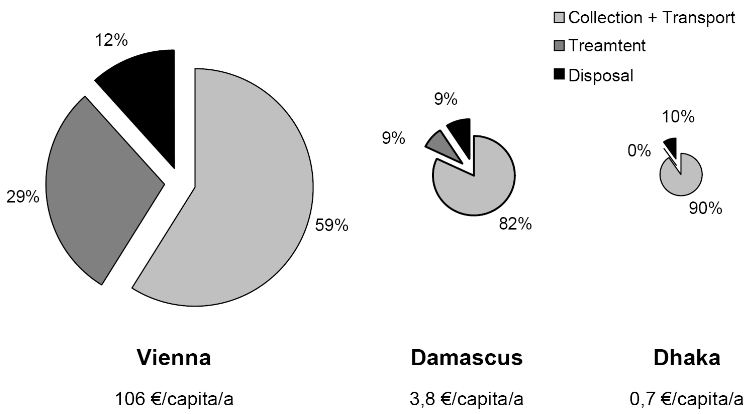
Figure 4-2 Development of MSWM in Vienna from 1970 to 2002



(Brunner and Fellner 2006)

Through the introduction of the new processes material recycling and composting, new cost components are introduced. Furthermore, the standards for emission reduction for the processes incineration and landfill became stricter. This leads to relative higher costs for waste treatment, especially if compared to the MSWM cost structure of urban regions from other countries (Figure 4-3).

Figure 4-3 Cost structure of MSWM for different urban regions



(Brunner and Fellner 2006)

The higher costs for treatment must be seen as cost for meeting higher standards set by society and their decision makers regarding emissions.

4.1.2 Results from field research Banda Aceh

Questionnaire survey

According to the questionnaire survey, about 65% of households hand their waste over to the municipal waste collection service of DKP, while 30% burn their wastes and about 5% choose a different disposal method. In June 2007, DKP covered 78 of the total 90 village (DKP et al. 2007:Annex 17). The 12 villages not covered have a population of 6 045, the villages covered 211 895, making a total of 217 940 inhabitants (DKP et al. 2007:Annex 18). The population figure utilized from BPS (2007) was with 219 657 exactly 1 717 higher then the DKP data.
Thus the population of the villages not covered by the collection service is about 3% of the total, which means that the great majority of people not using the waste collection service live in areas were they theoretically could have access. However, the question whether households who do not hand over their waste to the municipal authorities do not have access to the collection service or just do not use their access to it, can not be answered by the research results.

The interviews with the households showed that some of them used various disposal methods. For instance, some households reported that they put their organic waste into the next waste collection container, while they bury their inert wastes or burn their burnable waste in the backyard.
During the presentation of the research results on November, 23rd 2008 at Syiah Kuala University, one auditor questioned the figures presented, saying that the collection service coverage might be far lower. From his own studies he got different results on the collection service coverage in some villages, particularly were new housing for Tsunami-victims were built.

Waste sampling

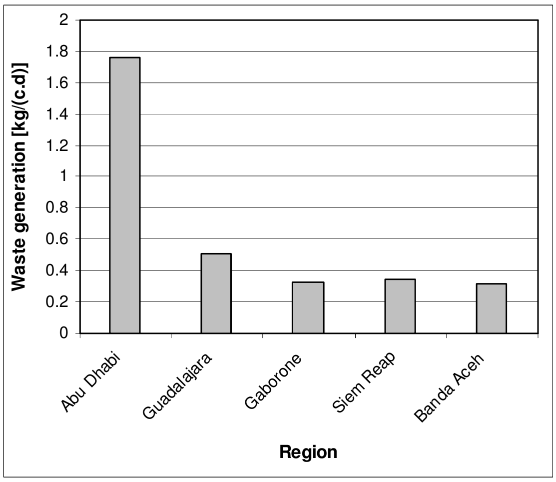
<u>Households</u>

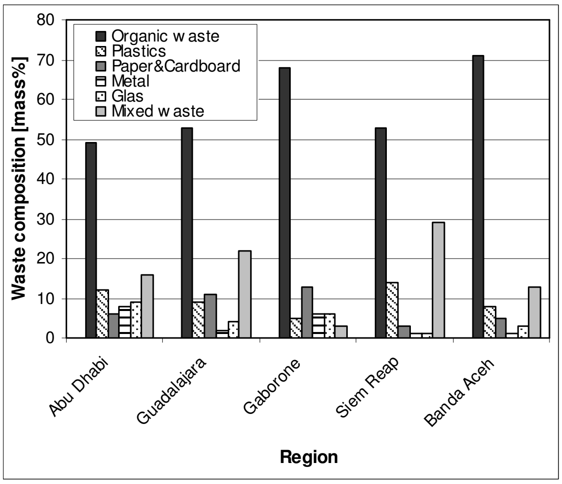
The calculated daily mean value sampled was 322 g/capita/day with a standard deviation of 45 g/capita/day. Expressed in a more common SI unit, it is 0.32 respectively 0.05 kg/capita/day. Compared to other studies using a similar methodology, this yield is in the lower range, but is quite comparable to data from Botswana and Cambodia (see Table 4-1 and Figure 4-4).

Table 4-1 Household waste generation rates from different studies

Region	Abu Dhabi	Guadalajara	Gaborone	Siem Reap
Country	UAE	Mexico	Botswana	Cambodia
Year	1995	1997	2001	2004
GNI_{real} €	14 067	5 329	4 037	314
GNI year	2004	2005	2005	2005
WGR[1]	1.76 [kg/(c.d)]	0.51 [kg/(c.d)]	0.33 [kg/(c.d)]	0.34 [kg/(c.d)]
Source	Abu Qdais et al. 1997	Bernache-Peréz et al. 2001	Bolaane et al. 2004	Patrizeau et al. 2006

Figure 4-4 Household waste generation and composition in Banda Aceh compared to other studies





The household sampling survey was stratified according to the household income. Furthermore, the attempt was made to include households with different household sizes. While there is a strong correlation between household size and household waste generation rate, the one between reported household income and household waste generation rate is quite weak (see Figure 3-23, page 92 and Figure 3-24, page 93).

Particularly for the income one should not pay to much attention on this result, as the sample size for households from income group 3 and 4/5 was with 5 and 4 respectively very small. For households from income group 1 and 2, it was with 20 households each far bigger.

The composition shows that organic waste dominates with about 70%, which is a high share compared to other studies, while the share of plastic, paper and cardboard, metal and glass is quite low (see Figure 4-4). The mixed waste fraction is the second biggest, but it must be said that this fraction contains materials that would technically better fit in other fractions, like small compound packing materials.

[1] WGR – Waste Generation Rate

Another key-finding regarding the waste composition was that the amount of recyclable materials in the household waste was very low. While recyclable materials with a high value per unit of mass, like metal and glass, are generally scarce, the paper and cardboard and the plastic found in household wastes is mostly not suitable for recycling. The plastic fraction usually contains plastic bags and small packing material and is, slike paper, generally of a small size. Furthermore, both are very dirty and wet, thus their value is so low that recycling of them is not practised.

<u>Other establishments</u>

Even though the result of this part of the sampling was not incorporated in the MFA calculation, it is of interest. Schools and offices, where one can have calculated the waste stream, do not contribute much to the total waste stream. In Banda Aceh, about 46 000 inhabitants are in school age, between 5 and 19 year (BPS 2007). As not all of them go to school, and these figures therefore generally might be too low[1], let us assume that there are 40 000 students in Banda Aceh. If multiplied with the waste generation per student from the sampling (50 g/student/day) and 300 schooldays/year, then divided by the population figure of 219 657, the waste flux from schools can be calculated as

$$40\ 000\left[students\right]*0.05\left[kg\ /\ student\ /\ day\right]*300\left[days\ /\ year\right]/\ 219657\ =\ 2.7\left[kg\ /\ capita\ /\ year\right] \quad (4.1)$$

which is only 1% of the total import flux of 272 kg/capita/year. A similar result can be expected for offices, where the waste generation per employee is about 70 g/employee/day.

The fraction of restaurants and small enterprises in the total waste stream might be larger, but due to the small sampling size and the existence of other MSW generation sources like markets, it does not make sense to incorporate them in the initial MFA calculation. Therefore the data from sampling these other generation sources than households will be applied later, when the calculated flows are crosschecked.

Another result from the waste sampling of other establishments than households and probably more revealing is the composition of wastes.
Offices and schools have a significant paper and plastic fraction. The paper and plastic found there has, due to its chemo-physical properties (polypropylene and polyethylene) and cleanness, a high value as recyclable material.
For small enterprises, cardboard is the dominating fraction. As found in the recycling survey, especially cardboard plays a major role as recycling material from MSW origin. This high amount of cardboard from enterprises can give an answer to the question, why cardboard is, with over 40% of all recyclable materials, the dominating fraction of recyclable materials traded by the sampled recycling agents.

[1] For instance, if the split-up population table from BPS (2007) is summed up, a total population figure for 2005 of about 175.000 inhabitants results. This figure is far lower than the more-likely total population figure of about 220.000 inhabitants, also from BPS (2007).

Recycling survey

The recycling survey shows large variations between the three sampled agents in terms of recycling materials quantity. Agent 1 trades 1 314 kg/day and thus five times more than agent 2 with 252 kg/day and over twice the amount than agent 3 with 576 kg/day. The average amount of recyclable materials per agent thus is 714 kg/day.

The two dominating materials in terms of mass are non-MSW metal, such as iron, steel and copper with 45% and paper and cardboard with 41%. It is very likely that iron, which dominates the non-MSW metal fraction, predominately comes from construction and demolition wastes, thus it is termed as non-MSW. While the amount of paper itself is small, cardboard makes almost 100% of the *paper and cardboard* fraction. The results from sampling other establishments than households suggest that this cardboard mainly comes from small enterprises, like shops. This assumption is backed up by the information gathered from the owner of the building materials shop sampled. As can be seen in Table 3-15, page 92, this shop generated about 5.9 kg/day, of which 95% is cardboard. All of this cardboard is sold to waste pickers or recycling agents. However, this information is the base for a projection when under point *MSW generation rate, material fluxes and uncertainties* (page 127 ff), the calculated MSW fluxes are validated.

For this reason, information on recycling gathered can be of interest. In the last days[1] of the research period, a spontaneous interview with one of the five big recycling agents who sends his recyclables for further processing to Medan, was held. As most of these big recycling agents, he was located on the way from town to the landfill. Nevertheless, he gave some indicative information on his business, the materials he collects and the volume of the recycling sector in Banda Aceh. Accordingly, this agent, who only collects cardboard, paper and plastics, sends 3-4 lorries of recycling material per week to Medan. One lorry can carry about 10-12 tons, depending on the material. Furthermore, he said that per day about 10 lorries of recycling material leave Banda Aceh heading to Medan. These particularly amazing amounts can also be used to assess the validity of the projected flux of recyclable materials.

Input landfill "Gampong Jawa"

For the MFA calculation, the landfill input data from 11 months between July 2006 and June 2007 was used. The fluctuation in Figure 3-26 (page 97) can only be partially explained, like the high values in September and October 2006 during the month of Ramadan, where similar to Christmas in Europe, higher MSW amounts can be expected.

Two more variables that might have an effect should be mentioned here, as they represent the difficulties in estimating waste amounts in Banda Aceh. First, construction and demolition wastes are also disposed at the landfill. This fraction can be quite large, as the Tsunami in the end of 2004 not only caused a huge amount of demolition wastes, but also lead to an immense reconstruction effort

[1] The interview was held on November, 22nd 2008. Unfortunately, it was one day before the author was leaving Banda Aceh. If this information would have been gathered earlier, a far better investigation of the recycling sector could have been achieved.

and thus an increase in the construction activity. While the removal of Tsunami demolition wastes have been officially completed, the second, meaning the reconstruction, is still on going and influences the amount of wastes disposed at the landfill.

MSW generation rate, material fluxes and uncertainties

<u>MSW generation rate</u>

The total MSW import into the current MSWM system, which can be also termed the MSW generation rate, is 272 kg/capita/year or 0.75 kg/capita/day. Considering the uncertainties, the MSW generation rate ranges from about 220 – 320 kg/capita/year or 0.60 – 0.90 kg/capita/day. If compared to data from the literature, this value might seem reasonable. Expressed in other units, the MSW generation rate is equal to 59 746 tons/year or 164 tons/day.

Table 4-2 MSW generation rates from Banda Aceh compared to values from literature

Country/Region	Banda Aceh	Indonesia	Banda Aceh	Urban LMICs
Source	Own calculations	Hoornweg 1999	DKP et al. 2007	Cointreau 2006
MSW [kg/(c.d)]	0.60 – 0.90	0.76	0.70	0.35 – 0.75

If the MSW generation rate is split up between household waste, waste from other sources and recyclables, one can see that the difference is not too big. 43% of MSW origins from households and 51% from other sources. The residual amount of recyclables origin most likely from other sources than households. However, if uncertainties are considered, this ratio could change, which makes sense to give a ratio between households and other sources (recyclables included) of from 35:65 to 50:50. DKP et al. (2007:37) cites a source called *Sogreah* which denotes that for urban areas, 25% should be added to the (household) waste to cover commercial and institutional sources. Thus, the ratio between household waste and commercial + institutional waste would be 80:20. Van Beukering (1999:17) gives a ration between household waste and commercial + institutional waste of 30:70 for Bangalore, India.

Table 4-3 Banda Aceh – contribution of different MSW generating sources to the MSW generation rate

Unit	Household	Other sources	Recyclables	Total
MSW generation rate [kg/(c.yr)]	117	139	16	272
MSW generation rate [kg/(c.d)]	0.32	0.38	0.04	0.75
Share in %	43	51	6	100

<u>MSW from households</u>

As the MSW fluxes from households were the subject of one questionnaire and one sampling survey, there is also a high likeliness of uncertainties and errors.

First, there is the waste sampling errors. It contains methodological errors, herein the systematic error due to selecting the wrong strata, in this case the income of households. Measurement errors refer herein to the error of analysis of the data, technical errors refer to the sampling equipment and transcription errors to the recording of data.

As seen in Figure 2-9 (page 38), the sampling equipment was rather basic, based on locally available kitchen scales. Presumable the technical error regarding these scales is large.

Second, the population figure does not likely reflect the actual population of Banda Aceh. Data varies between about 177 000 (BPS 2007), 217 000 (DKP 2007) and 220 000 (DKP 2007).

<u>MSW from other sources than households</u>

The MSW generation by other sources than households were calculated as 139 kg/capita/year and represents 51% of the total MSW generation (see Table 4-3). This figure was calculated through a material balance, as described earlier in this thesis. See page 45 for the methodology and page 99 for the result of the calculations. Basically, the data from the household sampling and the input data from the landfill were used to calculate the material flows. How this MSW flux from other sources than households partition on the processes *formal transport and collection*, *burning* and *informal disposal and dumping* was subject of an assumption. Thus, the sources of uncertainties can be listed as follows:

- Uncertainties from household sampling
- Uncertainties from input data landfill
- Uncertainties from the partition of the MSW flux from household
- Error in assuming the partition of the MSW flux from other sources than household

Particularly the uncertainties from the input data into the landfill should be mentioned here, as they not only affect the MSW flux from other sources than households, but also the MSW import flux total. This affects the MSW generation rate, which is a key figure in MSWM planning and design.

A basic validation of the calculated size of the MSW flux from other sources than household is done herein.
The MSW sources beside households considered herein are markets, small enterprises, gastronomy establishments, offices and schools. Not considered are for instance hospitals, the military force and all others.
For markets, the information was gathered that only from the central market (the biggest of Banda Acehs markets) per day 4 full loaded dump truck of waste are collected. Beside that, 3 permanent containers are placed in or close to the market. Both, containers and dump trucks have a capacity of 6 m³. If a waste density of 300 kg/m³ and a filling degree of 80% is assumed, the daily waste generation of the central market can be calculated as follows:

$$MSW_{centralmarket} = 7\ [loads/day] * 6\ [m^3/load] * 300\ [kg/m^3] * 0.8 = 10\ 080\ [kg/day] \quad (4.2)$$

If assumed that the central market generates about 33% of all market wastes[1], the total MSW generation of markets can be extrapolated.
DKP actually works on a register of enterprises in Banda Aceh. The state of affairs in November 2007 was that there are over 10 000 enterprises in the city (DKP 2007)[2]. Using this figure multiplied with the results from the sampling of small enterprises, the MSW generation from small enterprises can be calculated.
For gastronomy establishments, the result from the eponymous sampling survey is multiplied by an assumed number of 1 000 units.
For schools, the results from sampling, expressed as MSW per student and day, is multiplied by the assumed number of students in Banda Aceh, as shown at page 125 earlier this chapter.
Same as for schools, the result from sampling, expressed as MSW per employee and day, is multiplied by the number of civil servants. This number is calculated based on the %age of government employees in Banda Aceh of 36% (DKP et al. 2007:28) and the number of employed labour force of about 75 000[3] (ICASERD et al. 2005), which leads to about 27 000 government employees.

[1] Banda Aceh has 11 markets or market areas.
[2] The final register has not been published at the time of the field research.
[3] Pre-Tsunami figures of labour force are over 80.000, recently after the Tsunami about 65.000 (WFP 2005).

Table 4-4 Banda Aceh – checking calculation for the materials flux "MSW from other sources"

MSW generation source	MSW generation [kg/(c.yr)]	Share in %
Markets	50	50%
Small enterprises	38	39%
Gastronomy establishments	5	5%
Schools	3	3%
Offices	3	3%
Other sources than households total	**99**	100%

The result of about 99 kg/capita/year (see Table 4-4) shows that the 139 kg/capita/year calculated through MFA is 40 kg/capita/year or about 40% higher. Even though not all sources are covered and the calculation in Table 4-4 contains high uncertainties, it suggests that the value of 139 kg/capita/year calculated through MFA might be too high (see Annex 12.8, page 231)

<u>Recyclables</u>

Based on the results from the recycling survey, the flux of recyclable materials collected and transferred to processing was projected to 23 kg/capita/year mean value or 17-29 kg/capita/year. The basic rationale behind this calculation is that the three sampled intermediate recycling agents are representative, the number of intermediate agents is known (the number of 35 was assumed) and the material chain for recyclables is households/ waste pickers/ scavengers → intermediate recycling agents → recycling agents → export from the system. Thus, following sources of uncertainties can be listed:

- Sampled intermediate agents not representative
- Number of intermediate agents not correct
- Alternative material chains (see Figure 3-8, page 83), like material fluxes from waste pickers to recycling agents

Taking the information from the recycling agent as described in chapter *Recycling survey*, page 126, an alternative estimation of recyclables from MSW can be done. First, this agent reported that he sends 3-4 vehicles with 10-12 ton capacity each to Medan. As he only collects paper and cardboard and plastic, this recyclables can be considered as of MSW origin.

$$M_{recyclables,\ 1\ buyer} = 3.5\ [vehicles/week] * 11\ 000\ [kg/vehicle] * 50\ [weeks/year]\ /\ 219.657 = \\ = 8.8\ [kg/capita/year] \qquad (4.3)$$

That means that only one of five recycling agents trades with about 9 kg/capita/year. Taking the second information that per day 10 vehicles loaded with recyclable leave Banda Aceh to Medan, each vehicle has a load of 10 tons and that about 40% of these recyclables are from MSW origin (see page 126), the calculation looks as follows:

$$M_{recyclables} = 10\ [vehicles / day]\ *\ 10.000\ [kg / vehicle]\ *\ 360[days / year]\ *\ 0.4\ /\ 219.657\ =$$

$$=\ 66\ [kg / capita / year] \qquad (4.4)$$

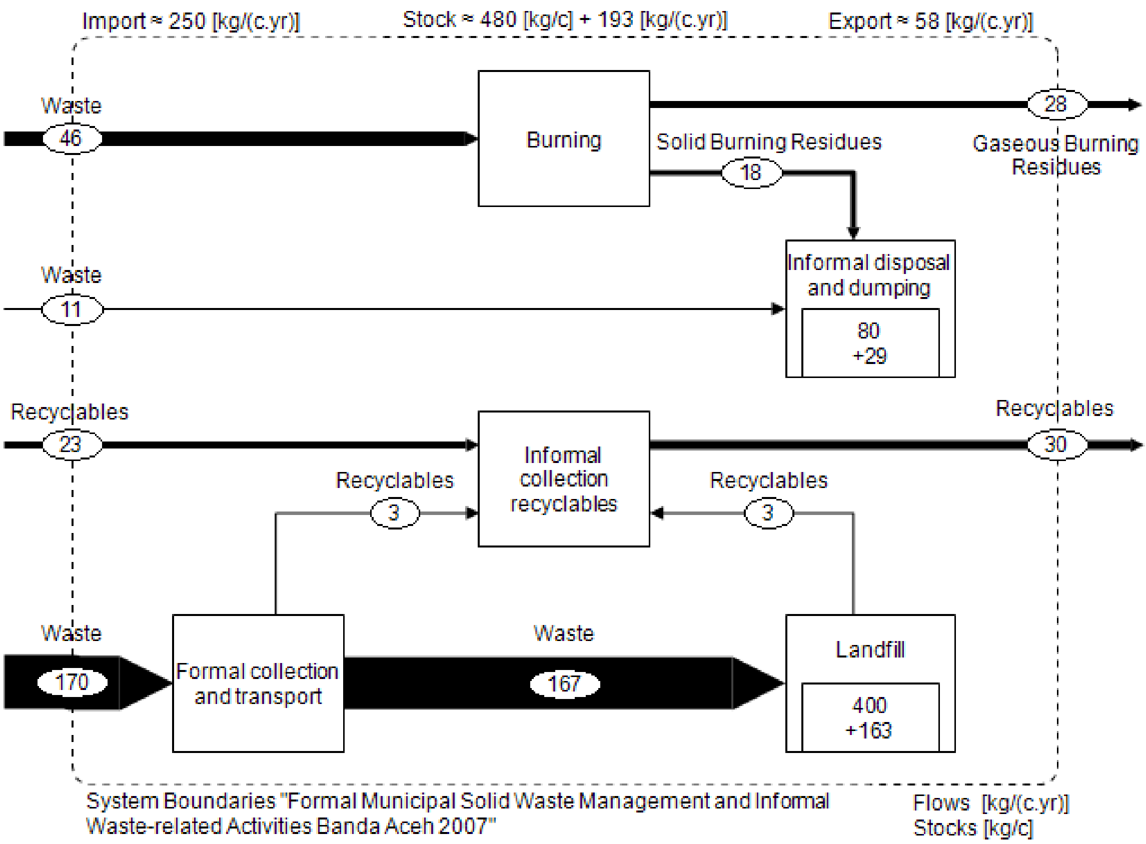
These two calculations shows that the real amount of MSW based recycling materials collected and transferred is likely to be higher than the calculated mean value of 23 kg/capita/year.

<u>Alternative MFA calculation for Banda Aceh 2007</u>

To illustrate, which influence the uncertainties noted can have on the MFA, the waste generation rate, but also on the indicators, an alternative MFA for the system MSW Banda Aceh 2007 can be exemplified calculated.

Taking a total MSW import flux of other sources than households of 110 kg/capita/year, based on the 99 kg/capita/year calculated in Table 4-4 plus 11 kg/capita/year to cover the sources not considered, an export flux of recyclables of 30 kg/capita/year and the same values for the import from households, an alternative MFA can be calculated as follows:

Figure 4-5 Banda Aceh – MFA calculation current system with different figures



The consequences are small but manifold. For instance, the MSW generation rate dropes slightly from 0.75 to 0.69 kg/capita/day, which is still within the margin of error of 0.6 – 0.9 kg/capita/day. Therefore, the MSW not recycled decreases from 92% to 88%. The slight difference in the MSW generation shows that the earlier MFA calculation might not be too far from reality, but additionally it shows that it makes sense to give a range instead of a single number.

4.1.3 Comparison MSWM systems Banda Aceh – Vienna

MSW generation and costs

If some aspects of the MSWM systems of the two cities are compared, one can see some, according to literature, typical characteristics. As the absolute figures are difficult to compare due to the different sizes of both cities, only some of the relative figures are discussed below.

The MSW generation rate is more than twice as high in Vienna than in Banda Aceh. Also, Vienna's MSWM system is far more expensive in absolute figures and also higher if expressed in % of GNI. While the factor in costs per ton MSW is 14, the one in costs per capita and year is close to 37.

Table 4-5 Comparison of the current MSWM systems of Vienna 2006 and Banda Aceh 2007

	Unit	Vienna	Banda Aceh
MSW generation	[tons/yr]	924 805	59 747
Inhabitants		1 651 437	219 657
MSW per capita and year	[kg/(c.yr)]	539	272
MSW per capita and day	[kg/(c.d)]	1.5	0.75
Total MSWM costs	[million €/yr]	182	0.85
Costs per ton MSW	[€/ton]	196	14
Costs per capita and year[1]	[€/(c*yr)]	110	3.1
GNI_{real} per capita and year (2005)	[€/(c*yr)]	26 995	934
GNI_{PPP} per capita and year (2005)	[€/(c*yr)]	24 192	2 716
Costs in % of GNI_{real}	[% of GNI_{real}]	0.41	0.33
Costs in % of GNI_{PPP}	[% of GNI_{PPP}]	0.45	0.11

Indicators

If the indicators are compared with each other, the picture is quite clear and also reflects, why the costs of MSWM are so much higher in Vienna. Nearly all households are connected to the MSW collection system, thus the amount of waste informally dumped/disposed/burned is also negligible, while in Banda Aceh one-quarter of the wastes are not formally collected. Also, more than one-third of the households do not have or use an access to the formal MSW collection system. An extensive waste

[1] For Vienna excluding, for Banda Aceh including street cleaning.

water and leachate collection and treatment system removes nitrogen compounds in Vienna, while in Banda Aceh about 200 g N/capita/year or 30 times higher amounts than in Vienna is released into the hydrosphere. Also, the global warming potential emissions in Banda Aceh are higher, but a different calculation methodology for both cities might be obtained, as the value for Vienna is taken from literature (Brunner and Fellner 2007).
However, materials recycling rate is three times higher in Vienna, thus the amount of MSW not recycled is 17% lower for Vienna. The required landfill volume is lower in Vienna.
In all, Vienna spends much more money for municipal solid waste management than Banda Aceh. The result denotes that Vienna has more desired values for all indicators.

Table 4-6 Assessment indicators of the current MSWM systems of Vienna 2006 and Banda Aceh 2007

	Unit	Vienna	Banda Aceh	Desired trend
Share of MSW informally disposed/dumped/burned	%	< 1%[1]	23%	lower
Share of households without access to MSW collection	%	< 1%[2]	35%	lower
Dioxin/furan emissions	[µg TEQ/(c.yr)]	n.d.[3]	45	lower
Nitrogen emissions hydrosphere	[g N/(c.yr)]	7	201	lower
Greenhouse gas emissions[4]	[kg GWP/(c.yr)]	27	205	lower
MSW not recycled	%	75%	92%	lower
Energy input - output	[MJ/(c.yr)]	n.d.	63	lower
Required landfill volume	[m³/(c.yr)]	0.14	0.19	lower

[1] Assumption
[2] Assumption
[3] n.d. – not determined
[4] Herein, a different methodology approach for Vienna and Banda Aceh must be considered in the results.

4.1.4 Comparison of current MSWM system Banda Aceh versus scenarios

As the MSWM systems are adequately described in the chapters 3.2 and 3.3, they are not further discussed herein. What is discussed is the affect of the scenarios on the indicators.

Indicators for human health and environment

Share of MSW informally disposed, dumped or burned

In the current system, 23% of MSWs are informally disposed, dumped or burned and is a hazard for the local population and their environment. Under the chosen circumstances, scenario II and III do not bring any positive change, the situation remain stable. Only scenario I bring a significant positive change to this situation.

Share of households not having access to formal MSW collection

According to the questionnaire survey, 35% of households do not have or receive a formal waste collection service, which have negative sanitary effects. Same as before, the situation remain stable for scenario II and III, while only scenario I can change the situation to the better with a full coverage collection service.

Dioxin and furan emissions

The dioxin and furan emissions mostly derive from burning of wastes. As the amount of waste burned remain constant for scenarios II and III, compared to the current state, where about 45 µgTEQ/capita/year are emitted, no significant change can be achieved. Only scenario I, where the dioxin and furan emissions tend towards zero, can change the situation to the better.
A comparison to total national dioxin and furan emission inventories of other countries show that the value of 45 µgTEQ/capita/year achieved in the current system and the scenarios II and III are very high (see Table 4-7)[1].

Table 4-7 Total dioxin and furan emissions of selected countries compared to values for MSWM Banda Aceh 2007

	Brunei	USA	Lebanon	Philippines	Jordan	Banda Aceh
Population[2]	0.38*106	$299*10^6$	$4.1*10^6$	$84.6*10^6$	$5.6*10^6$	$0.22*10^6$
Dioxin/furan total [g/yr] [3]	1.4*10-6	$2\,100*10^{-6}$	$68*10^{-6}$	$531*10^{-6}$	$70*10^{-6}$	n.d.
Dioxin/furan total [µg/(c.yr)] [4]	4	7	17	6	13	45

[1] Most of the dioxin in countries with comparable MSWM system to Indonesia, like the Philippines, Lebanon and Jordan, comes from uncontrolled burning processes, like burning of wastes. However, as the author did the calculation for Banda Aceh and thus has some superficially experience, he sees the figures presented in the UNEP Chemicals report (UNEP chemicals 2003) critical and probably too low.
[2] World Bank 2007
[3] UNEP Chemicals 2003:65,88,95,113;
[4] Only dioxin and furan emissions from waste

Nitrogen emissions into hydrosphere

About 200 g N/capita/year are released to water bodies in the current system. All investigated scenarios shows a decrease. The smallest decrease is for scenario II, resulting in 85 g N/capita/year emissions. For scenario I, the decrease is threefold to 61 g N/capita/year. The largest decrease is recorded for scenario III, where only 13 g N/capita/year are emitted.

