Assessment of the waste management system on Zanzibar

- a case study on Jumbi landfill, Mwanakwerekwe dumpsite and Tunguu dumping area

Kajsa-Stina Kalin and Johanna Skoog

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Department of Technology and Society

Environmental and Energy Systems Studies

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Abstract

Zanzibar, as a part of a developing country in East Africa, struggles with a bad municipal solid waste management system. This master thesis is an attempt to analyse the current waste situation on Zanzibar and the environmental and social effects of four dumpsites in order to give recommendations on how to improve the waste management system. The thesis was made as a Minor Field Study funded by SIDA and conducted as a literature study complemented by a field study on Zanzibar. Methods used in the field study included qualitative interviews, ocular waste composition analysis, water quality analysis, a plastic bottle survey and a waste collection point survey. In order to investigate the environmental effects from dumpsites on Zanzibar a method for landfill investigation with limited resources was developed.

In 2005 a study of the domestic waste composition in Stone Town was made. The study showed that the major domestic waste fraction in Stone Town was organic waste (85.6wt%) and the second largest fraction was plastic (4.4wt%). In the result analysis these figures were compared to the waste composition analysis conducted on Tunguu dumping area where the largest waste fraction was organic waste, representing 82wt%. Plastic represented only 1.6wt% in this survey. The result analysis does however conclude that there are little reasons to believe that an absolute decrease of the plastic waste fraction has happened. Furthermore the organic waste fraction is believed to have decreased even more than shown in the waste composition analysis.

Based on the landfill investigation Jumbi landfill, Mwanakwerekwe dumpsite and Tunguu dumping area have environmental and social impacts mainly through their bad siting, smell, vermin and closeness to surface- and ground water. The waste composition analysis on the sites together with the water quality analysis shows limited environmental impact from the sites. This is believed to be due to high organic content in the waste and low content of hazardous materials.

Major issues regarding the waste management system on Zanzibar are poor governance, low public awareness, aid dependency and no formal landfill together with tourism and population increase and more hazardous waste. However local recycling initiatives already exist together with plans for a future controlled landfill. Zanzibar also has good potential for municipal solid waste composting due to high organic content in the municipal solid waste and a favourable climate.

Keywords

Landfills, waste management, municipal solid waste, developing countries, Zanzibar

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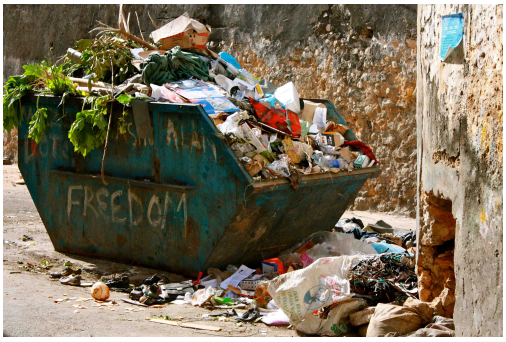

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Summary

Municipal solid waste management is a big and growing challenge for developing countries worldwide due to urbanization, industrialization, increasing populations and increasing waste amounts. Zanzibar, as a part of a developing country in East Africa, struggles with a bad municipal solid waste management system. Today Zanzibar is highly littered and polluted by waste, lacks a national plan regarding waste management and has no formal landfill. This master thesis aims to describe today's waste situation and waste management system on Zanzibar and to give recommendations on how to improve the waste management system.

This master thesis was made as a Minor Field Study funded by SIDA and conducted as a literature study complemented by a field study on Zanzibar. Methods used in the field study included qualitative interviews, ocular waste composition analysis, water quality analysis, a plastic bottle survey and a waste collection point survey. In order to investigate the environmental effects from dumpsites on Zanzibar a method for landfill investigation with limited resources was developed. The literature study and the field study together provide the foundation for reaching the master thesis aims.

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Major issues regarding the waste management system are poor governance, low public awareness, aid dependency and no formal landfill together with tourism and population increase and more hazardous waste. However local recycling initiatives already exist together with plans for a future controlled landfill. Zanzibar also has good potential for municipal solid waste composting due to high organic content in the municipal solid waste and a favourable climate.

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Introductory remark

We want to thank our tutors Eva Leire and Charlotte Retzner on the Department of Technology and Society at Lund Institute of Technology for their support, encouragement and for their constructive criticism and questioning. We also want to thank Fredrik Alfredsson and Erik Gulbrandsen on Zanrec Plastic for helping us formulate our master thesis aim, for recurring discussions on our work proceedings and for financial support. We are also very thankful towards SIDA and ÅForsk for their financial contribution that made the master thesis possible to realize.

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Kajsa-Stina Kalin and Johanna Skoog
Lund, 2012-05-31

Explanations of words and concepts

Cell	An area where the waste is spread, compacted and covered by a thin layer of soil at the end of each day.
Dumping area	In this master thesis defined as a widespread area where informal and scattered dumping takes place.
E-waste	Electronic- and electrical waste is often referred to as e-waste and includes for instance refrigerators, computers, mobile phones and battery driven toys.
Jamabeco	Jambiani Marine and Beach conservation, a NGO founded by ReCoMap.
Landfill gas	The mixture of carbon dioxide and methane gas produced during decomposition in a landfill.
Leachate	Leachate is a liquid produced when water percolates through a landfill and dissolves biological and chemical compounds in it.
Matemwe dumpsite	NGO since 2001 located in the village Matemwe.
MCAEE	Matemwe Control Aids Environment and Education, a community-based organization that works with poverty innovation.
MSW	Municipal solid waste.
NGO	Non governmental organization.
Organic waste	Waste that contain organic carbon which might include both biologic waste and plastic waste. In this master thesis it does however only refer to biologic waste.
ReCoMap	Regional Programme for the sustainable management of the coastal zones of the countries of the Indian Ocean, including Mauritius, Seychelles, Madagascar, the Comoros Islands, Kenya, Tanzania and Somalia. The programme started in 2006 and ended in 2011.
Scavenger	A person who makes a living on waste and depends on it for his or her livelihood.
Solid waste	All waste material except liquid waste, but including semi-solid sludge, produced from domestic,

	commercial or industrial facilities or processes including mining and agricultural operations and water treatment plants.
Waste	Every item, material or substance that the owner means to get rid off or is obligated to get rid off.
Zanrec Plastics	Private company that plans to implement a recycling system on Zanzibar. Also co-funders and collaboration partners in the work with the master thesis.
ZASEA	Zanzibar Scrapers Environment Association, a registered NGO in Stone Town that handles waste
ZMC	Abbreviation for Zanzibar Municipal Council, the executive and policy making office of Zanzibar's Capitol.

Schematic map

Map over Unguja, Zanzibar's biggest island and commonly referred to as Zanzibar. The original picture has been complemented with villages and sites mentioned in the master thesis.

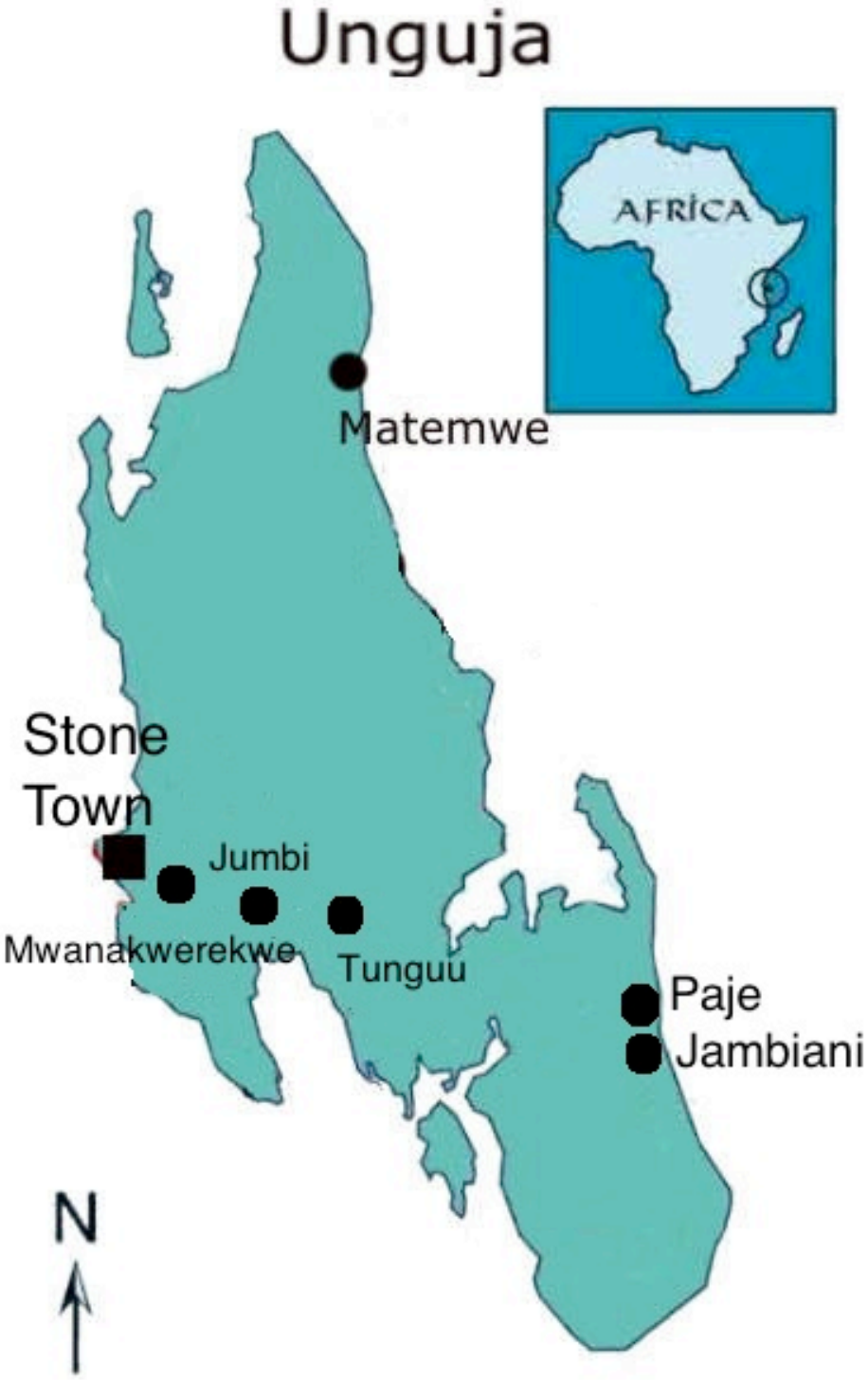

Figure 1. Map over Unguja. (SZ, 2012)

1 Introduction

1.1 Problem description

A country's waste management system has a substantial effect on the environment but is not a primary concern for the governments in developing countries. Due to limited resources the consequences of today's actions and how they might affect life tomorrow are less prioritized. The high biodiversity in the coastal tropical regions of many developing countries are of importance for the global environment. Therefore the uncontrolled disposal of waste in these areas has a negative ecological impact affecting the entire world.

Zanzibar is today highly littered and polluted by waste. It is estimated that 650 tonnes of solid waste is generated on the islands each day. Zanzibar Municipal Council, a local authority, handles about 30% of the total amount of waste generated on Zanzibar. The remaining 70% are randomly disposed of. In general all types of waste (hospital, industrial, domestic, institutional, etc.) are mixed, handled together and dumped. There is a low level of public awareness in achieving sustainable management of municipal solid waste. (SMOLE2, 2011) Waste is for instance randomly disposed on streets and beaches and burnt in backyards. Furthermore there is currently no formal landfill on Zanzibar and waste is dumped on uncontrolled dumpsites or in farm areas. The lack of proper waste management on Zanzibar leads to diseases, flooding and harms the environment (ZP, 2011).

This master thesis analyses the current waste situation and the environmental and social effects of four landfills/dumpsites/dumping areas in order to give recommendations on how to improve the waste management system. Figures in the master thesis should not solely be the basis for decisions on future waste management on Zanzibar but needs supplementation by other surveys.

1.2 Aim and questions

This master thesis generally explains waste challenges in developing countries and describes the present-day waste situation and waste management system on Zanzibar. It will also evaluate the environmental and social effects from the selected landfills/dumpsites/dumping areas. The aim is to analyse the local strengths, weaknesses, opportunities and threats in order to give recommendations on how to improve the waste management system.

The benchmark of the master thesis lies in the following questions:

1. What is the waste composition on Zanzibar (fractions and amounts)?
2. How is the waste currently treated on Zanzibar?
3. How can an investigation of a landfill be made with limited resources?
4. How do todays landfills and other waste management methods on Zanzibar affect the environment and the human population?
5. What could be the first steps when improving the waste management on Zanzibar, considering economic, social and environmental perspectives?

1.3 Delimitations

The master thesis focuses on the waste situation on Unguja, Zanzibar's biggest island. It only deals with municipal solid waste and does not include hospital waste. Legal aspects have not been included and law related to waste is not extensive. The chapter about landfill investigation only describes low-tech methods for analysis of a landfill since high-tech methods usually are unsuitable in developing countries due to limited resources. Since there are many low-tech methods a selection has been made and this is based partly on the advice of Swedish experts involved in the waste management business.

The theory chapter is limited to the waste situation in developing countries. The background, result and discussion chapters are based on experiences gathered during the field study on Zanzibar, on field surveys made on Zanzibar and on literature research related to waste issues in developing countries. It does however not claim to cover the complex of problems entirely.

1.4 Disposition

The report starts with problem description, aim and method. In chapter 2 the theory is presented, including general waste management in developing countries, general landfill theory and methods for low-cost investigation of a landfill. In chapter 3 a background to Zanzibar and its waste management system is presented. In chapter 4 results are given including the field study and field surveys on Zanzibar. Chapter 5 gives a result analysis and chapter 6 includes a general discussion and discussion of methods. Chapter 7 contains conclusions and in chapter 8 references are found. Appendix is found in the end.

1.5 General method

The work process, its aim and the reason for the selected methods are described below. The exact procedures of the field surveys are described in connection to the results.

The work with the thesis started with a literature research in the area of the waste treatment in Zanzibar. The theory includes topics regarding waste treatment in developing countries, the amounts and composition of the waste on Zanzibar, the socioeconomic structure on Zanzibar and landfill theory. All the work related to the master thesis has been done together by the authors and therefore no letter of contribution is made.

For the empirics, the focus has been to interview experts in the waste treatment industry in Sweden and developing countries. Interviews have also taken place with an anthropologist specialised on livelihood strategies for people who experience poverty on Zanzibar, an economist who has worked for UNEP in Africa, the management team at Zanrec Plastics and people involved in todays waste management system on Zanzibar, for instance an expert at the environmental department, the person in charge of the waste management system in Stone Town and several NGOs. All interviews have been conducted as dynamic conversations with open questions. Summaries of the interviews with people on Zanzibar can be found in Appendix 2. The purpose of the interviews

has been to gain knowledge of waste treatment and landfills as well as a better understanding of the culture, social conditions and people's perception of the environmental effects of their waste on Zanzibar.

Method for field study made on Zanzibar
The field study was made between 22nd of January and 18th of March 2012. Information about the society in general and the waste management system was gathered through observations during study visits to several governmental departments, landfills, farm areas, Zanzibarian homes and during time spent on the roads. Information has also been gained through interviews with local people and through taking part in every day life on Zanzibar. The method was chosen since it was considered the best way to get insight to a society where reliable data is not easily gained and without being hindered by people who wants to decide what you observe.

Method for field surveys made on Zanzibar
Data was also gathered during several landfill surveys on Zanzibar through observations of the surroundings, water sample collections and ocular waste composition analysis. The starting point for the waste composition analysis was a waste composition study made in 2005 in Stone Town and the data gathered was compared to the findings in this report (ZSDP2, 2005). The aim of the field surveys was to evaluate the environmental and social effects of the waste management system today with focus on landfills. The method was chosen based on the literature reviews and our limited resources and the access to the landfills.

During a field trip with a waste truck data was gathered through observations and interviews. The purpose of this field trip was to see what really happens to the collected waste since the information varied much depending on the information provider. The method was selected based on its possibility for own observations.

A plastic bottle survey was conducted in a hotel and a house where tourists lived in order to get further knowledge of the waste generated by tourists. The method was selected for its possibility to generate up-to-date information regarding the question.

A survey of a waste collection point through observations repeated daily was made in order to gain information about the waste amounts generated in a Zanzibarian village since this information does not exist. The method was chosen based on our limited time and resources and for its possibilities to provide the information needed.

2 Theory
The following chapter is based on literature reviews and interviews with experts on waste issues in developing countries.