As opposed to dioxin and furan emissions, nitrogen emissions from MSWM activities can be assumed to play a minor role compared to other emission sources. An MFA of the sources of nitrogen in the Danube river shows that agriculture plays a predominant role with over 50%. An study on nitrogen fluxes from the human activity *to nourish* suggests furthermore that from the total nitrogen input, about 24% come up in wastes from food production and only 2% in household waste (derived from Brunner and Rechberger 2004:199 and 218).
Banda Aceh is not Austria or Europe, but the difference in terms of relative importance of nitrogen emissions from MSW might not be to far from each other.

Greenhouse gas emissions

The current system emits 205 kgGWP/capita/year greenhouse gas emissions, expressed as global warming potential. This value increases in scenario I to 288 kgGWP/capita/year, which is due to the fact that more waste is collected and landfilled. Scenario II shows a decrease to 174 kgGWP/capita/year due to the implementation of composting. Scenario III emits the lowest amount with 115 kgGWP/capita/year, as no, through incineration pre-treated, active organic waste is landfilled anymore.

However, if these figures are compared to the total GWP emissions, one can get an idea about their relevance. The total GWP potential emissions of Indonesia in 1994 was about 4 850 kgGWP/capita/year (see Annex 12.10, page 232). Greenhouse gas emissions from the MSWM system and the scenarios are ranging between 115 to 288 kgGWP/capita/year, which is only about 3-6% of the total GHG emissions (Sugandi et al. 1999). Even though the calculation method was slightly different for both figures, the comparison gives a clearer picture on the situation.

Indicators for resource conservations

MSW not recycled

Actually, about 92% of the MSW import into the current system is not recycled. This situation does not change much for scenario I and III, but for scenario II it decreases to 86%. The reason for that is that through composting a share of another waste fraction is recycled.

Energy input – output

The current MSWM system demands an external energy demand of 63 MJ/capita/year, mainly through fossil fuels for waste collection. Scenario I has a higher demand of 97 MJ/capita/year, as the waste collection service is extended and thus more fossil fuel is consumed. Due to the settings the demand remains stable for scenario II compared to the current system. Only scenario III has through the *waste to energy* option through waste incineration the potential to reduce the external energy demand. In fact, the balance shows that there is a energy recovery of 336 MJ/capita/year, which means that scenario III generates more energy from the waste than is spent throughout the collection.

<u>Required landfill volume</u>

The current required landfill volume is 0.19 m³/capita/year. It increases to 0.25 m³/capita/year for scenario I due to the higher amount of waste collected and landfilled. Scenario II shows a decrease to 0.14 m³/capita/year, while scenario III only requires 0.06 m³/capita/year.

Costs

The initial costs of 3.1 €/capita/year of the current system increases by the factor 4.5 to 13.6 €/capita/year for scenario III. Reason for that are the high investment and maintenance expenditures for the waste incineration plant. The increase in costs through scenario I is with a factor of 2 to 6 €/capita/year far lower than for scenario III. The cheapest option is scenario II, were the costs only increase by 25% to 3.9 €/capita/year.
However, one should bear in mind that scenario II is only cheaper than scenario III as a smaller amount of waste is collected.

Summarizing the effects of scenarios on indicators

Tables 4-8 summarize the indicators for all scenarios, while and 4-9 shows the proportional change of indicators related to the current state.

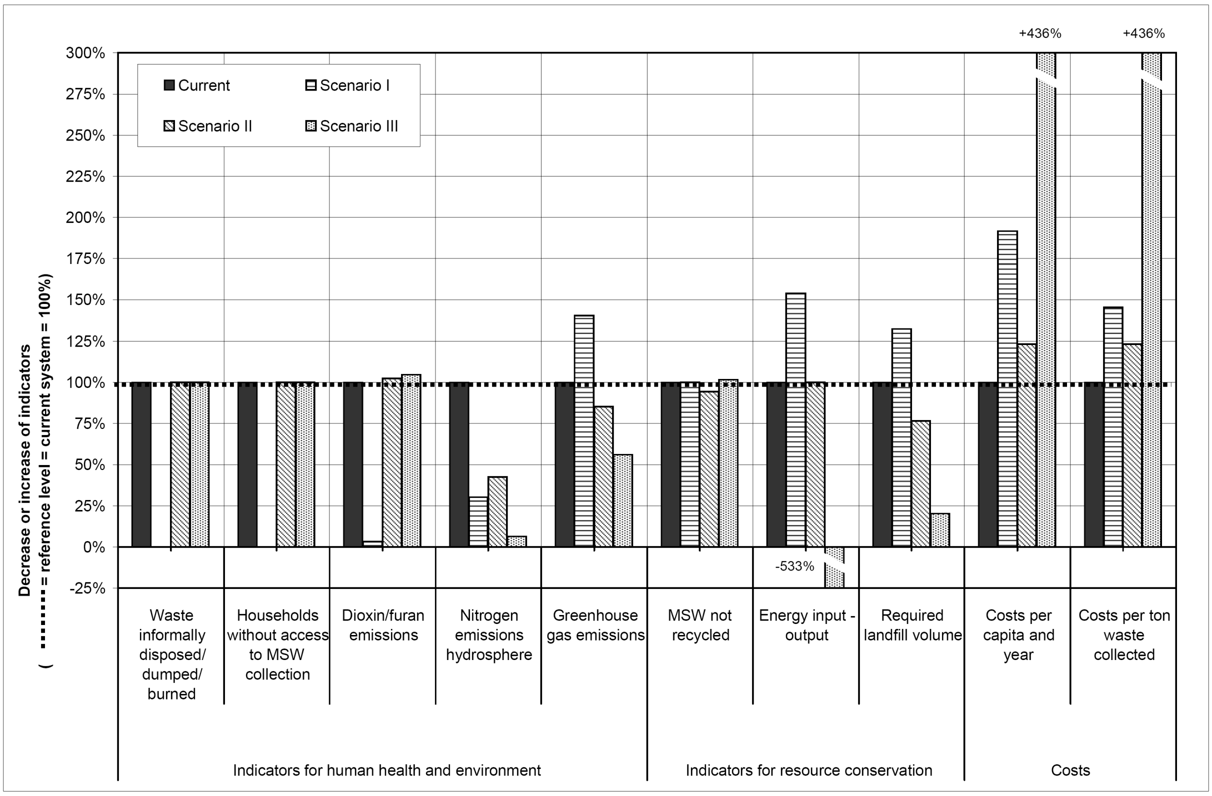
Table 4-8 Banda Aceh – comparison of indicators for each scenario

	Unit	Current	Scenario I	Scenario II	Scenario III
Share of MSW informally disposed/dumped/burned	%	23%	0%	23%	23%
Share households not access to MSW collection	%	35%	0%	35%	35%
Dioxin/furan emissions	[µgTEQ/(c.yr)]	45	2	46	47
Nitrogen emiss-ions hydrosphere	[g N/(c.yr)]	201	61	85	13
Greenhouse gas emissions	[kgGWP/(c.yr)]	205	288	174	115
MSW not recycled	%	92%	92%	86%	93%
Energy balance	[MJ/(c.yr)]	63	97	63	-336
Required landfill volume	[m³/(c.yr)]	0.19	0.25	0.14	0.4
Costs of MSWM	[€/(c.yr)]	3.1	6.0	3.9	13.6
Costs of MSWM	[€/ton MSW collected]	16	23	20	70
Costs of MSWM	[% of GNI_{real}]	0.3%	0.6%	0.4%	1.5%
Costs of MSWM	[% of GNI_{PPP}]	0.1%	0.2%	0.1%	0.5%

Table 4-9 Banda Aceh – changes of indicators for each scenario proportional to the current state

	Current	Scenario I	Scenario II	Scenario III
MSW informal disposed dumped/burned	100%	0%	100%	100%
Households not access to MSW collection	100%	0%	100%	100%
Dioxin/furan emissions	100%	3%	103%	105%
Nitrogen emissions hydrosphere	100%	30%	42%	6%
Greenhouse gas emissions	100%	140%	85%	56%
MSW not recycled	100%	100%	94%	102%
Energy balance	100%	154%	100%	-533%
Required landfill volume	100%	132%	77%	20%
Costs per capita and year	100%	192%	123%	436%
Costs per ton waste collected	100%	145%	123%	436%

Figure 4-6 Banda Aceh – result changes of indicators for each scenario proportional to the current state [1]



Generally, if two scenarios show no clear difference in one indicator, one should be cautious to draw clear conclusions from this indicator, as the uncertainties in calculating material flows and indicators are fairly large. Considering this limitation, it can be said that scenario I is the only scenario which is able to change the first three indicators on human health and environment significantly. To reduce the nitrogen emissions, scenario I is the second best option, while it is the only one that increases the greenhouse gas emissions. However, as shown at page 135, the relevance of MSWM for Indonesian greenhouse gas emissions is not substantial.

On the conservation of resources indicators, scenario I has the least desired effect, while scenario II and III both have hence positive affects.

In terms of costs scenario III is the least affordable. The increase in expenditures for scenario I is more significant than for scenario II but far smaller than for scenario III. Scenario II has the lowest impact on the costs, but one should bare in mind that if scenario II would process the same amount of waste than scenario I, the costs are higher.

[1] Note that the energy input - output for scenario III is not -50 % as shown in the figure, but -533%. Due to illustration reasons, the column was cut off at -50%. The "minus" in this case means a net output. The same can be said for the costs, where the column is cut off at 300%.

4.2 Discussing methodology

The methodology choice is for students probably the most difficult part of a diploma thesis. The student usually stands in the very beginning of his or her academic career and thus lacks the experience to know which methodology would be appropriate. Thus the discussion of the methodology is an essential part of a thesis as a reflection of whether the methodology was carefully selected or not, what worked out and what did not, in order to gain from this experience. Herein, experiences, opportunities but also limits of the applied methodology are briefly discussed. The selection which aspects are and which are not discussed refers to own thoughts, inspired by discussions with fellow researchers, supervisors and friends.

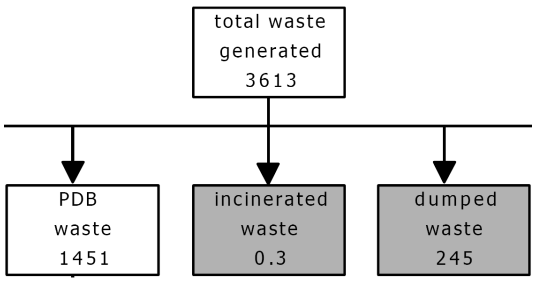
4.2.1 Material flow analysis

As mentioned in chapter 2.2 (page 11), MFA was selected as no other methodology can, in the authors' opinion, match it in the quantitative analysis of a MSWM system.

Usually a MSWM system is described by words, as it was done in the Waste management master plan for Banda Aceh (DKP et al. 2007) and various publications from MA 48 (MA48 2002,1; MA48 2007). A written description lacks a clearly defined terminology as well as the clarity of MFA, particularly if complex relationships should become more obvious. The same reason makes people drawing a sketch when giving directions to a, for the listener, unknown destination rather than describing it just verbally.

Flow charts can be used, like in Van Beukering (1999:20). Even though easier to understand then a written description, it lacks a clear methodology approach behind it. There are no system boundaries and no clear system definitions. The single line connection between what can be seen as processes does not reflect the size of the material stream. MFA uses a Sankey design, meaning the line width depends on the size of the material stream. At first glance one can see where the quantitative *hot spots* in the system are.

Figure 4-7 Flow chart to show waste flows



(Van Beukering 1999:20)

If the two MFA figures of the MSWM systems in Banda Aceh and Vienna (pages 75 and 100) are compared, another remarkable feature of the methodology becomes clear. The system of Vienna looks far more complicated, as a clearer distinction between different waste fractions is possible. For Banda Aceh, it looks far less complicated, as a distinction between different waste fractions was not possible. Depending on the information available, it is possible to draw the MFA figure and calculate the system more or less detailed. However, if done so, it must be clearly mentioned, otherwise one can draw the wrong conclusions.

4.2.2 Questionnaire survey

The objective of the questionnaire survey was first to find out the amount of households, small enterprises and restaurants choosing a particular waste disposal practise. Which practises are there was subject of the interviews and participant observation. The second objective was to get information about socio-economic backgrounds, namely household income and household size.
UNSTATS (2005:27ff) strongly recommends using probabilistic rather than non-probabilistic methods in household surveys. Generally the author agrees with UNSTATS. However, the latter was used in this study, and there is are two main reasons for doing so: the lack of time and money.
Probabilistic methods consume more time, as the process from the idea over the planning, the realization, the analysis and the interpretation follows a strict methodological approach. Therefore results are presumably better and uncertainties can be calculated. Now, what to do if neither the financial, nor the time budged is sufficient.
Well, the author and his research fellows decided to use a more basic, non-probabilistic method of judgemental sampling, but trifling honestly and transparently with this method and its potential shortcomings. Thus, some aspects of the survey should be discussed herein.

First, the sample size was assumed with about 500 households, which is approximately 1%. A scientific explanation why using this sample size can not be given, the decision was more a trade-off between the desire to consider as many households as possible and the limited time available. The research schedule allowed one week for the distribution and collection of questionnaires, the research budget the engagement of 5 students as helpers, leading to about 15 questionnaires per helper and day.

Second, the selection of survey areas was done judgemental. The selection criteria were presence or absence of waste collection containers of DKP in the area and a spatial geographic distribution. This seems reasonable under the resource limitations mentioned before, but a brief field visit of the research team to all villages considering in the questionnaire survey, should have been done beforehand.

Third, the preparation time for the helpers was quite short. Thus the aim and importance of the survey was probably not clear to them, which resulted in a diverse conduction among the helpers. For example, some helpers filled in the address of the surveyed households, some did not, which leads also to problems when reliability of data should be checked.

Fourth, the reliability of data was not checked. When, for instance, households living in the same street more or less uniformly answer that their waste is collected by municipal authorities and the data is collected by an external person, like the helpers mentioned before, the researchers should check the reliability of this data by visiting this street. If there are no collection bins in the street, but many fire places, it can be assumed that the collected information was wrong. Such spot checks, which were not done by the researchers, are strongly recommended.
Some more examples not mentioned here can be given, but it is clear now the data quality is not as good as one might expect from a questionnaire survey, which should be considered when using this data.

4.2.3 Waste sampling

Where waste data is scarce, alternative methods must be applied. Waste sampling at source was chosen due to various reasons, like its feasibility also with a small budget. There are also, of course, some problems when applying this methodology within a MFA approach which should be discussed herein.

Households

At first, the question of the reliability of information due to the relatively small sample size should be questioned. Other studies calculated the desired sample size, like Boolane (2004) and Abu Qdais (1997). In this study, the sample size was assumed to get a similar size than calculated in these other studies. In the end, 50 households over 15 days were considered. Now, 50 households is only about 0.1% of all households, a relatively small sample size. That is also the reason why it is stratified due to the household income. However, the household income is a questionable stratum. For instance, the presence or absence of a garden may have a bigger influence on the household waste generation. Now one can say, well, a richer household more likely has a garden, thus the positive correlation between income and waste generation rate is incorporated. On the other hand, one can assume that a richer household is not as depended on peri-urban agriculture as a poorer household, but an argument against this is that a poorer household probably does not even have land were the members can do peri-urban agriculture.

This discussion should simply show that there might be more than one stratum in a particular area. Thus a researcher should not be disappointed if the household waste generation does not correlate with the income – the amount of *Kentucky Fried Chicken* bags versus food preparation waste could be one possible explanation for such results.

Now, what to do, if there are many strata to incorporate that are probably even not known before? One approach could be not considering them in the beginning, but explaining extreme values afterwards. For instance, the household having the highest waste generation in the sampling is also a street vendor selling food.
Another approach would be to increase the sample size. If this is affordable, it should be done.

Compared to sampling at other stages of the waste chain, like at transfer stations, some arguments were given on pages 11 and 36ff why source sampling was used. One not mentioned before is that source sampling establishes a deeper contact to households, who should be the target group and the beneficiaries of proper waste management. Unfortunately, this deeper contact established over two weeks of collecting waste from the household, was so far not really incorporated in this thesis, which partly lies in the research questions and objectives.
However, to get an idea about what this closer relation between the target group and the researchers brought up, some aspects should be mentioned here. First, households were quite willing to participate in the study, even if they do not receive money for letting their waste be collected. Some household gave one possible explanation when they said that they were quite happy that their waste was collected every day, free of charge. Second, household members were quite curious about and had a positive attitude to the research. It can be concluded that people do care about sanitation issues, in contrary to the widespread opinion of people's attitude towards littering or lack of sanitation.
To get back to question whether it is better to collect data at the source of generation versus at transfer stations or the landfill, one thing should be mentioned. The ideal case would be if samples of all stages would be taken, so that the waste chain can be better described. If one decides to sample only one part of the chain, he or she does so because of lack of resources to consider all parts of the chain. If research resources are there, all parts should be considered.

Other sources than households

In the beginning, there was the idea that other sources should not be considered, as the effort seemed to be too big. However, in the end also some other sources of waste generation were sampled.
Now, this information was not used for the MFA calculation, but only to cross check the results. It is simply that the universe population for many sources is not known, like total number of restaurants and small enterprises, and thus neither predication about the sample size can be given, nor a projection can be done. Subsequently, the question arises, whether the sampling of other sources made any sense at all. Well, not so much for the MFA calculation. Thus it would probably have been better if instead of other sources more households should have been sampled. If all sources of MSW are considered to calculate the mass flow outgoing from the sources, they should be listed and their amount must be known.

Nevertheless, the information gathered can be important for the authorities and other actors. For instance, if a NGO is designing a collection or recyclables scheme it is important to know where the recyclable wastes are generated. The sampling showed that recycling materials are more likely found in waste from small enterprises, restaurants, schools or offices than in household waste. Thus a collection of recyclables from household would mean a big effort (as there are more households than enterprises for instance) with small benefits.

4.2.4 Assessment method

The desire was to find a method which is easy to apply, but also broad enough to assess both human health, environmental and resource conservation aspects.
Thus the same methodology as in Brunner and Fellner (2007) was applied, as it offers rapid computable indicators for protection of human health and environment as well as resource conservation. Beside these indicators, two other indicators were added, namely the calculation of dioxin and furan emissions[1] and the energy balance.

First, the assessment through indicators only makes sense if objectives are clearly defined before. While this is clear for the objective *conservation of resources*, some words should be said to the objective *protection of human health and the environment*, as it contains two parts, environment and human health and one can argue to consider them separately.
Some indicators used to assess this goal refer to both parts, such as *waste informally disposed, dumped or burned*, *share of households without access to formal MSW collection* and *dioxin and furan emissions*.
Nitrogen emissions into the hydrosphere have only direct impacts on human health if the water from the affected water bodies is consumed by humans. If they are discharged to water bodies not used as a drinking water source, like salt water bodies, it more affects the fauna in the water body and thus the environment. The connection between both is clear, as fish die-off caused by nitrogen emissions affects fishermen communities and their customers, but technically it *only* affects the environment.
Similar can be said for greenhouse gas emissions. Even though usually not an acute problem for human health, it might come back to humans through negative affects due to climate change.
Under the concept of sustainability and thus the consideration of long term effects, such as the described ones, it makes sense to consider all of these indicators together under the term *indicators to assess impacts on human health and the environment*.

Second, the two indirect indicators to assess impacts on human health and environment (*waste informally disposed, dumped or burned* and *share of households without access to formal MSW*

[1] Professor Gani from Syiah Kuala University proposed
this indicator, which is very reasonable in a region where a high quantity of MSW is burned.

collection) reflect the typical shortcomings when assessment methods origin from higher income countries are applied in lower income countries. Assessment methods in higher income countries consider mostly carcinogenic or respiratory diseases through chemical pollution to the air and water, such as dioxin-, CO-, SO_2-, NO_x- emissions and so on. Diseases and hazards origin from inadequate hygienic situations and transmitted through microbiological agents, like human plague or diarrhoea, are often not considered (Umweltbundesamt 2001:75ff). Reason for that is simply that the hygienic situation in most high income countries is adequate enough to avoid these diseases.
This can not be said for many lower income countries. Both, chemical pollution as well as inadequate sanitation is responsible for negative impacts there. Thus it is quite inappropriate to use assessment methods developed in high income countries for high income societies.
To overcome this shortcoming of some conventional assessments on MSWM, the indicators *share of MSW informally disposed, dumped or burned* and *share of households without access to formal MSW collection* were introduced. They are seen as indirect indicators in contradiction to the direct, chemical material based indicators dioxin/furan-, CO_2- and nitrogen emissions. Indirect in this manner means that they stand for many different diseases agents, communication pathways and diseases. All of them have in common that they more likely increase if the hygienic situation caused by MSW not collected is inadequate.

Third, one should be cautious on data uncertainties. If the indicators of two scenarios are close to each other, a clear conclusion which of both solutions is more able to reach the defined objectives can not be done. The same can be said for the calculated costs.

Fourth, it makes sense to bring the indicators into a broader context. Greenhouse gases, for instance, have many anthropogenic sources. There is difference if waste management is only responsible for less than probably 5% of anthropogenic greenhouse gas emissions, but probably for 50% of dioxin and furan emissions. Exemplified expressed, solution A reduces greenhouse gas emissions and nitrogen emissions to hydrosphere far more than solution B, but not dioxin and furan emissions. Now, waste management is only minor responsible for greenhouse gas emissions and nitrogen emissions, but main responsible for dioxin and furan emissions. Even though there are two indicators speaking for solution A and only one for solution B, the overall positive change is higher through solution B.
Such a contextualisation is also important to proof whether the selection of indicators helps to assess the system.

Fifth, social impacts are only directly considered through the costs of waste management and indirectly through human health indicators. This is on one hand clear, as they are not directly part of the defined objectives and it was never the aim of this thesis to discuss the objectives of waste

management. What is discussed are the principles how this objectives should be reached, namely the waste hierarchy. And therefore also, what is not incorporated in these principles.
Cost of MSWM thus is a direct socio-economic indicator, as it reflects which share of the budget a society wants and can spend for waste management. These costs must be paid indirectly through taxes or directly through contributions, which in the end always fall on the population that generates the waste.

Health indicators are indirect social indicators. The basic rationale behind this assumption is that especially people with lower income have less ability to see a doctor or to buy medicine, as they have to afford a bigger share of their income for the same activity than richer people. Thus they relatively benefit more from a reduction of negative impacts of wastes on human health.
On the other hand, there might be indicators, where a decrease has some positive impact on human health or resource conservation, but which also result high *social cost*s for a particular group. I purposely choose waste pickers and scavengers, which are people with comparably low income, for these examples.
Imagine the introduction of a formal recycling system as a scenario for extended MSWM which leads to an increase in the recycling rate. Which might be good for one indicator for resource conservation can have the reverse effect on informal waste pickers and scavengers. If they are not the ones employed for the formal collection of recyclables, their income is cut off and they have to find another niche for them.
The second example refers to an indicator to assess impacts on human health, which was mooted before, but then discarded for a reason demonstrated in the example below. The indicator would be the *share of people working with waste*. On one hand, this indicator technically makes sense, as health effects on waste workers, waste pickers or scavengers are higher than for the average population in working age (Cointreau 2006). But what happens if this indicator is desired to be reduced? Well, as a formal MSWM system always rely on waste workers, this indicator can only be reduced through prohibiting waste picking and scavenging, which again leads to income cut off for scavengers and waste pickers.

5 Conclusions goal oriented assessment

In a first step, the municipal solid waste systems of both selected regions, Banda Aceh and Vienna, were investigated. This was necessary, as a detailed knowledge of the system is essential for both, the assessment of the systems performance and as a base for planning extensions in the system. The results showed that in Vienna more waste is generated and the system contains more processes, like waste incineration, waste separation, formal collection and treatment of recyclable materials, composting and landfilling. This comprehensive MSWM system leads to high costs of 110 €/capita/year. In Banda Aceh, less waste is generated and the MSWM system contains less processes. Beside the formal collection and waste disposal at a control dumpsite, an informal sector of scavengers, waste pickers and recycling agents collects recyclable materials. Furthermore, a significant portion of the waste is informally burned, disposed or dumped and thus not formally collected. The MSWM costs in Banda Aceh are with about 3 €/capita/year about 37 times lower than for Vienna, which is due to lower labour costs and the less comprehensive MSWM system in Banda Aceh.

If both MSWM systems are assessed through selected indicators representing how the system can achieve the objectives of waste management, namely protection of human health and the environment and conservation of resources, Vienna more likely reaches these objectives than Banda Aceh, which is again a consequence of the more comprehensive system.

To upgrade Banda Aceh to a more sophisticated MSWM system, extensions are planned by municipal authorities and international organisations. Within this study, three scenarios for extensions in the system for Banda Aceh were exemplified designed and subsequently assessed. The scenarios refer to the waste hierarchy (reduce – reuse/recycle – safe final disposal), a waste policy that should, according to relevant national, international and private actors, be applied in high as well as in lower income countries.

Scenario I represent the safe final disposal scenario and include an extension to formal waste collection to 100% coverage and the construction and maintenance of a sanitary landfill.

Scenario II represents a recycling scenario with no changes in the formal collection or landfilling of wastes, but introduction of large scale composting for material recycling of organic waste.

Alike Scenario II, Scenario III represents a recycling scenario, but in this case an energy recycling through a waste incineration plant. The formal collection is not extended herein, but the landfilling is upgraded to meet the requirements of incineration residue disposal.

Then the same methodology than before to assess how the scenarios fulfil the objectives of waste management was applied and the results compared. Regarding to these results, the safe final disposal scenario more likely fulfils the objective of protection of human health and the environment, primarily

as it reduces the amount of waste informally disposed, dumped or burned, which is not the case for scenarios II and III.
Therefore both recycling scenarios more likely fulfil the objective of resource conservation. However, the costs are far highest for scenario III and the incineration with an increase of 336%, followed by scenario I (92%) and scenario II (23%) compared to the current state.

That means for decision makers that if they want to conserve resources, recover the energy from waste and have a big municipal budget, they should decide to introduce scenario III - incineration.
If they want to conserve resources but the available budget is lower, they should decide to build a large scale composting plant, as proposed in scenario II.
Finally, if decision makers care more about the health of their fellow citizens and their environment, they should decide to introduce scenario I – an extension of the formal municipal solid waste collection system to coverage of 100% and upgrade of the managed dumpsite to sanitary landfill standards.

In summary, societies and their decision makers can choose herein between three options, where two more likely conserve resources and one protects human health and the environment. From an ethical point of view that sees the protection of human health and the environment as far more important than the conservation of resources, the decision is clear. Before large scale composting is introduced, collection should be extended and sanitary landfilling should be applied. Waste incineration is for more reasons an inappropriate solution, as it not only does not really help to improve the situation for humans and their environment, but is also far too expensive. Beside that, practical considerations, like the low heating value of wastes in most lower middle and lower income countries, more likely leads to worsening the economical and – if the expensive off-gas and waste water cleaning of the incineration plant is turned-off due to lack of financial resources – environmental situation. And this counts for Banda Aceh as well as for Bandung or other cities in lower middle and lower income countries.

Based on these thoughts, solutions that rigidly follow the waste hierarchy are not appropriate to meet the desire of lower income societies for a *better* live. More than that, if the objectives of waste management are seen as hierarchal in their desirability, and the author does so, the *waste hierarchy* stands, in the case of Banda Aceh and many lower middle and lower income regions, contrary to these objectives.

Part III - Discourse analysis

6 Theoretical background for discourse analysis and the origin of the waste hierarchy

Referring to the results and findings in the previous chapters, it can be concluded that the options as suggested by the waste hierarchy and its proponents, do not necessarily benefit the urban population in developing countries and can be a financial burden too heavy to carry for the public. Subsequently, the question arises why and how the waste hierarchy got its important status in waste management policy strategy approaches, particularly in developing countries. A discourse analysis on the discourse on waste management in general and waste management in developing countries in particular, should help to answer this question.

6.1 Discourse Analysis

6.1.1 Discourse analysis and the environment – a literature review

Discourse analysis has become a more and more popular theory, if not to say *tool*, to investigate environmental issues, politics, movements, science, etc., which is expressed by a number of publications using this theory. The most important for this work are subsequently mentioned.

In his publication "The Politics of Environmental Discourse", Maarten A. Hajer (1995) analyzed the discourse on the progress in environmental policy making, thus the ecological modernisation of society and policy (Hajer 1995). Liz Sharp and Tim Richardson provide "Reflections on Foucauldian Discourse Analysis in Planning and Environmental Policy Research" (Sharp and Richardson 2001). There they not only review two prior studies which use discourse analysis[1], but furthermore incorporate both studies in their own discourse analysis. Fred Luks and Mark Hammer (2003) tried to apply discourse analytical principles on the scientific method of material flow analysis[2], material flow accounting and the rhetoric of ecological economics, such as *dematerialization* (Luks and Hammer 2003). John S. Dryzek (2005) too used a discourse analytical approach, comparing nine different types of environmental discourses he had traced out.

Even though all four publications are quite different in terms of quantity, material analyzed and case studies, they have in common that they refer to the discourse analysis as taught by the French scientist and philosopher Michel Foucault.

Another publication on the discourse regarding environmental issues is provided by Frank Schiller. His "*Diskurs über Nachhaltigkeit*" (Schiller 2005) or, in English, *discourse on sustainability*, refers to economy, the political-administrative system, the civil society and political science itself. Unlike the publications mentioned before, Schiller explicitly refers to the discourse analysis as taught by the German sociologist Jürgen Habermas.

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[1] One of the studies reviewed – Hajer (1995) – was mentioned before.

[2] The Method of Material Flow Analysis (MFA) itself has been described before. The research for a personal reflection on MFA as used in the scope of this thesis, resulted in the finding of Luks' and Hammers' paper, which gave the initial input to use discourse analysis additionally.

While Schiller provides a case study[1] which would be of big interest in the scope of this thesis, I decide to refer more to *Foucauldian group* mentioned before and thus to the *Foucauldian* discourse analysis. When theorising discourse analysis in environmental issues, not so much the original material of Foucault is used, but the secondary literature, namely Hajer (1995), Luks and Hammer (2003) and Sharp and Richardson (2001), as they provide enough material to fulfil this duty. Foucault's work itself is not described explicitly, but where necessary, e.g. for deepening the understanding of discourse analysis as presented in Hajer, Luks and Hammer, Sharp and Richardson, the "Method" section from "The History of Sexuality" (Foucault 1981) and the speech at his inaugural lecture at the *Collège de France*, published under the title "*L'ordre des discours*" or, as the German translation is taken, "*Die Ordnung des Diskurses*" (Foucault 1991), is used.

6.1.2 Applying discourse analysis

Definitions

Discourse analysis has become quite popular in social science, and due to this popularity it's no wonder that definition and understanding on discourses differs greatly among authors, even if they refer to the same *source*, like the teachings of Michel Foucault for instance. Sharp and Richardson stress this point when reviewing different discourse analysis approaches to environmental issues: "Researchers use many different notions of discourse, often without a clear definition of precisely what is meant by the term. In developing a research methodology, it is crucial that this issue is clarified, as it shapes the choices that must then be made about the research: where to look, what to look for and how to analyse what is found." (Sharp and Richardson 2001:195)

Hajer provides a clear definition, how discourse analysis is used in his book. Thus, "discourse is [...] a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995:44). Referring to this definition, Hajer's aim is "to understand why a particular understanding of the environmental problem at some point gains dominance and is seen as authoritative, while other understandings are discredited" (ibid.). The focus on the "environmental problem" comes from the case studies that Hajer has investigated, namely the discourse and policies on acid rain in the United Kingdom and the Netherlands. In the scope of this thesis, not directly the discourse on an "environmental problem", but more on an environmental policy strategy is investigated. Of course, this strategy is associated to environmental problems, but to transfer Hajer's aim to the aim of this thesis, discourse analysis should help to understand how the waste hierarchy became so popular.

[1] The case study is about the waste management legislation and the waste hierarchy in Germany in the mid nineties.

Stories, story-lines and metaphors

One helpful approach to that is what Davies and Harré (after Hayer 1995:56) calls *story-line*. Hajer interprets *story-line* as a "generative sort of narrative that allows actors to draw upon various discursive categories to give meaning to specific physical or social phenomena" (ibid.). Dryzek describes the term simpler, pointing out that "[D]iscourses enable stories to be told; in fact, the title of a discourse can be an abbreviated story line..." (Dryzek 2005:17). To give an example from environmental discourse analysis, Luks and Hammer consider "dematerialization" as such a story-line (cp. Luks and Hammer 2003:17).

Story-lines extensively use metaphors. Politicians and scientists, for instance, use metaphors, such as the comparison of the budget of a household and the budget of the state. Dryzek states metaphors commonly used in environmental discourses, one, the metaphor of the earth seeing as a "spaceship", will appear later in this section (cp. Dryzek 2005:18).

Methodological issues in discourse analysis

Sharp and Richardson show that the meaning of discourse can start from a quite simple level, e.g. the talk between two or more persons. If an ensemble of such talks, but also articles and statements are analyzed, it could be called a *discourse as text* (cp. Sharp and Richardson 2001:195). This view can be extended, the discourse can then be seen not simply as "a communicative exchange, but a complex entity that extends into the realms of ideology, strategy, language and practice, and is shaped by the relations between power and knowledge" (ibid.). Instead of just analysing communication, speeches and texts, other forms like practices and actions are incorporated too. The main characteristics of approaches in discourse analysis that refer to Foucault are summarized by Sharp and Richardson as follows:

- "a view of social change as shaped by and shaping changes in communication (in common with a Habermasian analysis);
- a view of social change as shaped by and shaping changes in practices (in contrast with a Habermasian analysis);
- a view that 'good' social change cannot be pre-specified by theory (in contrast with a Habermasian approach);
- a view of social change as shaped by power, conceptualized as competition between differing systems of meaning or 'discourses';
- a view of a discourse as a specific ensemble of ideas, concepts and categorizations that are produced, reproduced and transformed in a particular set of practices, through which meaning is given to physical and social realities;
- a view of discourse competition as shaped by power relations;
- a view that a Foucauldian analysis can challenge the status quo through narrating changes in the field of discourse competition over time" (Sharp and Richardson 2001:198)

In further developing a methodological design for a discourse analysis, Sharp and Richardson (2001:201) present some key variables and settings, which are summarized in Table 6-1. Some of these methodological aspects are helpful in the scope of this thesis.

Table 6-1Methodological questions and answers for a Foucauldian research approach (Sharp and Richardson 2001:201)

How are different discourses identified for research?	Before the research process, from broadly observed shifts in society and from literature review
Where are discourses manifested?	In policy rhetoric, documents, plans or programmes, but also in institutional structures, practices and events
How are struggles between discourses manifested?	In changing policy rhetoric, and in the minutiae of changing institutional structures and practices, in events within the policy process, and in policy outcomes
How are the outcomes of these struggles manifested?	In the form of policy rhetoric and in the institutionalization of new policy practices and outcomes
How are the research aims focused into a manageable research project?	By focusing on changes in communication, linkages with institutional structures and the construction of new practices
How can the story of discursive conflict be analysed and convincingly presented?	By reconstructing a critical narrative
Is the approach helpful in addressing the policy outcomes, implementation and broader social change?	Yes, by looking at the difference between policy rhetoric and what actually happens

The question of power

Going through the literature, it becomes apparent that *power* is crucial in discourses, as the *power relations* do shape discourses and thus the outcomes of discourses. But simply understanding *power* as something to dominate, like as with a ruler over subjects, does not help to analyse discourses. Foucault sees power more complex and far-reaching. Then, “power is not an institution, and not a structure; neither is it a certain strength we are endowed with; it is the name that one attributes to a complex strategic situation in a particular society” (Foucault 1981).

As mentioned before, Hajer’s aim when using discourse analysis is to understand why one particular issue becomes dominant over another issue. This question is closely related to *power*. Power is shaping the discourse, through “control, selection, organising and channelling” (Foucault 1991:11). One should be aware of the rational utilization of *power*, which is not only contradictory to the definition of power. “[P]ower is exercised from innumerable points, in the interplay of nonegalitarian and mobile relations [and] power relations are both, intentional and nonsubjective” (Foucault 1981). An example of shaping discourse with *power* is exclusion from discourses. Exclusion does not only happen through the most obvious form, the prohibition, but also through other methods. The forming of disciplines in science is such a method. In the discipline, one must use a substantial set of vocabularies which is recognized as *true* or *wahr* in German. Then the discipline is a principle of control of the production of a discourse (cp. Foucault 1991:22ff.).

What discourse is not meant to be

Discourse analysis is based on the notion of social constructivism. One, apparently common misunderstanding with discourse analysis is that everything is constructed, meaning what people talk about is entirely socially constructed. This is particularly the case for environmental problems and degradation which is not directly perceptible by the individual. A river full with fluorescent colours or algae on top is perceptible. Acid rain is less perceptible, and this ability to experience can further decrease. Climate change would be such a phenomenon. Luks and Hammer address this important question, not only by stating a joke that climate change would stop if people stop talking about it. They claim that there is of course a bio-physical reality, and also environmental problems are real. The discourse analysis just helps to investigate, why one problem attracts more attention than the other, even if there is no material prove that the problem is bigger (cp. Luks and Hammer 2003:10).

6.2 Origin and theoretical base of the waste hierarchy

6.2.1 First appearance as a policy strategy

When the question arises, who actually brought up the waste hierarchy, most authors refer to the European Community and the Organisation for Economic Co-operation and Development (OECD) as the *creators* of the hierarchy in terms of legislation and policy (cp. Rasmussen and Vigsø 2005:7; Wilson 2007:200; European Commission 1997).

According to Rasmussen and Vigsø (2005), the European Council Directive 75/442/EEC on waste is the first document, where parts of the hierarchy appear. Article 3 says that:

„Member States shall take appropriate steps to encourage the prevention, recycling and processing of waste, the extraction of raw materials and possibly of energy there from and any other process for the re-use of waste.“

However, neither the denomination *hierarchy*, nor an intentional hierarchisation is readable from this phrase, even though Rasmussen and Vigsø find it an implicit stating for a hierarchy. Wilson (2007) states the Second Environment Action Programme of the EU in 1977 as the starting point of the utilization of the term „waste hierarchy“, while the European Commission (1997) states that „in 1976, OECD Member Countries adopted the concept of a "hierarchy" of preferred options for waste management, in which waste avoidance and minimisation came at the top and permanent storage or disposal in or on land came at the bottom“ (European Commission 1997).

Afterwards and step by step, the waste hierarchy and its promoters have been successful in entering the discourse on waste management. Besides giving attention to the moment or rather the time frame where the waste hierarchy enters policies and strategy papers, the theoretical-scientific base for the waste hierarchy are reviewed. This is, even if not explicitly connected, the concepts of ecological economics and particularly dematerialization.

6.2.2 Dematerialization and the emergence of ecological economics

While the theoretical-scientific roots of ecological economics are sometimes traced back even to the 17th and 18th century, there is a more or less accepted consensus that the groundbreaking essay “The Economics of the Coming Spaceship Earth” of Kenneth E. Boulding (1966) plays an important role in the emergence of an ecological economics (Costanza et al. 1997:46; Rogall 2008:96). In his essay, Boulding picturized two contrasting types of economical systems. The first, which symbolizes the neoclassical economy at that time, is termed *cowboy economy* or *open economy*. This type of economical system is described as follows:

“In the cowboy economy, consumption is regarded as a good thing and production likewise; and the success of the economy is measured by the amount of tile throughput from the "factors of production", a part of which, at any rate, is extracted from the reservoirs of raw materials and noneconomic objects, and another part of which is output into the reservoirs of pollution. If there are infinite reservoirs from which material can be obtained and into which effluvia can be deposited, then the throughput is at least a plausible measure of the success of the economy." (Boulding 1966)

In other words, the *cowboy economy* does not consider limits, neither in terms of resources such as raw materials or soils, nor in terms of sinks for effluents of production and consumption.

Contrary to that, Boulding images an economy in a closed system, termed as *spaceman economy*, where "[material] throughput is by no means a desideratum, and is indeed to be regarded as something to be minimized rather than maximized" (Boulding 1966). Hence the earth resembles a *spaceship,* meaning a closed system, where every activity that is not circle oriented but linear, as in the *cowboy economy* will yield sooner or later to some sort of scarcity through deterioration. The claim for a dematerialization of the economy can be derivate from this essay, and, particularly important in the scope of this thesis, the suggestion of reducing the material input into production and enhancing material recycling respectively.

While Boulding clearly refers to the first law of thermodynamics and the equilibrium of mass and energy within a closed system, the Romanian born economist Nicolas Georgescu-Roegen take one step further. In his publication "The Entropy Law and the Economic Process", first edited in 1971, Georgescu-Roegen applied the second law of thermodynamics, better known as the entropy law, on material and matter. In analogy to the increasing entropy[1] of energy within a closed system, he concludes that there is also increasing entropy for matter in our closed system earth, or, as in his words:

"Even if only the physical facet of the economic process is taken into consideration, this process is not circular, but *unidirectional*. As far as this facet alone is concerned, the economic process consists of a continuous transformation of low entropy into high entropy, that is, into *irrevocable waste* or, with a topical term, into pollution." (Georgescu-Roegen 1974:281) An example would be the combustion of carbon in form of coal, which dilutes in the atmosphere in form of CO_2.

Another facet is how fast an economic system transforms low entropy into waste (Georgescu-Roegen 1974:305). Therein, Georgescu-Roegen blames not only the modern economic system for the *high entropy production velocity*, but also the at that time leading "modern school of economics [which] has paid no attention to the role of natural resources in the economic process" (Georgescu-Roegen 1977:16). In later publications, Georgescu-Roegen, probably as a reaction of critics for criticising modern economics, states eight major claims in his bio-economic program, from low input organic agriculture via reduction of consumption of luxury items to an increase in recycling (Maneschi et al. 1997:704). Georgescu-Roegen's thoughts on systems and their boundaries were further materialized

[1] The term *entropy* has been used for in various field of science – sometimes even to the dislike of particularly physicist, who claim the word for their use. However, for the purpose of this work it could be explained as the ever-increasing change of the state of energy. A practical example from the human economy would be transformation of electrical energy into heat through an electric motor. While the energy balance is steady, the heat energy which is released from the motor can never be utilized to produced the same amount of electrical energy as initially supplied. A short essay on the understandings and misunderstandings of entropy is presented by Van Kampen, N.G. (1997) Entropie. http://pluslucis.univie.ac.at/PlusLucis/973/entropie.pdf

by the popular publication “Limits of Growth”, written by economists (Meadows, Meadows, Randers and Behrens) for the Club of Rome in 1972 (Hajer 1995).

As partly mentioned before, both economists, Boulding as well as Georgescu-Roegen, were important scientists in the emergence of ecological economics. Not overstressing the subsequent history, development and key elements of ecological economics, which could be read in Costanza et al. (1997) or Common and Stagl (2005), some final conclusions should be remarked.

First, Boulding and Georgescu-Roegen found similar, if not identical, problems of the back then contemporary economic system. Both investigate industrial and industrializing societies, but draw their conclusions for the entire planet. Related to waste and the waste hierarchy, both concluded to reduce the material input into the economy, hence also the material output or waste. Both also concluded to increase recycling. And particularly in Georgescu-Roegen’s work, a hierarchy of choice between both can be derived, due to his empathetic finding that an increase in material recycling is on the cost of an increase of energy input for recycling. Thus both can be also seen as the theorists that broke the path for the later used waste hierarchy.

Second, between the publishing of “The Economics of the Coming Spaceship Earth” in 1966 and the first mentioning of the hierarchy (implicit or explicit) end of the 1970ies, a trace can be identified. Important publications like the works of Georgescu-Roegen and (for) the Club of Rome appeared and were successful in both, scientific and non-scientific circles. The United Nations Conference on Human Environment in Stockholm was held in 1972, with a broad resonance from governments, supranational agents like the European Community, but particularly in international organisations. These organisations, like UNEP, Worldbank or the OECD, played a key role in environmental issues, in defining objectives and environmental policies (Hajer 1995:96). Experts in the OECD or the European Commission became increasingly in, as Hajer calls it, secondary policy making, putting the governments or primary policy makers under pressure with claims for environmental protection and eco-efficiency. According to Hajer, these technocratic bodies were, amongst others, important actors, not only in the emergence of an ecological modernisation, and, more precisely, in the incorporation of the waste hierarchy as a waste policy or strategy.

Third, to understand the link from the origins of ecological economics, here represented by Georgescu-Roegen and Boulding, where the waste hierarchy was not explicitly formulated, and the later expression of the waste hierarchy, Foucault’s hypothesis on the reproduction of discourses from texts can help. According to that, one can distinguish between primary and secondary text sources. Two different secondary texts can refer to the same primary text, even though there conclusion differs greatly. One reasons, though an important one, is that secondary texts do not just reproduce, what is said in the primary text, but particularly, what has been *withhold* (*verschwiegen* in German) there (cp. Foucault 1991:19). Thus, even if the waste hierarchy has not been mentioned directly in Boulding’s and Georgescu-Roegen’s work, herein seen as primary texts, it can be linked to secondary texts.

7 Methodology Discourse Analysis

7.1 General methodological settings

In the theoretical part referring discourse analysis (6.1, page 151), some important terminologies have been regarded, which are important to work on the material used to answer the research questions. The material used is primarily scientific literature, policy strategy reports, information media from relevant actors and media. According to the material used, different actors are distinguished. How they contribute to the discourse will be analyzed through the material provided by them, but also literature on these actors. Other common used methods to gain material to be analyzed, like interviews and discussions with experts, activists or politicians, are not considered herein. Hence, the way how discourse analysis is used herein can be at best described as *discourse as text* (cp. Sharp and Richardson 2001:195).

7.2 What is considered? Framing of the discourse

It would be inevitable just repeating and interpreting what different actors say about the waste hierarchy, but to answer the research question through the selected theory of discourse analysis, one has to go deeper. On the other hand, boundaries of the *field* to be analyzed, must be drawn, as even waste management alone offers a huge field of discourses. Thus, the focus in this thesis is listed in three points:

- The field of research is municipal solid waste management and particularly municipal solid waste management in developing countries.
- The object of the analysis is the waste hierarchy and concepts considered as alike (zero waste, 3R, 4R,...).
- The quantitative-technical part assesses options referring to the waste hierarchy by reaching the objectives of waste management. Both objectives – protection of the human health and environment and resources conservation – will be addressed too in the discourse analysis.

Hence, the discourse on solid waste management focusing on the waste hierarchy and its application in developing countries is analysed.

7.3 Selecting primary literature

7.3.1 General

Solid waste management is an issue that matters many actors, be it an international organisation, a local authority, a NGO or an individual. This becomes even more obvious in searching for primary literature on the issue. For instance, a shopping tour on *amazon.com* with the search criteria *solid* *waste management* in the title yields 178 results[1]. Imagine if not only books, but also reports and articles in magazines would have been considered in the search for literature, not mentioning the fact that if the search criteria *solid waste management* is not only restricted to the title, but inserted in the *key words* search criteria.

According to these apparent difficulties, a clear statement why a certain primary literature source has been selected is required. As the type of literature differs depending on the actor and its primary communication channel, the statement why certain sources were selected is part of the following sub-chapter (7.3.2). This procedure is also conciliating to the principles of a Foucauldian discourse analysis as seen by Sharp and Richardson:

"In many discourse studies, particularly those using textually oriented analysis, the search for objectivity precludes recognition of the subjectivity of the researcher. In Foucauldian inspired discourse analytics, however, the position of the researcher needs to be acknowledged, to help the research audience understand the choices made." (Sharp and Richardson 2001:203)

7.3.2 Selection criteria

After a general statement on the principles of selecting the literature used, the selection criteria have to be revealed. The selection criteria can at best be described using screening steps.

- The first selection refers to the research field, herein *solid waste management*.
- The second selection refers to the particular research area and field, herein *solid waste management in developing countries*.
- The second selection refers to key words. *Waste hierarchy, 3R, 4R, zero waste* are the key words used.

The detailed selection then must be described separately for the different actors investigated, as it can deviate slightly from the general approach.

7.4 Actors selected

7.4.1 The scientific community and experts in the field of waste management

Scientists and scientific experts play an important role in a discourse, through power for instance. How much power scientists and experts can have in a discourse, is regarded by Hajer, when he reflects on the success of *Limits of Growth*. The authors, a group from the Massachusetts Institute of Technology (MIT), were considered as experts in their field, namely cybernetics. By using this theoretically approach combined with an apocalyptical rhetoric, *Limits of Growth* became so successful that Hayer calls it "an example of an extremely successful use of discourse as power" (Hajer 1995:82) in shaping the discourse on environmentalism. But scientists and experts can also play another role.

[1] This small experiment was conducted on January 5th 2009, by inserting the term „solid waste management" in the advanced search option in the field „title" including quote signs on the amazon.com homepage (http://www.amazon.com/)

As already mentioned before, scientific disciplines are seen by Foucault as a method for exclusion in a discourse and thus the exertion of power. Scientists and experts which are working in the scope of the discipline are then the ones who are reproducing the discourse and the exclusion, thus they can be viewed as agents of power. Considering waste management as a sort of discipline, this might be the case here as well.

It has been mentioned before that numerous primary literature sources are available. The particular selection process used herein can be described through three steps, reflecting questions and the corresponding answers I have asked and answered myself when selecting literature:

1. What are the most influential works (handbooks) on solid waste management in general?
   - ⇒ Identification through objective (citation index) and subjective (appearance as primary literature in secondary literature) criterion; this section mainly refers to books claiming a general view on solid waste management, not particularly focusing on developing countries.
2. What are the most influential works on solid waste management in developing countries?
   - ⇒ As the number of publications decrease significantly, it becomes easier to select the relevant primary literature; citation again becomes a criteria.
3. Which publications discuss the waste hierarchy?
   - ⇒ The search criteria becomes tighter, the small number of publications makes it possible to consider most literature published.

7.4.2 International organisations involved in waste management

Waste management in developing countries is something special. Compared to high income countries, far more actors from all over the world are involved, particularly in policy advising and on project implementation level. These are, among others, NGOs, national development agencies and international organisations. The latter is subject of this and the corresponding chapter in the results-section. How important these international organisations in discourse can be, has also been considered by Hajer, when he points out that “[a] key role [in the emergence of ecological modernisation] was played by secondary policy institutes such as the OECD, the UNEP, and the UN-ECE, which had started their own environmental directorates or committees in the early 1970s” (Hajer 1995:96).

The impact of international organisations on a discourse and its outcomes can thus be considered as high, and so is the notion to influence or even start a discourse, which is manifested through the amount of publications of international organisations on waste management. This notion is not only restricted to the United Nations Environment Program (UNEP), but covers more actors, like the World Health Organisation (WHO), the World Bank Group or the United Nations Development Program (UNDP).

According to the importance of international organisations, publications of the organisations just mentioned will be used for the discourse analysis. Again, a selection process must be applied, in order to frame the discourse.

Firstly, reports of general importance considering solid waste management subchapter are investigated. It became evident from the literature review that the Report of the Brundtland Commission (*Brundtland Report)* or the Agenda 21 from the Rio Summit on Environment and Development are the most important reports therein, hence they are used.

Secondly, more focused reports on solid waste management are considered. The selection refers again to the research field (*solid waste management*) and key words (*Waste hierarchy, 3R, 4R, zero waste*). According to the latter, a decision which international organisations are considered must be made. This decision is bound to the intensity how an international organisation works in the field of solid waste management. UN organisations are there, particularly UNEP, the Worldbank Group and the WHO. Often, they work together with international networks, like the International Solid Waste Association (ISWA). The results part will deliver a number of international organisations considered as actors in the discourse on solid waste management and the waste hierarchy.

7.4.3 Governmental actors

Major policies are of course set by governments and its civil servants. But seeing them just as a *play ball* between different and/or contradict interests would by far misinterpret their role in a discourse. Governmental organisations, the bureaucratique institutions and the government itself can be key-actors trying to shape discourses; hence they are considered here too.

Due to the actual research area, the Governments of Austria and particularly Indonesia and their contribution to the discourse on the waste hierarchy and similar policy approaches, is investigated. Beside that, initiatives of other governmental actors, like the national German development agency *Gesellschaft für Technische Zusammenarbeit* GTZ or the Japanese International Co-operation Agency (JICA), are observed. Then both, governmental actors from high and lower income countries are among. Therein it should be mentioned that both organisations stated above (GTZ and JICA) are furthermore agencies functioning as a *Bindeglied* or a transmitter between high and low income countries.

The primary literature consists of reports, legal texts and laws and a media analyse. Therein, particularly online magazines and information medias are used.

7.4.4 Non-state actors: environmental non-governmental organizations (NGOs), the private sector and other private actors

It has been highlighted by several authors that non-governmental play a key role in policy processes and the construction of environment and environmental problems (cp. Hajer 1995; Dryzek 2005; Schiller 2005). This is particularly true for solid waste management. The technical and organisational *sector* which could be termed as solid *waste management* is highly *technologized* and becomes more and more important as a business opportunity. Hence, the private sector engages too in the discourse. On the other hand the discontent with poor solid waste management or the fascination of new approaches to solve solid waste problems motivates individuals, activists and their sometimes self-proclaimed defender, namely NGOs to shape a discourse.

As a pre-selection, the focus herein confines on private companies working in the field of solid waste management and environmental NGOs. The process for selecting the NGOs and companies is similar to that already described, using defined key words. Additionally, a spatial and regional focus on Indonesia is incorporated.

8 The discourse on the Waste Hierarchy in practice – results, analyse and discussion

8.1 Review of primary literature sources

In Chapter 6.1 (page 151), the primary literature sources which are used for the discourse analysis are presented. The presentation of the literature is structured through identifying groups of actors which are assumed to be relevant in the discourse. This structure should help in make the discourse analysis part better understandable, but the borders between different actors are permeable.
It is merely that some literature sources can be addressed to more than one group of actors. Some experts, as the US waste management consulting company *CalRecovery*, do participate in report published by international organisations like UNEP.

8.1.1 The scientific community and experts in the field of waste management

Primarily two types of publications are used as primary texts, namely handbooks and paper publications. While the latter deals with, due to its length, with particular problems, the prior tries to give a summary about a whole field or discipline for practitioners, scientists, students and authorities.

Solid waste management

It has been mentioned that the waste hierarchy has appeared in the mid 1970ies. But which concepts have been used before? How was legislation and science discussing and presenting the issue solid waste management?
The oldest publication investigated is the Thrift G. Hanks' "Solid Waste/Disease Relationships – a literature survey" (Hanks 1967). Though about 40 years old, it is still cited, for instance in Tchobanoglous' "Integrated Solid Waste Management", which is particularly in times with so-called *rapid scientific innovations* remarkably. As it has already been described in the theoretical chapter of the goal-oriented assessment part, it will be just discussed briefly herein.
The study was published by the US Department of Health, Education, and Welfare in 1967. Aim of the publication was "to review with reasonable thoroughness the scientific literature reporting any relationships between disease and the solid wastes generated by the activities of man" (Hanks 1967:1). The reviewed literature in Hanks (1967), mostly published between 1900 and 1965, came from Europe and North America (including Mexico). From the division of chapters in "Solid Waste/Disease Relationships", one can see a strong focus on communicable diseases, which covers over two thirds of the book, while diseases associated with chemical wastes, injuries (waste workers for instance) or disasters associated with waste management activities (landfill slides e.g.) do more or less equally divide among the residual third. This should be highlighted, as nowadays, in the time of the excessive use of Life Cycle Assessments (LCA) in solid waste management decision making, usually only the influence of chemicals (heavy metals, micro organic compounds) is regarded. Not so in Hanks (1967), where diseases like leprosies or typhoid, transmitted through water or – even less imaginable for an

average contemporary European solid waste management expert – rats, flies or mosquitoes. Not imaginable does mean that these kinds of diseases are not present in Europe anymore.

Also for the time prior the waste hierarchy, the publication "SOLID WASTES: origin, collection, processing, and disposal" by Charles Letnam Mantell (1975) is exemplified presented. It is a classical engineering handbook sectioned in eight parts, mainly dealing with functions and technologies of a solid waste management system. The first part also covers the US national solid waste act, waste statistics and a case study by the United States Public Health Service, the Pennsylvania State Department of Health, city planers and other experts in Erie, Pennsylvania. The report to the study, called ERIELAND 2000, addresses the environmental health problems, which are considered in the area to be bigger than the problem of water pollution (Mantell 1975:53). Even though it is a primarily technical book, the author clearly states what is in his opinion the mean of waste management: "The preservation of public health and aesthetics of the environment should be of paramount consideration in management decisions involving solid wastes." (Mantell 1975:12). The waste hierarchy so far has not entered the field of solid waste management.

This happened in the years after Mantell published his work. Faber et al. (1989) for instance claim in their German written book publication "Umdenken in der Abfallwirtschaft. Vermeiden, Verwerten, Beseitigen" a shift in waste management. The second part of the title contains a German translation of the waste hierarchy[1]. Contrary to the book presented before, it is not focusing on technology, but on sociology and economics. The hierarchy does appear not only in the title. Explicitly, the waste hierarchy is stated as a "hierarchy of objectives"[2] , meaning that the fulfilment of the waste hierarchy becomes the objective of waste management (Faber et al. 1989:77).

If somebody enters *solid waste management* in the input field of a search engine like Google Scholar, the one English handbook publication which was cited most is George Tchobanoglous' "Integrated Solid Waste Management" (Tchobanoglous et al. 1993). Before the authors reach the technical part, which makes a good portion of the book, they describe a societal and technical history of solid waste management, as well as legal issues (see "Part I Perspectives", Tchobanoglous et al. 1993:3-36). Important in this introductions are the definitions and commitments towards solid waste management. The term *Integrated Solid Waste Management* is defined twice:

1. "*Integrated Solid Waste Management* is the term applied to all of the activities associated with the management of society's waste. The basic goal of Integrated Solid Waste Management is to manage society's waste in a manner that meets public health and environmental concerns

[1] Translation German – English: v*ermeiden* – to avoid; *verwerten* – to recycle; *beseitigen* – to dispose
[2] Original citation: „Die generelle abfallwirtschaftliche Zielhierarchie `Vermeiden, Verwerten, Beseitigen`…."

and the public's desire to reuse and recycle waste materials." (Tchobanoglous et al. 1993:XVII)

2. "...*integrated solid waste management* (ISWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals." (Tchobanoglous et al. 1993:15)

The second definition can be found under chapter 1-4, named *Integrated Solid Waste Management*, which also contains the first denomination of the waste hierarchy, therein termed "Hierarchy of Integrated Solid Waste Management" (ibid.), making both terms inextricable connected to each other. The waste hierarchy itself is stated in terms of activities, namely "source reduction, recycling, waste transformation, and land filling" (ibid.). Literature sources for the hierarchy and *Integrated Solid Waste Management* are generally reports from the US EPA and other governmental bodies dealing with waste management, which indicates that US policy makers were using the term before it was picked up by scientists and experts in the field of waste management.
Generally, the publication focuses on the US and to a lesser extend on European countries. Developing countries are not part of it, neither in terms of policy, nor in terms of technology. The waste hierarchy is closely connected with the concept of *Integrated Solid Waste Management* and refers primarily to policy papers and law from US policy makers. However, the waste hierarchy becomes an important and positive term, placed in the very beginning of a – according to its status in the discipline of solid waste management – important publication.