Municipal solid waste management is a big and growing challenge for the developing countries due to urbanization, industrialization, increasing

populations and increasing waste amounts. New waste types such as e-waste and hazardous waste due to improved living standards, improved health care and globalization further accentuate the problem. The lack of collection system, suitable waste treatment and public awareness leads to uncontrolled dumping, which cause severe damage to the environment and hazards for the population. (Zurbrugg, 2003: Sandec, 2008: UNEP5, 2011)

2.1 Introduction to general MSW management in developing countries

All waste produced, collected, transported or disposed of within the area of a municipal authority is referred to as municipal solid waste, MSW. MSW usually consists of household waste, commercial waste, institutional waste and street sweepings but industrial waste and faecal waste are often found in MSW and therefore also handled together with it. MSW management includes all actions from waste generation and composition to waste collection, treatment and in the end waste disposal. (Sandec, 2008)

MSW in developing countries usually contains a larger proportion of inert materials such as sand, ash, dust and stones compared to industrialized countries. Furthermore the MSW generally contains 60-85% organic waste, which also is much compared to industrialized countries. The high level of organic waste and inert material makes the MSW wet and heavy and leads to a low recycling potential but also makes it hard to manage in collection and transport. Waste trucks and other waste handling machines on the market are usually adapted to the less dense waste of industrialized countries and therefore less suitable in developing countries. (TWB2, 2008: Zurbrugg, 2003: Rönnols, 2012: Sandec, 2008)

A lot of the waste produced in developing countries is inaccessible, reached only by roads or alleys unsuitable for large waste trucks because of their width, slope, congestion or surface. (TWB2, 2008: Zurbrugg, 2003) Typically one to two thirds of the waste generated in developing countries is not collected leading to indiscriminately dumping of waste in the streets. Dumping in the streets cause flooding, is a breeding ground for insects and other pests and thereby leads to the spread of diseases. The waste collected is often disposed off in uncontrolled dumpsites and/or burnt which, leads to pollution of air, water and land resources. (Zurbrugg, 2003: Garfi et. al., 2011) A typical driver in developing countries for an improved waste management system is the public health (UNHSP, 2010)

The most prevalent way of disposing MSW in developing countries is open dumping, dumping on riverbanks and dumping directly into the sea. This informal dumping is considered to be the easiest and cheapest method of removing waste from the immediate environment. (Kurian et. al, 2008)

Challenges related resources and governance

Waste management is one visual municipal service that might indicate difficulties in delivering public services in developing countries. Distribution of responsibility, problems with financing, inefficiency and non-transparent management processes are all problems typical for these countries. Focus on the

governance is crucial to obtain an effective waste management system. The national governance also needs to look at underlying issues such as corruption. (UNHSP, 2010)

Most governments recognize the waste problem but the rapid population growth overwhelms the capacity of most municipal authorities in developing countries. Even to provide the most basic services such as waste collection is an issue. One of the main reasons is the lack of financial resources to cope with the generated amount of waste produced in the fast growing cities. Inefficient institutional structures, inefficient organized procedures, lack of management capacity as well as inappropriate technologies are other factors that affect the waste management system. For instance, technology suitable for industrialized countries is often chosen and when it breaks down there is not enough knowledge, spare parts and/or money to fix it. (Zurbrugg, 2003)

In most developing countries labour is available at a low cost, making it both logical and economically efficient to use human workforce for collection instead of waste trucks and other technical solutions. Hand-carts and micro trucks are economically favourable if the landfill/dumpsite is located near the source of MSW generation. (Zurbrugg, 2003: USHSP, 2010) High costs for building and operating facilities however favour large facilities located outside the town area. (UNHSP, 2010)

Local authorities in developing countries typically spend 60-90% of their revenue on waste management. Still many of these countries only have the capacity to handle 40-50% of the waste generated. (Ogwueleka, 2009).

Challenges related to increased income level

There is a direct link between the amounts of waste generated, income level and social status, see Figure 2. The higher income level the greater amount of waste generated due to that consumption increases and lifespan of the products decreases. The waste composition varies between rural and urban areas but also with income level. In rural and low-income areas MSW usually consists of organic waste in difference to urban and high-income areas where it also contain packaging material such as plastic, metal and glass etc. (Sandec, 2008: UNHSP, 2010)

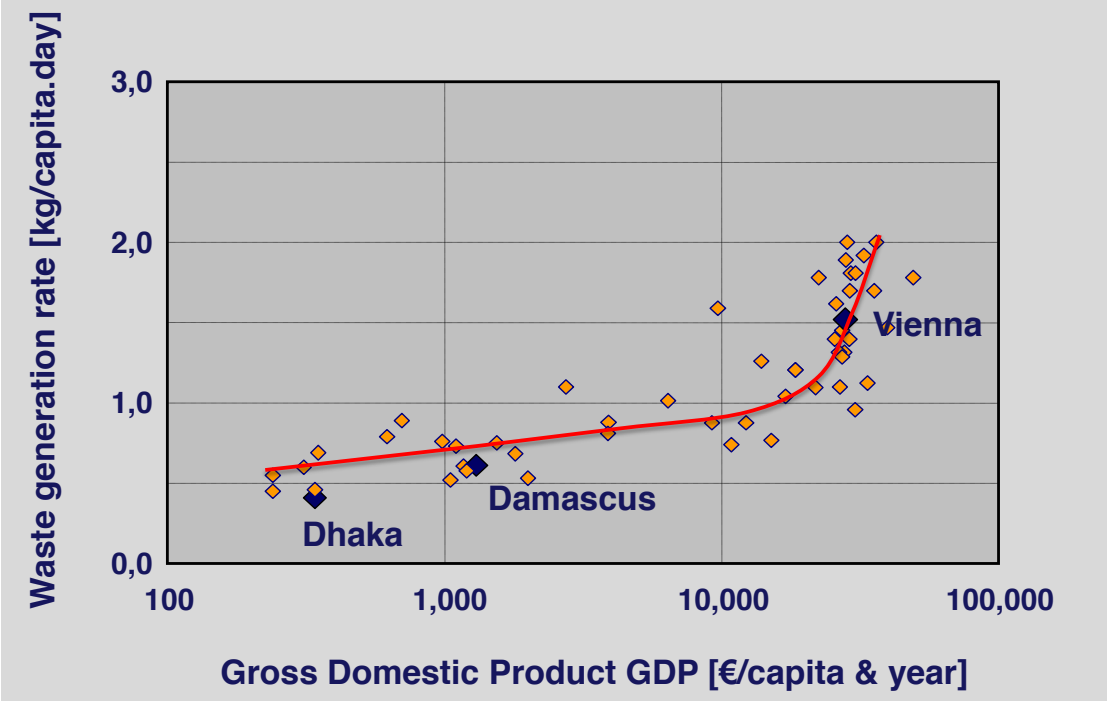

Figure 2. Correlation between waste generation rate and GDP. (Brunner, 2012)

Challenges related to public awareness

Public awareness and attitudes have proven to have a large effect on MSW management. All steps in the waste management system depend on the population, for example littering, sorting of waste and paying for collection service. Raising awareness and motivation is therefore crucial for a successful waste management system. (TWB2, 2008: Zurbrugg, 2003)

Waste management is generally not considered a priority for the leaders in developing countries. This is especially true in villages with bad communications. Poor people in precarious situations are more likely to try to improve their economic wellbeing without taking into account the negative impacts that their actions can represent on natural resources. (Salustro, 2009)

Environmental and human effects

The major environmental effects from waste and waste management in developing countries are air pollution that includes smell, smoke and dust, pollution from waste disposal sites via flooding because of blocked drains and methane leakage from dumpsites that contributes to global warming. Poor MSW management is also associated to some major health effects concerning both animals and people. These are for example convulsion, dermatitis, irritation of nose/throat, plastic anemia, skin burn, chest pain, blood disorder, stomachache, vomiting diarrhea and lung cancer. However research is still needed to link waste exposure to some diseases. Other health issues related to poor waste management include vermin such as insects and rats that may carry diseases and breed in blocked drains and waste. (Adewole, 2009)

Scavenging

Estimations made by the World Bank establish that about 2% of the population in developing countries make their livelihood as scavengers. Low education

level, poverty and high unemployment are often the factors forcing people to waste picking, also referred to as scavenging. Paper, plastic, glass, cardboard and metals are the main materials recovered and sold. Scavengers often suffer from health problems due to long-time exposure to waste. (Sandec, 2008: Rönnols, 2012) A more developed waste management system with recycling might offer scavengers an opportunity to make a living through collection and sorting. The often already existing informal waste dealing however leads to challenges when improving the official waste management system. (SIDA, 2011: Rönnols, 2012)

Challenges related to increasing e-waste

Electronic- and electrical waste is often referred to as e-waste and includes for instance refrigerators, computers, mobile phones and battery driven toys. E-waste is the waste fraction that increases the most all over the world and since it contains hazardous substances it has become a global social and environmental issue. The hazardous substances can be released to the environment as e-waste degrades and to avoid leakage of hazardous substances it is of great importance that e-waste is taken care of properly. The e-waste in most countries is today handled together with the MSW and therefore often ends up on landfills where it might be burnt. (NV, 2011)

A large part of the e-waste generated in the western world is shipped, usually illegally, to developing countries. Poor people then dismantle the e-waste to get the valuable metals that it might contain. The job is usually done by hand and the remaining parts are most commonly disposed on a landfill. Since uncontrolled burning is common on landfills in developing countries, dangerous emissions from the e-waste reach the air as well as pollute the ground. These emissions are toxic and have a severe health effect on the people working or living in the area. (NV, 2011)

2.2 Methods for waste management in developing countries

In connection to each method general theory is presented, followed by examples from developing countries.

2.2.1 Collection

The collection rate is usually 30-60% in low-income countries. A high waste collection rate usually indicates good governance showing commitment and effort to keep a city clean and healthy. Usually there is an informal sector dealing with collection in most developing countries where waste is picked and traded. It is of high importance for a developing country to have a collection system that is adapted to the country and serves its needs and wishes to an affordable rate. There is usually no umbrella framework that keeps record of all small-scale waste businesses. This causes miscalculations when trying to estimate the generated waste as well as the amount of waste available for collection and might be a problem when developing a waste management system. It is not unusual that up to 20% of the generated amount of waste is removed by different waste businesses in a developing country. (USHSP, 2010)

Clean fractions are a necessity for efficient recycling and also relief the burden on the municipality due to more efficient waste management. Clean fractions are

easiest derived through sorting and collection of waste near the source of generation. This is however seldom done in developing countries. (Sandec, 2008: UNHSP, 2010)

A description of the waste collection on Zanzibar is found in chapter 3.

2.2.2 Reuse and recycle

Waste reduction has proven a great challenge to the world's countries. In developing countries there is however a great but informal market for reused products. (UNEP5, 2011) The informal reuse and repair system of many developing countries can achieve recycling rates that can be compared to the ones in the industrialized world without any cost for the municipality. (UNHSP, 2010)

Benefits of waste recycling include reduction of the waste amounts that need to be collected, transported and disposed off and is often an opportunity for unemployed or poor people to get an income. Furthermore recycling extends the lifespan of products and materials, which can have a positive effect on the economy since valuable material are recovered and reused. (Sandec, 2008: Ogwueleka, 2009) All recycling is however not economically defendable today. For instance is recycling of glass and batteries so costly that it usually takes national or even international collection rates to reach a profitable level. (Salustro, 2009)

Plastic recycling

Plastic is usually made from petroleum products. It is generally not biodegradable and if it decomposes it takes several decades. About 80% of all plastic waste is package material and can be recycled. Recycling of plastic waste benefits both the environment and the economy since the amount of virgin material can be reduced and energy can be saved through less energy consumed in production of recycled plastic. Almost all types of plastic contain additives to give the plastics its specific qualities and some of these additives are hazardous for humans and the environment. If plastic is burnt, harmful emissions dangerous for humans and the environment are released. Plastic waste also pollutes visually. (Salustro, 2009: IVL, 2012)

Plastic is a small fraction of MSW due to its low weight but is a large component by volume. This can be a big problem if landfill space is scarce. Due to its long decomposition time, plastic disposed on a landfill can become a storage problem. Plastic recycling facilities are easy to adapt to local conditions and the investment for inventories, for example shredders and grinders, usually pays off due to the large plastic quantities that can be collected. (Salustro, 2009)

Paper recycling

In developing countries the paper fraction in MSW is relatively low. The low abundance of paper makes extensive transportation and storage needed in order to make the recycling process profitable. Low investment capital in developing counties makes it hard to invest in paper recycling and it is common that recycled paper produced in developing countries is sold below market price due

to low quality. For optimal recycling paper should be clean and dry, both factors are hard for many developing countries to cope with. To get a clean fraction, paper waste should be separated at the generation source and not mixed with other MSW as it makes it dirty and damp. Tropical climate is unfavourable for paper recycling since the high humidity makes the paper damp, and stored paper might even rot due to the humidity. (Salustro, 2009)

Metal recycling

The fraction of metal in MSW in many developing countries is below 1% per tonne in rural areas and 2-2.5% per tonne in urban areas (Salustro, 2009). Aluminium and lead are the most common metals. The majority of the metals are taken care of by local operators, usually informal, that are motivated by the commercial demand. Recycling of metal saves a lot of energy since there are few places in the world where virgin metals can be found and due to the high energy cost for purification. However recycling of metals is very costly and the investment is big and therefore a large quantity of metal waste is needed, a quantity that is hard to reach in developing countries. It is of importance to get a clean fraction and polluted recycled metal is common due to poor sorting. At the same time the environmental risks with metal recycling are high. The air gets polluted as well as water and ground since the recycling usually takes place in the open air in developing countries and the slag is disposed at an open dumpsite. It is directly hazardous for humans to work with metal recycling under open-air circumstances. (Salustro, 2009)

Recycling centre in Dar es Salaam, Tanzania

The Recycling Processing Centre in Dar es Salaam is a facility for recycling of paper and plastics through production of intermediate products from these materials. The paper and plastic used in the production comes from households, institutions and businesses etc. The aim is to sell the processed paper and plastic to the local industrial market, but if there is no demand the organization behind the centre will look for other markets. In excess of the processing function the processing centre also aims to have a social function to stimulate the recycling in the area as well as educate different sectors in the marketing of materials. (Scheinberg, 2005)

Four years after the start some conclusions where drawn; profits from recycled paper are modest and most likely to remain so but plastics appears to have big earning potential. In order to operate with a profit a recycling facility not only needs to be able to buy, process and sell recycled materials it also needs to be compensated for the amount of waste it hinders to end up at a dumpsite. Compensation is however not to be expected from the Dar City Council, in Dar es Salaam, since their waste management system lacks a plan for waste reduction and recycling. Further more the Dar City Council don't take a fee for the waste collection and therefore there is no money to compensate waste prevention. Even if a waste collection fee was introduced, the inhabitants of Dar es Salaam are not "reliably paying for collection, let alone disposal". (Scheinberg, 2005)

2.2.3 Biological treatment (composting and digestion)

Biological treatment includes composting and anaerobic digestion. Composting is the degradation of waste in presence of oxygen and leads to volume and weight reduction, stabilization and hygienization. Waste volumes of organic waste can be reduced up to 80% through composting. It also leads to a product that in some cases can be used as a soil fertilizer instead of artificial fertilisers. (Sandec, 2008) Anaerobic digestion is the degradation of waste in the absence of oxygen. The products are biogas (a mixture of methane and carbon dioxide) and a slurry that can be used as soil fertilizer. The volume and weight of the waste is slightly reduced. The simplest application of the gas is to use it directly as cooking gas to run stoves. The gas can also be used to generate electricity, a process with high heat losses, or upgraded and used as vehicle fuel, which needs much higher investment costs. (Rönnols, 2012) The tropical climate of many developing countries is ideal for composting and digestion. (Hoornweg et al., 2000)

Composting study in Stone Town

A study to examine the possibility of composting MSW has been made in Stone Town. In the study both MSW and by-products from rice milling was digested under different conditions in order to evaluate their potential. The study showed that it was an effective technique to reduce the waste volume and thereby the large demand for landfill area. MSW composting decreased the volume with almost 60% (Vuai, 2010). If plastic and other inorganic materials are separated from the organic waste, composting can be a good way to handle the organic waste and by that reducing the waste amounts ending up at dumpsites. Furthermore the compost produced from the MSW under proper management was good enough to improve the fertility of a wide range of soil types. (Vuai, 2010)

Small-scale biogas production on Zanzibar

The Department of Livestock on Zanzibar started a biogas program in 2006. This program has been developed in collaboration with Danish experts through the DANTAN program, which is financed by DANIDA, the Danish equivalent to SIDA. 14 small-scale biogas plants were built by DANTAN between 2007 and 2011 on Zanzibar. (Hendriksen, 2012)

The biogas reactors only use cow dung for the gas production. DANTAN have considered using organic waste, but realized that organic waste, such as leaves and straw, is better used as feed for the cows. They do however see great potential for organic waste collection from markets to produce biogas but today there are no investors. (Kirknæs, 2011)

The Zanzibar government plans for a biogas project with the aim to install up to 400 biogas plants, each with a volume of 6 m^3, over the next 5 years (Hendriksen, 2012). One plant should be able to produce enough gas for a family of 6 and 2-3 cows are needed to produce the right amount of dung for this gas production. Organic household waste will not be used initially in the biogas project. Organic household waste makes the process more complicated and increases the risk

that something goes wrong. The biogas plant should function well before other materials than cow dung are added. (Hendriksen, 2012)

It is challenging to get farmers on Zanzibar to invest in small-scale biogas production since biogas is regarded a luxury. Biogas instead of firewood reduces the time spent in the kitchen but since women and children are the ones doing the cooking this affects the farmers' interest to invest negatively. Furthermore the biogas replaces firewood, something that the farmers can get for free. An investment in a biogas plant is likely to be compared to an investment in a new cow. The cost is almost the same but it is easier for a farmer to see the profit from a new cow. (Hendriksen, 2012)

Biogas production in hotels
Hotels in developing countries might be a good starting-point to introduce biogas production. For them it can be a good marketing strategy and it is fairly simple for them to separate their own organic waste and use the biogas in the kitchen for cooking. There are examples of hotels in India producing biogas for this purpose. There are also examples of Indian societies that collect organic waste, primarily from hotels, and use the produced gas to generate electricity. The challenge is to keep the organic waste fraction clean. (Rönnols, 2012)

2.2.4 Burning and incineration
Burning of waste is a widespread method used in developing countries to reduce the volume of waste as well as to get rid of the stench of rotting waste. Uncontrolled burning is however a source of dioxins and furans and a major health problem. (Garfi, 2011) High-tech incinerators are used to prevent toxic emissions and to make use of the heat for residential heating or power production in many European countries. Incinerators have however proved a bad option in many developing countries due to, among others, high construction and maintenance costs and lack of knowledge and opportunity to deal with toxic by-products in a proper way. There are numerous examples of aid agencies and donors that have funded incinerators in developing countries that were never used, for instance in Nigeria 1979 and during the early 1990s in the Philippines and Indonesia. The reason why they were not used was partly due to the different waste composition compared to the industrialized world. The high moist level and high amount of inert material often found in the waste in developing countries leads to a requirement for extra fuel to be added to maintain combustion and makes the process uneconomic. Further more the incinerators are of Western design with a technology not suitable for developing countries. (Ogwueleka, 2008: UNHSP, 2010)