But the waste hierarchy is often criticized too, for instance due to the lack of scientific back-up. Particularly since the mid 1990ies, some scientists have tried to challenge the waste hierarchy.
The first edition of White et al.'s handbook "Integrated Solid Waste Management: A Lifecycle Inventory" (White et al. 1995) questions the universal applicability of the waste hierarchy. In chapter 2.3, which is directly addressed to the proponents of the waste hierarchy, the author admit that "the hierarchy gives important general guidelines on the relative desirability of the different management options, but it has limitations", which are firstly that "using the hierarchy rigidly will not always lead to the greatest reduction in the overall environmental impacts of a given system" and secondly "the danger [...] that the hierarchy will become accepted as dogma" (White et al. 1995:20). Then, uneconomical decisions would be made, bearing too high costs for the society. Beside that, a strict preference of material recycling with long transport distances might lead to a far higher energy demand and higher environmental impacts than choosing for another option which does not have such long transport distances. Finally, the authors claim to use the arbitrary approach *waste hierarchy* just in case when there is not enough data to conduct their preferred decision tool, namely the lifecycle inventory and lifecycle assessment approach (cp. White et al. 1995:324).

In the second edition of this book, the focus of integrated solid waste management, lifecycle assessment and the critics on the waste hierarchy is extended to developing countries. (cp. McDougall et al. 2001:26).

Another publication, which was published earlier than the ones mentioned before, is the meaningful named paper "Questioning the Waste Hierarchy: The Case of a Region with a Low Population Density", written by Alan Barrett and John Lawlor from The Economic and Social Research Institute in Dublin, Ireland (Barrett and Lawlor 1997). There the authors discuss and "question the wisdom of applying the waste hierarchy in a region with a low population density" (Barrett and Lawlor 1997:19) by adopting some sort of cost accounting to the Irish solid waste management system. At first, scenarios for different disposal and treatment options for Ireland's solid wastes are designed. Then the internal and external costs for each option are projected. The result shows that the – according to the waste hierarchy – least desired option, namely land filling, is much cheaper than options which are placed higher in the hierarchy, such as incineration, recycling and re-use. These findings leads the authors to the conclusion, that the options suggested through the waste hierarchy are probably viable for high, but not for low density areas. The reason for this contradiction lies in the fact that "[t]he hierarchy was first developed with reference to the high population density areas such as the core of the EU", like Germany, France and Great Britain.
The publication "Rethinking the Waste Hierarchy" from the Danish Environmental Assessment Institute (EAI) argues partially in a similar direction (Rasmussen and Vigsø 2005). The publication contains papers from various authors, all more or less well known environmental economists, who apply cost benefit or social cost benefit analysis on various waste management options. For instance, some authors compare land filling and incineration, while others focus on the packaging and landfill directive of the EU and on recycling. According to the authors, the aim of the publication is "to provide an understanding of the social costs and benefits of the current European Union waste policy and the underlying principles of the waste hierarchy" (Rasmussen and Vigsø 2005:3). The findings are accordant to each other, leading to recommendations for EU and national policy makers in the EU member states. These findings indicate that, even though there might be an environmental benefit through strictly applying options as recommended by the waste hierarchy, the costs for the society might be too high. Hence, "the waste hierarchy must be considered a very general and flexible guideline for formulating waste policies" (Rasmussen and Vigsø 2005). As before, the costs of waste management options are the main argument for criticising the waste hierarchy approach. The recommendation to see the waste hierarchy more flexible and general is then understated than one might be expect from the title, as the general concept is not criticized to such an extend.
Both publications do have two things in common which are important for the analysis. The first, namely their focus on costs when assessing the waste hierarchy, has already been mentioned. The

second, however, reflects the proponents of the waste hierarchy's supporters and founders: seeing the waste hierarchy as a choice of various available technologies, thus a strong technological focus.

The critics of unproved environmental benefits has also been tried to catch up by Schmidt et al. (2007). In their paper the authors apply the Life Cycle Assessment (LCA) approach to evaluate waste hierarchy oriented options in the Danish paper industry. Their key-finding is that the waste hierarchy options perform better than options which do not follow the hierarchy, but they also conclude that this is not necessarily true for other kinds of waste. However, while the LCA approach can generally replace the waste hierarchy, meaning that options are not ranked beforehand, but after an evaluation, it can have an important pedagogical effect on consumers (cp. Schmidt et al. 2007).
Amalendu Bagchi, senior engineer at the Wisconsin Department of Natural Resources, incorporates the critics into his justifying of the waste hierarchy. He sees a "consensus [...in solid waste management...] to allow ISWM planners flexibility to choose from different elements of waste management options...", rather than taking the waste hierarchy *too hierarchal* (Bagchi 2004:4). Furthermore, according to Bagchi, many waste managers define Integrated Solid Waste Management through the waste hierarchy, which is contrary to his own views (ibid.).

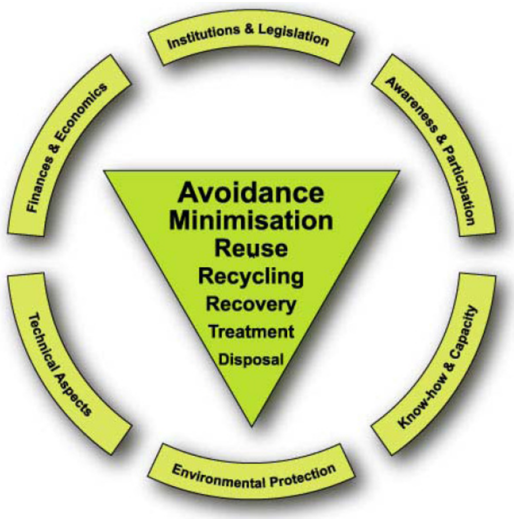
Solid waste management in developing countries

The literature which has been reviewed and presented so far, is primarily focusing on economically developed countries, except for McDougall et al. (2001): "When available resources and MSW composition are considered, it is apparent that the waste hierarchy is too rigid to be relevant for waste management in countries with developing economies" (McDougall et al. 2001:26).

Martin Medina's paper "Globalization, Development, and Municipal Solid Waste Management in Third World Cities" (Medina 2000) focuses on solid waste management in developing economies' urban regions, therein particularly on waste recycling and scavenging, but also points out the major problems of developing countries' urban regions:
„Municipal Solid waste management (MSWM) constitutes a serious problem in many Third World cities. Most cities do not collect the totality of wastes generated, and of the wastes collected, only a fraction receives proper disposal. The insufficient collection and inappropriate disposal of solid wastes represent a source of water, land and air pollution, and pose risks to human health and the environment." (Medina 2000:1) Subsequently, he also addresses solid waste management policies. There again, the *Integrated Solid Waste Management* approach receives special attention. Unlike Bagchi, Medina sees the approach defined through the waste hierarchy, but it has to „be adapted to the local conditions when implemented in Third World cities" (Medina 2000:17). What is meant by adapted is unfortunately not stated.

A paper with similar focus, but probably less intensive dealing with social issues than Medina, was written Christian Zurbrügg from the Swiss *Department of Water and Sanitation in Developing Countries (SANDEC)* at a meeting in Durban, South Africa. „Urban Solid Waste Management in Low-Income Countries of Asia How to Cope with the Garbage Crisis“ (Zurbrügg 2001) presents data, describes waste management systems and practises, their problems and challenges. Unlike other works where the waste hierarchy appears usually in the beginning, it could be found therein at the very end, meaning in the conclusions:
„Although the fundamental aspects of the waste management hierarchy [...] remain valid, large flexibility to use different approaches for different local situations and actively involving residents at an early stage in planning and implementation are elements which have shown to be most promising.“ (Zurbrügg 2001:10).

Figure 8-1The waste hierarchy, as shown in Zurbrügg (2001:10)



Agamuthu Periathamby, professor at the Institute Of Biological Sciences of the University of Malaya (Kuala Lumpur, Malaysia), is, among other fields, working in the field waste management. His handbook “Solid waste: principles and management: with Malaysian case studies” (Agamuthu 2001) is focusing not only on Malaysia, but also on other countries in the region, most of them low or middle income countries. The publication provides an overview on technical solid waste management issues, solid waste management legislation and case studies on waste management in Malaysia. The introduction chapter provides general definitions, among them a seven stage waste hierarchy (Agamuthu 2001:5), but beside the denomination, no further discussion can be found. Generally, the book is quite technical, also on the definition in terms of policy.

As for developed countries, the application of the waste hierarchy is particularly questioned for developing countries as well, this time by Brunner and Fellner (2007) from the Vienna University of Technology. In their paper „Setting priorities for waste management strategies in developing countries“ they investigate the solid waste management systems of three urban regions with different economic wealth, namely Vienna (Austria), Damascus (Syria) and Dhaka (Bangladesh). Then they assess each region on how the solid waste management systems achieves the objectives of waste management, stated as 1) the protection of human health and environment and 2) the conservation of resources. These objectives are represented by seven indicators, such as the „percentage of the population having direct contact with waste“, „Greenhouse gas emissions“ or „the rate of material recycling“ (Brunner and Fellner 2007:235). In the assessment the two regions with lower income, Dhaka and Damascus, perform weaker than Vienna. Subsequently, scenarios for extended waste management systems are drawn for both cities, including full collection service, separate collection of recyclables, sanitary land filling, mechanical biological treatment and incineration. Finally, these scenarios are assessed too by using the same indicators than before and the percentual change to the status quo is shown as a bar chart. From the results the authors conclude that the scenarios higher ranked by waste hierarchy do more likely reach the objective of resource conservation (separate collection of recyclables e.g.), while options lower ranked are beneficial for the protection of human health (sanitary land filling e.g.). High technology options are too expensive, while a full collection service will have the highest positive impact on the protection of human health. Thus the authors conclude that „based on case studies, it was found that for [low income] regions spending 1–10 € capita^{-1} year^{-1} for waste management, the ‘waste hierarchy’ of prevention, recycling and disposal is not an appropriate strategy“ (Brunner and Fellner 2007:234).

Unlike the critics on the waste hierarchy which has been presented before, Brunner and Fellner do not express their assessment indicators as costs, like in a cost benefit analysis. However, their approach is goal oriented and partially tailored for developing countries, using an indicator which is hardly ever used in assessments in developed countries, namely the percentage of population in direct contact with waste. The conclusion is somewhat comparable to Barrett and Lawlor (1997): there are economic difficulties for many regions to apply options and technologies which are high ranked through the waste hierarchy.

8.1.2 International organisations involved in solid waste management

It was in 1987 when the so called Brundtland Report *Our Common Future* (WCED[1] 1987) was published. The concept of sustainability was born, of course not out of nothing, but the impact of the report was very relevant in shaping subsequent discourses on development and environment (cp. Hajer 1995; Schiller 2005; Elblinghaus and Stickler 1996). One outcome which has been major influenced by *Our Common Future* was the UN Conference on Environment and Development (UNCED) in Rio de Janeiro. The *Agenda 21* is one published result of the conference (UNCED 1992). There, 27 principles on sustainable development are dealt with, among them the generation and problems with solid waste (chapter 21). *Agenda 21* concludes that just the sanitary disposal or the recovery of wastes

[1] WCED stands for World Commission on Environment and Development

does not go far enough. Unsustainable production and consumption is the root of the problem, which could be solved by using following strategy:
„21.5. Accordingly, the framework for requisite action should be founded on a hierarchy of objectives and focused on the four major waste-related programme areas, as follows:

(a) Minimizing wastes;
(b) Maximizing environmentally sound waste reuse and recycling;
(c) Promoting environmentally sound waste disposal and treatment;
(d) Extending waste service coverage“ (UNCED 1992)

Some critics from various experts and scientists which has been cited before (cp. Zurbgrügg 2001) is subsequently incorporated, as the authors sees that „[T]he mix and emphasis given to each of the four programme areas will vary according to the local socio-economic and physical conditions, rates of waste generation and waste composition." (ibid.) The health issue associated with waste is also raised in this chapter, for instance in the commitment that waste not collected is a major threat to the human health of the urban population.

But it has not always been that the waste hierarchy was automatically a part of a report on solid waste management.
"Environmental Management of Urban Solid Wastes in Developing Countries. A Project Guide" is a report written by the consultant Sandra J. Cointreau for the World Bank's *Urban Development Technical Paper Number 5-* series (Cointreau 1982). It is really a *pre-hierarchy*, published in a time the waste hierarchy was just about to enter policy guidelines etc., focusing on solid waste management in developing countries' urban areas. And unlike later published works (cp. Medina 2000), it not so much focuses on recycling, but primarily on health issues. The whole report is for consultants and city authorities for organising first of all a sufficient waste collection, before heading on to disposal and recycling of waste. In summary, waste is therein primarily dealt with as a health and environment, but not so much a resource issue. But would have been if the same report was published 10 years later?

Probably the WHO publication "Urban Solid Waste Management" (Pescod 1991) gives an answer to this question. Though focusing on Europe, it gives a good image on what has changed since 10 years before. As a report for an organisation intrinsically dealing with health issues, they are very present, from the beginning to the final chapter. The initial statement is somewhat remarkably, as it merges the waste hierarchy and the objectives of waste management as stated in part I. Hence, solid waste management has "to achieve the following objectives:

- protection of public health,
- promotion of hygiene,
- recycling of materials,
- avoidance of waste,

– reduction of waste quantities, and
– reduction of emissions and residuals". (Pescod 1991:15)

After some chapters on different solid waste management options and practises in Europe, an outlook on the future of waste management completes the report. There, finally, the waste hierarchy appears. Interestingly, the chapter where each step of the waste hierarchy is presented, is ordered according to the hierarchy (cp. Pescod 1991:245 ff.).

In a report published 15 years later which too aims to focus on solid waste and health in Europe, the waste hierarchy is seen more critically by the authors who mention the hierarchy in their contribution. Therein, Mohan et al. (2007) conclude that simply using the options as pre-suggested through the waste hierarchy is not sufficient for decision making. LCAs and health impact assessments (HIA) must be carried out as planning tool. However, the authors conclude too that "[w]aste management is clearly an issue in which health professionals have a role and can make a positive difference. Public health professionals should be aware of the fact that unless their voice is heard in the sustainability debate in which waste management is an important issue, it may remain focussed on technical and economic issues." (Mohan et al. 2007:42) Interestingly, the authors immediately state at the end of their paper that their views are not necessarily shared by their employing organizations, namely the British Health Protection Agency (ibid.).

Considering WHO reports for solid waste management in developing countries, though in the era where the waste hierarchy became really popular, the focus about the aims of waste management changes compared to publications just mentioned before. "Municipal Solid Waste Management in Middle- and Lower Income Countries" is a report published by the WHO regional office for Europe (MacFarlane 1996). Therein, the major problems for solid waste management in developing countries refer to health and environmental issues caused by inadequate collection and thus low sanitation standards. The waste hierarchy does not appear at all.

"The resolution of both social and health problems lies predominantly in the improved collection of waste, rather than improvements in its disposal." (MacFarlane 1996:21).

As seen before, the *World Bank* is involved in solid waste management issues too. About 15 years after releasing a report primarily focusing on health issues in solid waste management in developing countries (Cointreau 1982), Hoornweg et al. (1999) wrote the report "What a waste: Solid waste management in Asia". Asia is seen to be the one world region with the highest growth rates, in economic but also in waste terms (Hoornweg et al. 1999:1). The report is rather formulated in general terms, highlighting the main challenges in solid waste management, such as the health and environmental impacts of solid waste, but also resources. Thus, the *Integrated Solid Waste Management* approach as stated in Tchobanoglous (1993) and the waste hierarchy is stated.

„Waste hierarchies are usually established to identify key elements of an ISWM plan. The general waste hierarchy accepted by industrialized countries is comprised of the following order:

- reduce
- reuse
- recycle
- recover waste transformation through physical, biological, or chemical processes (e.g., composting, incineration)
- landfilling“ (Hoornweg et al. 1999:18)

While these elements seem to be consensual accepted, in Asian countries "[a]ll levels of government should promote the hierarchy of waste management (i.e., reduce, reuse, recycle, recover) and encourage waste separation to maximize flexibility to deal with future changes. Wherever appropriate, governments should view solid waste as a resource, rather than just a "local problem."“ (Hoornweg 1999:25)

On the other hand, the World Bank's Urban Paper Series takes up the health affects of solid waste management in developing countries separately too. 24 years after writing "Environmental Management of Urban Solid Wastes in Developing Countries. A Project Guide" (Cointreau 1982), Sandra Cointreau again attends herself to "Occupational and Environmental Health Issues of Solid Waste Management. Special Emphasis on Middle- and Lower-Income Countries“ (Cointreau 2006). Therein, primarily the health and environmental impacts of and through solid waste are highlighted, but not the waste hierarchy.

Probably the most important international organisation in solid waste management issues is the United Nations Environment Program (UNEP) found in 1972 in the course of the UN Summit on Environment in Stockholm. Its reports on solid waste management are the longest and most intensive that has been reviewed herein. What has been observed too is the focus of UNEP in terms of waste management strategy setting if compared to WHO for instance.

Two reports are exemplified presented. The first mentioned herein is the "International Source Book on ESTs: Municipal Solid Waste Management IETC TPS 6“, which is available to view online (UNEP 1996). This source book or, in this case, source website, is extended frequently. Focus area are developing countries. While the waste hierarchy is not directly mentioned there, it comes in a, let's say, more subtle way, namely in the organisation of chapters.

"1.1 Overview of the Sound Practices Section; 1.2 Waste Reduction ; 1.3 Collection and Transfer; 1.4 Composting; 1.5 Incineration; 1.6 Landfills; 1.7 Special Wastes“ (UNEP 1996)

Other UNEP reports state the waste hierarchy more explicitly. The "Integrated Waste Management Scoreboard. A Tool to Measure Performance in Municipal Solid Waste Management“ (Wetherill 2005), which aims to provide a tool for evaluating solid waste management systems on all

administrative levels in ASEAN countries, excessively uses the term waste hierarchy, which even more often occurs than the term *health*. Even a whole chapter is dedicated to this strategy, which starts with the phrase: “The ‘Waste Management Hierarchy‘ is an internationally recognised strategy for management of municipal solid wastes.“ (Wetherill 2005:7) It also becomes the means of evaluation, as “in order for a solid waste management system to be successful the principles of sustainable development, integrated solid waste management, and the waste management hierarchy must be embraced, coordinated, and implemented at the national, state/provincial/regional, municipal, community, and institutional levels.“ (Wetherill 2005)
The largest UNEP publication is the more than 500 pages containing “Solid Waste Management“ book, written by the waste consulting experts CalRecovery (CalRecovery 2005). Compared to the publication mentioned before, it more resembles a handbook of solid waste management but the wording used and the context in which the waste hierarchy is set remains the same. Hence, “[t]he waste management hierarchy is a widespread element of national and regional policy and is often considered the most fundamental basis of modern MSWM practice.“ (CalRecovery 2005:8).

But the international organisations are not just giving general advises, they also help to establish and set up networks to promote the waste hierarchy in several parts oft the globe. One such initiative is the *3RKH* network, whose aim is described on its homepage:
“The Asian Development Bank (ADB), Asian Institute of Technology (AIT) and United Nations Environment Programme Regional Resource Centre for Asia and the Pacific (UNEP RRC.AP) are similarly interested to develop a partnership in establishing a regional knowledge hub (the Knowledge Hub) on the subject of reduce, reuse and recycle (3R)” (3RKH: no date). The driving force behind this network is the Government of Japan, and the main target countries are located in East-, South-east- and South-Asia. Indonesia is one of them.

8.1.3 Governmental actors

In developed countries: Austria - Vienna

Solid waste management is of course a matter for state, regional and municipal governments and authorities, as they are the ones who have to set policy strategies, laws and legislations or incentives. Thus, even terminologies, such as the one of “Municipal Solid Waste Management” (MSWM), are defined through social and political responsibilities. In the just mentioned case, a good (waste) is defined not only through its physical and chemical properties, but judicative. Hence, the good *Municipal Solid Waste* can be defined firstly through its origin (private households and small enterprises, but also waste alike the waste of these two sources) and secondly who is responsible to handle, treat and dispose it (public authorities).

Now there would be many possible case studies for investigation, as “virtually all countries” have adopted some sort of waste hierarchy (UNEP 2005:8), but due to the case studies considered in the goal-oriented assessment, mainly sources referring to Austrian and Indonesian authorities are taken.

In Austria, waste management laws are community laws and thus adjusted to solid waste management directives of the European Union. The most general EC law on waste management is the *Framework Directive on Waste* (Directive 2008/98/EC), which focuses more on general waste issues, for instance the definition of waste. Therein, the waste hierarchy is stated too in Article 4:

“1. The following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy:

(a) prevention;

(b) preparing for re-use;

(c) recycling;

(d) other recovery, e.g. energy recovery; and

(e) disposal.

2. When applying the waste hierarchy referred to in paragraph 1, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.” (Directive 2008/98/EC:10)

The waste hierarchy has been manifested in Austrian waste management regulations years before Austria has become a member of the European Community. The actual guiding law on waste management, which is the “Waste Management Act 2002 (WMA 2002)” or “Abfallwirtschaftsgesetz 2002 (AWG 2002)”, contains the waste hierarchy in §1(2), after mentioning the objectives of waste management in §1(1).

1. Objectives of waste management (WMA 2002):

- “to protect humans, animals and plants as well as their resources and their natural environment
- to minimize air pollution and gases harmful to the climate
- to conserve resources (raw materials, water, energy, landscape, areas, landfill volumes)
- to ensure that the materials reclaimed are not more hazardous than the primary raw materials
- to deposit the waste from waste treatment in a manner that is safe for future generations.” (FWMP 2006:119)

2. Principles of waste management (WMA 2002):

- “qualitative and quantitative waste prevention
- waste recovery that takes ecological and economic factors into account
- waste disposal through appropriate treatment procedures” (ibid.)

Taking ecological factors into account could mean that any choice of waste options should also undergo a comparative life cycle assessment, as suggested in the EC's "Framework Directive on Waste" intended (Directive 2008/98/EC).
The "Waste Management Act" of the city of Vienna (LGBl. Nr. 13/1994; last modified through LGBl. Nr. 33/2007) goes a step further, when writing the waste hierarchy in the objectives of waste management in §1.

Developing countries: Indonesia – Banda Aceh

It took a long time and numerous adoptions until the actual version of the EC's Waste Directive was enacted (cp. Euractiv.com 2008). The same has been observed in Indonesia during drafting and enacting the Waste Management Act of 2008 (Act of the Republic of Indonesia Number 18/ Year 2008) (cp. The Jakarta Post, June 5th 2008; October 4th 2007; September 21st 2006).
Finally the law was signed by the Indonesian President on May 7th 2008. Therein, the claim of environmental non-government organisations like WAHLI for fully stating the waste hierarchy or the – in the Indonesian context more often used term *3R-* or *4R- Principle* – was not fulfilled. According to the act, "[t]he objective of management of waste is to increase public health and environmental quality as well as to utilize waste as energy source" (Article 4).While there is the obligation to waste producers to reduce waste at source (Article 12), the specification of the law on waste from households sees its management to be consisted of "a. waste reduction; and b. waste handling" (Article 19). Hence, waste reduction means "a. limitation of waste generation; b. recycling of waste; and/or c. re-using of waste" (Article 20). The definition of waste handling is given in Article 22, summarized the collection, transformation, processing and final disposal of waste. Article 29 lists prohibits, like open burning or uncontrolled dumping of wastes, which is, as showed later, a common problem in Indonesian cities.
Interestingly, energy is mentioned quite often, not only in Article 4 (objectives), but also in the annexed "Elucidation" (page 17). "The new paradigm considers waste to have economic value and it could be utilized as energy, compost, fertilizer and industrial raw material."
On the same page, when the problems regarding waste management are listed, the focal point lies on the growing waste quantities, the popular reckoning of waste as something unusable, the contemporary reliance on end-of-pipe waste chains, such as collection, treatment, disposal and the production of methane. However, the health impacts through waste if not collected or waste dump slides are not mentioned, probably not seen as such a big problem as the already mentioned ones.
Even though the waste hierarchy or the more common used *3R- / 4R- principle* do not appear explicitly in the act, the Indonesian government and national authorities or parts of it are quite positive towards the waste hierarchy. For instance, the Ministry of Environment promotes the waste hierarchy in *Percik*, the information media of its *Working Group for Water Supply and Sanitation* (WGWSS 2006). Therein, the waste hierarchy appears quite often as the *3R- Principle* (17 times on 56 pages),

for example in an interview with Mohammad Hilmi, Assistant to Deputy for Domestic and Small Business Waste Pollution Control, Ministry of Environment: "We are pushing the Pemdas [= Regional Governments] to put 3R into practice." (WGWSS 2006:9)

Recipients are the regional and local governments, such as the Municipality of Banda Aceh in the north-west of the Indonesian island of Sumatra. The town was partially destroyed during the Tsunami in 2004. With a huge aid-effort, the city was rebuilt in both, material and capacity terms, also regarding waste management. Beside actions, like the removal of huge amounts of debris, the construction and rehabilitation of landfills and the provision of equipment, a new "Solid Waste Management Master Plan – Report for Post-Tsunami Banda Aceh, Republic of Indonesia" was drafted (DKP et al. 2007).

The report was prepared by European experts in solid waste management and the municipal authorities of Banda Aceh, herein particularly civil servants from the *Sanitary and Park Department* (DKP). Aim is to get "a planning document and a set of objectives, targets and related development measures, phased in short-term, medium-term and long-term activities" (DKP et al. 2007:6) for municipal solid waste management in Banda Aceh. The objectives of waste management are, as stating in the report:

- "to promote the health and well-being of the entire urban population,
- to protect the quality and sustainability of the urban environment,
- to promote the efficiency and productivity of the urban economy, and
- to generate employment and income" (ibid.)

Unlike most other strategy papers observed, the authors have set criteria, in order to evaluate the accomplishment of the waste management system. Such criteria are hygiene and sanitation, equality of citizens, financial resources, sustainability in both, socio-economic and technical terms, but also efficiency and fairness towards all stakeholders. Efficiency is described as "to maximize the benefits, minimize the costs and optimize the use of resources, based on a local version of the waste hierarchy principle (the preferred priority of waste prevention, minimization, material recovery, energy recovery, and final disposal)" (ibid.).

Tough the waste hierarchy appears, there are clear objectives too, set in a more prominent place than the hierarchy. And contrary to the Indonesian waste management act, more emphasis was put on health and local population well-being.

Other government actors: National development agency from high income countries

Regional actions and national policies are by far not just influenced by national actors. This is the case for Austria, which is embedded in the European Community. In developing countries, far more different actors are influencing and shaping national, regional and social policy and actions. International bodies, like the UN Organisations, are present, international NGOs, and also development agencies from European, North-American, East-Asian and other, predominately high-

income countries. The latter are very active in the field of developing waste management policies, strategies, programs and projects.
For instance, the German Technical Co-operation (GTZ), together with the international cement manufacturer Holcim, tried to promote the co-processing of solid wastes in cement manufacturing. Waste is used as a fuel in the energy intensive process. Therein, the level of co-processing in the waste hierarchy is highlighted (cp. Holcim et al. 2006). Beside that, GTZ promotes the waste hierarchy in various report on waste management in developing countries (cp. GTZ 2005).
An initiative which is by far exceeding the promotion efforts of the GTZ were introduced by the Japan International Cooperation Agency (JICA) through establishing the “3R Initiative” (JICA no date). The aim of this program is “to promote the "3Rs" (reduce, reuse and recycle) globally so as to build a sound-material-cycle society through the effective use of resources and materials” (ibid.). Its main operation area is East, South-east and South Asia, meaning an emerging region which receives high attention by the Japanese export economy. Indonesia is among the focus countries, participating in 3R workshops and meetings (Indonesian Ministry of Environment 2006).

8.1.4 Non-state actors: environmental non-government organisations (NGOs), the private sector and other actors

Beside science, experts and governmental actors, non-governmental actors are involved too in the discourse on solid waste management. The group considered here is the probably most heterogeneous of the distinguished actors, from their organisational form, their objectives or their positions, but also in their relation to governmental organisations.