2.3 General landfill theory
A landfill is a place selected for waste disposal with the purpose to isolate waste from its surroundings. There are several types of landfills ranging from uncontrolled open dumpsites, which lack planning, monitoring and mitigation, to sanitary landfills, which are constructed and operated in ways that seek to minimize their impact on the environment. Open dumping is the most common way to dispose waste in the world today and a cost-effective method of waste

disposal in developing countries. (Lagerkvist, 1999: ISWA1, 2011: UNEP1, 2005: Kurian et. al, 2008: Visvanathan et. al, 2005)

Environmental effects of a landfill

Landfills have an effect on the environment through emissions of for instance leachate (more detailed description below), landfill gas (more detailed description below), pollutants (including nitrogen oxides, sulphur oxides, dioxins, furans and particulate matter) dust and smell. In addition to this there is visual impact, vermin and potential instability and erosion issues. This put together implies that a landfill, if not mitigated, has negative effects on the environment as well as peoples health both locally and globally. Mitigation can however reduce the effect of a landfill largely and includes for instance siting, planning, monitoring, control, exit-strategy, liners and cap-system (low permeable barriers laid under or over a landfill to prevent infiltration, leakage and emissions), daily covering, leachate treatment, landfill gas collection (for flare or use), immediate compaction and secure fencing. (Lagerkvist, 1999: Kurian et. al, 2008)

Leachate is a liquid produced when water percolates through a landfill and dissolves biological and chemical compounds in it. Leachate usually contains material that may contaminate ground- and surface water. High levels of ammonium and chloride are common in leachate and this is one of the major reasons behind its toxicity. The leachates impact on the environment can be mitigated through the use of liners and cap-system combined with run-off collection and leachate treatment in sedimentation ponds. It can also be mitigated through good planning, for instance a location more than one kilometer away from surface waters, wetlands or flood plains. (Lagerkvist, 1999: Kurian et. al, 2008: SGI, 2011)

Decomposition of waste also results in gas production, mainly CO_2 and CH_4, often referred to as landfill gas. CH_4 is flammable in air and a risk that has to be considered on landfills. Released to the air it greatly contributes to the climate change and today it is accountable for about 1,5% of anthropogenic global greenhouse gas emissions. Upstream measures including waste reduction and composting can reduce the gas production. CH_4 can also be mitigated through collection for flaring or utilisation. (UNHSP, 2010: Lagerkvist, 1999)

Decomposition phases

A landfill undergoes three characteristic decomposition phases depending on for instance the age of the dumpsite, the biodegradability of the waste being dumped and the climate. (Lagerkvist, 1999)

The first phase, known as the *aerobic phase*, takes place in the presence of oxygen. It lasts for a couple of weeks and during these weeks aerobic bacteria decomposes waste into water and CO_2. pH is normally around 8 and due to high microbial activity the heat release is fairly large resulting in temperatures up to 80°C. (Lagerkvist, 1999)

The next phase is the *acidogenic phase*. It occurs when the oxygen level decreases. During this phase facultative bacteria further decompose the waste into organic acids and lowers the pH to about 5, thereby increasing the potential for high emission of heavy metals and the production of aggressive leachate. Heat release during this phase is low. (Lagerkvist, 1999)

The third phase is called the *methanogenic phase*. It takes place within 6 months to several decades after the waste disposal when the oxygen is depleted. During this phase anaerobic microorganisms decompose the remaining organics into CO_2, CH_4, and water. pH is about 7 and the heat release is low. (Lagerkvist, 1999)

All decomposition phases can occur at the same time at different locations in a landfill since waste is disposed at different times and has different biodegradability. The duration of the decomposition phases also varies with the biological and chemical surroundings. (Lagerkvist, 1999) Access to water is necessary for the biological processes to occur and if the landfill is covered they will slow down or stop entirely (SGI, 2011). To the three main decomposition phases a fourth can be added. The fourth phase is the oxidative phase, which occurs when the organics suitable for landfill gas production have been consumed and air can diffuse into the landfill again. This can lead to increased heavy metal emissions. (Lagerkvist, 1999)

Siting of a landfill

Many aspects have to be considered and contrasted towards one another in the siting of a landfill. Some of these are listed below.

- *Distance from the area where waste is generated.* (Long distance increases the use of fuel for transportation but the closer the landfill is to the place where waste is generated, the larger the risk of negative impacts on humans.)
- *Access to the site.* (A landfill leads to increased truck traffic and roads might have to be upgraded.)
- *Distance to surface water including lakes, rivers, wetlands etc. and ground water.* (The further away the landfill is from water the better, since this lowers the risk of surface- or ground water contamination.)
- *Permeability and stability of the bedrock.* (A geologically stable area decreases the health- and environmental risks and less permeable bedrock lowers the risk of ground water pollution.)
- *The character of the waste.* (The suitability of a landfill siting differs with the character of the waste planned to be disposed there.)
- *Public acceptance.* (The public acceptance varies and low public acceptance increases the distance needed between the landfill and any residential areas.)
- *Access to cover material.* (An ideal siting has good access to adequate soil cover material.)
- *Current and historical land use.* (The suitability of a landfill siting varies with the current land use as well as the historical land use.)
- *Local climate and predominant wind direction.* (Climate such as precipitation and temperature vary locally. Less precipitation means less risk of water contamination. Consideration of wind direction is of importance in order to minimize the amount of people affected by odour from the landfill.)

(Lagerkvist, 1999: Kurian et. al, 2008: Knödel et al, 2007)

2.4 How to investigate a landfill with limited resources

Methods to investigate a landfill with limited resources and with methods applicable in developing countries will be described in this chapter. The take-off point is open dumpsites, since this is the most common way of waste disposal in low-income countries. This chapter is based on literature research as well as interviews with Swedish experts with experience of waste treatment in developing countries.

The general starting-point for investigation of a landfill with limited resources is to conduct as much of the analyse possible through map studies of the area. Drilling and chemical analyses should only be made if it is economically viable. (Knödel et al, 2007: Rosqvist, 2012)

2.4.1 Historical review

The starting-point of a landfill investigation should be to obtain as much information as possible about the sites' history. This information can sometimes be found in official documents and can also be gathered through interviews with people who live or used to live or work in the area. Information of interest is for instance the prior use of the area, the construction of the landfill, used treatment methods, the time of operation, the waste composition and waste quantities disposed. (Knödel et al, 2007)

More expensive methods include for instance the use of electromagnetic methods to identify concealed abandoned landfills and hyperspectral scanning to investigate the internal structure of a landfill. (Knödel et al, 2007)

2.4.2 Landfill appearance, accessibility, land use and vegetation in the surroundings

The appearance of a landfill can be described in terms of for instance slope gradient, compaction level, smell, vermin, nature and dispersion of different waste types, method of waste disposing and security systems. The information can be gained through maps, interviews and through visits to the site.

The accessibility of a landfill is investigated through analysing the number and quality of roads between the landfill and the area where waste is generated (Kurian et. al, 2008). The distance between the landfill and the area where waste is generated is of interest as well as the traffic pattern of these roads, the type of vehicles used for collecting and disposing waste and the fuel they use (Lagerkvist, 1999). This information can either be gained through observations, through interviews or through reports and maps.

The appearance of landfill surroundings is described through analysing maps and photos and by visits to the area. Information of interest is for instance land use, vegetation, settlements (especially distance to the nearest neighbour and number of residents affected by the landfill), businesses in the area that might affect the environment, eventual surface water in the area, geologic structures, topography, ecological aspects such as nature reserves or water protection areas. (Knödel et al, 2007)

2.4.3 Decomposition phase

The currently dominating decomposition phase of a landfill is of interest since the level of different pollutants varies with the phases. A quite simple way to estimate the decomposition phase is to measure the ratio between biological oxygen demand, BOD, and chemical oxygen demand, COD in the leachate. This ratio is much higher in the initial phases than in the later ones. Another way to estimate decomposition phase is through measuring pH, which is low in the acidogenic phase and higher in the aerobic and methanogenic phase. (SGI, 2011)

2.4.4 Potential for landfill gas and air quality

Landfill gas is only produced under anaerobic conditions and the efficiency of the process is affected by for instance moisture, temperature, nutrients and pH. The landfill gas potential depends on the amount of degradable organic carbon in the waste together with the conditions under which it is degraded. Gas is produced fast in easily degradable waste but can stop completely in dry waste and if the landfill is covered. Normally the gas production is estimated to decrease exponentially. Gas production is however not consistent and there is a tendency for gas pressure to build up in areas of a landfill and to leave the landfill in pushes. (SGI, 2011) Landfill gas production can be estimated using synoptic equations (Lagerkvist, 2003). It can also be measured to fairly low cost using gas chambers that are placed over randomly drilled holes at a landfill during a defined period. After this period the gas produced is measured. If more resources are available special methane gas gauges can be used to measure gas content in drilled holes. (Hogland, 2011: Rosqvist, 2012)

Burning of waste on landfills, often practised in developing countries to reduce volume, can result in emissions of toxic substances to the air including nitrogen oxides, sulphur oxides, dioxins, furans, heavy metals (mercury, lead, chromium, cadmium, etc) and particulate matter. Information might be found in reports of air-quality. The pollutants deriving from burning of waste can otherwise be measured through sample-taking and analyses using a gas chromatograph. This is however costly. (Kurian et al, 2008)

The level of smell deriving from a landfill might be hard to compute. One way is to ask people living nearby how they experience the smell. Another way to go about it can be to measure emissions of hydrogen sulphide, since this is one of the major sources of bad smell from a landfill.

2.4.5 Waste composition

The environmental and social effect of a landfill differs with the character of the waste disposed there. Recommended treatment of the waste on a landfill differs likewise. Waste composition analyse can be made to figure out the level of for instance hazardous waste, the moisture content, the contamination level and the calorific value.

Waste composition can be examined either at the primary source, at the collection point or at the landfill depending on the purpose of the study. The waste composition at these locations usually differs, for instance the level of

valuables, such as metals, are likely to be reduced at the collection points and further reduced at the landfill. Waste composition also differs with season and time of the week or day. Interviews with locals may help to determine a good time for the survey when representative data can be gathered. The sites where the waste composition is analysed must be randomly selected to ensure the reliability of the analyse. The statistical accuracy and confidence level increases with higher number of samples. For waste composition analyze the confidence level is usually set between 80% and 90%. The number of samples needed to reach this confidence level is affected by the variation of waste types in the samples. (UNEP3, 2009)

Methods to examine waste composition can be divided in two categories, ocular examination and characterization through hand sorting. They differ in terms of cost and effort and which one to use depends on the available resources and the information requirements. Ocular examination is cheaper and when the waste is fairly homogenous it is a suitable method. Weight estimation of different waste types can be done by applying volume-to-weight conversion factors. There are general volume-to-weight conversion factors, but ideally these should be locally established. When hand sorting a scale is used for the weight estimation. (UNEP3, 2009)

Ocular waste composition analyse on garbage trucks
The waste composition can be analyzed through observing and estimating the unsorted waste in the waste trucks reaching a landfill. Through estimations of the volume of the waste trucks and calculations of the number of trucks reaching the landfill each day, the daily and annual amount of different waste types reaching the landfill can be estimated. (Retzner, 2012)

Ocular waste composition analyse on the landfill
Waste composition can be analysed through recording of different types of waste at randomly selected sites on a landfill. In order to increase the repeatability and reliability in the ocular examinations a quadratic frame, for instance 1x1 meter, with a grid can be placed on each site. (Retzner, 2012)

If the volume of the landfill is known, the volume of the different waste types on the landfill can be estimated based on the assumption that the areal distribution is the same as the bulk distribution. The reliability in this assumption can be judged through interviews with local experts. It can also be more precisely estimated through drilling of holes at randomly selected sites and recording of depth variations.

Waste composition analyse on a landfill using hand sorting
Waste composition on a landfill might also be analysed through hand sorting. In order to get representative data it is of importance to know how the landfill is built up. For instance, if the landfill is divided in cells samples should be taken from different cells. (Hogland, 2011)

The take-off point is digging or drilling a couple of holes. A number of representative scoops of waste are collected in (eventual) different cells and at

different depths. The waste is then mixed together and divided in fourths, mixed and divided in fourths until 200 - 1000 kg remains. The waste is roughly divided into different waste types and then divided further in finer and finer fractions. The last division is made using a tweezer. (Hogland, 2011)

The most cost effective way to analyse waste composition through sorting in developing countries is likely through manpower. However, a project with larger resources might use a trommel, a cylinder used to separate materials by size. (Hogland, 2011)

2.4.6 Climate and predominant wind direction and force

The local climate including for instance annual precipitation, mean evapotranspiration and mean temperature have an effect on for instance the production of leachate (SGI, 2011). Predominant wind direction and force as well as the frequency of strong winds are of interest in evaluating the spread of smell, dust and airborne pollutants (Knödel et al, 2007). Both climate data and wind data might be found in scientific reports, maps or other official documents.

2.4.7 Hydrogeology, soil quality, ground and surface water quality

Knowledge about the stability of the ground on a landfill is necessary for a risk assessment. The groundwater system that might be affected by a landfill includes >10 km^2 and during a landfill investigation a general survey of this area is recommended. A detailed study should in general be carried out in an area of 0.1-1 km^2 and to a depth of 50 meters around the landfill itself. (Knödel et al, 2007)

Maps and satellite images are good take-off points when analysing the environmental effects from a landfill on the bedrock and groundwater system. Parameters to be analysed are for instance thickness and homogeneity of geological units, geotechnical stability, frequency of geogenic events, chemical composition of the soil, groundwater table, groundwater flow and hydraulic conductivity. A field survey gives further information about hydrogeology, soil quality and the ground and surface water situation. For instance can abnormal plant growth, discoloration of soil and visibly wet areas in the surroundings of a landfill indicate potential groundwater contamination. (Knödel et al, 2007) The risk of groundwater contaminated by for instance heavy metals, aromatic hydrocarbons and other toxic organic substances can be estimated through a survey of the businesses in the surrounding area that could contribute with for instance drug residues and pesticides. (Rönnols, 2012)

Shallow drilling and sample-taking can be used as means in the investigation if more resources are available. (Knödel et al, 2007) A landfill can include almost all types of contaminants simultaneously and it is challenging to conduct a representative sample-taking of solid material. Outside the landfill it is usually enough to examine electrical conductivity, chloride and ammonium levels in the surface and/or groundwater. If no enhanced levels are found, it is unlikely that the levels of other substances are high. (SGI, 2011)

Ground and surface water quality investigation with limited resources
If wet areas are detected close to a landfill sample-taking and chemical analysis of surface and groundwater is recommended. (Knödel et al, 2007) A good take off point is to examine pH and conductivity upstream, downstream and around the landfill at different distances from it (Rosqvist, 2012). Leakage from a landfill generally lowers pH and increases the conductivity in the run off water. Electrical conductivity is a sensitive parameter for monitoring contaminants from landfills in soil and water but it does not give any information about metal concentrations. Further more conductivity cannot be trusted as a measurement of contaminants if there is a risk of salt-water intrusion. (Knödel et al, 2007: Rönnols, 2012: Rosqvist, 2012) The salinity level can be used as an indication of salt-water intrusion (Jumbe, 2012). In ten Swedish landfills, unaffected by salt-water, mean salinity is 8.3 ppm (SGI, 2011).