National and international non-governmental organisation (NGOs)

Hajer has pointed out the important role of NGOs on environmental discourses (cp. Hajer 1995:94) in general. Waste management is too a field were NGOs are very active, primarily claiming to represent the interest of civil society and the environment.
Regarding the waste hierarchy, European NGOs are quite active during drafting new laws on waste management, newly intended waste treatment facilities, waste transports or illegal activities regarding waste management. One example is the active role of NGOs during the new EC directive on waste (Directive 2008/98/EC). *Friends of the Earth* and other organisations which participated in the bargaining were, however, quite disappointed with the result (see their statements on EurActive.com, 18.06.2008). The frontiers seem to be clear: Environmental NGOs generally support the waste hierarchy, but are discordant with other actors about its implementation and the hierarchal ranking. Claims like Greenpeace statement to “[p]lace [waste] incineration with energy recovery at the bottom of the waste hierarchy, below landfill of separated, stabilised waste” (Greenpeace 2001) are common in the scene. Particularly the question of where to set waste incineration in the framework of the waste hierarchy attracts the activists and organisations. Very active in this question is the *Global Alliance for Incinerator Alternatives*, also *Global Anti-Incinerator Alliance* (GAIA). GAIA is an umbrella

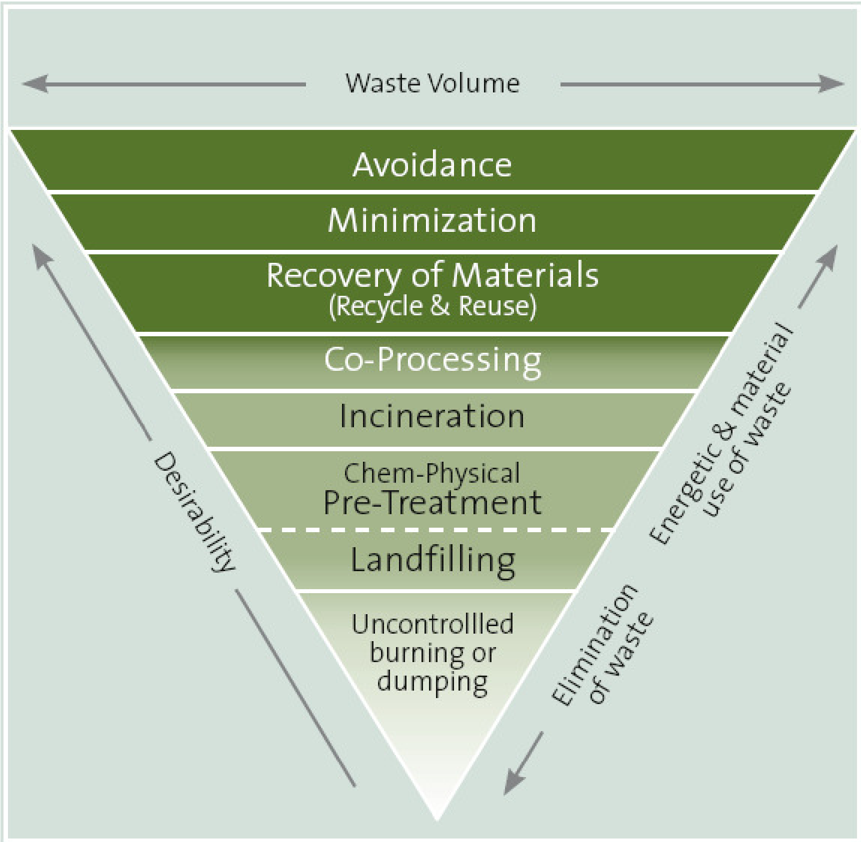
organisation for different NGOs from all-over the globe. The secretary is Manila, Philippines, but there are offices too in the United States of America and Argentina. In its report “Waste incineration: A dying technology” (Tangri 2003), GAIA subsumes their views and the global resistance against waste incineration, but also alternatives to it, mainly the zero waste approach, which “aims to achieve 100 percent [waste] diversion rates through a mixture of waste minimization, industrial redesign, composting, recycling and reuse programs” (Tangri 2003:51). This would be, so to say, a waste hierarchy, extended by industrial redesign, but without incineration or land filling.
Gaia is operating all over the world, and Indonesia is though not a *blank spot on its map*, where the NGO *Bali Fokus* is part of the network. Another NGO which is, according to the homepage of GAIA, not a member but more prominent in promoting the *3* or *4 R principle*, the *zero waste* approach and against waste incineration is the Indonesian NGO network Friends of the Earth Indonesia or, in Indonesian*, Wahana Lingkungan Hidup Indonesia* (WALHI). WALHI’s actions in waste management are very wide ranging. Support of communities protesting against solid waste facilities, like landfills or incinerators, are part of their program, as well as lobbying (cp. WALHI’s homepage). In the latter, WALHI was very active during the drafting of the Indonesian Waste Management Act in 2008. As a declared opponent of waste incineration, but also land filling, WALHI has called policy maker to place more emphasis on the *3* or *4 R principle* (cp. WAHLI 25.05.2007; WAHLI 25.04.2007).

Companies, private firms and consultants in the field of solid waste management

In the struggle on waste management facilities, strategies and policies, private companies working in the field of solid waste management are often opponents of environmental NGOs, but not always. They can also be important allies. However, that might not be the case for the discussion around the drafting of the EC directive on waste (EurActive.com, 18.06.2008) and also for the first example mentioned here, namely the Swiss cement producer Holcim.
Holcim is a company which has production units in many countries in the world, developing and developed nations among, also in Indonesia. Now, cement production is not regarded as very *eco-friendly*, for instance due to the high energy demand during the production of clinker. However, HOLCIM invests not only in cement manufacturing facilities, but also in its corporate social responsibility program and in various research projects, as the study about the co-incineration possibilities of solid wastes in cement kilns (cp. HOLCIM et al. 2006). This study, which has been conducted in co-operation with the German GTZ and the *Fachhochschule Nordwestschweiz*, tried to assess the applicability of co-incineration of solid wastes in cement production particularly in developing countries, concluding that:
“As populations increase in the developing world, so do waste management problems, and so does the need for more cement and concrete for housing and the infrastructure of development. The properly managed use of wastes as fuels and raw materials in cement kilns can help manage wastes while contributing to the sustainable development of our world.” (HOLCIM et al. 2006:2)

Therein, the authors do not forget to address the waste hierarchy:
"Co-processing of wastes does not conflict with the waste hierarchy, as it can be classified as a technology for energy and material recovery" (HOLCIM et al. 2006:D).

Figure 8-2 The waste hierarchy, according to HOLCIM et al. (2006:9)



Other companies working in the field of waste management like the multinational *Veolia*, argue similar (cp. Veolia South Africa homepage, VEOLIA 2008). It seems as companies go *d'accord* with the waste hierarchy and rather on arguing against it, they try to underline how beneficial for waste management and in the scope of the waste hierarchy their approach and their technology is.

8.2 Analyse and Discussion Discourse Analysis

Four groups of actors in the discourse on solid waste management options, strategies and policies have been considered. The selection of these actors was twofold. Firstly, the selection was according to the actors who shaped the discourse on environmental issues from the 1960s to the 1990s as stated in Hajer (1995). The second reason incorporates actors who gather their importance in the discourse from the relation between developed and developing countries.

8.2.1 Waste management discourse in developed countries

Environmental paradigm shifts and solid waste management in industrial societies

The analysis of scientific and technical literature investigated shows a dramatic paradigm shifts in solid waste management policy and wording. This paradigm shift was also mentioned by Wilson when identifying "Development drivers for waste management" (Wilson 2007). Thus, in industrial societies, the main driver was public health until the 1970s. But more and more, environmental protection and conservation of resources stepped in, shaping waste management and the discourse on waste management. This paradigm shift is heavily influenced by the believe (and of course reality) that "public health is largely 'taken for granted' and is no longer a major driver" for waste management in Europe (Wilson 2007:200).

The turning point, which is of course not a point as a single moment in time but rather a time frame, can be traced out between the 1970s and the 1990s. Within this time, publications have changed the way how environment has been seen. "The Entropy Law and the Economic Process" (Georgescu-Roegen 1971) and "Limits of Growth" (Meadows et al. 1972) are two publications that gave the starting point, others have followed. Also, new scientific currents or disciplines did emerge, such as *Ecological Economics*, *Industrial Ecology* or *Ecological Modernization*. Solid waste management, like other human activities related to the human environment, was targeting therein as well.

This paradigm shift can best be explained by comparing two solid waste management technical handbooks, which have been published in the same country at different times. Mantell's "SOLID WASTES: origin, collection, processing, and disposal" (Mantell 1975) was published at a time, when this paradigm shift was in its *fledging states*. Because of that the waste hierarchy does not all appear in there, and the time, when waste was predominately seen as a hazard to human health in terms of sanitation was not too long ago. One should remember that Thrift G. Hanks literature study on solid waste and health relationships, which focuses mainly on communicable diseases origin from low sanitary standards, has just been published about ten years before, in the mid 1960s (Hanks 1967). Contrary to this publication, Tchobanoglous' 1993 published "Integrated Solid Waste Management" has incorporated the waste hierarchy in its chapter on "Evolution on of Solid Waste Management". The paradigm shift has already taken place.

The major technical components of a solid waste management system (collection, transport, separation, transformation and treatment, disposal) remain, but of course the innovations have changed dramatically during these 18 years. Air pollution control systems have been installed in waste incineration facilities, dumpsites have been upgraded to sanitary landfills with gas and leachate collection and treatment. When Mantell wrote his book, waste collection in urban areas has been established in developed countries, in order to raise the sanitary standard and eradicate most communicable diseases investigated by Hanks (1967). The next step, meaning the upgrade of landfills, incinerators and other waste treatment facilities to reduce urban air or water pollution has recently been started (in the case of waste incinerators) or was on its heyday (in the case of sanitary landfills). For instance, Mantell states that during the year 1969, three of a total of eleven waste incinerators in New York had to be shut down because of air pollution and the fact that they could not have been upgraded, while the residual incinerators have been equipped with an air pollution facility (cp. Mantell 1975:21). Another example refers to solid waste management legislation in Pennsylvania in the late 1960s. Even in the 1960s, the most common waste disposal option in the US was open dumping with subsequent burning (cp. Mantell 1975:13). Hence, the challenge at Mantell's times was to transform waste management into a more health and environmentally sound state, with traces of a focus on depleted resources conservation. This has to a large extend happened during the following years, and at the time when Tchobanoglous has published his book, environmental problems as described by Mantell have been already (partially, of course) *solved* in some way.

When mentioning the waste hierarchy, Tchobanoglous also refers to the US legislation on national, state, regional and local level, which has adopted the waste hierarchy into their laws and acts (Tchobanoglous 1993:34ff.). The paradigm shift in the environmental discourse can too be identified for political administration in developed countries as well. Until the 1970s, authorities tried to react on environmental problems when they already have appeared, or as Hajer writes, some kind of 'react and cure policy' (cp. Hajer 1995:26ff). To give an example for such an approach, imagine a landfill for mixed municipal solid wastes in the early 1980s in Austria. The leachate, containing significant amounts of potentially problematic substances, is collected in a container, which is emptied once a week. During heavy rainfall, the container proved to be too small; leachate spills over and pollutes the surroundings. After some months and some reclamation by residents, the authorities make the operator of the landfill to empty the container twice a week[1], thus reacting on and curing an environmental problem.

Later on, during the 1980s, the paradigm shift has taken place in administration too, shifting from a '*react and cure'* to an '*anticipate and prevent'* approach (cp. Hajer 1995:26ff.). To set this shift in a context with the above mentioned landfill example: by applying the '*anticipate and prevent'* approach, authorities could have forecasted that the container would be too small. They could also go one step

[1] This example is inspired by my childhood memory when growing up next to a landfill.

back, questioning whether proper waste incineration, higher recycling rates or – finally – reduction of waste generation would have made the landfill supersede at all. Clearly, this might be a very pointed remark, but it should become clear that waste management strategies like the waste hierarchy have emerged and found their way into waste legislation through paradigm shifts that have lead to approaches like '*anticipate and prevent'*.

It is now a difficult question to answer on which of both actors (scientists/experts and governments/authorities) has influenced and *driven* the other. Most likely, it has been a mutual influencing, but also a strategic discourse coalition in shaping the discourse on environmental issues like waste management.

Another factor influencing the discourse and subsequently practise in waste management was the growing influence of international and supranational bodies, like the OECD, the UN organisations and the European Community. It has been highlighted by Hajer that organisations like OECD, UNEP and UN-ECE have majorly shaped the discourse on environmental issues, by setting up environmental committees within the organisation (Hajer 1995:96). The experts working in these organisations had the possibility to develop ideas and guidelines independently from the daily administrative business, which probably consumes too much time for governing, so that there is no remaining space for strategic thoughts. Interestingly, Hajer does not mention therein the European Community experts working in the European Commission. As shown before under chapter 6.2, the waste hierarchy was first mentioned by the OECD and the EC. In the case of the later, the decision to include concepts like the waste hierarchy has had far more impact on far more countries. The reason is simply that EC decisions binding for its now 27 member states, while OECD decisions are not.

Other actors observed have been of non-state nature, like NGOs and private companies. Hajer (1995:94ff.) has regarded the role of the former in the emergence of *Ecological Modernization* intensively, concluding that their tactics have changed, with the result of growing influence. Earlier, NGOs have placed more emphasis on activism and civil disobedience. Then, during the 1970s and 1980s, a professionalization took place. NGO members became more important through changing state-civil relations, the were attending as parties in *Environmental Impact Assessments* (EIA) and build up lobbying groups in bodies like the European Community. Increasingly, they started to present their self rather as experts than as activists, with success: if a media brings an article about an environmental issue, *Greenpeace* or *Friends of the Earth* members are interviewed for their expertise. Beside that, political constellations have changed; former activists and NGO members became representatives or even ministers, like the new leader of the *Austrian Green Party*, who has formerly been working for *Global 2000*, the Austrian *Friends of the Earth* branch.

While the argumentative direction of environmental NGOs is more or less clear, it is not so for private companies, particularly those in the field of waste management. A clear trend can not be identified. For instance, in the discussion on the ECs waste directive the statements of private companies' lobby groups like the packaging industry or the waste incinerator operators were quite unhappy with the initial idea to set fixed target rates for recycling. However, their lobbying seemed to be successful, as this initial idea was given up in the final text. On the other hand, particularly the waste and recycling industry is benefiting from concepts like the waste hierarchy, as they can develop and provide *sound* solutions. When promoting these solutions, it seems to be evident to set them in the context of the waste hierarchy, as the example of Holcim shows (cp. Holcim et al. 2006). Then just the reclamation of a technology into the waste hierarchy becomes the argument for applying this technology.
Lately, the scene and its argumentation are rather ambivalent towards the waste hierarchy.

The waste hierarchy as a metaphor and a story line in the discourse

The paradigm shift in environmental issues and waste management too has been presented. But what is then the role of the waste hierarchy in the discourse?
Clearly, the waste hierarchy is embedded within the discourse on waste management which, as has been identified in the last chapter, is nowadays more resource and less public health oriented than it has been before the 1970s.
Now, many authors have criticized the concept of the waste hierarchy, questioning its applicability, either because of economical reasons (as stated in Barrett and Lawlor 1997) or the missing prove that it really represents the environmentally soundest choice of solutions (as in White et al. 1995). Particularly the later challenge the waste hierarchy solutions with the LCA concept to assess environmental impacts. The same was done by Schmidt et al. (2007), who brought a very important input for this thesis.
"The waste hierarchy principle has some pedagogical advantages such as when citizens use it to make decisions on whether to throw away empty beer cans into the countryside, into the rubbish bin or to collect them into a separate box for recycling." (Schmidt et al. 2007:1529)
Thus, not necessarily natural-scientific, but psycho-social arguments do count for the waste hierarchy: The waste hierarchy as a pedagogical concept for sustainability, metaphorical and easy to understand. Within this discourse on waste management, the waste hierarchy can be seen as one of the important metaphors, a metaphor that represents sustainable or integrated solid waste management. Dryzek has pointed out the importance of such metaphors in a discourse (cp. Dryzek 2005:18). Metaphors are the fundament for a *story-line*, meaning a story which is constructed. The story is sustainable waste management, the metaphors describing the fundamentals of this story is the waste hierarchy.

Discipline and disciplinary action

In a discourse, the production, reproduction and transformation of concepts and ideas are crucial. The waste hierarchy, as a metaphor in the discourse on waste management, is there no exception.

While some try to explain it, most authors just reproduce it, extend it from three to eight steps (cp. CalRecovery 2005) or use different names for the concept, like the *3R* principle. If the waste hierarchy is questioned, there is still some consensus among the authors that it is not fundamentally wrong, but its application is limited. Then the wording in the conclusion is mostly similar, saying that the waste hierarchy should be used as a guiding principle, but the choice of options should not be seen too strictly (cp. Rasmussen and Vigsø 2005; Schmidt et al. 2007).

Now, why is this reproduction so important? And what is the reason why this reproduction is so excessive? Foucault himself gives an explanation, which refers to disciplines as a mode of control in the production of discourses (cp. Foucault 1991:22ff.). A phrase or a word is just associated with a discipline, if it fulfils some criteria. If it does not fulfil this criteria, it is *not included anymore,* hence not a part of the discourse. For instance, in the discipline of botanic, plants were earlier described not only by the physical properties, but also about there spiritual meaning. This has changed from the late 17th century. The spiritual meaning was not used anymore in the discipline of botanic, as it has been seen as unscientific and *superstitious.*

Now, to turn this around, a discipline has some wording and some phrases which are seen as an integrated part of the discipline. I argue that the *waste hierarchy* and the alike is such a word which becomes inextricably with *waste management*. And I do further argue that in the actual discourse on waste management at least a simple statement of the waste hierarchy is required to fulfil the criteria of the discipline of waste management, in order not to be excluded from the discourse. Hence, it is easier for somebody to participate in the discourse if the waste hierarchy is stated, thus reproduced.

To make such ideas like the waste hierarchy publically accepted, some power is needed. However, to deal herein with the *question of power* is kind of tricky, as the concept as Foucault has seen it is not an easy task to get. Because of that, just two exemplified aspects of power within the discourse on waste management are brought herein. The first example was the waste hierarchy as a word or metaphor which helps to open the door to the discourse. The second example comes from the common wording around the waste hierarchy. It has been investigated that there is and was a discussion on the waste hierarchy. But numerable authors do see a *consensus* how the waste hierarchy looks like, which waste management option and technology is ranked higher (cp. CalRecovery 2005:8; Wetherill 2005:7). But is there really a consensus how the waste hierarchy looks like, if there is even no consensus about the concept itself?

I would say that there is not. But just to use the word *consensus* implies a consensus, and this fictional consensus cements the waste hierarchy. This cementing of the waste hierarchy is some form of power.

8.2.2 Waste management discourse in developing countries

Some aspects on the discourse on waste management in developed industrialised countries have been investigated in the anterior chapters (8.2.1). In summary, along with the paradigm shift on environmental issues from the 1970s to the 1990s, also the discourse in solid waste management has

changed, from a public health to a more resources oriented discourse. The significant improvement in sanitation is one very important social and physical factor for this.
But how is the discourse on waste management held in or – due to the western political dominance in the world – for developing countries, where the sanitary situation is much worse than in developed countries?

The environmental paradigm shift and its effect on developing countries

Before, the environmental paradigm shift and the change on the waste management discourse has been sketched for developed countries. A similar, but more contradictory shift can be observed for the discourse on waste management in developing countries too. What is meant by contradictory is argued later in the conclusion.
During the 1970s and 1980s, the concept of development and developing countries' issues became more popular. The list of publication on development issues became longer and longer, though for waste management in developing countries.
One of the earlier publications is Sandra Cointreau's "Environmental Management of Urban Solid Wastes in Developing Countries. A Project Guide" (Cointreau 1982). Therein, the elements of health aspects are still dominating over the resources aspect. A crucial element for the discourse was probably the *Agenda 21* of the Johannesburg Summit (UNCED 1992). The environmental problems which are described therein are presented as global problems, requiring global strategies and solutions. One of these globally applied solutions is the waste hierarchy. It is now difficult to quantify the *real* impact of *Agenda 21* on the subsequent discourse on waste management in developing countries, but two things can be observed: firstly, that the waste hierarchy is far more often stated in publications written after the beginning of the 1990s; and secondly, that the citing of reports and publications which are internationally considered to be important, has become increasingly *en vogue*. For instance, Imran et al. (2008) state the Brundtland Report "Our Common Future" in the introduction, while others refer to the *Agenda 21*.
While it has been shown in the literature sources review, that the recommendation of the waste hierarchy as a policy strategy for developing countries is forced by various actors, the wording is interesting. Contrary to the early stages – and also to the discourse in developed countries – the suffix "*that the hierarchy cannot be followed rigidly*" (CalRecovery 2005:9) due to socio-economic difficulties in financing the waste management options. Similar statements can be found in Hoornweg et al. (1999) or Zurbrügg (2002), while Medina (2000) and Wetherill (2005) in his publication for UNEP seem to be more rigid in terms of waste hierarchy implementation. But going back to Hoornweg, Zurbrügg or CalRecovery, it seems as there is a discomfort with the implementation of the waste hierarchy in developing countries. However, it also seems as it is still required to state it.

The export of a discourse

Waste management in developing countries is different in large extents to that in developed countries. This is a main finding of most authors who deal with this issue. The problems are different, particularly the lower ability to finance waste management options, accountability of parties involved and the effect of waste on particular groups.

However, even though these differences are recognized by most authors, the strategically solutions for developing countries are not too different from that in developed countries. The waste hierarchy is a good example for such a strategy, which has been evolved in the developed nations and then exported to developing nations.

The probably most important key actor in this process of transport is international organisations, like UNEP or the World Bank. Their reports on waste management are usually filled with policy strategy recommendations. The precautionary principle, the producer pays principle and – of course – the waste hierarchy.

International Organisations are predestined for policy strategy and for discourse transfer, and this for many reasons. First, they usually do have projects and programs in a country on the topic of the discourse. This is so for waste management too, where The World Bank is involved in numerous development projects. In selecting the projects and programs, the organisation can be selective what should be financed. And if the policy of the organisation favours, as in the waste hierarchy, recycling and not so much land filling, its funds will probably more likely flow to recycling projects. Second, international organisations do provide a lot of literature for free. A technical handbook like Tchobanoglous' "Integrated Solid Waste Management" costs about 50 €, which is a lot of money for a researcher or a policy maker in a lower income country. But UNEP's "Solid Waste Management" (CalRecovery 2005), which provides information probably as useful, can be downloaded for free. Thus this channel is likely more effective than expensive hand books.

National development agencies of high income countries do fulfil a similar role like international organisations, except that the ratio between projects and publications might be different. GTZ and JICA are good examples. Particularly the latter is very offensive in shaping the discourse on waste management in Asian developing countries. But what is the aim of this engagement? Well, both nations do have in common that they are exporters of high technology equipment, also environmental technology. This is of course not the only motivation, but environmental technology transfer is usually accompanied by policy strategy transfer. Otherwise the recipient might question why he should buy and use this equipment.

Another important factor in shaping discourses are discourses coalitions (Hajer 1995:65ff.). A good example for a discourse coalition is again GTZ, together with Holcim. A private company which is working in afield with a high pollution potential, like cement industry, does have a big interest to be accredited through a renowned expert in development and environmental issues. A contra position to the waste hierarchy would be contra productive, thus it makes more sense to present the own technology within the framework of a sustainable considered policy framework as the waste hierarchy. Then the normative aspects of the discourse on waste management are not violated.

From discourse to action: what is the impact of the shift in the discourse on waste management?

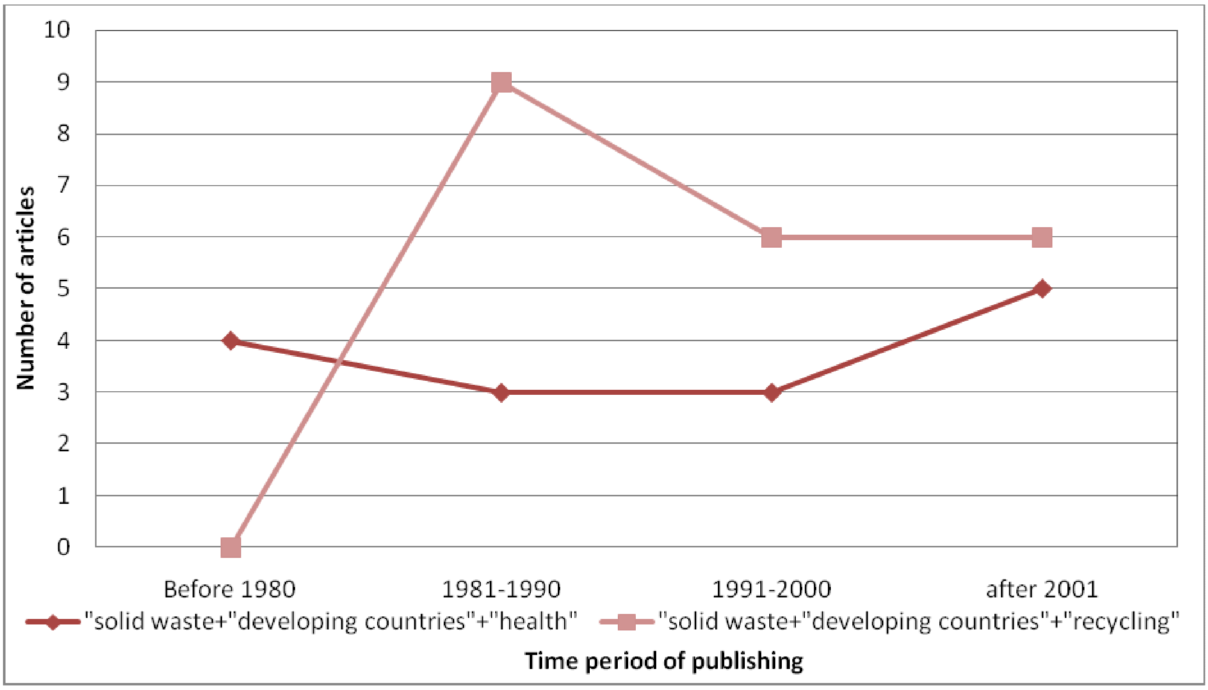
Once again, the definition of discourse analysis has to be stressed to come to the final point, which I will formulate as question: What are the "set of practices" (Hajer 1995:44) that can be addressed to the discourse on waste management in developing countries?
To answer this question is somewhat challenging, as it is highly interpretative and quantitatively probably impossible to show. It is not so difficult, to address the written word to another written word, but more difficult to associate the written word with a practice.

To show the first, meaning the context between the written words, the Indonesian strategies on waste management and legislation, the Waste Management Act of 2008 and the previous discussion on it gives a good example. During the time of drafting, various actors have tried to influence the act, like the environmental NGO WALHI. Their claim was to solve the waste problem with the *Zero Waste* approach or the *4R* principle, but not with waste incineration. The government only partially followed this claim in the Act, but in its waste management strategy, as shown in the publication of Percik (WGWSS 2006). If the discussion on the drafting of a law, but also the law itself is seen as practice, it is definitely the result of the discourse on waste management. Another example for written practice is the waste management master plan of Banda Aceh (cp. DKP et al. 2007)

Secondly, the practice on solid waste management in developing countries research might has been changed through the discourse. This should be illustrated by examples:
Scientists from the University of Indonesia (Jakarta) and the Gajah Mada University (Yogyakarta) have undertaken a research study in Jakarta and West Java, published under the title "Institutionalization of Sustainable Waste Management: An Extension Program of Environmental Awareness in Jakarta and West Java" (Imran et al. 2008). Aim of the research, which has been undertaken by an interdisciplinary research team, was to "facilitated forums for all stakeholders", to provide "a concept of sustainable waste management" and to "increase public participation" (Imran et al. 2008:7). The term sustainability is described according to the Brundtland-Report, while the way how sustainability can be achieved is "implying that the concept of waste management hierarchy of popularly 3R is the basic requirement for sustainability in waste management" (Imran et al. 2008:5). Now, the social action that follows is the focus of the research and the conclusions. According to the research report, the first step was to determine the waste composition of solid wastes from households. Therefore, the waste is split up into the fractions organic waste, recyclables and other wastes (cp. Imran et al. 2008:8ff.). The result shows that the amount of recyclables is fairly small (about 6 mass

%), which leads the authors to the conclusion that the amount of other wastes (about 40 mass %) should be reduced.
Regarding to the sampling and the recommendation and based on the own research from Banda Aceh, I would ask firstly why the waste has been split up in the three fractions mentioned and secondly why the waste composition, but not the access of households to a proper waste management, waste management practises or the contents of potentially hazardous materials in wastes.
Not knowing the answer, I assume that at first, the stipulating of fractions to follow a waste hierarchy inspired intention. Recyclables are selected as a category, as recycling is a part of the waste hierarchy and thus seen as a sustainable waste management option. Organic wastes are contained, as they are firstly compostable, thus recyclable, and secondly difficult to reduce. Mainly these are food wastes, and a researcher would not suggest somebody to eat less. Other wastes are a category that is seen as reducible, probably as even senseless waste, as it neither can be composted, nor recycled in the actual recycling scheme.
The second assumption refers to the not-consideration of access to solid waste collection, solid waste management practises or potential hazardous waste. These are typical health issues, as solid waste collection is the first thing to establish sanitation, while hazardous wastes are important to identify in order to protect people working with wastes. Solid waste management practises, such as open burning or dumping, should be identified in order show the negative hot spots in sanitation. How ever, health issues are not investigated (or have been, but not mentioned?) separately beside the general statements, even though it is very likely (some would say a known fact) that many people in Indonesia do not receive a waste collection service or scavengers who collect recyclables have a higher risk towards diseases related with waste.
According to both points (1) the conclusions from the waste composition and 2) not considering waste collection, waste handling practises and hazardous wastes) I conclude that the whole research is more focusing on waste reduction and recycling, thus on resources, and not so much on public health.
But is this a single case? I would deny this question. During the research for the literature review for the quantitative part, the experience was made that the main focus of literature on solid waste management in general, but also in developing countries, has changed. Figure 8-3 shows the number of publications which could be found on Google Scholar by using different search terms.