For a more detailed ground and surface water analysis, to indicate if there is an influence from a landfill, measurements of the following parameters could be prioritized, according to Rönnols: BOD, COD, suspended material, conductivity, sulfate, chloride, pH, total-nitrogen, ammonium-nitrogen, total-phosphorus, heavy metals (zinc, cadmium, lead, chrome, nickel, iron, manganese, mercury). (Rönnols, 2012) The oxygen concentration in ground and surface water affects the water quality for living organisms and the chemical reactions that occur in the water (Knödel et al, 2007). High oxygen consumption can lead to anaerobic conditions in the ground or surface water, which in turn leads to smell through hydrogen sulfide production. BOD and COD are indicators of the amount of oxygen consuming matter in the water. (Rönnols, 2012)

The level of suspended material, a measure of the particles able to settle, is of interest in the selection of leachate treatment method. Particles can settle in ponds while soluble material have to be precipitated or anaerobically digested. A simple way to estimate if the contaminants are dissolved or attached to solids is to compare analysis of filtered and unfiltered water samples. (Rönnols, 2012)

Sulfate levels are usually high in the initial acidogenic phase. The concentration later decreases through reduction to sulfite and during the following methanogenic phase sulfate levels are low. Sulfate levels can be used to estimate the dominating decomposition phase of a landfill and since hydrogen sulfite is one of the major sources of bad smell from a landfill it is of interest to know the levels. Sulfite also forms strong chemical compounds with metals and is considered one of the major binding mechanisms for heavy metals in a landfill. (SGI, 2011)

High levels of ammonium-nitrogen and chlorides are an indication of contaminated water. The level of ammonium and chloride is often used to judge the leachates' toxicity since ammonium and chlorides might conceal other substances. Ammonium is in equilibrium with ammoniac and can also be nitrified to nitrate and denitrified to nitrogen gas. Both ammonium and nitrate contributes to eutrophication. Saltwater recipients are extra sensitive to high levels of nitrate since their limiting factor is phosphate. For freshwater recipients it is the other way around, for them phosphate is the biggest contributor to

eutrophication. The toxicity of ammonium depends on temperature and pH since this affects the ammonium/ammoniac equilibrium. Canadian guidelines for acceptable levels of ammonium during different pH and temperature conditions are presented in Figure 3. (SGI, 2011)

Temp ^{o}C	pH							
	6	6,5	7	7,5	8	8,5	9	10
0	231	73,0	23,1	7,32	2,33	0,794	0,250	0,042
5	153	48,3	15,3	4,84	1,54	0,502	0,172	0,034
10	102	32,4	10,3	3,26	1,04	0,343	0,121	0,029
15	69,7	22,0	6,98	2022	0,715	0,239	0,089	0,026
20	48,0	15,2	4,82	1,54	0,499	0,171	0,067	0,024
25	33,5	10,6	3,37	1,08	0,354	0,125	0,052	0,022
30	23,7	7,50	2,39	0,767	0,256	0,094	0,043	0,021

Figure 3. Canadian guidelines for ammonium levels in water (mg/l) if aquatic life is to be kept safe. (SGI, 2011)

Heavy metals are not as common in leachate as one could think considering the metal concentrations disposed on a landfill. The levels normally meet the standards of drinking water. The methanogenic phase usually has the lowest levels of metal concentrations in the leachate due to its high pH. The toxicity of heavy metals is dependent on their state. Free ions have the highest toxicity. Mercury, cadmium, chrome and lead are highly toxic for many organisms and therefore interesting to measure. However levels are normally so low that they are immeasurable. Iron is usually available in high levels and easy to measure. Conclusions about other metal levels can usually be drawn based on the availability of iron. Conclusions can also be drawn based on pH. Higher pH is an indication of less free metal ions. (Rönnols, 2012: SGI, 2011)

World Health Organization, WHO, provides international guidelines for drinking water quality in order to provide safe drinking water, which is important for health and development. The guidelines include recommendations on how to manage risks that may affect the access to safe drinking water, minimal requirements on drinking water and guideline values regarding indicators of water quality. The purpose is to provide guidance when developing national standards for drinking water. (WHO, 2011)

2.4.8 Social and health impact

Waste in an open dumpsite can become a breeding ground for potential carriers of diseases such as vermin and flies. Burning of waste can cause chronic respiratory and other diseases. (UNEP1, 2005) Flooding of landfills might lead to the spread of waterborne diseases, for instance cholera (ACRA, 2012). Potential psychological affects related to the landfill such as visual impact, smell and anxiety must also be taken into consideration together with the conditions for the workers on the landfill. (Kurian et. al, 2008)

In order to examine the level of social and health impact from a landfill it is of interest to figure out the number of people that could be affected by the landfill as well as to find out if there are especially sensitive populations. (Kurian et. al, 2008) The potential effect of airborne pollution on public health can be evaluated through wind data, including wind direction and force. If a landfill is believed to cause public health issues one way to examine it is to physically examine children and adolescence living in its surroundings and compare their results with children and adolescence from other areas (UNEP2, 2007). This might however be a costly procedure. A more inexpensive procedure is to interview people living close to the landfill. The workers conditions can be estimated through checking the workers access to eventual safety equipment and training in safety procedures. It can also be analyzed to some extent through data over physical wounds (in case it is available).

3 Background to Zanzibar and its waste management system

This chapter is based on literature reviews, interviews made on Zanzibar and with experts of the islands as well as observations made during the field study on Zanzibar.

3.1 An introduction to Zanzibar

Zanzibar consists of several islands situated in the Indian Ocean outside the coast of Tanzania in East Africa, see Figure 1. The two main islands are called Unguja and Pemba. Unguja is 1 666 km^2 and Pemba is 988 km^2, which together almost compares to the size of the Swedish island Gotland. According to the last national census made in 2002 Zanzibar has a population of 982 000 people. This population is believed to have increased to 1.3 million people in 2010. Unguja, the largest island and often referred to as Zanzibar, held 622 500 inhabitants in 2002 and is estimated to have 745 000 inhabitants 2010. (NE, 2011: NB, 2011)

Unguja has five regions, each with two districts, and each district is subdivided into shehias. A shehia is a small administrative unit, which in urban areas is a demarcated area and in the countryside consists of one or several villages. (ZSDP1, 2005) Zanzibar Town, commonly referred to as Stone Town, is the capitol of Zanzibar. It is situated on the west coast of Unguja and has about 200 000 habitants, making it the largest city of Zanzibar. (ZSDP1, 2005)

While speaking of Zanzibar in this Master thesis we will only include Unguja and while speaking of Stone Town we will refer to Zanzibar Town.

Society

The major part of the population is Africans who stem from the mainland, but there is also a group of Arab descendants as well as minority of people with Indian roots. About 97% of the population are Muslim. Main language is Swahili but English is widely spoken and many people also speak Arabic. (UI, 2012: NE, 2011: ZTC, 2011)

Primary school enrolment in Zanzibar improved from 75.5% in 2006 to 81.4% in 2010 but about 40% of the Zanzibaris are still illiterate and 60% of these are women. (AEO, 2011: ZPRP, 2011) The school facilities are poor and the students

have to pay for schoolbooks and school uniforms themselves. It is uncommon that Zanzibari students continue to the university. (Tobisson, 2011)

Freedom of the press is not guaranteed on Zanzibar and there have been incidents where the regime has tried to stop journalists and newspapers from publishing. There is a governmental television channel on the islands but it has limited reach and radio is still the most important channel of information for a majority of the population. Both the television channel and the radio are controlled by the state. (UI, 2012: UD, 2007) Scientific information, maps and other data are difficult to access on Zanzibar. The studies made on Zanzibar are few and reports are treated as merchandise. Freedom of information legislation is not practised.

Zanzibar is an autonomous part of Tanzania since 1964. (NE, 2011) It has its own parliament, government and constitution with decisive power in questions regarding Zanzibar. (UI, 2012) The last election was held in 2010 and resulted in a unity government. The president and the second vice president are from the socialistic party, CCM, and the first vice president is from the liberal party, CUF, who mainly gets their support from the Muslim population. (UI, 2012: AED, 2012) Zanzibar Municipal Council, ZMC, and the shehias are part of the executive power and have decisive power in some questions concerning their geographic region. Zanzibaris have a deep respect for the elders and this is shown in the dynamics of a village where the elders often make up village councils, the decision making function of the village.

In a restricted project appraisal document, written in 2011 of a well-recognized, supranational organization, the Zanzibarian government is described as dysfunctional. Several problems are mentioned including unclear assignment of responsibilities, lack of appropriately trained personnel and limited authority and resources transferred to the shehias and ZMC. People working in departments under the government are not always paid by the end of the month. During the eight-week field study this happened once and was explained to happen frequently.

The legal system has improved lately but it is still inefficient and corrupted. Human rights organization Amnesty International has several times criticised Tanzania for detaining people because of their beliefs. According to Amnesty International and the Swedish Ministry of Foreign Affairs this is especially common on Zanzibar. (UI, 2012: UD, 2007) During the field survey on Zanzibar drivers were observed to bribe policemen on daily basis. Policemen appear to have made a business out of standing along the road claiming money from cars passing by.

Women have gained social status in the last twenty years. A major drive is seaweed cultivation, which mainly employ women and provide them with an extra income. The women who are successful seaweed growers sometimes take the initiative to divorce their husbands. However men have single right to the children after a divorce and also inherit twice as much as women. Men are entitled to four wives, this is uncommon, but many have two wives. The

parliament has to have a certain number of women, however these are usually quoted in since not enough women are elected. (UD, 2007: Tobisson, 2011)

Tourism
Zanzibar has three principal drives of economic growth: tourism, agriculture and trade. Tourism is the largest employer and one of the most important economic activities. Tourist arrivals increased by 8% between 2005 and 2009, reaching 135 000 tourists in 2009. (POFEDP, 2011) The ambition of the government is to increase the tourism industry focused on high spending tourists. (Tobisson, 2011) However, a problem related to tourism increase is the overuse of freshwater, which might lead to seawater intrusion in wells. In Nungwi in the northern part of Zanzibar none of the wells contain freshwater anymore and in other areas of the island increasing salinity have been recorded. (Gössling, 2001) Today the risk of a well being affected by seawater can not be excluded in any area of Zanzibar (Jumbe, 2012).

Furthermore the tourism business is viewed as an annoyance by many of the elders. The western dress code, the parties, the alcohol and loud music are generally not appreciated. Several beach bars in the village Paje have had to close the last years due to heavy complaints from the villagers. In Paje there is also a conflict between the kite surfing businesses for tourists and the women involved in seaweed cultivation where both parties want the beach to themselves. However everybody does not have a negative attitude towards the tourists. Shop owners and people involved in the trade business appreciate the increase in income that the tourism gives.

Economy
Tanzania is one of the poorest countries in the world and also one of the countries most dependent of international aid. Almost nine out of ten development projects and close to half of the government's expenses are funded through aid money. The economy is however starting to recover. Tanzania had a GDP growth of 6.8 % in 2010 making it one of the fastest growing economies in Africa. The prevalence of poverty in Zanzibar is expected to have declined from 49 % in 2004 to 40 % in 2009. (UI, 2012: AEO, 2011) While the Government of Tanzania has accepted aid assistance for a long time, Zanzibar did not open up for aid workers until the 1970's. Partly due to this Zanzibar has remained relatively poor and the education sector lags behind that of mainland Tanzania. (Tobisson, 2011)

Agriculture is a large employer and engages slightly more than one third of the population. It is mainly dominated by small-scale-subsistence farming with low productivity of land. (POFEDP, 2011) Seaweed is a relatively new export that was introduced in 1990 and has gained importance (Tobisson et al, 1998). Zanzibar used to be the world's biggest producer of cloves but has recently lost their dominance to Indonesia. Regarding the trade, it could increase in importance since the country's capacity to export is still to be exploited. (UI, 2012: POFEDP, 2011)

The industry on Zanzibar is almost non-existing. This is partly due to almost daily recurring power-cuts. The electricity on Zanzibar is produced by waterpower in Tanzania that are subject to frequent draught leading to water scarcity. Other reasons for the weak industrial sector is a poorly maintained transport network, low domestic demand and currency shortage that hinder reparations and import of spare parts. (UI, 2012)

Nature, wildlife and environmental challenges
Zanzibar is the habitat of several unusual animals and plants, for instance the red-listed Red Colobus Monkey that only lives on Zanzibar and the endangered Jozani frog. Mangrove forests with high biodiversity grow along the shorelines and the marine wildlife is rich. Marine conservation zones surrounds the islands with the purpose to protect the coral reefs. The coral reefs are however rapidly degrading and marine wildlife is decreasing. This is recognized as one of the major environmental threats by the government. (MANZ, 2011: CTZ, 2011)

Today's population growth on Zanzibar is putting pressure on the environment, especially in the coastal zones and urban areas. (MANZ, 2011) The islands also struggle with forest degradation due to illegal deforestation, illegal limestone and sand mining as well as soil degradation. (Mwinyi, 2012: Jumbe, 2012)

Zanzibar is currently preparing for climate change. The island is not in the cyclone area but stands a risk for more heavy rains and tsunamis. (Jumbe, 2012) The sensitive and rich wildlife of Zanzibar makes it an important environment to protect in a global perspective and in the context of the UN Convention on Biological Diversity.

Climate and hydrogeological conditions
Zanzibar has tropic monsoonal climate with high temperature all year. The coolest month, July, has a mean temperature of 25°C while the hottest month, February, has a mean temperature of 28°C. The rainy season occurs between April and May and normally there is a shorter rain season in November and December. (NE, 2011)

The western part of the island receives more rain than the east and south part due to the topography of the island. The annual rainfall in the western part is up to 2000 mm while on the east and south part it differs between 1000-1500 mm. In comparison the annual rainfall in Sweden varies between 500-1500 mm. However evapotranspiration on Zanzibar is much higher than in Sweden. High evapotranspiration in combination with water tables close to the sea level and shallow freshwater lenses makes access to freshwater in some parts of the islands poor during the dry season. (Lagerkvist, 1999: Colbert et al, 1987: Gössling, 2001)

The bedrock on Zanzibar was formed during the Miocene and Quaternary time and mainly consists of coral limestone, for more details see Figure 4. Coral limestone is formed almost completely from corals but is chemically almost the same as regular limestone. It is a sedimentary rock, which is basic and has high permeability making drainage fast. The soils are mostly sandy mixed with loam

and clay. Most soils are fertile and good for cultivation of tropical crops such as coconuts and spices. In central Zanzibar clove cultivations are common. However todays intensified cultivation and vast population growth leads to fast degradation of the soils. (Gössling, 2001: NE, 2011: RGZ, 2008: Colbert et al, 1987)

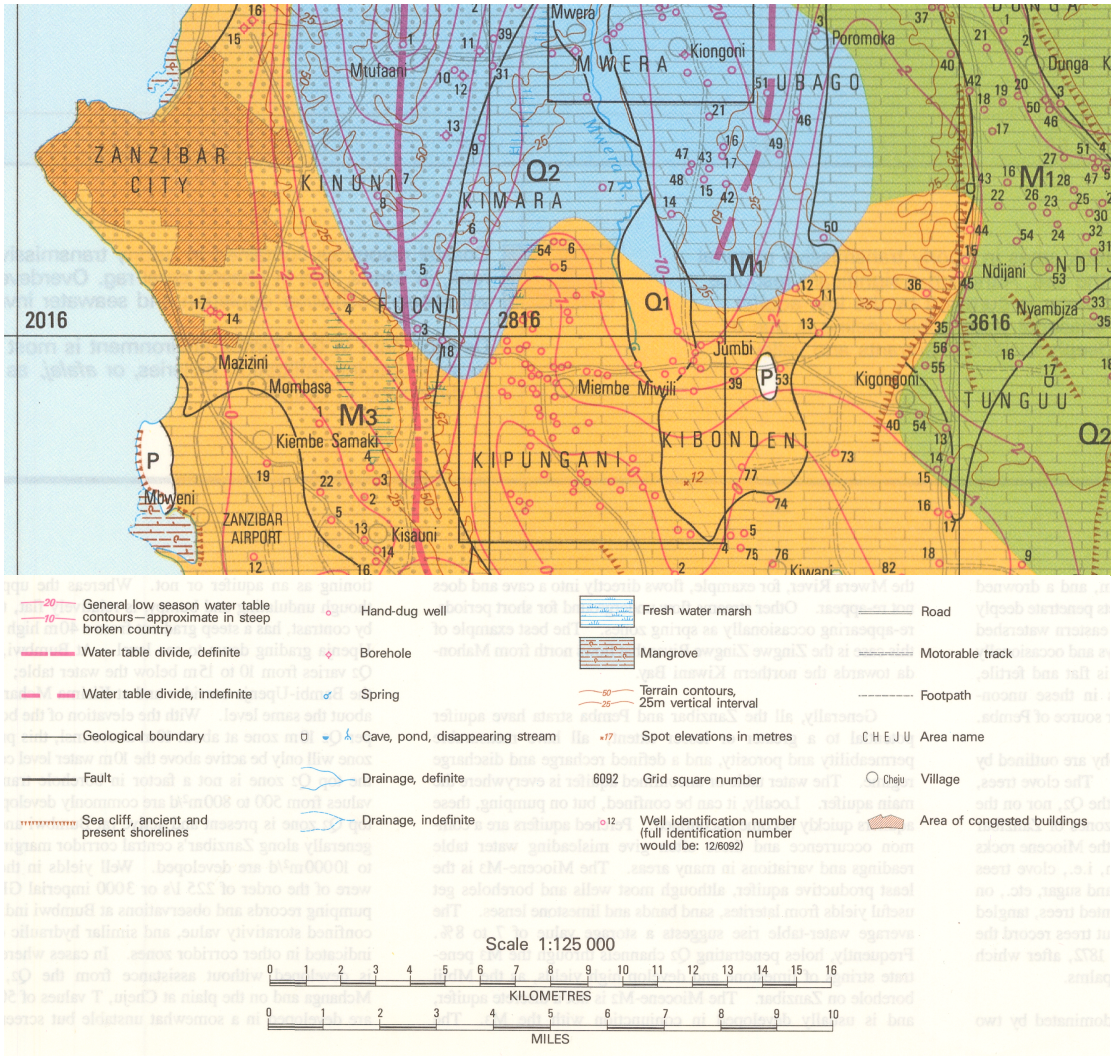

Figure 4. Hydrogeological map over Stone Town with surroundings. (Colbert et al, 1987)

Culture and mind

The following part focuses on the differences, from a Swede's perspective, of the Zanzibaris culture in general and more specific on business culture and Zanzibaris relationship to the environment.

Zanzibaris value personal relationships and businesses are almost only made with people who are thought of as trusted friends. Written contracts are therefore of little importance and agreements are preferably made in front of reliable witnesses such as family or relatives. People are usually hired due to kinship. (UI, 2012)

Zanzibaris does in general not use the word “no” nor admit to not knowing the answer to a question. Instead they postpone the answer or make up an answer. Punctuality is uncommon and schedules are seldom kept. (UI, 2012)

Zanzibaris are in generally indifferent to the nature and do not consider or reflect over its aesthetic values. The understanding of environmental issues and threats is also low. Those who are dependent of the sea do however show a greater level of environmental awareness and usually hold great knowledge of the local nature based on the experience of several generations. (Tobisson et al, 1998: Tobisson, 2011)

The level of public awareness in achieving sustainable management of MSW is also low. (SMOLE1, 2011) The common way to get rid of waste is to drop it directly on the ground. Recently a campaign against plastic bags showing a cow being smothered by waste has however raised public awareness on the effect of waste on animals. (Tobisson, 2011) During the field study the effect of waste on cattle was repeatedly referred to as the major waste challenge.

The sea is in some areas of Zanzibar used for waste disposal. During low tide people dump waste at the shoreline, which is later washed away by the high tide. (Tobisson, 2011) Things defined as waste in Sweden is however seldom recognized as waste on Zanzibar. There is an informal reuse and recycling system, which makes for instance plastic and metal rare components in the waste collection points and dumpsites. Plastic bottles are often reused several times. A common notion is that waste is a problem related to tourism and that tourists alone are the ones guilty of creating waste.

3.2 Todays waste situation on Zanzibar

Zanzibar is today highly littered and polluted by waste. Waste is lying everywhere for instance on the ground, in the streets, in the backyards and on the beaches. Cattle and other animals are frequently seen walking around in the waste eating from it. Children are often observed playing in the waste and people have been seen picking stuff out from the waste in dumping areas. Almost every morning and sometimes at other hours during the day there is a strong smell of waste being burnt in the backyards and by the streets.

There is currently no national policy regarding waste management on Zanzibar. Governmental waste management efforts have so far only focused on Stone Town and resources outside this area, where most of the population resides, have been very limited. (SMOLE1, 2011) No formal dumpsites exist on the island, instead waste is being dumped in farming areas, in the bush and in old quarries used as informal dumping areas. It is estimated that 650 tonnes of solid waste is generated on the islands per day (SMOLE2, 2011). In Stone Town ZMC administers a waste collection system, which today only manages to take care of 45% of the waste generated in the town (Juma, 2012). Outside Stone Town more or less formal waste collection systems take care of waste generated in the villages, there is however no documentation of how they handle it or how much waste they handle.

One recent governmental initiative is a ban on the use of plastic bags. Since August 2011 it is illegal to manufacture, distribute, sell, store and use all sorts of plastic bags on the islands. The reason for the ban is that plastic bags are considered to contribute largely to littering and violation of the ban can lead to fines or prison in six months. (EABW, 2011: TDN, 2011) However during the field study plastic bags were observed to be used frequently on the markets with no fear of consequences.

Waste management on Zanzibar is today severely hampered due to lack of resources (Juma, 2012). It is dependent on development aid money and several international organizations and government agencies are present on the island, for instance Italian ACRA (Associazione di Cooperazione Rurale in Africa e in America Latina), Finnish SMOLE (Sustainable Management of Land and Environments), UN-HABITAT and The World Bank. There have been several projects focused on remediation of the waste situation and there are also initiatives planned for the future. (SMOLE1, 2011: ZSDP1, 2005: BP, 2011) Many projects however struggle with lack of end-strategies and lack of commitment from governmental institutes.

The level of public awareness regarding the waste situation is low and so is also the willingness and ability to pay for waste related services (SMOLE1, 2011: Juma, 2012). Some hotel-owners do however ask for better waste management services and are willing to pay for it. Some of them are today served by private initiatives that collect their waste but there is no record of where this waste ends up. (Lundsor, 2011)

Today's lack of proper waste management contributes to outbreaks of cholera, typhoid and malaria, as well as contamination of water sources, flooding and animal extermination. (ZP, 2011: Vuai, 2010)

In a report written in 2005 by H.P. Gauff Ingenieure on behalf of the Zanzibar Municipal Council, suggestions regarding future improvements of the waste management system on Zanzibar are made (ZSDP1, 2005). The recommendations include implementation of an affordable, effective and sustainable collection system in Stone Town and safety clothes for the waste collectors and conversion of organic waste in MSW to compost. The authors also highlight the importance of a new, engineered landfill and recommend it to be built in Kisakasaka before the end of 2006. In the meantime the authors recommend Jumbi landfill to be upgraded with a leachate storage tank, fencing and better compaction of waste. (ZSDP1, 2005)

3.2.1 Waste composition

206 tonnes of MSW (including domestic waste, commercial waste, waste from public institutions, waste from street sweeping and waste from harbour and industry) was generated daily in Stone Town in 2002. In 2010 this figure had increased to 220 tonnes, correlating to a volume of almost 235 000 m^3 (Juma, 2012). The majority of the waste (74%) in Stone Town has domestic or commercial origin. (ZSDP2, 2005: Juma, 2012) The waste composition of the waste generated outside Stone Town is unknown.

The daily production of domestic waste was estimated to 90.3 tonnes in 2002 and the average density was 0.33 kg/l. With a population of 206 293 in Stone Town 2002, the daily waste production rate per person is calculated to 0,45 kg/day. In 2010 this rate had risen to 0.5 kg/day and person. (ZSDP2, 2005: Juma, 2012) In Sweden the waste production rate per person was 463 kg/year in 2010, which means that the daily waste production rate was about 1.27 kg/person. (SOPOR, 2012) In low-income countries the waste production rate is 0.4-0.6 kg/day and person. (ZSDP2, 2005) Considering this, the figures for Zanzibar seem realistic.

A forecast of future waste quantities in Stone Town is described in Table 1. It is based on a population growth of 1.72% and annum, the assumption that the amount of household waste will not change much and that the growth rate of commercial and institutional waste will be similar to the population growth. (ZSDP2, 2005)

Table 1. Forecast of future waste quantities in Stone Town in tonnes per day. (ZSDP2, 2005)

Year	Domestic waste	Commercial waste	Waste from public institutions	Waste from street sweeping	Waste from harbour and industry	Total
2002	90.3	62.5	25	12.5	15.5	**205.8**
2011	105.3	72.9	27	13.7	15.5	**234.3**
2012	107.1	74.1	27.2	18.8	15.5	**237.8**
2013	109	75.9	27.5	13.9	15.5	**241.3**
2014	110.8	76.7	27.7	14.1	15.5	**244.8**
2015	112.7	78	27.9	14.2	15.5	**248.4**

There is a tendency that other types of waste than organic waste, in particular plastic and e-wastes, are increasing rapidly. (SMOLE1, 2011)

Waste composition study in Stone Town 2005

In 2005 a feasibility study of the waste composition in Stone Town was made. The study was conducted in different parts of the town, all representing different income groups. The study took place during the rain season. There is a variation in waste composition and waste production rates between dry and rain season and this difference was not taken into account. It may however be assumed that this difference is smaller than in countries with more distinct climate differences. The study showed that the major domestic waste fraction in Stone Town was organic (85.6wt%). The second largest fraction was plastic (4.4wt%). Paper and cardboard represented 2.7wt% and metal made up 0.2wt% of the waste. The complete results of the study are seen in Table 2. (ZSDP2, 2005)

Table 2. Average composition of household waste in Stone Town 2005. (ZSDP2, 2005)

Waste fraction	wt%
Organic	85.6
Plastic film	3.6
Plastic bottles	0.8
Paper	2.1
Cardboard	0.6
Textiles	2.5
Metal	0.2
Wood	1.04
Glass	0.4
Diapers	1.9
Non-classified	2.2

3.2.2 Existing local waste projects

There are a few small-scale local pilots handling solid waste on Zanzibar. Since there is no umbrella-organization and information about these initiatives is forwarded mouth-to-mouth the list is most likely incomplete. The following chapter does not include large-scale initiatives from big organizations such as the World Bank and UN-HABITAT.

Zanzibar Scrapers Environment Association, ZASEA

ZASEA is a registered NGO in Stone Town that handles waste and is funded by several different stakeholders one of them is UN-HABITAT. They collect, treat and sell different types of waste such as plastics, aluminium, stainless steel and electrical items. 35 people work at ZASEA, which is a youth project where all participants are under the age of 32. Waste is brought to ZASEA from Matemwe dumpsite and from street boys. Jamabeco organisation also wants to start bring their gathered plastic bottles to ZASEA. (Hamed, 2012)

The main business is plastics and today they shred and mix PP (polypropylene) and PET (polyethylene terephthalate) plastics and sell it to Dar es Salaam, Tanzania. Each day ZASEA receives 0.5–1 tonnes of plastic but they have a capacity to handle up to 2 tonnes a day. ZASEA are currently unable to recycle hard plastics, plastic bags and glass but aim to do so in the future. (SMOLE2, 2011: Hamed, 2012)

Matemwe dumpsite

Matemwe dumpsite is a NGO (non governmental organization) since 2001 located in the village Matemwe on the northeast coast, which focus on collecting MSW from hotels in the area. Contracted hotels pay a monthly fee to get their waste collected on a daily basis. On the dumpsite waste is separated into different fractions including plastics, metals, organic waste and glass and some fractions are sold. For instance plastic is sold to ZASEA. The organic waste is

made into compost on the dumpsite but the production sometimes struggles with water scarcity. (SMOLE2, 2011: Lundsor, 2011)

Jamabeco, Jambiani Marine and Beach conservation
Jamabeco was founded in the village Jambiani in 2001, registered in 2005 and currently have 35 members. It is a NGO founded by ReCoMap with the aim to make the environment in Jambiani and adjacent villages cleaner. (Okala, 2012)

They have built a waste collection point in Jambiani where plastic and batteries are collected for storage until it can be handled in a sustainable way. A future goal is to build a recycling center in Jambiani. They collaborate with the local schools and kindergartens to educate children in proper waste management sometimes as a waste collection competition. (Okala, 2012)

Zanrec Plastics Ltd
Zanrec Plastics is a private company that plans to implement a locally adapted recycling system on the whole island, starting with paper and plastic, during 2012. The idea is to buy or collect paper and plastic waste, grind it and turn it into recycled raw material, which either is sold or processed into new products. The recycling system project is partly funded by Swedish SIDA. (Alfredsson, 2012)

MCAEE, Matemwe Control Aids Environment and Education
MCAEE started in 2007 and is a community-based organization, which works with poverty innovation. The organization is about to start a project that will convert organic waste into chicken feed through collection of organic waste from the markets in Stone Town in collaboration with ZMC and through collection of coconut leftovers and organic waste from hotels in Matemwe. A survey has been made on the amounts of organic waste possible to collect. The project aims to engage young people between the age of 15 and 32. The goals are to clean the environment, minimizing the waste on the landfills and to lower the price on chickens through lowering the price of chicken feed. (Othman, 2012)

3.3 Todays waste collection system on Zanzibar
The responsibility for the waste management on Zanzibar is on the municipality or on the village council in the different shehias, if there is any organised waste management at all. The municipality in Stone Town are the only ones that own waste trucks.

3.3.1 Todays waste collection system in Stone Town
Generally, all types of waste are mixed and handled together in all steps. (SMOLE1, 2011) The waste composition varies depending on where the collection point is situated, but usually include large amounts of household and commercial waste (ZSDP2, 2005). The municipality offers door to door services at a few streets in Stone Town, collection and transporting of MSW from different collection points and street sweeping. (BP, 2011) Large areas of Stone Town do not have access to regular collection. (ZSDP2, 2005)

It is estimated that 220 tonnes of waste is generated every day in the Stone Town area. About 45 % of this waste is believed to be taken care of by the municipality. Currently this waste is brought to informal dumping areas and farm areas in the town surroundings. This is due to that the official dumpsite on Zanzibar was closed in December 2011. (Juma, 2012) The remaining 55 % of the waste generated in Stone Town is collected and reused by people, incinerated, buried, randomly dumped, eaten by animals, swept away by the rain (into the storm water channels or directly out to the sea) or just stay as accumulated heaps in many parts of the town. (BP, 2011)

The old Stone Town area as well as the western part of Stone town is given priority in waste collection services from the municipality due to their high importance for the tourism. It is estimated that about 80% of the total waste collection workforce is used here. (BP, 2011)

Different types of collection points

There are several types of collection points in Stone Town, for instance open collection on the ground (so called slabs), collection in containers, concrete boxes, bins, wooden sheds and air-conditioned cabins at hotels. Residents can either bring their waste straight to the collection point or leave their waste in plastic bags, plastic bins, larger tins or palm leaf baskets on the roadside for collection during the morning, see Figure 5. Shop owners, restaurants and small guesthouses also put their waste on the roadside. The municipality workmen then walk around in the narrow alleys and empty the waste collected on the roadside in a handcart to bring it to the larger collection points where trucks later can be used for removal of waste from the city centre. (ZSDP1, 2005)

Figure 5. Plastic bin, handcart and braided palm-leaf basket.

A lager collection point is usually a container, a skip, with a volume of 7 m^3 or open collection on the ground, a slab. In total there are about 50 skips and 20 slabs serving the whole town area, these figures do however shift depending on report or person. The skips are usually placed in block tower areas where a lot of people live. (ZSDP1, 2005) It is believed that around 65% of MSW collection in Stone Town is done through skips, while the rest of the collection through slabs, i.e. 35% (Juma, 2012). The frequency of collection is not known but collection is recommended by the municipality to take place at least twice a day at the most frequently used collection points. There is however no schedule for when the waste is collected and the skips tend to be brimful for a long time before being emptied, see Figure 6. Full containers cause both environmental and health problems for people living nearby as animals feed on the waste, scatter it and may transfer pathogenic germs to the population (ZSDP1, 2005).

Figure 6. Brimful skip in a block tower area in Stone Town 27th of January 2012.

The Zanzibar municipal council believes that the current collecting system is inefficient, unhealthy, unhygienic, labour intensive and not suitable to face the current waste situation. (ZSDP2, 2005: Juma, 2012)

Waste trucks

Three different types of waste trucks are currently operating in the Stone Town area. There is a waste truck with a compressor, skip trucks and open trucks, see Figure 7. The open trucks and compressor serves the slabs and the skip trucks pick up the skips. In February 2012, the municipality had six skip trucks but only three of them were working. There are two working open trucks and one working compressor truck. (Juma, 2012) All trucks are old and in bad condition.

Figure 7. A skip truck and a compressor truck in Stone Town the 20th of February 2012.

Two persons usually operate a skip truck, while the compressor truck and open truck has a crew that usually consists of one driver and five or six workmen. Large plastic bags are used as catapults when loading waste from the slabs onto the compressor trucks and open trucks. This method cause intense scattering of waste around the collection point. One loading takes approximately one hour and is both labour intensive and time consuming. The workers do not wear safety clothing to protect them from sharp items and unhygienic waste components.

The accessibility for the collection trucks differs, as the streets in Stone Town usually are narrow, crowded and with sharp corners.

Collection in the Stone Town outskirts

Most waste from the city outskirts is usually brought to small collection points, dumped or incinerated in an uncontrolled manner. During the rain season there is increased environmental and health problem caused by flooding. During dry season the problem with incineration of waste that pollutes the air increases. (ZSDP2, 2005)

In some areas in the outskirts of Stone Town shop owners can subscribe for waste collection from a private person who has made it his living. The shop owners collect their waste in baskets braided by palm leaves and these baskets is later collected using a cart dragged by a cow, see Figure 8. This waste collection is unofficial and not organised by the municipality. Where this type of waste ends up in unknown but it is believed to be dumped in the forest somewhere nearby. Random dumping is high in the outskirts of Stone Town (BP, 2011).

Figure 8. Cart dragged by cow in the Jumbi area 7th of Feruary 2012.

3.3.2 Todays collection system in the village Paje

Paje is a small village with about 3000 residents located on the east coast of Zanzibar. During the tourist season a lot of tourists visit Paje, many of them are kite surfers. The waste generated in the village is taken care of through collaboration between the Danish Adventure School and the Paje village committee. A part of the education at the Adventure School is to build collection points as well as to inform and educate local school children in waste management. Paje village committee consists the village elders, and has one chainman and 20 members. The committee is divided into subgroups, such as water, waste and forest etc. (Luca, 2012)

In Paje waste is burned on regular basis and the collection points were built in order to keep the beach clean. Before the collection points, locals left their waste on the beach to be taken out by the tide, however the beach got filthy leading to bad business for the hotels. (Luca 2012: Kwatcha, 2012) During the field study much waste was seen being burnt, both small fires in the backyards of residents houses as well as big fires burning for hours in the backyards of the hotels.

When the collaboration started eight wooden shed collection points were built at different places in Paje. There were problems with the wooden shed collection points as the wood were stolen, leaving the waste open for animals to feed on it. Another problem was the burning of waste, when burning the waste inside the wooden shed, the shed burnt down. In February 2012 there are four collecting points of different character left. One collection point is a concrete shed with a door, one is made from wood and concrete and two are concrete slabs with one or two concrete walls. (Luca, 2012)

The concrete shed collection point was designed for two waste fractions, one fraction to burn and one not to burn. The fraction not to burn was supposed to be used for compost. However the villagers did not sort properly and the collection of the waste was random, leaving the collection points overloaded with waste as villagers continued to leave their waste outside the collecting points. (Luca, 2012)

In December 2011 the Paje village committee, hotel owners, people from the kite centres and shop owners met to discuss the problem with the brimful waste collection points. The meeting ended with an agreement that all should to pay a monthly fee to the Paje village committee so that they could organise a truck and personnel to empty the collection points at least once a month. So far no money have been collected since the meeting in December 2011, as the hotel owners refuse to pay until Paje village committee can declare how the money collected was used, i.e. who were paid and what did he do for the money. (Mwinyi, 2012: Kwatcha, 2012)

"The villagers are poor and you can not ask them to pay for waste collection and it is the hotels which generate most of the waste. If the collection points aren't emptied, maybe they will start putting waste in the sea again?" (Mwinyi, 2012)

The waste collection from the collection points is supposed to happen once or twice a month. A truck owner in the village does the waste collection and gets paid by the village committee with the money collected from hotels, shop owners and kite centres. The waste is dumped at an informal dumpsite Hakunamajewi, an old quarry a few kilometres outside Paje. (Kwacha, 2012) During the field study none of the collection points were emptied.

4 Results

This chapter is based on results from the field surveys made on Zanzibar.

4.1 Plastic bottle collection at a hotel and in a private house

The purpose of the plastic bottle survey is to make a rough estimation of the annual number of plastic bottles used by tourists on Zanzibar. This is of interest in order to analyse the potential recycling market.

In order to investigate how many plastic bottles one tourist uses per day, used water bottles were collected during two weeks at a hotel and in a private house, where tourists lived, and then counted. The house was used for accommodation and as a workplace. The number of hotel- and houseguests were also recorded during this period. Each bottle contains 1.5 liters of water.

Five people lived in the house during the survey. Week one 55 bottles were gathered and week two 48 bottles were gathered. Mean value of plastic bottles used per person and day was 1.5. This figure does not include water bottles consumed outside the house. However the people in the survey spent most of their time in the house since it served as both office and accommodation.