Figure 8-3 Publications on solid waste management in developing countries by using different key words for search in title (Source: Google Scholar 21.01.2009)



Though not representative and probably even unscientific, a shift in the focus towards resources and away from health can be observed. That does not mean that health issues are not considered at all anymore. But the importance of conservation of resources is increasing.

The third would be the impact of a paradigm shift in the discourse on waste management and its effect on development project work. This would be the ultimate objective in this research. However, I will not do so, as the thesis has already grown beyond its scope, but I will state it as a question that would be worthwhile to investigate: Has the paradigm shift in waste management discourse towards resource conservation lead to a higher focus on development projects containing waste recycling or reduction, with a parallel displacement of projects focusing on health issues and waste?

9 Conclusion Discourse Analysis

Much has been researched on environmental discourses and how the perceptions on the environment have been changed. Some of the resulting publications have been stated and cited in this work too. But unlike the most studies observed, which primarily focus on a general environmental discourse in developed countries, this work differs twice. First, the environmental discourse was narrowed on the issue of solid waste management. And second, the transmission of a discourse from a political and economical dominating to a subordinate *world* was investigated and discussed.

There is a general agreement that industrialized countries went through an environmental-political transition during the 1970s and 1980s. This can also be observed for waste management. Old problems have been left behind, mainly the negative impacts on health through lacking sanitation, but new have been created through the growing industrialization and consumption. Resources, instead of public health, have become the new challenge, and thus the new driving force in waste management. These new problems, which have not even become crucial at the time of recognizing them, have influenced the discourse on the environment and waste management too. One outcome of this new current in the discourse on waste management are strategies like the precautionary principle or the herein discussed waste hierarchy.

At the same time, a globalization, not only of commodity production chains, but also of ideas emerged. Globally defined concepts, like *sustainability*, were produced and reproduced, but also strategies which fits in this concepts. The waste hierarchy is one of them and has thus appeared in the discourse on waste management in developing countries, transferred by various national and international, governmental and non-governmental agents. In the developing countries itself, the discourse is shaped and ideas like the waste hierarchy are reproduced again, by scientists, experts, authorities, activists and so on. The paradox situation is that the social conditions which lead to the shift of discourse in developed countries, has not been achieved in developing countries. Health problems associated with lacking sanitation are still present. Now, the discourse on waste management in developing countries is still containing public health impacts of solid waste, but is increasingly influenced by conservation of depleting resources. Hajer (1995:67) would probably call this *superimposition* a 'discursive contamination'.

The reason for this discourse superimposition is the exogenous impact through the globalization of environmental discourse and the export of discourses from developed to developing countries.

Part IV - Conclusion

10 Conclusion

In Part II, the application of the waste hierarchy in lower income countries has been challenged by setting its recommendations into practise in municipal solid waste management. The result has shown that the options favoured by the waste hierarchy do not necessarily help to achieve the objectives of waste management and can carry unmanageable high financial burdens for municipalities and thus the society. The health and environmental benefit of options like waste incineration and to a lesser extend composting are small if compared to the costs that arise. On the other hand, an improved waste collection, which is not even mentioned in the waste hierarchy, would yield to the highest benefit in terms of public health.

But how come that the waste hierarchy is still suggested as a viable strategy for lower income countries, even if its applicability is limited and does not necessarily improve peoples living conditions? Part III aims to provide one answer to this question. In high income developed countries in Europe, waste management, same as environmental issues in general, have underwent a paradigm shift, a paradigm shift that can be sketched through the change in the patterns of the discourse on waste management. While earlier, roughly before the 1970s, waste management was primarily seen from the side of public health, the point of view changed. Increasing amounts of waste and depletion of natural resources on one hand and the steady improve of sanitation on the other have driven the waste management discourse towards conservation of resources.

However, the conditions which have led to the shift in the waste management discourse in developed countries are only partially fulfilled in developing lower income countries. There the sanitary situation, also because of improper solid waste management, is still worse than it has been in most European countries when the discourse shift happened there. For instance, communicable diseases, eradicated in Europe until the mid 20th century, are still present there.

The reason why the resource orientation have superimposed health issues in the waste management discourse in and for developing countries is simply that through a globalization of ideas and concepts a transmission of concepts like the waste hierarchy from the globally hegemonial high income countries to the peripherical lower income countries has occurred.

Now, one can claim that if developing countries do put regard on resources and long-term environmental issues, it would be to their own benefit. This can, of course, be true. But rather than totally denying the importance of resources, I claim that the actual resource orientation in the waste management discourse must not shift aside the public health orientation in the discourse. This claim comes from the fear that exactly this is what is partially happening.

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12 Annex

12.1 Questionnaires

12.1.1 Questionnaire Household survey

Nomor:	Organisasi: Universitas Syiah Kuala Fakultas Teknik - Jurusan Teknik Kimia		Tujuan : Manajemen Pengolahan Limbah Padat di Banda Aceh
Tanggal:	Nama desa:	Zona:	Nama pemeriksa:

Kuisioner / Lambar Pertanyaan

"Manajemen Pengolahan Limbah Padat di Banda Aceh"

Rumah Tangga

Universitas Syiah Kuala – Fakultas Teknik – Jurusan Teknik Kimia

1. Alamat anda ?

Jalan	Desa/Kelurahan	Kecamatan	Kabupaten/ Kota Madya

2. Berapa orang yang tinggal di rumah anda?

a) 2 b) 3 c) 4 d) 5 e) 6 f)__________

3. Berapa pendapatan rata-rata perbulan rumah tangga anda? (jumlah pendapatan semua anggota keluarga)

a) < 1.500.000 b) 1.500.000 – 3.000.000 c) 3.000.000 – 4.500.000

d) 4.500.000 – 6.000.000 e) > 6.000.000

4. Apa yang anda lakukan terhadap sampah yang dihasilkan dirumah ?

Sampah organic (sayuran, buah, sisa makanan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar d) Lainnya____

Sampah plastik (botol plastik, kertas plastik, botol aqua, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar d) Lainnya____

Sampah kertas dan karton (kertas, tisu, koran, karton, majalah, kertas bungkusan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar d) Lainnya____

Sampa lain (karet, lampu, sampah lainnya, metal, kaca, gelas, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar d) Lainnya____

5. Seberapa sering anda membeli makanan (nasi bungkus,mie bungkus....) diluar (warung, restoran...) dalam seminggu (bukan dalam bulan ramadhan)?

Angota Keluarga	1	2	3	4	5	6	7	8	9	10
Umur										
1 kali										
2 kali										
3 kali										
4 kali										
5 kali										
6 kali										
__ kali										

12.1.2 Questionnaire restaurant survey

Nomor:	Organisasi: Universitas Syiah Kuala Fakultas Teknik - Jurusan Teknik Kimia		Tujuan : Manajemen Pengolahan Limbah Padat di Banda Aceh
Tanggal:	Nama desa:	Zona:	Nama pemeriksa:

Kuisioner / Lambar Pertanyaan

"Manajemen Pengolahan Limbah Padat di Banda Aceh"

Restoran

Universitas Syiah Kuala – Fakultas Teknik – Jurusan Teknik Kimia

1. **Alamat restoran anda ?**

Jalan	Desa/Kelurahan	Kecamatan	Kabupaten/ Kota Madya

2. **Berapa luas restoran anda (m^2) ?**

a) < 20 m^2 b) 20 – 40 m^2 c) 40 – 60 m^2 d) 60 – 100 m^2 e) >100 m^2

3. **Berapa kapasitas/ jumlah orang yang dapat ditampung di restoran anda ?**

a) < 20 b) 20 - 40 c) 40 – 60 d) 60 - 80 e) > 80

4. **Apa yang anda lakukan terhadap sampah yang dihasilkan di restoran anda ?**

Sampah organic (sayuran, buah, sisa makanan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampah plastik (botol plastik, kertas plastik, botol aqua, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampah kertas dan karton (kertas, tisu, koran, karton, majalah, kertas bungkusan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampa lain (karet, lampu, sampah lainnya, metal, kaca, gelas, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

12.1.3 Questionnaire small enterprise survey

Nomor:	Organisasi: Universitas Syiah Kuala Fakultas Teknik - Jurusan Teknik Kimia		Tujuan : Manajemen Pengolahan Limbah Padat di Banda Aceh
Tanggal:	Nama desa:	Zona:	Nama pemeriksa:

Kuisioner / Lambar Pertanyaan

"Manajemen Pengolahan Limbah Padat di Banda Aceh"

Tempat usaha

Universitas Syiah Kuala – Fakultas Teknik – Jurusan Teknik Kimia

1. Alamat tempat usaha anda ?

Jalan	Dasa/Kelurahan	Kecamatan	Kabupaten/ Kota Madya

2. Jenis tempat usaha ?

a) Kelongtong b) Pelengkapan kantor dan sekolah c) Bahan makanan

d) Pakaian d) dan lain –lain ____

3. Luas tempat usaha anda (m^2) ...?

a) < 20 b) 20 – 40 c) 40 – 60 d) 60 – 80 d) > 80

4. Apa yang anda lakukan terhadap sampah yang dihasilkan di tempat usaha anda ?

Sampah organic (sayuran, buah, sisa makanan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampah plastik (botol plastik, kertas plastik, botol aqua, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampah kertas dan karton (kertas, tisu, koran, karton, majalah, kertas bungkusan, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

Sampa lain (karet, lampu, sampah lainnya, metal, kaca, gelas, ...)

a) Membuang ke tong (container) sampah (diambil oleh petugas dinas kebersihan DKP)
b) Membuang ke keranjang sampah (diambil oleh petugas dinas kebersihan DKP)
c) Membakar
d) Lainnya____

12.1.4 Questionnaire recycling agents

Nomor:	Organisasi: Universitas Syiah Kuala Fakultas Teknik Jurusan Teknik Kimia	Tujuan : Manajemen Pengolahan Limbah Padat di Banda Aceh
Tanggal:	Nama pemeriksa:	

Kuisioner / Lambar Pertanyaan

"Manajemen Pengolahan Limbah Padat di Banda Aceh"

Recycling Agent/ Buyer

Universitas Syiah Kuala – Fakultas Teknik – Jurusan Teknik Kimia

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1. **Nama anda?**

2. **Alamat tempat usaha anda ?**

Jalan, Nomor	Dasa/Kelurahan	Kecamatan	Telephone nomor

3. **Jenis barang apa yang anda beli atau tampung (karton, kertas, kaleng, botol plastik, ...)?**

4. **Berapa banyak barang yang anda peroleh perhari (kilogramm atau ton per hari) ?**

5. **Dari mana anda dapatkan barang – barang tersebut (permulung, agent lain, orang lain,....)?**

6. **Apakah anda tahu dimana agen lain di sekitar sini ?**

12.2 Vienna – balance sheet according to Closing of account 2005

Balance sheet, according to Closing of account 2005

Population 2006	1 651 437	inhabitants
Depreciation period	10	years

1. Including Street Cleaning

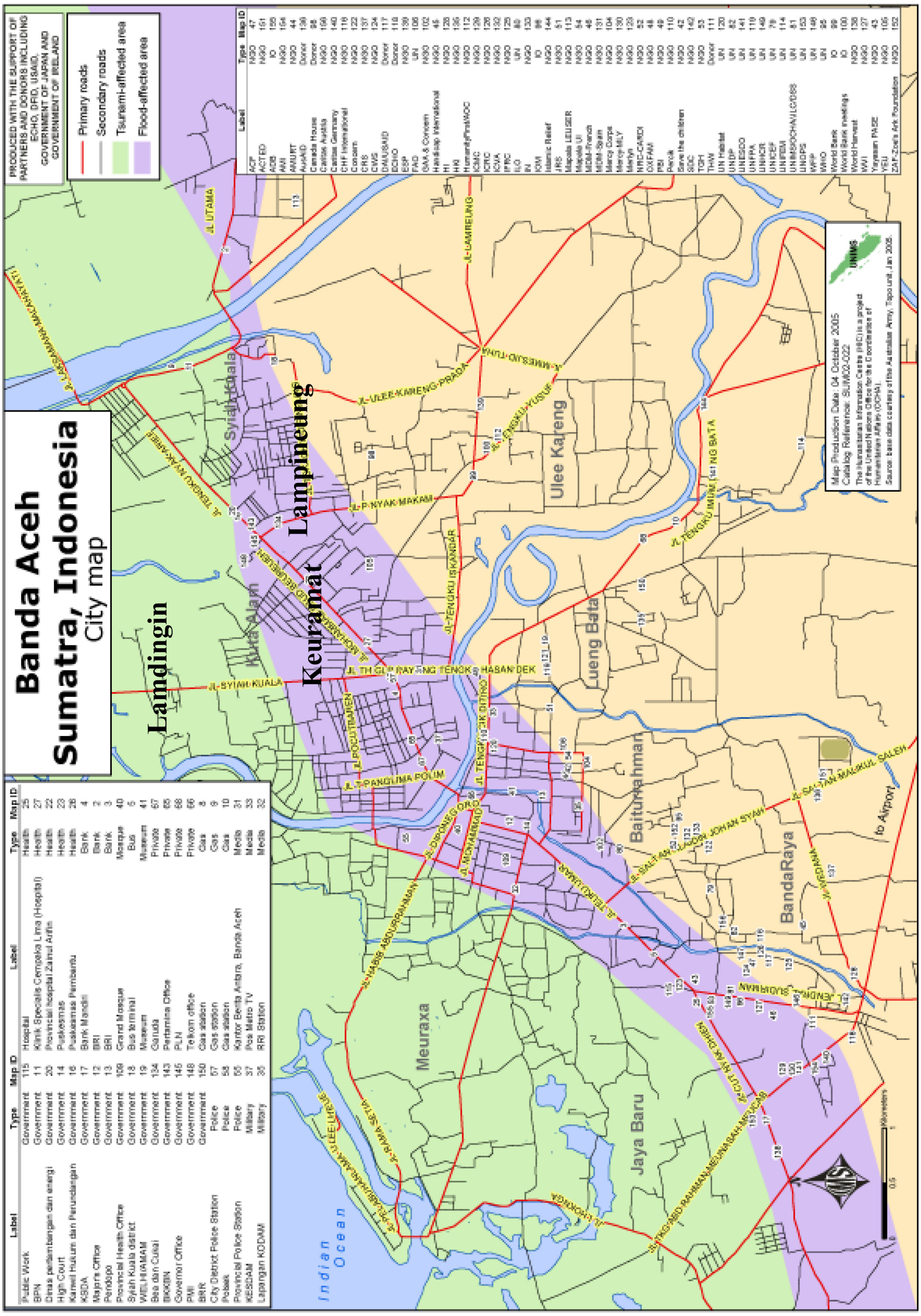
Budget Item	Category	Amount	Amount specific
		€	€/capita/year
8140	Street cleaning		
	Income	9 955 593	6.03
	Expenditures	87 797 356	53.16
8210	Fleet		
	Income	1 315 043	0.80
	Expenditures	2 200 973	1.33
8520	Waste (Collection and) Disposal		
	Income	220 535 286	133.54
	Expenditures	190 910 532	115.60
Total income		231 805 922	140.37
Total expenditures		280 908 861	170.10
Investments			
8140	Street cleaning		
	Expenditures	3 491 517	2.11
8210	Fleet		
	Expenditures	176 775	0.11
8520	Waste (Collection and) Disposal		
	Expenditures	12 989 410	7.87
Expenditures Investments		16 657 701	10.09
Expenditures without Investments		264 251 160	160.01
Expenditures including depreciated Investments		265 916 930	161.02
Expenditures for personnel		154 827 346	93.75
Expenditures for miscellaneous services		70 048 758	42.42

2. Without Street cleaning

Total income		221 850 330	134.34
Total expenditures		193 111 505	116.94
Investments			
8210	Fleet		
	Expenditures	176 775	0.11
8520	Waste (Collection and) Disposal		
	Expenditures	12 989 410	7.87
Expenditures Investments		13 166 185	7.97
Expenditures depreciated investments		1 316 618	1
Expenditures without Investments		179 945 320	108.96
Expenditures including depreciated Investments		181 261 939	110
Expenditures for personnel		91 123 409	55.18
Expenditures for miscellaneous services		58 442 659	35.39

12.3 Waste sampling

12.3.1 Selected areas for sampling



12.3.2 Results sampling households

Household Number	Capita per Household	Number of Samples	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste Generation Rate	Waste_Generation
			29.10.07	30.10.07	31.10.07	01.11.07	02.11.07	03.11.07	04.11.07	05.11.07	06.11.07	07.11.07	08.11.07	09.11.07	10.11.07	11.11.07	12.11.07	average	standard dev
			[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]
1	9	11			169	136	434	206	458	267	101	324	250			478	21	258	152
2	2	11			1.135	520	1.630	1.155	775		1.670	1.135	675	100		500	625	902	489
3	4	13			750	1.134	375	335	300	153	215	415	925	458	213	363	475	470	293
4	3	14		400	553	380	197	283	233	217	150	763	317	380	333	383	33	330	178
5	4	14		485	478	550	520	318	420	780	665	1.965	250	705	163	563	288	582	436
6	8	13			130	139	109	149	266	165	124	96	294	163	88	125	219	159	64
7	7	13			284	63	33	354	393	400	334	91	150	139	407	114	236	231	139
8	6	13		163	257	65		267	63	242	132	212	150	68	258	192	333	185	87
9	7	14		736	27	260	274	424	377	420	450	439	329	400	264	307	207	351	159
10	3	14		720	440	337	173	557	557	977	430	373	583	413	1.267	1.767	1.617	729	493
11	7	12		286	46	181	201	136	140	144	116	70	429		414		236	200	123
12	8	14		271	85	110	299	265	223	173	219	154	200	281	150	250	144	202	67
13	8	13			330	459	206	293	369	363	515	340	331	608	350	513	388	389	107
14	2	12	625	125		785		555	910	335	1.525	175	250	260	775		925	604	409
15	3	14	650	273	517	63	610	387	603	667	280	810	267	467		467	967	502	240
16	5	7		264			1.374	188	504	246		306		1.410				613	541
17	8	13	409	119	389	208		251	241	553		606	381	290	1.213	469	281	416	277
18	7	15	174	240	244	70	127	293	507	559	109	300	257	506	250	550	150	289	165
19	4	14		125	150	518	568	1.043	2.005	613	193	165	888	225	300	250	293	524	512
20	9	15	137	250	149	61	237	522	164	361	251	436	372	353	193	428	163	272	133
21	10	13	94	45		141	37	75	18	38	52	32		153	35	110	102	72	44
22	5	12	182	12	44	64	66	88	60	94	138		220	30			532	128	141
23	13	13		41	95	115	254	243	212	239	171	86	115	88	112		173	150	70
24	5	10	182	50	38		280	206	260	274			460	256			180	219	121
25	6	10	95	210	297			348		118	193		725	165	58	250		246	191
26	7	13	211	249			310	150	257	553	261	183	314	169	93	86	79	224	127
27	?																		
28	6	14		775	1.268	810	1.062	702	1.038	933	1.067	1.607	1.433	1.038	367	517	1.183	986	338
29	8	14	258	195	321	290	184	291	174	338	388	156	356	164	213		178	250	80
30	10	14	406	363	144	220	332	228	225	205	252	211	490	327	155		885	317	191
31	3	13	107		483	187	583	403	367	127	600	70	250	167	183		537	313	191
32	6	15	220	132	88	492	350	275	927	328	655	285	450	367	308	442	357	378	207
33	7	15	390	81	110	167	191	127	371	71	154	101	257	244	100	279	86	182	104
34	6	15	308	52	327	52	412	625	500	175	268	432	175	107	108	217	177	262	170
35	7	14	569		709	247	176	369	634	550	420	466	429	314	350	564	249	432	159
36	3	10		1.090		480	167		1.133	667	867	413	383	313			1.000	651	350
37	7	15	43	49	24	49	126	33	36	37	87	104	57	10	29	100	89	58	34
38	4	15	278	110	213	118	288	333	218	128	185	13	525	398	213	225	225	231	125
39	5	12	412	34		20	116	192	70	218		36	80	18	40	90		111	115
40	4	14	168	270	250	105	88	323	415	263	213	178	250		138	275	125	218	92
41	5	12	114	346	124	154	214	218	630	410	412	224	560			900		359	239
42	5	15	222	68	94	66	48	226	220	28	14	128	220	50	80	260	92	121	84
43	4	15	445	100	328	305	183	370	403	148	105	450	700	313	150	325	313	309	160
44	5	15	452	62	230	158	558	302	398	312	296	394	400	24	310	330	274	300	141
45	7	15	120	37	37	59	144	111	101	134	60	91	79	111	29	43	164	88	43
46	4	14	148	163	30	100	148	143	348	138	145	98	163	110	63	75		133	74
47	3	11	217	1.773	223		347	450		387	257	327	200			283	110	416	460
48	4	14	343	108	333	368	138	170	238	60	113	173	288		150	125	200	200	98
49	5	14	1.152	204	68	50	140	42	108	84	130	200	180	172	90	1.130		268	374
50	5	15	368	366	104	258	98	334	432	226	930	822	130	512	40	50	146	321	268
Mean value per day		**13,27**	**306**	**279**	**282**	**253**	**320**	**320**	**411**	**311**	**354**	**358**	**366**	**299**	**251**	**369**	**350**	**322**	**46**
Standarddeviation per day		**1,71**	**225**	**333**	**275**	**238**	**323**	**220**	**352**	**230**	**361**	**389**	**256**	**268**	**272**	**323**	**344**		
Samples total		**650**																	

12.3.3 Results sampling households – only waste fractions

Household number	Capita per Household	Income Group	Samples	Organic waste	Platics	Paper and Cardboard	Metall	Glass	Mixed waste	Waste total calculated	Organic waste	Platics	Paper and Cardboard	Metall	Glass	Mixed waste	Waste total calculated
				[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]	[g/c.d]
1	9	3	7	11.280	810	500	400	1.180	2.480	16.650	179	13	8	6	19	39	264
2	2	2	8	13.860	1.300	550	30		2.130	17.870	866	81	34	2		133	1.117
3	4	2	8	13.890	480	65	160	310	330	15.235	434	15	2	5	10	10	476
4	3	2	9	8.590	830	680	220	1.370	10	11.700	318	31	25	8	51	0	433
5	4	3	9	19.830	1.410	1.400			260	22.900	551	39	39			7	636
6	8	1	8	4.750	800	1.610	350	230	1.330	9.070	74	13	25	5	4	21	142
7	7	2	8	8.090	1.020	580		330	1.260	11.280	144	18	10		6	23	201
8	6	2	8	6.280	770	1.430	130	520	620	9.750	131	16	30	3	11	13	203
9	7	3	9	17.980	1.910	550	100	300	1.310	22.150	285	30	9	2	5	21	352
10	3	3	9	9.400	920	250	50	30	110	10.760	348	34	9	2	1	4	399
11	7	4	8	7.620	470	1.080	50	90	1.170	10.480	136	8	19	1	2	21	187
12	8	2	9	12.510	1.220	1.760	510	770	1.090	17.860	174	17	24	7	11	15	248
13	8	5	8	8.920	1.780	1.950	130	630	7.200	20.610	139	28	30	2	10	113	322
14	2	2	8	8.880	970	670			280	10.800	555	61	42			18	675
15	3	2	10	14.320	1.880	1.690		630	1.110	19.630	477	63	56		21	37	654
16	5	2	6	10.840	1.110	850		40	2.660	15.500	361	37	28		1	89	517
17	8	5	8	9.900	1.870	1.450	50	820	7.230	21.320	155	29	23	1	13	113	333
18	7	3	10	10.250	1.660	1.120	50		2.270	15.350	146	24	16	1		32	219
19	4	1	9	16.490	2.700	630	1.150	50	1.220	22.240	458	75	18	32	1	34	618
20	9	2	10	15.960	1.210	1.120	60	260	2.780	21.390	177	13	12	1	3	31	238
21	10	2	9	2.830	730	1.070	110		350	5.090	31	8	12	1		4	57
22	5	2	9	2.200	670	320			1.220	4.410	49	15	7			27	98
23	13	1	9	9.540	1.010	780	250	600	4.930	17.110	82	9	7	2	5	42	146
24	5	1	7	3.870	940	260	710		290	6.070	111	27	7	20		8	173
25	6	5	6	5.560	390	540	180	780	590	8.040	154	11	15	5	22	16	223
26	7	2	8	9.240	1.550	830	300	810	1.660	14.390	165	28	15	5	14	30	257
27																	
28	6	1	9	40.970	3.810	2.730	100	800	2.870	51.280	759	71	51	2	15	53	950
29	8	1	10	17.200	1.740	600	50	260	1.470	21.320	215	22	8	1	3	18	267
30	10	2	10	19.710	1.880	1.290	10	120	1.300	24.310	197	19	13	0	1	13	243
31	3	2	9	7.810	860	470	150		1.310	10.600	289	32	17	6		49	393
32	6	2	10	20.000	1.160	230	10		850	22.250	333	19	4	0		14	371
33	7	2	10	8.140	710	770		540	2.340	12.500	116	10	11		8	33	179
34	6	2	10	14.860	910	510	100		3.670	20.050	248	15	9	2		61	334
35	7	1	9	18.520	1.340	1.430	230	270	4.270	26.060	294	21	23	4	4	68	414
36	3	1	7	10.880	280	260			1.100	12.520	518	13	12			52	596
37	7	1	10	4.760	440	200			40	5.440	68	6	3			1	78
38	4	1	10	6.300	390	70		110	230	7.100	158	10	2		3	6	178
39	5	1	8	2.470	420	220	10		1.280	4.400	62	11	6	0		32	110
40	4	2	9	4.740	2.150	60	40	300	740	8.030	132	60	2	1	8	21	223
41	5	1	9	5.040	690	350	70	590	5.690	12.430	112	15	8	2	13	126	276
42	5	1	10	4.700	940	550	60		430	6.680	94	19	11	1		9	134
43	4	1	10	1.540	630	110	100	250	8.240	10.870	39	16	3	3	6	206	272
44	5	1	10	8.510	760	1.090	40	660	3.970	15.030	170	15	22	1	13	79	301
45	7	1	10	3.790	880	410			690	5.770	54	13	6			10	82
46	4	1	10	2.730	1.220	270	40		1.020	5.280	68	31	7	1		26	132
47	3	1	7	7.090	750	400	50	200	2.290	10.780	338	36	19	2	10	109	513
48	4	2	9	4.440	1.020	990	220	440	1.670	8.780	123	28	28	6	12	46	244
49	5	1	10	9.410	1.430	1.170		250	770	13.030	188	29	23		5	15	261
50	5	1	10	11.080	1.440	940	10	300	4.790	18.560	222	29	19	0	6	96	371
Average per Household			**8,84**	**10.154**	**1.148**	**793**	**170**	**450**	**1.978**	**14.505**	**235**	**26**	**17**	**4**	**10**	**42**	**329**
Total			**433**	**497.570**	**56.260**	**38.855**	**6.280**	**14.840**	**96.920**	**710.725**							
Average Percentage				**70%**	**8%**	**5%**	**1%**	**3%**	**14%**	**100%**	**71%**	**8%**	**5%**	**1%**	**3%**	**13%**	**100,0%**
Standard deviations											**4,0%**	**1,4%**	**1,3%**	**0,3%**	**1,2%**	**3,1%**	

12.3.4 Results sampling other establishments than households, expressed in different units

Results sampling other establishments than households - Waste total, all samples:

In gram per day [g/d]

No.	Classification	Name	Name abbreviated	No. Samples	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total
					06.11.07	07.11.07	08.11.07	09.11.07	10.11.07	11.11.07	12.11.07	13.11.07	14.11.07	15.11.07	16.11.07	17.11.07	18.11.07	19.11.07	20.11.07	21.11.07	22.11.07	Mean value	SD	SD
					[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	%
1	K1 - Office	Dinas Pendidikan	DP	7	2.740			8.450			4.400	2.240	2.650	2.650	2.300							3.633	2.245	62%
2	K2 - Office	Dinas Pertanian - Tanaman Pangan dan Holtikultura	DP - TPH	10	16.000	3.650	15.050	15.550	16.250		5.960	4.730	21.080	4.800	5.130							10.820	6.520	60%
3	K3 - Office	Dinas Permuda dan Olahraga	DPO	7		11.370	10.750	3.250				6.150	1.110	1.400	400							4.919	4.605	94%
4	R1 - Coffeehouse	Warung Kopi 1	WK1	8	4.660	3.800		3.100		2.950	4.060	3.550		3.700		2.250						3.509	738	21%
5	R2 - Coffeehouse	Warung Kopi 2	WK2	8		650	1.200			2.000		1.700	1.650	1.800	1.800	2.000						1.600	459	29%
6	SD - School	Sekolah Dasar	SD	9			5.800	7.800	5.200		6.090	5.400	4.750	7.500	7.400	5.950						6.210	1.099	18%
7	SMP - School	Sekolah Menengah Pertama	SMP	10			23.450	20.950	13.000		10.450	14.140	17.180	17.400	15.550	10.750	7.100					14.997	4.984	33%
8	SMA - School	Sekolah Menegah Atas	SMA	4											23.400	41.900	35.050	40.200				35.138	8.349	24%
9	T1 - Grocery Store	Kelongtong	K	6		670		800	2.800	1.150				710		1.850						1.330	844	63%
10	T3 - Restaurant	Warung Nasi	WN	8		4.300	5.000	4.540		5.850		3.700	5.400		5.200	4.100						4.761	724	15%
11	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 1	5								1.000	1.900	1.150	1.300	1.950						1.460	438	30%
12	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 2	5								700	800	850	600	5.600						1.710	2.177	127%
13	Building shop	Toko Bangunan	TB	2																3.100	8.750	5.925	3.995	67%
Total				89																		96.011		