The hotel survey was unsuccessful since the water bottles collected were stolen before they were counted. The hotel manager believes that children stole the bottles and sold them to women who use them in their juice business.

The number of tourists reaching Zanzibar annually is estimated to be 135 000. Given that each tourist spends 7 days on the islands the annual amount of plastic bottles used by tourists is roughly calculated to 1 400 000. Assuming that one bottle weighs 50 grams the weight of this plastic is approximately 70 tonnes.

In 2010 220 tonnes of MSW was generated daily in Stone Town (Juma, 2012) and according to the waste composition study conducted in 2005 in Stone Town, the plastic bottle waste fraction represents 0.8wt% (ZSDP2, 2005). This implies that about 1.8 tonnes of plastic bottle waste is generated daily and about 640 tonnes yearly. If this is the case, tourism is accountable for 10wt% of the plastic bottle waste generated on the island.

4.2 Field trip with a skip truck

On the 20th of February 2012 a field trip was made with one of the municipalities skip trucks. Two men, working for the municipality, where the ones managing the skip truck, i.e. the pick up and dumping of waste gathered in skips in Stone Town. The driver was handed a list of skips to empty during the day in the municipality office first thing in the morning. Usually 7-11 skips are on the list and the work starts at 5 o'clock in the morning every day of the week. The workday is over when all the skips are emptied. The skip truck used is very old, about 15 years, and the maximum speed of the truck is about 40 km/h.

A full skip was already loaded on the truck when the field trip started at 7 o'clock in the morning in Stone Town. After a drive that lasted about an hour, first on good, asphalted roads then on bumpy roads in the farm areas, the skip was emptied in a forest, about 15 km east of Stone Town, on a farmers land, see Figure 9. The farmer had called the driver earlier that morning to tell him that he wanted waste brought to his farm since it's used as fertilizer. *"Everybody wants the garbage. They use it for growing bananas. They grow very fast when you pour waste on them"*, says the driver. The farmers pay 5000 TSH (about 25 SEK) for one skip of waste if they have money, but if the farmer cannot pay he will get it for free. According to the driver, who has worked with waste collection for three years, this kind of dumping has been going on in the farm areas on Zanzibar for several years or at least as long as he has been working for the municipality.

Figure 9. Skip emptied in the forest in a farm area outside Stone Town the 20th of February 2012.

Once the skip was emptied the truck drove back to Stone Town where the empty skip on the truck was unloaded and replaced with a full one. The new skip was collected in a part of Stone Town with narrow roads not suitable for a truck to drive on. The field trip ended after picking up the new skip.

4.3 Field survey of one waste collection point in Paje

The purpose of the waste collection point survey is to make a rough estimation of the amount of waste generated in Paje. This is of interest in order get some information about waste generation in rural areas since no reports or information regarding this subject has been found.

During six days a collection point in Paje was visited and photographed every evening around 6 pm in order to document the pace of the waste generation.

The collection point chosen for the survey is one of the smallest in Paje and it has not been renovated as some of the others have. However, all collection points are estimated to have about the same number of residents living nearby. The studied collection point is one of the first concrete collection points built by the Danish Adventure School. It is situated close to several hotels, restaurants and residential buildings in the southeast part of the village and is mainly used by the villagers. Cows, goats and chickens are often seen walking around inside the collection point, eating and spreading the waste. Children play in and nearby the collection point and have been observed to collect waste and remove it. There were no extraordinary events, such as holidays or heavy rains, taking place during the survey that could affect the waste amount generated.

During the survey the waste collection point was not emptied a single time and no direct observations were made of people throwing their waste in the collection point. The ocular examination however concluded a daily increase of approximately less than 1 m^3 per day. During 6 days the waste amount was estimated to increase with less than 5 m^3 in total. The increase can be seen in while comparing Figure 10, displaying the waste collection point photographed at day one, and Figure 11, displaying the waste collection point documented at day 6.

Figure 10. Day one of the waste collection survey in Paje (25 February 2012).

Figure 11. Day 6 of the waste collection survey in Paje (1 March 2012).

4.4 Investigation of four landfills/dumping areas on Zanzibar

4.4.1 Introduction

All landfills on Zanzibar are of open dumpsite character. (ZSDP1, 2005) An open dumpsite is a disposal area where waste is indiscriminately thrown or disposed of without planning and consideration to health standards. Furthermore, all landfills on Zanzibar are informal which means that the government does not approve them.

During the field study several dumpsites and dumping areas were visited. They all lack proper siting, control and management. During the rain season they all stand a risk of polluting the environment through heavy leachate release caused by the extreme downpour and lack of lining and cap-system. Burning is a common method to reduce the waste volume on all dumpsites and has a negative effect on air quality and on human health. Animals feeding on the waste have been observed on almost all dumpsites and several mentions of cattle suffocating after eating plastics have been made. There is a smell from rotting organic waste in conjunction with all the dumpsites and people are often heard complaining of the stench.

4.4.2 Method

The current situation of the four chosen sites is described in regard to physical factors, such as hydrogeology, soil quality, land use, ground and surface water quality and waste composition. The sites are also described from a social perspective, which includes the health and emotional impact they have on people living in their surroundings. Data have been gathered through visits to the sites, water sample collection, waste composition surveys, interviewing people with knowledge about the sites, map studies and reading official documents.

Method of selection

Four landfills/dumping areas on Zanzibar have been chosen for further analysis. The method of selection is presented below.

Kisakasaka is an old quarry and the site where ZMC plans to start a new landfill. Until now there is no dumping in the area. Kisakasaka was visited on the 1st of February 2012.

Mwanakwerekwe is selected since it is one of the oldest dumpsites with still on-going dumping. The risk of negative environmental impact from Mwanakwerekwe is high due to the presence of a wetland/pond in its immediate surrounding as well as its closeness to residential areas. Mwanakwerekwe was visited several times between 27th of January and 7th of February 2012.

Jumbi is chosen because it is the landfill that was most recently used legally on Zanzibar. It was closed in December 2011. Currently it is also the biggest landfill and therefore most likely contains the biggest amount of waste. ZMC plans for

composting and plastic collection in connection to the landfill in the future. Jumbi was visited several times between 27th of January and 7th of February 2012.

Tunguu is a farming area where informal dumping is believed to have been going on for several years on irregular basis, increasing in intensity when Jumbi was closed. Tunguu is interesting from a waste recycling perspective since the waste in the area is unspoiled by fire. Furthermore it is thought to be the area where the majority of todays waste from Stone Town is dumped, which makes it interesting from a waste composition analysis perspective. Tunguu was visited several times between 27th of January and 3rd of February 2012.

Method for water sample collection
The water samples were collected between 11 am and 2 pm on February 7th 2012 in the surroundings of Jumbi and Mwanakwerekwe. No water samples were collected on Tunguu and Kisakasaka since there were not enough resources to take samples in more than two areas. Jumbi and Mwanakwerekwe were prioritized since they have a longer history of dumping and since more expertise was to be found regarding these areas.

February is dry season on Zanzibar and because of this it was hard to find surface water. In the surroundings of Jumbi no surface water were found. In the immediate surroundings of Mwanakwerekwe one sample of surface water was collected from a pond overgrown of water lettuce. Groundwater was collected from two wells in the surroundings of Mwanakwerekwe and from three wells in the surroundings of Jumbi. The samples were collected in areas recommended by the environmental department on Zanzibar who believed them to be affected by the dumpsite and the landfill. The domestic areas that surrounds the dumpsite and the landfill are however also likely to affect them.

Water samples were collected in plastic bottles. The plastic bottles were washed in sample water before the samples were collected. Simultaneously with the sample-taking air temperature and water temperature was measured and the coordinates of the location together with the depth of the wells were noted with a GPS. When all the samples were collected they were brought to Zanzibar Water Authority, ZAWA, in Stone Town for analysis. The parameters selected for the analyse were based on the parameters possible to measure by ZAWA, the parameters to prioritize based on recommendation from Eric Rönnols (mentioned in chapter 2) together with our knowledge of Zanzibar and limited resources which meant that all parameters could not be analysed.

Most of the results from the ZAWA analyse were received two days later. The chloride concentration and the salinity took an extra week to get since ZAWA had to buy reagents.

Method for waste composition analysis
On February 3rd 2012 an ocular waste composition analysis was conducted at Jumbi, Mwanakwerekwe and Tunguu. Kisakasaka is not used as a landfill yet and was therefore excluded since there is no waste to analyse.

A 1x1 meter frame, see Figure 12, was placed on 10-15 randomly picked spots at the sites. The purpose of the frame was to make the ocular examination easier and more reliable. The frame was used for analysing the waste composition by dividing the waste in different fractions. The waste fractions were selected based on their abundance in MSW and their recycling potential. Glass was for instance excluded because of its low abundance and the glass found is included in the non-classified material. The waste fractions were: plastic, metal, paper, organic matter, gravel and ash and non-classified material. The examination of the fractions was done through eye measuring at the site and estimated in percentage.

Figure 12. The frame used for the waste composition analysis.

Method for volume to weight conversion

A volume to weight conversion of the results given in the waste composition analysis on Tunguu was made in order to get figures comparable to the waste composition study in Stone Town 2005. Tunguu dumping area is believed to have the waste composition most representative for Stone Town MSW today.

A report from UNEP called "Waste Characterization and Quantification with Projections for Future" provided material density estimates for use in visual waste characterization methods (UNEP3, 2009). The materials found in the table included several types of paper, plastic and metal. For paper a mean value was calculated based on the assumption that 50% of the paper observed in the ocular survey was cardboard and 50% was newsprint. For plastic the average density was estimated based on the assumption that half of the plastic found was film and half was PET-bottles. For metal half of the waste fraction was assumed to consist of aluminium and half of tin cans. The organic waste fraction was assumed to only consist of food waste and the non-classified waste fraction was roughly estimated through a mean value of carpet (since the density of no other textiles was found) and glass.

The surface distribution of each waste fraction was then multiplied with the estimated density of the waste fraction, giving the weight-distribution in relative figures. The "total weight" of the waste fractions was calculated through adding the relative figures of every fraction and then the weight-distribution in percentage was calculated through dividing the relative figure of each waste fraction with the "total weight". For further information, see Appendix 1.

4.4.3 General conditions for the four landfills/dumping areas

All the surveyed landfills and dumping areas lie in the western part of Zanzibar. The exact local figures of mean annual rainfall have not been found or received upon request but the average annual rainfall in the western part of Zanzibar is 2000 mm. This is the biggest annual mean rainfall on the islands. (Gössling, 2001)

Data on wind direction and force in the areas where the four landfills and dumping areas lie has not been found. Since no mentions regarding wind data have been made there is reason to believe that these analysis have never been made. However the areas are not situated in direct link with the coast and therefore most likely not affected by coastal winds.

4.4.4 Kisakasaka

Kisakasaka is not yet an operating landfill and therefore the questions regarding decomposition phase and waste composition become irrelevant. However ZMC plans to locate a new, well managed, landfill in the area. The ambition is to have compost production, a recycle plant where the waste is sorted on site and to flare the methane gas from the landfill (in order to earn carbon credits and thereby raise the revenue). The area has earlier been used as a murram quarry and the government owns the land. (Juma, 2012)

Landfill appearance, accessibility, land use and vegetation in the surroundings

Kisakasaka is a 7 hectares big area located 15 km south of Stone Town. The maximum waste capacity of the area has been estimated to 1 160 000 m^3 which is thought to be sufficient to serve as a landfill for 20 years. Top elevation of the planned landfill will be 20 meters above sea level. (SMOLE1, 2011)

The road from Stone Town to Kisaksaka is asphalted and narrow with just about enough room for two cars to meet. The roads in the Kisakasaka area are sandy, narrow and bumpy and the possibility for two waste trucks to meet on the roads is limited.

Figure 13. One of the sandy, narrow roads at Kisakasaka.

In the surroundings of the planned landfill are a residential area with a school and some farms. The closest neighbour is about 100 meters away from the site. The vegetation mostly consists of bushes and grass with few trees and there is no observed surface water in the area.

Potential for landfill gas and air quality

The future potential for landfill gas in Kisakasaka is high if ZMCs' plan for dumping all the waste generated in Stone Town at the site is realized. The waste in Stone Town has a high organic content, currently over 80% leading to a high amount of degradable carbon. This together with a relatively high annual mean temperature gives a fast gas production. ZMC plans to flare the methane gas generated at Kisakasaka.

Official reports regarding the air quality on Kisakasaka has not been found, nor received on request. Since no data on air quality have been found and no mentions have been made regarding air quality tests there is reason to believe that they have never been made. There is currently no bad smell in the area. Domestic waste is however likely to be burnt in the backyards of the houses as it is in other areas of Zanzibar contributing to local air pollution, this was however not observed during the field survey on the 1st of February.

Hydrogeology, soil quality, ground and surface water quality

The bedrock in the area was formed during the Miocene time, see Figure 14, and consists of limestone that have potential to hold a large number of aquifers. (Colbert et al, 1987) The soil in the area is less fertile compared to other parts of Zanzibar. There are patches of visible coral rock in the area, which makes it barren and less suitable for farming, see Figure 15.

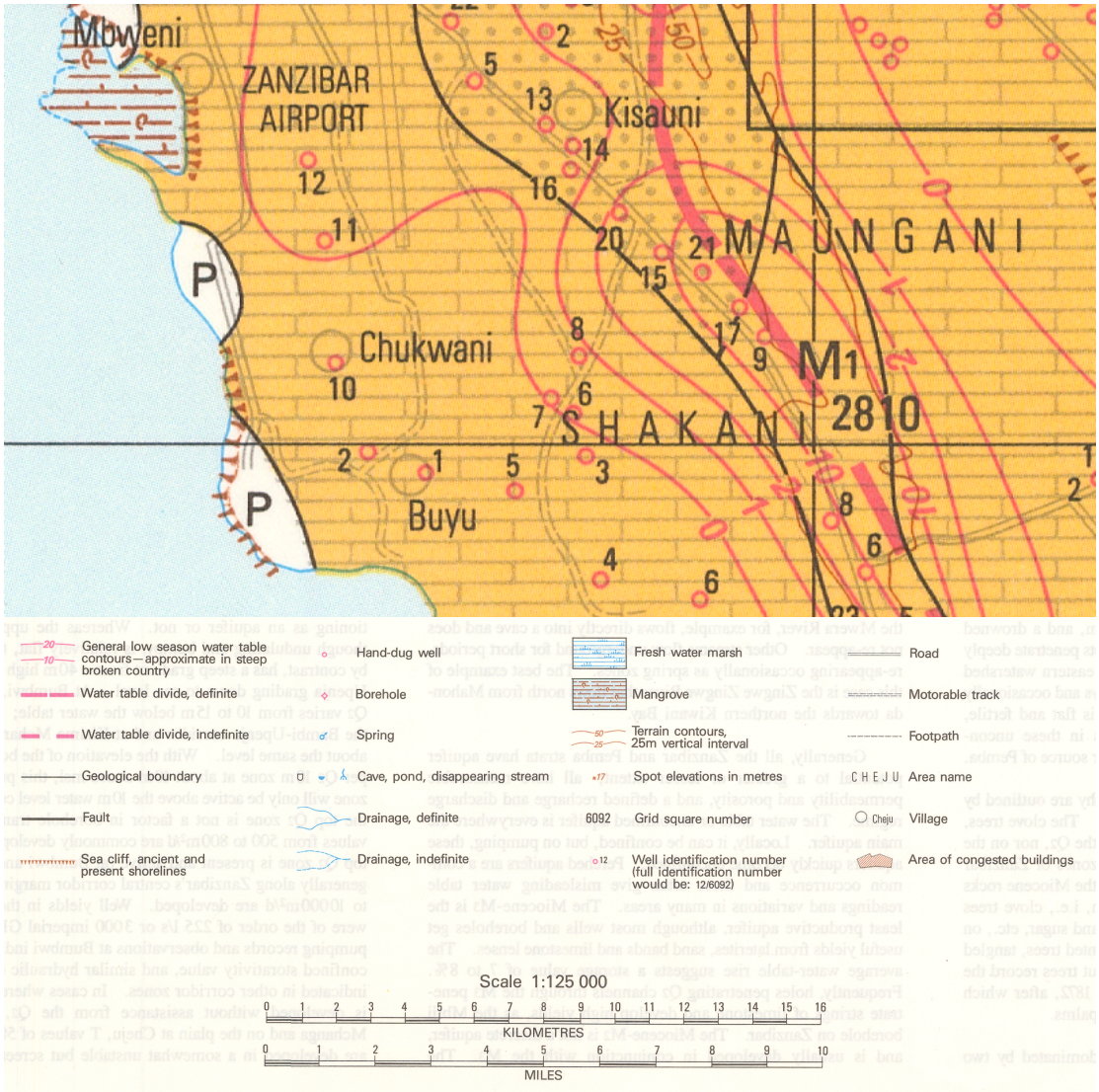

Figure 14. The hydrogeology in the Kisakasaka area. (Colbert et al, 1987)

Figure 15. Typical environmental appearance in the Kisakasaka area.

The groundwater table in the Kisakasaka area is 0-10 meters according to Figure 14. There is also a lot of groundwater in the area. (Hendriksen, 2012) However the risk of seawater intrusion is heightened at the site compared to other parts of Zanzibar. (Colbert et al., 1987) The ground- and surface water quality was not tested in the Kisakasaka area due to limited time and resources.