In kilogram per day [kg/d]

No.	Classification	Name	Name abbreviated	No. Samples	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total
					06.11.07	07.11.07	08.11.07	09.11.07	10.11.07	11.11.07	12.11.07	13.11.07	14.11.07	15.11.07	16.11.07	17.11.07	18.11.07	19.11.07	20.11.07	21.11.07	22.11.07	Mean value	SD	SD
					[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	[kg/d]	%
1	K1 - Office	Dinas Pendidikan	DP	7	2,7			8,5			4,4	2,2	2,7	2,7	2,3							3,6	2,2	62%
2	K2 - Office	Dinas Pertanian - Tanaman Pangan dan Holtikultura	DP - TPH	10	16,0	3,7	15,1	15,6	16,3		6,0	4,7	21,1	4,8	5,1							10,8	6,5	60%
3	K3 - Office	Dinas Permuda dan Olahraga	DPO	7		11,4	10,8	3,3				6,2	1,1	1,4	0,4							4,9	4,6	94%
4	R1 - Coffeehouse	Warung Kopi 1	WK1	8	4,7	3,8		3,1		3,0	4,1	3,6		3,7		2,3						3,5	0,7	21%
5	R2 - Coffeehouse	Warung Kopi 2	WK2	8		0,7	1,2			2,0		1,7	1,7	1,8	1,8	2,0						1,6	0,5	29%
6	SD - School	Sekolah Dasar	SD	9			5,8	7,8	5,2		6,1	5,4	4,8	7,5	7,4	6,0						6,2	1,1	18%
7	SMP - School	Sekolah Menengah Pertama	SMP	10			23,5	21,0	13,0		10,5	14,1	17,2	17,4	15,6	10,8	7,1					15,0	5,0	33%
8	SMA - School	Sekolah Menegah Atas	SMA	4											23,4	41,9	35,1	40,2				35,1	8,3	24%
9	T1 - Grocery Store	Kelongtong	K	6		0,7		0,8	2,8	1,2				0,7		1,9						1,3	0,8	63%
10	T3 - Restaurant	Warung Nasi	WN	8		4,3	5,0	4,5		5,9		3,7	5,4		5,2	4,1						4,8	0,7	15%
11	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 1	5								1,0	1,9	1,2	1,3	2,0						1,5	0,4	30%
12	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 2	5								0,7	0,8	0,9	0,6	5,6						1,7	2,2	127%
13	Building shop	Toko Bangunan	TB	2																3,1	8,8	5,9	4,0	67%
Total				89																		96,0		

Results sampling other establishments than households - Waste total, all samples, in reference units:

In gram per reference unit and day

No.	Classification in sampling	Name abbreviated	No. Samples total	Reference unit	Number of reference units	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total	Waste total
						06.11.07	07.11.07	08.11.07	09.11.07	10.11.07	11.11.07	12.11.07	13.11.07	14.11.07	15.11.07	16.11.07	17.11.07	18.11.07	19.11.07	20.11.07	21.11.07	22.11.07	Mean value	SD	SD
						[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/ru.d]	[g/d]	%
1	K1 - Office	DP	7	Employee	160	17			53			28	14	17	17	14							23	14	62%
2	K2 - Office	DP - TPH	10	Employee	76	211	48	198	205	214		78	62	277	63	68							142	86	60%
3	K3 - Office	DPO	7	Employee	106		107	101	31				58	10	13	4							46	43	94%
4	R1 - Coffeehouse	WK1	8	Establishment	1	4.660	3.800		3.100		2.950	4.060	3.550		3.700		2.250						3.509	738	21%
5	R2 - Coffeehouse	WK2	10	Establishment	1		650	1.200			2.000		1.700	1.650	1.800	1.800	2.000						1.600	459	29%
6	SD - School	SD	9	Student	80			73	98	65		76	68	59	94	93	74						78	14	18%
7	SMP - School	SMP	10	Student	338			69	62	38		31	42	51	51	46	32	21					44	15	33%
8	SMA - School	SMA	4	Student	808											29	52	43	50				43	10	24%
9	T1 - Grocery Store	K	6	Establishment	1		670		800	2.800	1.150				710		1.850						1.330	844	63%
10	T3 - Restaurant	WN	8	Establishment	1		4.300	5.000	4.540		5.850		3.700	5.400		5.200	4.100						4.761	724	15%
11	Copyshop	PKS 1	5	Establishment	1								1.000	1.900	1.150	1.300	1.950						1.460	438	30%
12	Copyshop	PKS 2	5	Establishment	1								700	800	850	600	5.600						1.710	2.177	127%
13	Building shop	TB	2	Establishment	1																3.100	8.750	5.925	3.995	67%
	Total		91																						

12.3.5 Results sampling other establishments than households – only fractions

Results sampling other establishments than households - Waste fractions

No.	Classification	Name	Name abbreviated	No. Samples	Organic waste	Plastik	Paper and Cardboard	Metall	Glass	Mixed waste	Waste fractions sum up	Waste fractions sum up	Organic waste	Plastic	Paper and Cardboard	Metall	Glass	Mixed waste	Organic waste	Plastic	Paper and Cardboard	Metall	Glass	Mixed waste
					[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	[g/d]	%	%	%	%	%	%
1	K1 - Office	Dinas Pendidikan	DP	6	2.580	4.430	12.300	-	-	3.470	22.780	3.797	430	738	2.050	-	-	578	11%	19%	54%	0%	0%	15%
2	K2 - Office	Dinas Pertanian - Tanaman Pangan dan	DP - TPH	7	10.050	9.790	28.480	-	-	7.500	55.820	7.974	1.436	1.399	4.069	-	-	1.071	18%	18%	51%	0%	0%	13%
3	K3 - Office	Dinas Permuda dan Olahraga	DPO	5	7.750	2.320	11.900	-	-	600	22.570	4.514	1.550	464	2.380	-	-	120	34%	10%	53%	0%	0%	3%
4	R1 - Coffeehouse	Warung Kopi 1	WK1	6	15.900	1.800	2.750	320	150	1.950	22.870	3.812	2.650	300	458	53	25	325	70%	8%	12%	1%	1%	9%
5	R2 - Coffeehouse	Warung Kopi 2	WK2	1	1.500	150	150	-	-	-	1.800	1.800	1.500	150	150	-	-		83%	8%	8%	0%	0%	0%
6	SD - School	Sekolah Dasar	SD	3	2.340	3.650	9.800	-	-	4.050	19.840	6.613	780	1.217	3.267	-	-	1.350	12%	18%	49%	0%	0%	20%
7	SMP - School	Sekolah Menengah Pertama	SMP	6	10.490	36.950	33.300	-	-	8.500	89.240	14.873	1.748	6.158	5.550	-	-	1.417	12%	41%	37%	0%	0%	10%
8	SMA - School	Sekolah Menegah Atas	SMA	3	26.850	47.600	19.050	-	350	11.650	105.500	35.167	8.950	15.867	6.350	-	117	3.883	25%	45%	18%	0%	0%	11%
9	T1 - Grocery Store	Kelongtong	K	4	1.270	710	2.050	-	-	-	4.030	1.008	318	178	513	-	-	-	32%	18%	51%	0%	0%	0%
10	T3 - Restaurant	Warung Nasi	WN	8	38.090	-	-	-	-	-	38.090	4.761	4.761	-	-	-	-	-	100%	0%	0%	0%	0%	0%
11	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 1	5	-	-	7.300	-	-	-	7.300	1.460	-	-	1.460	-	-	-	0%	0%	100%	0%	0%	0%
12	Copyshop	Pelengkapan Kantor dan Sekolah	PKS 2	5	400	-	8.150	-	-	-	8.550	1.710	80	-	1.630	-	-	-	5%	0%	95%	0%	0%	0%
13	Building shop	Toko Bangunan	TB	2	300	300	11.250	-	-	-	11.850	5.925	150	150	5.625	-	-	-	3%	3%	95%	0%	0%	0%
Total				61	117.520	107.700	146.480	320	500	37.720	410.240	93.414	24.353	26.620	33.501	53	142	8.745	31%	15%	48%	0%	0%	6%

Results sampling other establishments than households - Waste fractions, classified

No.	Classification	Name	Name abbreviated	Reference unit	Number of reference units	No. Samples Fractions	Organic waste	Plastic	Paper and Cardboard	Metall	Glass	Mixed waste	Organic waste	Plastic	Paper and Cardboard	Metall	Glass	Mixed waste
							[g/unit.d]	[g/unit.d]	[g/unit.d]	[g/unit.d]	[g/unit.d]	[g/unit.d]	%	%	%	%	%	%
1	K1 - Office	Dinas Pendidikan	DP	Employee	160	6	3	5	13	-	-	4	11%	19%	54%	0%	0%	15%
2	K2 - Office	Dinas Pertanian - Tanaman	DP - TPH	Employee	76	7	19	18	54	-	-	14	18%	18%	51%	0%	0%	13%
3	K3 - Office	Dinas Permuda dan	DPO	Employee	106	5	15	4	22	-	-	1	34%	10%	53%	0%	0%	3%
Mean value offices							12	9	30	-	-	6	21%	16%	53%	0%	0%	10%
4	R1 - Coffeehouse	Warung Kopi 1	WK1	Establishment	1	6	2.650	300	458	53	25	325	70%	8%	12%	1%	1%	9%
5	R2 - Coffeehouse	Warung Kopi 2	WK2	Establishment	1	1	1.500	150	150	-	-	-	83%	8%	8%	0%	0%	0%
10	T3 - Restaurant	Warung Nasi	WN	Establishment	1	8	4.761	-	-	-	-	-	100%	0%	0%	0%	0%	0%
Mean value gastronomy establishments							2.970	150	203	18	8	108	84%	5%	7%	0%	0%	3%
6	SD - School	Sekolah Dasar	SD	Student	80	3	10	15	41	-	-	17	12%	18%	49%	0%	0%	20%
7	SMP - School	Sekolah Menengah Pertama	SMP	Student	338	6	5	18	16	-	-	4	12%	41%	37%	0%	0%	10%
8	SMA - School	Sekolah Menegah Atas	SMA	Student	808	3	11	20	8	-	0	5	25%	45%	18%	0%	0%	11%
Mean value schools							9	18	22	-	0	9	16%	35%	35%	0%	0%	14%
9	T1 - Grocery Store	Kelongtong	K	Establishment	1	4	318	178	513	-	-	-	32%	18%	51%	0%	0%	0%
11	Copyshop	Pelengkapan Kantor dan	PKS 1	Establishment	1	5	-	-	1.460	-	-	-	0%	0%	100%	0%	0%	0%
12	Copyshop	Pelengkapan Kantor dan	PKS 2	Establishment	1	5	80	-	1.630	-	-	-	5%	0%	95%	0%	0%	0%
13	Building shop	Toko Bangunan	TB	Establishment	1	2	150	150	5.625	-	-	-	3%	3%	95%	0%	0%	0%
Mean value enterprises							77	50	2.905	-	-	-	10%	5%	85%	0%	0%	0%

12.4 Results recycling survey

12.4.1 Results

Material group by source		Agent Lamdingin	Agent Keuramat	Agent Gampung Mulia	Mean value	Share of each fraction
	Material Group / Unit	in kilogram per day				in percent
		[kg/day]	[kg/day]	[kg/day]	[kg/day]	%
Materials from MSW	Paper and Cardboard	497	0	387	295	41%
	Plastics	90	55	17	54	8%
	Metall (MSW)	13	9	4	9	1%
	Glass bottles	40	24	28	31	4%
Materials not from MSW	Metall (non-MSW)	666	155	140	321	45%
	Batteries	8	9	0	6	1%
Total	Total	1314.33	252.28	575.96	714	100%

Material group by source	in kilogram per day	In Percent
	[kg/day]	%
Materials from MSW	388	54%
Materials not from MSW	326	46%
Total	714	100%

12.4.2 Calculation of material flux „export recyclables“ (R4)

Inhabitants Banda Aceh 2007	219 657	
1 [kilogram]	0.001	[tons]
1 [kilogram]	1000	[gram]
Days per year	364	
Uncertainty	25%	assumption

Material Group	Agent Lamdingin	Agent Keuramat	Agent Gampung Mulia	Recycling material per buyer	Recycling material per buyer	Number of buyers	Recycling material total	Un-certainty	Recycling material total	Uncertainty
	in kilogram per day			mean value	in percent	Assumption	in kilogram per day		in kilogram per capita and year	
	kg/day	kg/day	kg/day	kg/day	%		[kg/d]	[kg/d]	[kg/(c.yr)]	[kg/(c.yr)]
Paper and Cardboard	497	0	387	295	76%	35	10 309	2 577	17	4
Plastics	90	55	17	54	14%	35	1 901	475	3	1
Metall, MSW	13	9	4	9	2%	35	298	75	0	0
Glass bottles	40	24	28	31	8%	35	1 074	269	2	0
Total	640	88	436	388	100%	35	13 583	3 396	23	6

12.5 Calculation of material fluxes

12.5.1 Estimation for share of scavengers on collecting recyclables

Descripiton	*Data*	*Source*
Number of scavengers:	40	DKP 2007
Daily income per scavenger:	30.000 – 100.000 IR	Field visit Gampung Jawa 2
Price for 1 [kg] of Cardboard:	400 [IR/kg]	DKP et al. 2007:40
Price for 1 [kg] of Plastics:	1.600 [IR/kg]	DKP et al. 2007:40
Price for 1 [kg] of Aluminium can:	10.000 [IR/kg]	DKP et al. 2007:40
Share of Cardboard collected:	60 %	Assumption, based on data from Recycling survey
Share of Plastics collected:	35 %	Assumption, based on data from Recycling survey
Share of Aluminium collected:	5 %	Assumption, based on data from Recycling survey
Collected Recyclables total:	13.580 [kg/day]	See chapter 12.4, page 219
Uncertainty:	30 %	

Calculations:

Estimated average daily income: = (30.000 + 100.000) / 2 = 65.000 [IR]

Recyclables per scavenger and day: m = 65.000/(0,6*400+0,35*1600+0,05*10.000) = 50 [kg/person/d]

Recyclable material total per day: m total = 50*40 = 2.000 [kg/d]

Recyclable material in kg/capita/year: <u>m total = 2000*364/219.657 = 3,3 kg/capita/year</u>

Uncertainty: <u>dm = 3,3*0,3 = 1,0 [kg/(c.yr)</u>

As share of total <u>m% = (2000/13.580)*100 = 15 %</u>

12.5.2 Estimation for share of waste workers on collecting recyclables

Same values as for scavengers:

Recyclable material in kg/capita/year: m total = 2000*364/219.657 = 3,3 [kg/(c.yr)]

As share of total m% = (2000 / 13.580) * 100 = 15 %

12.5.3 Calculation input landfill Gampung Jawa

Inhabitants Banda Aceh 2007		219 657	
1 kg		0.001	tons
Days per year		365	
Filling degree correction factor:	cfV =	80%	
Mean value density:	ρ =	300	kg/m3
Standard deviation filling degree:	dV =	10%	
Standard deviation density:	dρ =	50	kg/m3

Month	Reported Volume	Mass mean value	Standard deviation volume	Standard deviation mass calculated	Mass mean value	Standard deviation mass
	V	M=ρ*V*cfV	dV	dM = √(V²*dρ² + dV²*ρ²)		
	m3/day	kg/day	m³	kg/day	[kg/(c.yr)]	[kg/(c.yr)]
07 - 2006	368	88 200	37	21 429	147	36
08 - 2006	571	137 088	57	33 306	228	55
09 - 2006	563	135 000	56	32 799	224	55
10 - 2006	541	129 840	54	31 545	216	52
11 - 2006	448	107 568	45	26 134	179	43
12 - 2006	406	97 488	41	23 685	162	39
01 - 2007	451	108 216	45	26 292	180	44
02 - 2007	537	128 928	54	31 324	214	52
04 - 2007	502	120 360	50	29 242	200	49
05 - 2007	488	117 000	49	28 426	194	47
06 - 2007	407	97 584	41	23 709	162	39
Mean value	480	115 207	48	27 990	191	47

12.5.4 Calculation import into the MSWM system from households

Inhabitants Banda Aceh 2007	219 657	
1 kilogram =	1 000	gram
1 kilogram =	0.001	ton
1 year =	365	days
Insert value: Import waste from households =	117	[kg/(c.yr)]

Flux		Share of each flux of Import total	Waste total	Waste total
No.	Description		[kg/(c.yr)]	[t/yr]
	Import waste from households	100%	117	25 728
WH1	Collection waste household	65%	76	16 595
WH2	Burning waste household	30%	35	7 718
WH3	Uncontrolled disposal waste	6%	6	1 415

12.5.5 Calculation import into the MSWM system from other sources

Inhabitants Banda Aceh 2007	219 657	
1 kilogram =	1 000	gram
1 kilogram =	0.001	ton
1 year =	365	days
Insert value: WO1 - Collection waste other sources =	119	[kg/(c.yr)]

Flux		Share of each flux of Import total	Waste total	Waste total
No.	Description		[kg/(c.yr)]	[t/yr]
	Import waste other sources total	100.0%	140	30 752
WO1	Import formal collection waste other sources	85.0%	119	26 139
WO2	Import burning waste other sources	10.0%	14	3 075
WO3	Import uncontrolled disposal waste other sources	5.0%	7	1 538

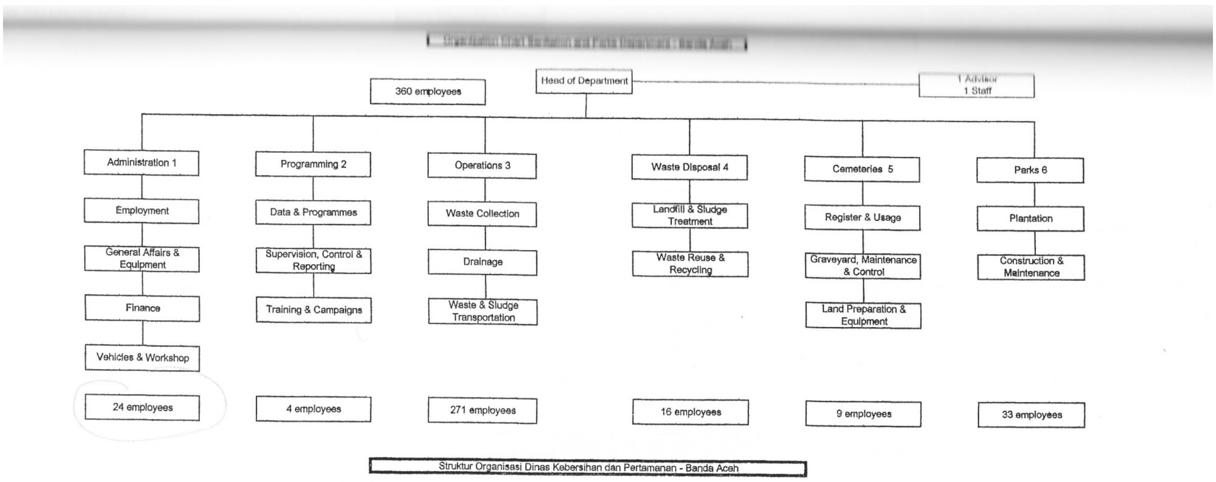
12.6 Estimation of MSWM costs in Banda Aceh

12.6.1 Break down of the budget of DKP 2007

BREAK-DOWN OF THE 2007 BUDGET OF DKP

1.08.04	Salary and allowance for civil servants	1.192.567.183	8.58 %
1.08.04.01.01	Public utilities (telephone, water, electricity)	62.400.000	0.45 %
1.08.04.01.10	Office goods (paper, writing requirement)	6.488.050	0.05 %
1.08.04.01.11	Office goods (printing, copying)	16.788.800	0.12 %
1.08.04.01.12	Office goods (electric facility)	4.202.400	0.03 %
1.08.04.01.13	Office goods (tools an desk goods)	137.108.450	0.98 %
1.08.04.01.15	Subscriptions	1.440.000	0.01 %
1.08.04.01.17	Snacks, coffee, tea, etc	301.440.000	2.16 %
1.08.04.01.18	Travelling expense & accommodation	30.000.000	0.22 %
1.08.04.01.19	Salary for worker & insurance	6.836.695.000	49.07 %
1.08.04.02.10	Office tables & chairs	74.420.000	0.53 %
1.08.04.02.24	Maintenance of equipments (spare parts) and fuel	1.836.294.750	13.18 %
1.08.04.02.28	Office building maintenance	4.100.000	0.03 %
1.08.04.03.01	Presence registration machine	40.000.000	0.29 %
1.08.04.03.02	Uniform for civil servants	11.700.000	0.08 %
1.08.04.03.03	Working cloths for worker	103.950.000	0.75 %
1.08.04.05.03	Training and technical assistance	8.000.000	0.06 %
1.08.04.15.02	Office building construction & handcart		
	Motorcycles procurement	896.404.500	6.43 %
1.08.04.15.04	Procurement/construction in landfill	494.708.000	3.55 %
1.08.04.15.07	Co-finance project budget and billboard	592.125.500	4.25 %
1.08.04.15.13	Pilot project Gampong Bersih	371.135.000	2.66 %
1.08.04.15.14	Sediment clearance and special waste collection	493.406.800	3.54 %
1.08.04.24.05	Parks maintenance	418.552.500	3.00 %
	Total	13.933.926.933	100.00 %

12.6.2 Organisational structure DKP



12.6.3 Calculation of employment structure

Employment structure of DKP, based on the Waste Management Master Plan 2007, ANNEX 9.1 - 9.8

Employment structure DKP total

Sub-department	Ad-ministration	Program-ming	Operations	Waste Disposal	Cementeries	Parks	Total	According to DKP
Source	DKP et al. (2007: Annex 9.2)	DKP et al. (2007: Annex 9.3)	DKP et al. (2007: Annex 9.4)	DKP et al. (2007: Annex 9.6)	DKP et al. (2007: Annex 9.1)	DKP et al. (2007: Annex 9.8)	Calculation	Interview DKP 2007
Employees total	0	0	263	13	8	30	314	343
Employees MSWM	0	0	204	11	0	0	215	235
Employees MSWM [%]	0%	0%	77%	85%	0%	0%	68%	69%
Civil Servants total	24	4	8	4		2	42	42
Civil Servants MSWM	*15*	*3*	6	3	0	0	27	
Civil Servants MSWM [%]	63%	75%	75%	75%	0%	0%	64%	

Employment structure of Municipal Solid Waste Management

Employees MSWM	0	0	204	11	0	0	215	235
Employees Collection	0	0	204	0	0	0	204	
Employees Disposal	0	0	0	11	0	0	11	
Employees Collection [%]	0%	0%	100%	0%	0%	0%	95%	
Employees Disposal [%]	0%	0%	0%	100%	0%	0%	5%	
Civil Servants MSWM	15	3	6	3	0	0	27	42
Civil Servants Collection	*12*	*2*	6	0	0	0	20	
Civil Servants Disposal	*3*	*1*	0	3	0	0	7	
Civil Servants Collection [%]	80%	67%	100%	0%	0%	0%	74%	
Civil Servants Disposal [%]	20%	33%	0%	100%	0%	0%	26%	

Note: Italic numbers represent assumed figures!

12.6.4 Cost and organisational data from the waste management master plan of Banda Aceh

Cost structure according to DKP - Waste Management Master Plan 2007, Annex 19

Number		Costs total	Share MSWM		Source	Share MSW Collection		Share MSW Disposal	
		IDR	[%]	IDR		[%]	IDR	[%]	IDR
1.08.04	Salary and allowances for civil servants	1.192.567.183	64%	766.650.332	DKP et al. 2007	74%	567.321.246	26%	199.329.086
1.08.04.01.01	Public utilities	62.400.000	65%	40.560.000	Assumption	90%	36.504.000	10%	4.056.000
1.08.04.01.10	Office goods I	6.488.050	65%	4.217.233	Assumption	90%	3.795.509	10%	421.723
1.08.04.01.11	Office goods I	16.788.800	65%	10.912.720	Assumption	90%	9.821.448	10%	1.091.272
1.08.04.01.12	Office goods I	4.202.400	65%	2.731.560	Assumption	90%	2.458.404	10%	273.156
1.08.04.01.13	Office goods I	137.108.450	65%	89.120.493	Assumption	90%	80.208.443	10%	8.912.049
1.08.04.01.15	Subscriptions	1.440.000	65%	936.000	Assumption	90%	842.400	10%	93.600
1.08.04.01.17	Snacks, coffee, tea	301.440.000	65%	195.936.000	Assumption	90%	176.342.400	10%	19.593.600
1.08.04.01.18	Travelling expense and accomodation	30.000.000	65%	19.500.000	Assumption	90%	17.550.000	10%	1.950.000
1.08.04.01.19	Salary for workers and insurance	6.836.695.000	68%	4.670.290.056	DKP et al. 2007	95%	4.436.775.553	5%	233.514.503
1.08.04.02.10	Office tables and chairs	74.420.000	65%	48.373.000	Assumption	90%	43.535.700	10%	4.837.300
1.08.04.02.24	Maintenance of equipments and fuel	1.836.294.750	65%	1.193.591.588	Assumption	90%	1.074.232.429	10%	119.359.159
1.08.04.02.28	Office building maintenance	4.100.000	65%	2.665.000	Assumption	90%	2.398.500	10%	266.500
1.08.04.03.01	Presence registration machine	40.000.000	65%	26.000.000	Assumption	90%	23.400.000	10%	2.600.000
1.08.04.03.02	Uniform civil servants	11.700.000	64%	7.521.429	DKP et al. 2007	74%	5.565.857	26%	1.955.571
1.08.04.03.03	Working cloths	103.950.000	68%	71.010.430	DKP et al. 2007	95%	67.459.908	5%	3.550.521
1.08.04.05.03	Training and technical assitance	8.000.000	65%	5.200.000	Assumption	90%	4.680.000	10%	520.000
1.08.04.15.02	Office building construction/handcart etc.	896.404.500	65%	582.662.925	Assumption	90%	524.396.633	10%	58.266.293
1.08.04.15.04	Procurement/construction landfill	494.708.000	100%	494.708.000	Assumption	0%	-	100%	494.708.000
1.08.04.15.07	Co-finance project budget and billboard	592.125.500	65%	384.881.575	Assumption	90%	346.393.418	10%	38.488.158
1.08.04.15.13	Pilot project Gampong Bersih	371.135.000	65%	241.237.750	Assumption	100%	241.237.750	0%	-
1.08.04.15.14	Sediment clearance and special waste collection	493.406.800	65%	320.714.420	Assumption	100%	320.714.420	0%	-
1.08.04.24.05	Parks maintenance	418.552.500	0%	-	Assumption	0%	-	0%	-
	Total	13.933.926.933	66%	9.179.420.509		87%	7.985.634.017	13%	1.193.786.491

Cost structure according to DKP - Waste Management Master Plan 2007, Annex 19

1 IDR = 0,000080 Euro

Number		Costs total		Share MSWM			Share MSW Collection			Share MSW Disposal		
		IDR	Euro	[%]	IDR	Euro	[%]	IDR	Euro	[%]	IDR	Euro
1	Civil servants	1.204.267.183	96.111	64%	774.171.761	61.785	74%	572.887.103	45.721	26%	201.284.658	16.064
2	Workers	6.940.645.000	553.922	68%	4.741.300.486	378.396	95%	4.504.235.461	359.476	5%	237.065.024	18.920
3	Special MSW	494.708.000	39.482	100%	494.708.000	39.482	0%	-	-	100%	494.708.000	39.482
4	Miscellaneous	4.875.754.250	389.126	65%	3.169.240.263	252.932	92%	2.908.511.453	232.124	8%	260.728.809	20.808
5	Not MSW	418.552.500	33.404	0%	-	-	0%	-	-	0%	-	-
Total		13.933.926.933	1.112.045	66%	9.179.420.509	732.595	87%	7.985.634.017	637.321	13%	1.193.786.491	95.274

12.6.5 Calculations depreciation of vehicles for collection and landfilling

Cost of collection equippment, linear abbreviated

1 Euro = 12.530 Indonesian Rupiahs

MSW Classification	Vehicle	Price per unit	Price per unit	Units	Price total	Abbreviation time	Price per year	Total	Total
		€	IDR		IDR	years	IDR	IDR	€
Collection	Dump Truck	15.000,00	187.950.000	26	4.886.700.000	15	325.780.000	747.623.333	59.667
	Hydraulic Hook Lift	15.000,00	187.950.000	11	2.067.450.000	15	137.830.000		
	Pick Up	8.000,00	100.240.000	10	1.002.400.000	5	200.480.000		
	Compactor Trucks	20.000,00	250.600.000	4	1.002.400.000	15	66.826.667		
	Sweeping Machine	20.000,00	250.600.000	1	250.600.000	15	16.706.667		
Disposal	Wheel loaders	30.000,00	375.900.000	5	1.879.500.000	15	125.300.000	751.800.000	60.000
	Back hoe loaders	50.000,00	626.500.000	5	3.132.500.000	15	208.833.333		
	Bull dozers	100.000,00	1.253.000.000	5	6.265.000.000	15	417.666.667		
Total					20.486.550.000		1.499.423.333	1.499.423.333	119.667

Prices based on following sources (last accessed 18.02.2008):
http://www.autocarprices.com/toyota_car_price.htm
http://www.contractorshotline.com/CEG_Annual/annual_description.htm
http://www.europe-machinery.com/
http://www.europe-machinery.com/annonces.asp?trich=Iprop2&triordre=DESC&page=1&urlrub=skid%2Dsteer%2Dloader&Iprop1=3360
http://www.europe-machinery.com/annonces.asp?action=rech&numrub=313
http://www.europe-machinery.com/annonces.asp?trich=Iprix&triordre=DESC&page=1&valider=Start+search&numrub=4&aprop2=&Iprop1=3458&iprop3=&localisation=&aff=&action=rech
http://cltruck.en.alibaba.com/

12.6.6 Costs for different waste management alternatives

	LOW INCOME COUNTRY	MIDDLE INCOME COUNTRY	HIGH INCOME COUNTRY
Average WASTE GENERATION	0.2 t/capita/y	0.3 t/capita/y	0.6 t/capita/y
Average INCOME FROM GNP	370 $/capita/y	2,400 $/capita/y	22,000 $/capita/y
Collection Cost	10-30 $/t.	30-70 $/m.	70-120 $/t.
Transfer Cost	3-8 $/t.	5-15 $/t.	15-20 $/t.
Sanitary Landfill Cost	3-10 $/t.	8-15 $/t.	15-50 $/t.
TOTAL COST WITHOUT TRANSFER	13-40 $/m.t.	38-85 $/t.	90-170 $/t.
TOTAL COST WITH TRANSFER	16-48 $/t.	43-100 $/t.	105-190 $/t.
Total Cost per Capita	3-10 $/capita/y	12-30 $/capita/y	60-114 $/capita/y
COST AS % OF INCOME	0.7-2.6%	0.5-1.3%	0.2-0.5%

Table Notes:

1. Income based on 1992 Gross National Product data from the World Development Report 1994 published by the World Bank.
2. Costs are for owning, operation, maintenance, and debt service in 1995, assuming no equipment provision through grants. Appropriate (affordable) best practical standards of service and environmental protection for the skill and income level of the country are assumed.
3. If sanitary landfill can be located with an economic haul distance that allows direct haul in collection vehicles, the cost of transfer can be avoided. An economic haul time for a small truck carrying 2 to 6 tonnes commonly is within 30 minutes one-way from the collection area to the unloading point. Depending on traffic conditions, 30 minutes one-way would be 15 to 30 kilometers one-way. Larger trucks can readily haul for 30 to 50 kilometers one-way.
4. $/t means US Dollars per metric tonne, and $/capita/y means US Dollars per capita per year.