Social and health impact

Kisakasaka is not yet an operating landfill and therefore it has no physical health impact. However the people living in the surroundings of Kisakasaka are currently negative to the plan for a landfill and demonstrations have been taken place against it. (Juma, 2012)

4.4.5 Mwanakwerekwe

Mwanakwerekwe is an old sand quarry and a former open dumpsite, which lacked a planned construction. The waste body was partially covered with soil when closed. Today it is an informal dumpsite since dumping never stopped. It is situated about 6 km east of Stone Town. On top of Mwanakwerekwe a market area was established about fifteen years ago and the eastern slope is still used to dump waste generated at the market, see Figure 16 and Figure 17. (ZSDP1, 2005: Jumbe, 2012) There are no official records of the waste amounts and waste composition disposed on Mwanakwerekwe. Waste is today randomly placed on the dumpsite without compaction.

Figure 16. Mwanakwerekwe dumpsite with part of the market to the right.

Landfill appearance, accessibility, land use and vegetation in the surroundings

The dumpsite is in general in level with the market but has an uneven surface. Non-compacted, steep slopes of waste lead down towards a pond in the eastern end of the dumpsite. There is burning on the dumpsite on a daily basis. The waste at the dumpsite mostly contains of waste from the market. Waste generated in the market is disposed on the dumpsite at all time during the day using carts and buckets. There is a stench caused by rotting waste and lots of flies and other vermin. Cattle wander the dumpsite eating the waste and scavengers have been observed at the dumpsite. There is no fencing or security system.

The accessibility for the merchandisers at the market is good and they are the ones mainly using the dumpsite. The accessibility for trucks is also good since there is a two-lane asphalted road from Stone Town passing the dumpsite. The roads in the residential areas are narrow, non-asphalted and sandy.

The dumpsite is located in an urban area with two small corn cultivations close to it. Next to the dumpsite is a carwash, a gas station, a mosque and a wetland overgrown of water lettuce. The major part of the area surrounding Mwanakwerekwe is low-income residential. There are no industries but there is a lot of commerce going on in the residential areas. Small shops, hairdressers, video libraries etc., face the streets in almost every other house.

Figure 17. The pond next to Mwanakwerekwe during the dry season in February.

Decomposition phase

The BOD and COD values can be used to establish the dominating decomposition phase. Due to limited resources and expertise BOD and COD were not measured. However pH is also a good indicator of decomposition phase and it was measured on the 7th of February 2012 in the pond next to the dumpsite. The pond is likely to receive runoff water from the dumpsite but it also receives water from storm water channels. The storm water channels were however dry when the pH was measured. The pH in the pond was measured to 7.5, a value indicating that the dominating decomposition phase is the methanogenic phase.

Potential for landfill gas and air quality

The potential for landfill gas at the dumpsite is likely to be high due to the high organic content, the dumpsite being dominated by the methanogenic phase and regularly observed steam rising from it indicating high temperature in the dumpsite and therefore good conditions for landfill gas production. Since the volume of the dumpsite is unknown it is however hard to estimate the exact level of gas produced using a synoptic equation.

Official reports regarding the air quality on Mwanakwerekwe has not been found, nor received on request. Since no data on air quality have been found and no mentions have been made regarding air quality tests there is reason to believe that they have never been made. The air quality in Mwanakwerekwe is however likely to be mainly affected by the dumpsite and the road next to the dumpsite. Repeatedly burning on the dumpsite together with the smell from rotting of organic waste affects the air quality negatively.

Waste composition

On the 3rd of February 2012 the waste composition at Mwanakwerekwe was estimated on 10 randomly picked spots. The waste was divided in the fractions metal (including foil and cans), paper (including newsprint and cardboard), plastic (including film and bottles), organic matter and non-classified (including textiles, gravel, ash, batteries, porcelain, etc.) since these were the most common waste fractions in Mwanakwerekwe. The mean distribution of the waste fractions at the 10 spots in surface percentage can be seen in Figure 18.

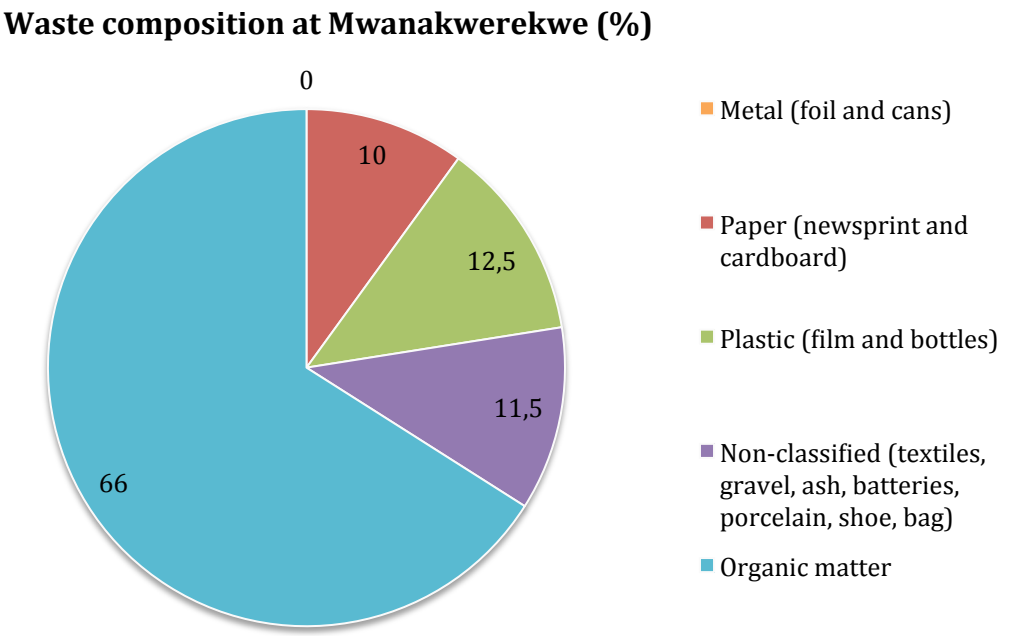

Figure 18. Waste composition at Mwanakwerekwe estimated in surface percentage.

The waste distribution was fairly similar on the 10 randomly picked spots. Organic matter was the major part in 8 of the 10 spots where it made up 70-95% of the waste. Metal only existed in so small amounts that it fell in the error margin. Plastic were evenly distributed over the 10 spots and varied between 5% and 30% with the median value 10% and the mean value 12.5%. Paper varied more than plastic and organic matter. At 3 of the 10 spots it was non-existing while in the other spots it varied between 5% and 30% with the median value 10% and the mean value 7.5%.

Hydrogeology, soil quality, ground and surface water quality

The bedrock in the area was formed during the Miocene time, see Figure 19, and consists of dense, chalky rocks. This bedrock may affect the water quality through an increased concentration of sulphates and chlorides. It does not have a significant potential for aquifers. (Colbert et al., 1987) The soil in the area is a fertile mix of marls, clayey sands and sandy clays. (Jumbe, 2012: Colbert et al., 1987). The roads and part of the ground in the area is typically covered by light beige sand. During the rain period big amounts of soil in this area is usually washed away leading to soil degradation. (Jumbe, 2012)

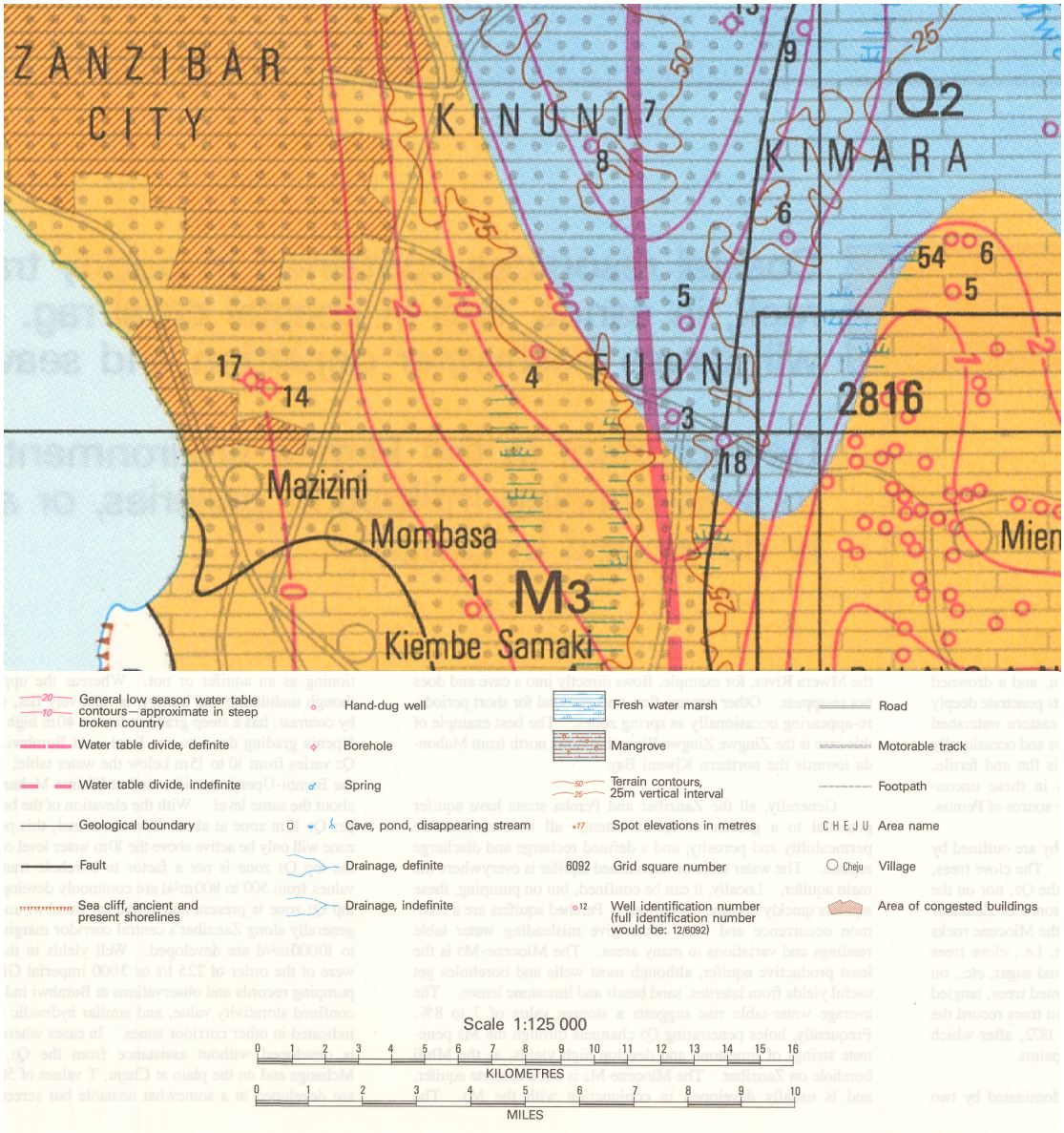

Figure 19. The hydrogeology in the Mwanakwerekwe area. (Colbert et al, 1987)

The groundwater table in the area is 2-20 meters according to Figure 19. Next to the dumpsite is a wetland area covered with water lettuce during the dry season. During the rain season when the water level is higher the wetland has an open water mirror. There are no rivers in the area but there are storm water channels for collection and removal of run-off water after heavy rains. The area is low-lying and therefor the destination for lots of storm water during rain season, see Figure 20. Dirty water occasionally floods houses around the wetland during the rain season (Golder, 2010).

Seawater intrusion to the groundwater has been recorded in the western regions of Zanzibar in the Stone Town area. This intrusion may have an effect on the salinity and conductivity of the water in Mwanakwerekwe. (Gössling, 2001)

Figure 20. Storm water channel in Mwanakwerekwe, close to collection point GW2.

Ground- and surface water samples were collected at three different spots on the 7th of February 2012. Surface water was collected close to the shore in the southern part of the wetland next to the dumpsite, see Figure 21. The wetland is most likely affected by runoff from the dumpsite since the dumpsite ends directly in it. It is also affected by water from storm water channels ending up in the wetland.

Figure 21. Collection point of surface water.

The first groundwater sample, GW1, was collected in a village lying on a hill in the immediate surroundings of the dumpsite. The well is located in the backyard of a house, see Figure 22, and the water is used for drinking. The ground water table in the area varies between 2 and 20 meters. The elevation of the dumpsite is 21 meters above sea level and the elevation where GW1 was collected is 22 meters above sea level. The depth of the well is 20 meters. Based on the closeness to the dumpsite and the depth of the well, GW1 is most likely affected by the dumpsite. But since the hydrology in the surroundings of Mwanakwerekwe is not completely known and also varies with season it is not possible to draw absolute conclusions.

Figure 22. Collection point of GW1.

The second groundwater sample, GW2, was collected in a village several hundred meters from the dumpsite, see Figure 23. The water in the well has been used for drinking purposes but not anymore. The well is located north and uphill of the dumpsite and the elevation is 30 meters above sea level. The ground water table in the area varies between 2 and 10 meters. The depth of the well is 4 meters. Based on this it is likely that GW2 lies upstream the dumpsite and therefore most likely is not affected by the dump. For the same reasons as mentioned before, it is however difficult to be absolute sure.

Figure 23. Collection point of GW2.

The ground- and surface water was brought to ZAWA to be analysed. The result of the analysis can be found in Table 3 together with drinking water quality guidelines from WHO and Tanzania (TZ).

Table 3. Ground- and surface water results at Mwanakwerekwe.

Mwanakwerekwe	Surface water	GW1	GW2	WHO	TZ
Temperature water (°C)	29	31.5	29		
Temperature air (°C)	29	30	28.5		
Elevation (meters above the sea)	21	22	30		
Ground water table, dry period (meters)	2 – 20	2 – 20	2 – 20		
Depth of well (meters)	–	20	4		
pH	7.5	7.4	7.2	6.5 – 8.5	6.5 – 9.2
Conductivity (µS/cm)	490	630	990	400	1500
Fe, total, (mg/Fe)	0.16	0	0.02	0.3	0.5
Mn (mg/Mn)	0.013	0.009	0.011	0.1	0.5
NH_4^+ (mg/l)	0.221	0.013	0.143	–	–
Total dissolved solids (mg/l)	270	347	545	1000	–
Cl^- (mg/l)	54.982	58.981	69.97	250	800
Salinity (ppt)	0.0992	0.1064	0.1263	–	–

There are some values that catch the eye. Conductivity is too high in all the water samples according to WHO guidelines but not according to Tanzanian guidelines. The conductivity is however lowest in the surface water and highest in GW2, the well that is believed to be unaffected by the dumpsite.

The ammonium level in the surface water of 0.221 mg/l is almost twice as high as the level in GW2 and 20 times higher than in GW1.

Social and health impact
The dumpsites' direct contact with a market and residential areas increases its social and health impact. Vermin, such as flies, has been observed in large quantities on the dumpsite and the wetland character of the land surrounding it has potential to be a good breeding ground for mosquitos and for the spread of waterborne diseases such as cholera. This risk is heightened during wet season due to flooding.

The regular waste burning on the dumpsite affects the air quality and could cause respiratory conditions for people living nearby. There is also a stench rising from the landfill, which has a negative effect on the surroundings.

The dumpsite does not employ anyone and therefore working conditions are irrelevant to analyse. However scavengers and people disposing waste are exposed to the risk of land sliding (due to no compaction).

4.4.5 Jumbi
Jumbi landfill includes an area of 2 hectares and is situated 12 km east of Stone Town inside the residential area of Jumbi village. Jumbi landfill started operating in 1996 and was until recently the only formal landfill on Zanzibar (Juma, 2012). Prior to its use as a landfill it was used for limestone mining. It was closed in December 2011 due to complaints from the neighbours of smell and vermin and also because the compactor broke down. Neighbours of Jumbi landfill have built a stonewall to stop waste trucks from unloading waste on the landfill, see Figure 24. (ZSDP1, 2005: Juma, 2012)

Figure 24. The 0.3 m high stonewall on the entrance to Jumbi landfill.

Landfill appearance, accessibility, land use and vegetation in the surroundings

Jumbi landfill is an open landfill where waste trucks have disposed waste in an unorganized way. The waste has not been divided into cells. (ZSDP1, 2005)

When Jumbi landfill was operating waste was compacted and burnt every day in the dry season. (Juma, 2012) The landfill is <3 meters deep and the ground is ashy, flat and in level with the surroundings, see Figure 25. In the outskirts of the landfill a few non-compacted piles of waste <2 metres high can be found, see Figure 26. The landfill is currently unexploited by humans and animals. There is no security system and no fencing on the landfill except for the stonewall built to block the entrance by the neighbours.

Figure 25. Jumbi landfill, January 27th 2012. The ground is mostly flat and burned.

Figure 26. One of few non-compacted piles on Jumbi landfill.

Waste trucks were used to bring the waste from Stone Town to Jumbi landfill on a daily basis when the landfill was operating. The asphalted road parallel with Mwanakwerekwe also passes Jumbi landfill making it easy to access with waste trucks. The rest of the roads in the area are sandy and narrow with less accessibility.

In the landfills immediate surroundings there are farms including fruit plantations and several rice fields. These farms could have an influence on the

environment through fertilizers used on the rice fields. Businesses that could affect in the environment to a larger extent have not been found.

The vegetation in the area includes forests with trees, bushes and high grass, see Figure 27. There are no nature reserves or water protection areas in the surroundings.

Figure 27. One of several rice fields next to Jumbi landfill.

Decomposition phase

Due to dry season when water samples were collected no leachate could be found in conjunction with the landfill and therefore neither pH, BOD or COD tests could be made. Therefore the decomposition phase is unknown.

Jumbi landfill was however regularly burnt during its 16 years of operation. Even though the combustion most likely was not complete, considerable amounts of carbon is likely to have left to the atmosphere as carbon dioxide affecting the usual procedure of decomposition. Since Jumbi landfill has not received any new waste since December 2011 the major part of the landfill is most likely not in the aerobic or acidogenic phase but in a comparatively unproductive methanogenic phase.