Source: Sandra Cointreau

Cointreau (2006:8)

	Low Income	Middle Income	High Income
Avg. Waste Generation (Mg/cap/yr)	0.1	0.2	0.7
Income (US$/cap/yr)	500	3,000	25,000
Collection cost (US$/Mg)	15 to 40	25 to 75	75 to 150
Transfer cost (US$/Mg)	4 to 10	6 to 20	20 to 25
Sanitary landfill (US$/Mg) (US$/Mg)	5 to 25	15 to 20	30 to 100
Total Cost without Transfer	20 to 65	40 to 95	105 to 250
Total Cost with Transfer	24 to 75	46 to 115	125 to 275
Cost as % of Income	0.4 to 1.6%	0.2 to 0.7%	0.3 to 0.8%

1. Average income values based on selected world development indicators from the World Development Report 2000/2001, published for The World Bank by Oxford University Press.
2. Costs are for owning, operation, maintenance, and debt service in 2002, and assuming no equipment provision through grants.

Table D-2. Disposal costs of alternative technologies for large cities

	Low Income	Middle Income	High Income
Open dumping (US$/Mg)	0.5 to 2	1 to 3	Not applicable
Sanitary landfill (US$/Mg)	5 to 25	15 to 30	30 to 100
Composting (US$/Mg)	5 to 25	15 to 40	30 to 80
Incineration (US$/Mg)	30 to 60 (Note 5)	30 to 80 (Note 4)	70 to 100 (Note 4)

1. The above sanitary landfill costs are for cities of over 500,000 people, or over 250 tonnes/day, in order to capture economies-of-scale. For smaller cities, costs could be higher.
2. The higher range of costs for sanitary landfill is for systems with plastic membrane bottom liners and leachate collection and treatment systems; while the lower range of costs is for natural attenuation landfills, where site conditions do not require leachate management.
3. The higher range of costs for composting is for systems with mechanised classification, pulverisation, and forced aeration, while the lower range of costs is for systems with hand sorting, trommel screening, and simple turned windrows.
4. The higher range of costs for incineration is for systems with modern air pollution control and ash handling systems, while the lower range of costs is for systems with limited air pollution control equipment and no specialised ash handling equipment.
5. Limited air pollution control equipment and no specialised ash handling.

CalRecovery (2005:504)

12.6.7 Calculation of costs for all scenarios

Costs Current MSWM system - pre-calculation

Inhabitants Banda Aceh 2007	219 657	
Waste collected 2007	194	[kg/(capita.year)]
Waste collected 2007	42 613	[ton/year]
Waste landfilled 2007	188	[kg/(capita.year)]
Waste collected 2007	41 296	[ton/year]

	Collection			Disposal			Total	
	IDR	€	[%]	IDR	€	[%]	IDR	€
Costs Banlance Sheet	6 068 627 400	484 328	85%	1 092 891 406	87 222	15%	7 161 518 806	571 550
Cost Vehicles	747 623 333	59 667	50%	751 800 000	60 000	50%	1 499 423 333	119 667
Cost Total	6 816 250 733	543 994	79%	1 844 691 406	147 222	21%	8 660 942 139	691 216
Cost Total per capita and year	31 031	2.48		8 398	0.67		39 429	3.15
Cost Total per ton waste	159 955	12.8		44 671	3.5		203 244	16

Costs Current MSWM system

Inhabitants Banda Aceh 2007	219 657	
1 kg =	0.001	ton
Waste collected 2007	194	[kg/(capita.year)]
Waste landfilled 2007	188	[kg/(capita.year)]

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[€/ton]	[€/year]	[€/(capita.yr)]	[%]
Collection	194	42 613	13	543 994	2.5	79%
Landfill	188	41 296	3	142 669	0.6	21%
Total			16	686 663	3.1	100%

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[IDR/ton]	[IDR/year]	[IDR/(capita.yr)]	[%]
Collection	194	42 613	159 955	6 816 250 733	31 031	79%
Landfill	188	41 296	44 671	1 844 691 406	8 398	21%
Total			204 626	8 660 942 139	39 429	100%

Costs Scenario I

Inhabitants Banda Aceh 2007	219 657	
1 kg =	0.001	ton
Waste collected =	256	[kg/(capita.year)]
Waste landfilled =	249	[kg/(capita.year)]

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[€/ton]	[€/year]	[€/(capita.yr)]	[%]
Collection	256	56 232	13	717 848	3.3	55%
Sanitary Landfill	249	54 695	11	598 906	2.7	45%
Total			24	1 316 754	6.0	100%

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[IDR/ton]	[IDR/year]	[IDR/(capita.yr)]	[%]
Collection	256	56 232	159 955	8 994 640 143	40 949	55%
Sanitary Landfill	249	54 695	137 250	7 506 832 889	34 175	45%
Total			297 205	16 501 473 032	75 124	100%

Costs Scenario II

Inhabitants Banda Aceh 2007	219 657	
1 kg =	0.001	ton
Waste collected =	194	[kg/(capita.year)]
Waste composted =	48	[kg/(capita.year)]
Waste landfilled =	144	[kg/(capita.year)]

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[€/ton]	[€/year]	[€/(capita.yr)]	[%]
Collection	194	42 613	13	543 994	2.5	64%
Processing and Composting	48	10 544	18	192 420	0.9	23%
Landfill	144	31 631	3	109 278	0.5	13%
Total			34	845 692	3.9	100%

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[IDR/ton]	[IDR/year]	[IDR/(capita.yr)]	[%]
Collection	194	42 613	159 955	6 816 250 733	31 031	64%
Processing and Composting	48	10 544	228 750	2 411 833 860	10 980	23%
Landfill	144	31 631	44 671	1 412 955 120	6 433	13%
Total			433 376	10 641 039 713	48 444	100%

Costs Scenario III

Inhabitants Banda Aceh 2007	219 657	
1 kg =	0.001	ton
Waste collected =	194	[kg/(capita.year)]
Waste incinerated =	191	[kg/(capita.year)]

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[€/ton]	[€/year]	[€/(capita.yr)]	[%]
Collection	194	42 613	13	543 994	2.5	18%
Incineration + Disposal	191	41 954	58	2 450 142	11.2	82%
Total			71	2 994 137	13.6	100%

Process	Waste	Waste	Costs mean	Costs mean	Costs mean	Costs mean
	[kg/(capita.year)]	[ton/year]	[IDR/ton]	[IDR/year]	[IDR/(capita.yr)]	[%]
Collection	194	42 613	159 955	6 816 250 733	31 031	18%
Incineration + Disposal	191	41 954	732 000	30 710 684 484	139 812	82%
Total			891 955	37 526 935 217	170 843	100%

12.7 Calculation of indicators

12.7.1 Emission factors for dioxin/furan emissions

Table 14: Emission factors for municipal solid waste incineration

Classification	Emission Factors - µg TEQ/t MSW Burned		
	Air	Fly Ash	Bottom Ash
1. Low technology combustion, no APCS	3,500	-	75
2. Controlled combustion, minimal APCS	350	500	15
3. Controlled combustion, good APCS	30	200	7
4. High technology combustion, sophisticated APCS	0.5	15	1.5

UNEP Chemicals (2005:44)

Table 50: Emission factors for diesel engines (*i.e.* trucks)

Classification	Emission Factors – µg TEQ/t of Diesel				
	Air	Water	Land	Product	Residue
Diesel engines *	0.1	NA	NA	NA	ND

UNEP Chemicals (2005:123)

Table 54: Emission factors for waste burning and accidental fires

Classification	Emission Factors – µg TEQ/t of Material Burned				
	Air	Water	Land	Product	Residue
1. Landfill fires	1,000	ND	600	NA	[600]
2. Accidental fires in houses, factories	400	ND	400	NA	[400]
3. Uncontrolled domestic waste burning	300	ND	600	NA	[600]
4. Accidental fires in vehicles	94 (per vehicle)	ND	18 (per vehicle)	NA	[18 (per vehicle)]
5. Open burning of wood (construction/demolition)	60	ND	10	NA	[10]

UNEP Chemicals (2005:130)

Table 75: Emission factors for landfills and waste dumps

Classification	Emission Factors – pg TEQ/L in Water and µg TEQ/t in Residues Disposed of				
	Air	Water	Land	Product	Residue
1. Hazardous wastes	NA	200	NA	NA	50
2. Non-hazardous wastes	NA	30	NA	NA	6

UNEP Chemicals (2005:175)

Table 78: Emission factors for composting

Classification	Emission Factors - µg TEQ/t d.m			
	Air	Water	Land	Product = Residue
1. All organic fraction	NA	NA	NA	100
2. Garden, kitchen wastes	NA	NA	NA	15
3. Green materials from not impacted environments	NA	NA	NA	5

UNEP Chemicals (2005:180)

12.7.2 Calculation dioxin/furan emissions

Capita Banda Aceh 2007 =	219 657	
1 g =	1.0E+03	mg
1 g =	1.0E+06	µg
1 mg =	1.0E+03	µg

System	Annual Releases (g TEQ/year)					
	Air	Water	Land	Product	Residue	Total
Current	3.2	0.0	6.5	0.0	0.3	10.0
Scenario I	0.0	0.0	0.0	0.0	0.3	0.3
Scenario II	3.2	0.0	6.5	0.3	0.2	10.2
Scenario III	3.2	0.0	6.5	0.0	0.7	10.4

System	Annual Releases (mg TEQ/year)					
	Air	Water	Land	Product	Residue	Total
Current	3 229	1	6 458	-	265	9 953
Scenario I	0	2	-	-	328	330
Scenario II	3 229	1	6 458	308	207	10 202
Scenario III	3 250	0	6 458	-	709	10 417

System	Annual Releases (µg TEQ/capita.year)					
	Air	Water	Land	Product	Residue	Total
Current	15	0	29	-	1	45
Scenario I	0	0	-	-	1	2
Scenario II	15	0	29	1	1	46
Scenario III	15	0	29	-	3	47

System	Annual Releases (mg TEQ/year)				
	Incin-eration	Trans-port	Open burning	Disposal +Composting	Total
Current	-	0	9 687	266	9 953
Scenario I	-	0	-	330	330
Scenario II	-	0	9 687	515	10 202
Scenario III	713	0	9 687	17	10 417

System	Annual Releases (µg TEQ/capita.year)				
	Incin-eration	Trans-port	Open burning	Disposal +Composting	Total
Current	-	0	44	1	45
Scenario I	-	0	-	2	2
Scenario II	-	0	44	2	46
Scenario III	3	0	44	0	47

System	Share of each compartiment in [%]					
	Air	Water	Land	Product	Residue	Total
Current	32%	0%	65%	0%	3%	100%
Scenario I	0%	0%	0%	0%	99%	100%
Scenario II	32%	0%	63%	3%	2%	100%
Scenario III	31%	0%	62%	0%	7%	100%

12.7.3 Calculation of nitrogen emissions

Nitrogen emissions into hydrosphere

	MSW				Nbiogenic concentration				Mobilization factor				Non-removal factor				N - emissions hydrosphere			
Scenario	Cur.	Sc.I	Sc.II	Sc.III	Cur.	Sc.I	Sc.II	Sc.III	Cur.	Sc.I	Sc.II	Sc.III	Cur.	Sc.I	Sc.II	Sc.III	Current	Scenario I	Scenario II	Scenario III
Process Unit	[kg/(capita.year)]				[g N / kg material]												[g N / (capita.year)]			
MSW informally dumped	13	0	13	13	5	0	5	5	0,2	0	0,2	0,2	1	0	1	1	13	0	13	13
MSW landfilled	188	0	144	0	5	0	2,5	0	0,2	0	0,2	0	1	0	1	0	188	0	72	0
MSW sanitary landfilled	0	244	0	0	0	5	0	0	0	0,2	0	0	0	0,3	0	0	0	61	0	0
Organic waste composted	0	0	48	0	0	0	0,01	0	0	0	1	0	0	0	0,3	0	0	0	0,2	0
Total																	201	61	85	13

Pre-calculation for composting:
Leachate generation = 0,04 [l/kg waste]
N-concentration in leachate = 0,4 [g/l leachate]
Nbiogenic-concentration in leachate, referring waste mass = 0,01 [g/kg waste]

12.7.4 Calculation of global warming potential

GWP Factors:
CO_2 = 1 GWP
CH_4 = 25 GWP
N_2O = 298 GWP
1 Mg = 1.000 kg
Capita Banda Aceh 2007 = 219.657

Scenario	Current	Scenario I	Scenario II	Scenario III
GHG	[Mg/yr]	[Mg/yr]	[Mg/yr]	[Mg/yr]
CO2	3.601	1.580	3.601	20.454
CH4	1.635	2.463	1.330	151
N2O	2	0	5	3
CO2 GWP	3.601	1.580	3.601	20.454
CH4 GWP	40.878	61.584	33.249	3.780
N2O GWP	486	7	1.428	985
GWP total	44.965	63.172	38.278	25.219

Scenario	Current	Scenario I	Scenario II	Scenario III
GHG	[kg/(c.yr)]	[kg/(c.yr)]	[kg/(c.yr)]	[kg/(c.yr)]
CO2	16	7	16	93
CH4	7	11	6	1
N2O	0	0	0	0
CO2 GWP	16	7	16	93
CH4 GWP	186	280	151	17
N2O GWP	2	0	7	4
GWP total	205	288	174	115

Scenario	Current	Scenario I	Scenario II	Scenario III
GHG	[%]	[%]	[%]	[%]
CO2 GWP	8%	3%	9%	81%
CH4 GWP	91%	97%	87%	15%
N2O GWP	1%	0%	4%	4%

12.8 Checking the MFA calculation for the MSWM system Banda Aceh 2007

12.8.1 Checking the MSW import flux "waste from other sources than households"

Inhabitants Banda Aceh 2007 = 219.657 capita

No.	MSW generation sources	MSW per unit	Reference unit	Units/ Factor	MSW total	Days per year	MSW total	Share
		[kg/u.d]			[kg/d]	[d/yr]	[kg/(c.yr)]	[%]
1	Markets	10.080,00	Extrapolation markets	3	30.240	360	49,6	50%
2	Small enterprises	2,60	Enterprises	9.000	23.400	360	38,4	39%
3	Gastronomy establishments	3,30	Gastronomy establishments	1.000	3.300	360	5,4	5%
4	Schools	0,05	Students	40.000	2.000	300	2,7	3%
5	Offices	0,07	Employees	27.000	1.890	300	2,6	3%
	Other sources than households total						**98,6**	100%

12.8.2 Alternative MFA calculation for MSWM system Banda Aceh 2007

Waste import households = 117 [kg/(c.yr)]
Waste import other sources = 110 [kg/(c.yr)]

No	Process	Import MSW households		Import MSW other sources		Import MSW total	
		%	[kg/(c.yr)]	%	[kg/(c.yr)]	%	[kg/(c.yr)]
1	Formal collection	65%	76	85%	94	170	75%
2	Burning	30%	35	10%	11	46	20%
3	Informal disposal	5%	6	5%	6	11	5%
	Total	**100%**	**117**	**100%**	**110**	**227**	**100%**

12.9Comparison MSWM system Banda Aceh-Vienna in IDR

	Unit	Vienna	Banda Aceh
MSW generation	[tonne/year]	924 805	58 648
Inhabitants		1 651 437	219 657
MSW per capita and year	[kg/(capita.year)]	560	267
MSW per capita and day	[kg/(capita.day)]	1.5	0.7
Total MSWM costs	[million IDR/year]	2 276 176	8 604
Costs per ton MSW	[IDR/ton]	2 461 250	146 703
Costs per capita and year	[IDR/(capita*year)]	1 378 300	39 170
GNI real per capita and year	[million IDR/(capita*year)]	338.3	11.7
GNI PPP per capita and year	[million IDR/(capita*year)]	303.1	34.0
Costs in % of GNI real	[% GNI of real]	0.41%	0.33%
Costs in % of GNI PPP	[% GNI of PPP]	0.45%	0.12%

12.10 Calculation greenhouse gas emissions Indonesia 1994

	CO2	CH4	N2O	Total
Emission (Gg/yr)[1]	748 607	6 409	61	
Capita 1994[2]	191 000 000	191 000 000	191 000 000	
GWP factor	1	25	298	
GWP [kg/(c.yr)]	3 919	839	95	4 853

Note: The emission figures should be taken cautiously, as the calculation tables in the publication are unclear and probably not correct.

[1] Sughandy (1995:3-4)
[2] Sughandy (1995:1-1)

Abstract

The hierarchy of waste management (waste reduction, recycling, disposal), which is a result of the affluent societies of high income developed countries in the 1970s, has entered waste policies in both, developed and developing countries. This thesis challenges the applicability of this approach in developing countries twofold: first by assessing how waste management options and technologies that follow the waste hierarchy fulfil the objectives of waste management (protection of human health and the environment, conservation of resources); and second by investigating the discourse on waste management in developed and developing countries.

For the assessment of waste management options, two urban regions, one in a high income (Vienna, Austria) and one in a lower-middle income country (Banda Aceh, Indonesia) are selected. Subsequently, the waste management systems of both urban regions are investigated through material flow analysis, but also the expression of per capita expenditures for waste management. As unsafe waste management practises, such as illegal dumping and burning, but also incomplete waste collection, are reported from Banda Aceh, scenarios for improved waste management in Banda Aceh are designed. These scenarios refer to the waste hierarchy. Thus, two recycling scenarios (composting and waste incineration with energy recovery) and one disposal scenario (collection service for all waste generators and sanitary landfilling) are designed. The disposal scenario is lower ranked through the waste hierarchy.

The subsequent goal-oriented assessment through indicators that refer to the objectives of waste management (1) protection of human health and the environment and 2) conservation of resources) shows that the actual waste management system of Vienna rather fulfil the objectives of waste management than Banda Aceh, but also costs 37times more per capita. Unsound practises in waste management in Banda Aceh, such as open burning and illegal dumping caused by incomplete waste collection, are main responsible for this weaker performances of Banda Aceh's waste management system.

The comparison of the three scenarios with the current state of waste management in Banda Aceh shows that composting and incineration with energy recovery more likely reach the objective of resource conservation, while the extension of collection to each waste generating source and sanitary landfilling more likely protects human health and the environment. The cost increase through improved waste management if compared to the current state is far highest for introducing waste incineration with energy recovery, followed by extension of collection and sanitary landfilling. The lowest increase in costs per capita can be observed for composting.

Subsumed, the one option which is considered as least desirable through the waste hierarchy (extension of collection + sanitary landfilling) has the highest positive impact to reach the objective of protection of human health and the environment. While incineration is too expensive, composting more likely reaches the objective of conservation of resources. Hence options which are favoured

through the waste hierarchy do not necessarily help to fulfil the objectives of waste management or can be economically unfeasible respectively.

This contradiction is investigated through analyzing the discourse on solid waste management in developed and developing countries, with special regards to the appearance of the waste hierarchy. For that reason, literature from various actors in the discourse on waste management is reviewed and analyzed. The discourse analysis is based on environmental policy analysis which refers to Michel Foucault. The actors which are analyzed are 1) scientific community and experts in the field of solid waste management, 2) international organisations, 3) national and local authorities and bilateral development co-operation agencies and 4) private actors, such as NGOs and private companies.
The result shows that since the 1970s, the discourse on waste management in developed countries has slowly shifted away from the protection of human health towards environmental concerns and resource conservation. The main reasons for this shift are the improved sanitary situation through more sound solid waste collection, disposal and treatment and the shifting relations between governmental actors, non-governmental actors and individuals. One outcome of this shift is the waste hierarchy, which has become an important metaphor in the discourse on solid waste management, used by scientists, experts, NGOs, but also stipulated in solid waste management policies and strategies. Developing countries have inherited parts of this discourse, such as the waste hierarchy. While international organizations have globalized this approach, national development agencies from industrialized countries, scientists and experts have helped to disseminate concepts like the waste hierarchy. On the other hand, societies in developing countries have not undergone the shifts that have led to policies like the waste hierarchy, such as the fundamental improve in the sanitary situation. This causes a superimposition of public health and resource conservation in the discourse on solid waste management in developing countries. Through this superimposition and the shift towards resource conservation, there might be the threat that protection of human health, in a first step established through improved sanitation, might looses its importance in solid waste management in developing countries.

Kurzfassung

Die Abfallhierarchie (Vermeidung – Verwertung – Sichere Entsorgung von Abfällen), entstanden in wohlhabenden entwickelten Ländern in den 1970er Jahren, wurde zu einer wichtigen Abfallwirtschaftsstrategie, sowohl in Entwicklungs-, als auch in entwickelten Ländern. Diese Diplomarbeit untersucht die Anwendbarkeit und Anwendung der Abfallhierarchie in Entwicklungsländern auf zwei Ebenen: Zuerst wird durch eine Zielorientierte Bewertungsmethode versucht zu ermitteln, wie Abfallwirtschaftsoptionen und –Technologien, welche der Abfallhierarchie folgen, die Ziele der Abfallwirtschaft (Schutz der menschlichen Gesundheit und der Umwelt; Schonung der Ressourcen) erreichen. Anschließend wird der Diskurs über Abfallwirtschaft in Entwicklungs- und entwickelten Ländern untersucht.

Für die Bewertung der Abfallwirtschaftsoptionen werden zuerst zwei urbane Regionen, eine in einem Land mit hohem Einkommen (Wien, Österreich) und eine in einem Land mit niedrigerem Einkommen (Banda Aceh, Indonesien), ausgewählt. Die Abfallwirtschaftssysteme beider Städte werden mit einer Güterflussanalyse dargestellt und berechnet. Zusätzlich werden die Ausgaben für Abfallwirtschaft ermittelt. Da aufgrund von Berichten davon auszugehen ist, dass in Banda Aceh unsichere Praktiken, wie illegales Verbrennen und Ablagern von Abfällen, hervorgerufen auch durch eine unvollständige Abfallsammlung, existieren, werden drei Szenarien für mögliche Abfallwirtschaftsoptionen entworfen. Diese Szenarien beziehen sich auf die Abfallhierarchie. Zwei der Szenarien, eine Kompostierung und eine Abfallverbrennungsanlage mit Energiegewinnung, sind durch die Abfallhierarchie erwünschter als das dritte Szenario, nämlich ein Entsorgungsszenario mit Ausweitung des Anschlussgrades der Abfallsammlung auf alle Abfallproduzenten und –Produzentinnen mit anschließender hygienischer Deponierung.

Die anschließende Zielorientierte Bewertung wird anhand von Indikatoren durchgeführt, welche zeigen sollen, wie gut ein Abfallwirtschaftssystem die Ziele der Abfallwirtschaft (Schutz der menschlichen Gesundheit und der Umwelt; Schonung der Ressourcen) erreicht.

Die Ergebnisse zeigen, dass das Abfallwirtschaftssystem von Wien eher diese Ziele der Abfallwirtschaft erreicht als jenes von Banda Aceh, jedoch pro Einwohner circa 37mal höhere Ausgaben mit sich bringt. Hauptverantwortlich für das relativ schlechtere Abschneiden von Banda Acehs Abfallwirtschaftssystem sind unsichere Praktiken, wie illegale Abfallverbrennung und Ablagerung, hervorgerufen unter anderem durch unvollständige Abfallsammlung.

Bei der vergleichende Bewertung des Abfallwirtschaftssystems in Banda Aceh mit den drei Szenarien für die Stadt zeigt, dass das Kompostierungsszenario und das Abfallverbrennungsszenario mit Energiegewinnung bei den Indikatoren für Ressourcenschonung besser abschneidet, während das Entsorgungs- und Deponierungsszenario eher bei den Indikatoren zum Schutz der menschlichen Gesundheit und der Umwelt besser liegt. Die Kostensteigerung gegenüber dem Status Quo ist am größten beim Abfallverbrennungsszenario mit Energiegewinnung, gefolgt vom Entsorgungs- und Deponierungsszenario. Das Kompostierungsszenario zeigt die geringsten Kostensteigerungen.

Zusammenfassend kann gesagt werden, dass jenes Szenario, dass am ehesten die menschliche Gesundheit schützt, von der Abfallhierarchie am wenigsten favorisiert wird. Während das Abfallverbrennungsszenario mit Energiegewinnung zu hohe Kosten mit sich bringt, verbessert das Kompostierungsszenario hauptsächlich die Ressourcenschonung. Das bedeutet das Optionen und Technologien, welche durch die Abfallhierarchie von vorne herein bevorzugt werden, nicht unbedingt die Ziele der Abfallwirtschaft besser erreichen beziehungsweise umsetzbar sind.

Dieser Widerspruch wird durch eine Diskursanalyse des Diskurses über Abfallwirtschaft in Entwicklungs- und entwickelten Ländern, mit spezieller Berücksichtigung der Abfallhierarchie, untersucht. Die Analyse lehnt sich an Umweltpolitikanalysen, basierend auf Michel Foucault, an. Analysiert wird Literatur von und über verschiedene Akteure, welche nach einer ersten Recherche als wichtig erachtet werden: 1) Forscher/-innen und Expert/-innen im Bereich der Abfallwirtschaft; 2) Internationale Organisationen; 3) Nationale-, Regionale Behörden und Staatliche Entwicklungszusammenarbeitsorganisationen; 4) Private Akteure, wie NGOs oder Unternehmen.
Die Analyse zeigt das wohlhabende entwickelte Länder seit der 1970er Jahre eine Veränderung im Diskurs über Abfallwirtschaft erlebt haben, weg von der Betrachtung von Abfall als ein Gesundheitsproblem, hin zur Betrachtung als ein Umwelt- und Ressourcenproblem. Die Hauptgründe für diesen Wandel sind verbesserte Siedlungshygiene durch Abfallsammlung und sauberere Deponien und Behandlungsanlagen, aber auch veränderte Beziehungen zwischen Staatlichen Akteuren, Nicht-Staatlichen Akteuren und Individuen. Ein Resultat dieser Veränderung im Diskurs ist die Abfallhierarchie, welche eine wichtige Metapher im Diskurs über Abfallwirtschaft darstellt. Entwicklungsländer haben diesen Diskurs übernommen und mit ihm auch die Abfallhierarchie. Während Internationale Organisationen den Begriff globalisierten, wurden er von Entwicklungsorganisationen, Forscher/-innen und Expert/-innen weiterverbreitet und verfestigt. Andererseits haben Gesellschaften in Entwicklungsländer nicht jene Veränderungen erlebt, wie jene, die zu Konzepten wie der Abfallhierarchie in entwickelten Ländern geführt haben. So ist etwa die Siedlungshygiene in vielen Entwicklungsländern ein großes Problem für die Gesundheit der dort lebenden Menschen.
Durch die Aufnahme der Abfallwirtschaftsdiskurselemente der entwickelten Länder ergibt sich eine Überlagerung von Ressourcenschonung und Menschlicher Gesundheit im Diskurs über Abfallwirtschaft in Entwicklungsländern. Durch diese Überlagerung besteht die Gefahr, dass die Menschliche Gesundheit, welche zuerst durch eine ausreichende Siedlungshygiene herzustellen ist, gegenüber der Ressourcenschonung verdrängt wird und somit ihre Wichtigkeit im Abfallwirtschaftsdiskurs in Entwicklungsländern einbüßt.

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Fachliche Interessen:

- Abfallwirtschaft und Ressourcenmanagement
- Umweltdiskurs in der Entwicklungszusammenarbeit
- Nachhaltige Verkehrs- und Siedlungsplanung
- Wasserversorgung und Siedlungshygiene in Entwicklungsländern