Potential for landfill gas and air quality

The potential for landfill gas is likely to be low due to its history of regular burning. Official reports regarding the air quality in Jumbi has not been found, however it has most likely been affected by the landfill. One of the reasons behind its closure was complaint on burning and the smell that it caused (Juma, 2012). The burning probably caused air pollutants such as furans and dioxins. Since the burning stopped, there is only minor smell rising from the landfill, which will only be noticed by people walking on the landfill.

Waste composition

On the 3rd of February 2012 the waste composition at Jumbi landfill was estimated on 10 randomly picked spots. The waste was divided in the fractions metal (including foil and cans), paper (including newsprint and cardboard), plastic (including film and bottles), gravel and ash and non-classified (including textiles, gravel, ash, batteries, porcelain, etc.) since these were the most common waste fractions on Jumbi landfill. The mean distribution of the waste fractions at the 10 spots in surface percentage can be seen in Figure 28.

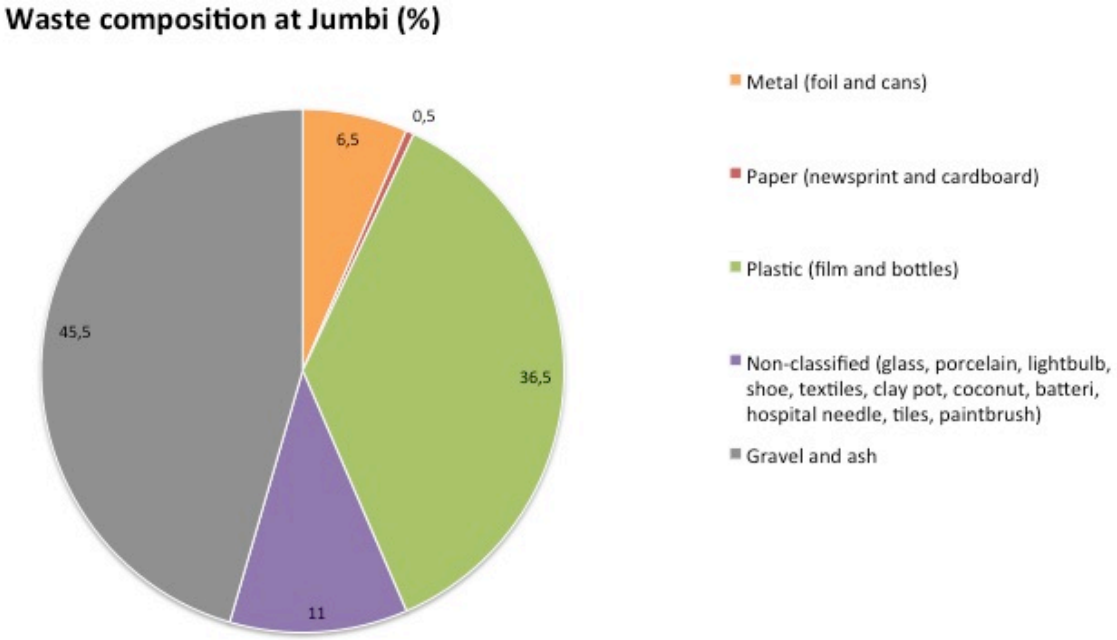

Figure 28. Waste composition on Jumbi landfill estimated in surface percentage.

The waste distribution was fairly similar on the 10 randomly picked spots. Gravel and ash was the major part in 7 of the 10 spots where it made up 40-75% of the waste. Paper was only found at one of the spots. Burnt plastic varied between 0% and 75% over the 10 spots with the median value 32.5% and the mean value 36.5%. Metal was more evenly distributed than plastic. At 3 of the 10 spots it fell outside the error margin while in the other spots it varied between 5% and 15% with the median value 7.5% and the mean value 6.5%.

Hydrogeology, soil quality, ground and surface water quality

The bedrock in the area was formed during the Quaternary time, see Figure 29, and consists of limestone fragments and thin tropical laterite that is typically iron rich. It has potential to hold local aquifers. (Colbert et al., 1987) The soil is loamy and good for rice cultivation. (Jumbe, 2012)

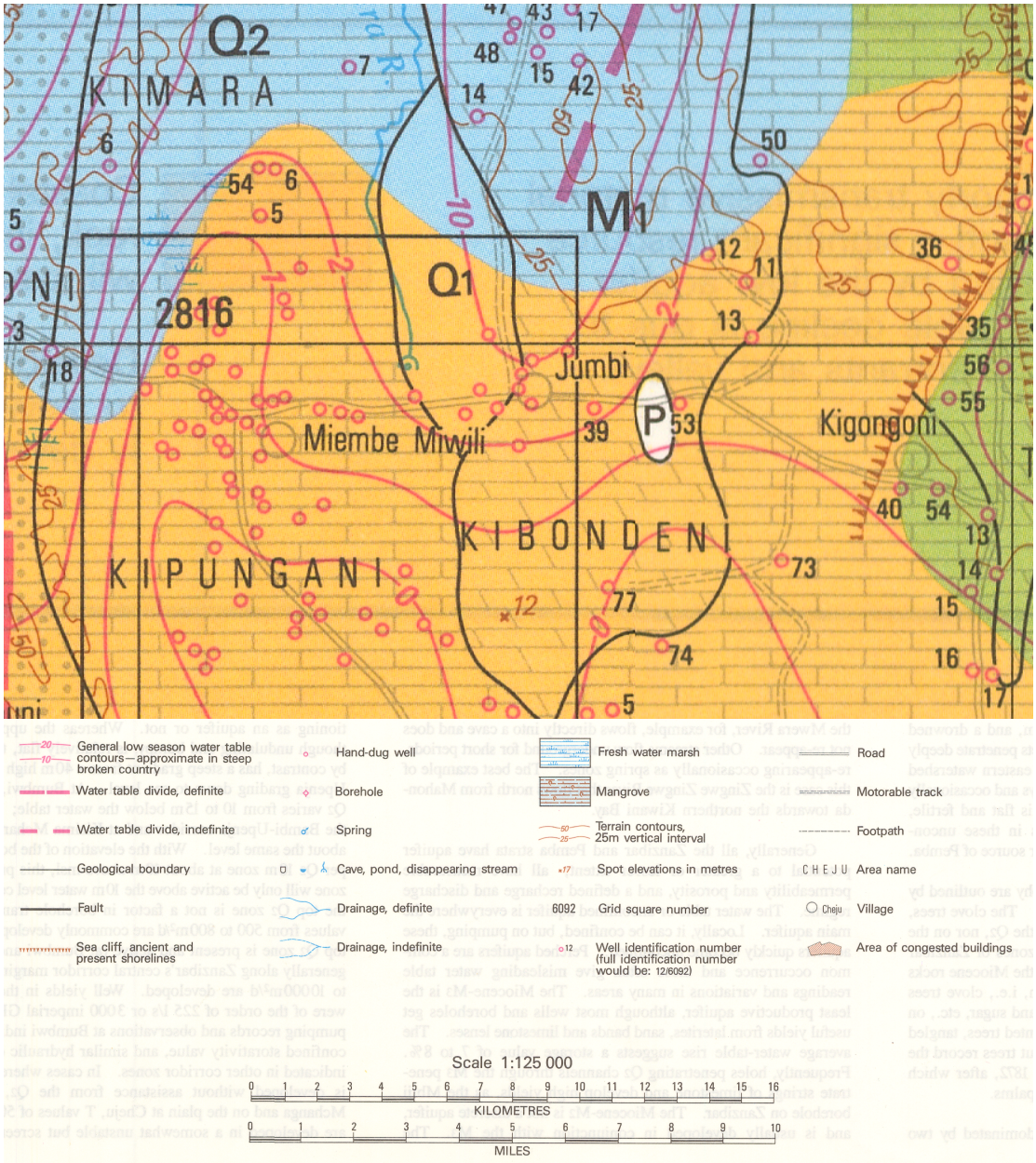

Figure 29. The hydrogeology in the Jumbi area. (Colbert et al., 1987)

The ground water table in the area varies between 2-10 meters, see Figure 29, and the shallow ground water level increases the risk of leachate polluting ground and surface water in the area, especially during the rain season. Groundwater pollution happened in a groundwater well built in 2004 upstream Jumbi landfill and this water is now considered non-potable (ZSDP1, 2005). Next to the landfill are several rice fields where fertilizers are used. The rice fields are occasionally completely covered by water and during heavy rainfalls Jumbi landfill itself can be completely covered with water. Mwera river passes 500 meters from the western end of the landfill. The area is at risk of seawater intrusion. (Colbert et al., 1987)

Ground water samples were collected at three different spots on the 7th of February 2012. The first groundwater sample, GW3, was collected in a well, used for irrigation, in the middle of a rice field a few hundred meters from the landfill.

The ground water table in the area varies between 2-10 meters. The elevation of the landfill is 16 meters and the elevation where GW3 was collected is 16 meters. The depth of the well is 5 meters. Based on the closeness to the landfill and that the well is believed to be located down stream Jumbi landfill by Dr. Jumbe, it could be affected by the landfill. But since the hydrology in the area is not completely known and also varies with season it is not possible to draw absolute conclusions. Fertilizers containing nitrogen, phosphorous and potassium are used on the rice field and are also, most likely, affecting the well.

The second ground water sample, GW4, was collected in a private well located next to a farmers' house 200 meters from the western edge of Jumbi landfill. The water in the well is used for drinking purposes. The ground water table in the area is 2-10 meters. GW4 was collected at an elevation of 22 meters and the depth of the well is 12 meters. The well was drilled two years ago since the farmer thought that the water in the old well was contaminated. Based on the closeness to the landfill GW4 could be affected by the landfill. But since the hydrology in the area is not completely known and also varies with season it is not possible to draw absolute conclusions.

The third ground water sample, GW5, was collected in a well next to a farm 100 meters from the western edge of Jumbi landfill. It is the well that is believed contaminated by the farmer with the well where GW4 was collected. The water in the well is used for drinking purposes. The ground water table in the area is 2-10 meters. GW5 was collected at an elevation of 16 meters and the depth of the well is 12 meters. Based on its closeness to Jumbi landfill it could be affected by the landfill.

The ground water samples were brought to ZAWA to be analysed. The result of the analysis can be found in Table 4 together with drinking water quality guidelines from WHO and Tanzania (TZ).

Table 4. Ground water results at Jumbi.

Jumbi	GW3	GW4	GW5	WHO	TZ
Temperature water (°C)	28	28.5	28.5		
Temperature air (°C)	32	28.5	28		
Elevation (meters above the sea)	16	22	16		
Ground water table, dry period (meters)	2 – 10	2 – 10	2 – 10		
Depth of well (meters)	5	12	12		
pH	7.1	7.2	7.3	6.5 – 8.5	6.5 – 9.2
Conductivity (µS/cm)	240	430	450	400	1500
Fe, total, (mg/Fe)	0.43	0.01	0.03	0.3	0.5
Mn (mg/Mn)	0.017	0.008	0.006	0.1	0.5
NH4+ (mg/l)	2.535	0.052	0.052	–	–
Total dissolved solids (mg/l)	132	237	248	1000	–
Cl- (mg/l)	34.989	42.986	46.985	250	800
Salinity (ppt)	0.0631	0.0775	0.0849	–	–

Not many results differ between GW4 and GW5 and since they also have the same depth and are lie close to each other it is likely that they use the same water body. Conductivity exceeds WHO standards for drinking water in both GW4 and GW5 while the water sample collected from GW3 passes. The iron concentration is however high in GW3, exceeding WHO guidelines. Also ammonium levels are high in GW3 in comparison with the other two wells.

Social and health impact
The landfills closeness to a residential area increases it social and health impact. Farms in the immediate surroundings of the landfill use water for irrigation that might be affected of leachate from Jumbi landfill and this also increases the potential health impact.

When Jumbi landfill was operating there where complaints regarding smell and vermin from the people living nearby. The regular burning of the landfill is likely to have affected the air quality and thereby could have negatively affected peoples health. Occasional flooding of the landfill during rain season increases the risk of waterborne diseases spreading in the area.

The landfill currently does not employ anyone and therefore working conditions are irrelevant to analyse.

4.4.6 Tunguu
Tunguu lies about 14 km east of Stone Town. Dumping in the Tunguu farming area and other farming areas in the western and central part of Zanzibar has been going on for at least three years. Waste from Stone Town is brought to the farms with waste trucks. An unofficial system exists where the farmers call the waste truck drivers if they want waste. Before Jumbi landfill was closed the dumping on farms mainly took place during the night but now it has increased and takes place during the day. ZMC are aware that the farm dumping is harmful to the environment but since there are currently no official landfills on Zanzibar they use it as a disposal alternative.

Landfill appearance, accessibility, land use and vegetation in the surroundings
Tunguu dumping area is approximately 2x1 km wide. Dumping of waste takes place both on plantations and on random spots in the bush. The waste is usually evenly spread over the plantations in a layer <0.5 meters thick, see Figure 30. In the bush waste is placed in piles <2 meters high, Figure 31. Waste is not compacted.

Figure 30. A banana plantation in Tunguu with an evenly spread layer of waste.

Figure 31. A pile of waste in the bush in Tunguu.

Waste trucks are used to bring the waste from Stone Town to Tunguu on a daily basis. The asphalted road parallel with Mwanakwerekwe and Jumbi also passes Tunguu. The roads leading in to the farm area from the main road are however sandy, narrow and bumpy with limited accessibility, especially during the rain season.

The area consists of small farms with cattle and fruit plantations. Large bush areas are present between the farms and the vegetation includes trees, bushes

and high grass. Coral stone mining is present at several places in the area. There are no nature reserves or water protection areas in the surroundings.

Decomposition phase
The waste is spread over the plantations in thin layers and is not compacted. Therefore decomposition is likely to take place during aerobic conditions. The waste piles found in the bush appear to have been disposed recently (within a couple of months) and are likely also in the aerobic decomposition phase.

Potential for landfill gas and air quality
The potential for methane gas production at the plantations is low. The thinness of the scattered waste (<0.5 meters) together with the low compaction level implies a well-aerated waste lacking potential for methane gas production. Carbon dioxide is however likely produced during the decomposition. The same goes for the waste in the waste piles in the bush. Due to their recent placement they are still most likely aerated and therefor methane gas is not produced.

Official reports regarding the air quality on Tunguu has not been found, nor received on request. The air quality in Tunguu is however likely to be mainly affected by smell from rotting of organic waste caused by the dumping in the area.

Waste composition and contamination level
On the 3rd of February 2012 the waste composition in Tunguu dumping area was estimated. Two plantations were examined with the aim to see if there was a difference in waste composition between different plantations in the dumping area. At the first site 10 randomly picked spots were analysed and at the second site 5 randomly picked spots. No big difference was found and therefor the combined result of the examinations is presented. The waste at the two examined sites where neither completely fresh nor completely degraded. The waste was divided in the fractions metal (including foil and cans), paper (including newsprint and cardboard), plastic (including film and bottles), organic and non-classified (including textiles, shoes, carpet, batteries, glass, etc.) since these were the most common waste fractions in Tunguu. The mean distribution of the waste fractions at the 15 spots in surface percentage can be seen in Figure 32.

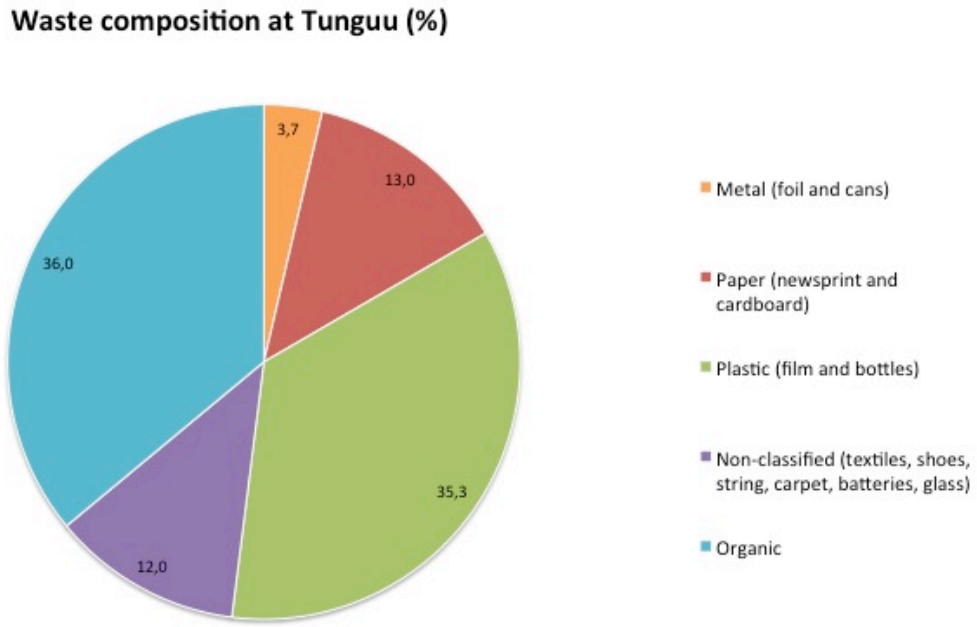

Figure 32. Waste composition on Tunguu estimated in surface percentage.

The organic waste fraction varies between 10% and 75% within Tunguu. The mean value for the organic waste fraction is 36% and that makes the organic fraction the dominating waste fraction in Tunguu area.

The plastic fraction varies less than the organic fraction probably due to slower degradation. The mean value for the plastic fraction is 35.3%.

The paper fraction varies between 0% and 30% with a mean value of 13%.

The metal fraction is non-existing in six of the fifteen spots and varies between 5% and 10% in the remaining nine spots. The mean value for the metal fraction is 3.7%.

Only surface waste distribution was analysed, however the thinness of the waste layer makes it reasonable to assume that the surface waste distribution is representative for the waste further down. Given that the surface distribution is representative for the waste composition further down, the volume of the waste fractions can be estimated and converted to weight fractions using a weight-conversion factor (see Appendix 1). The mean distribution of the waste fractions at the 15 spots in weight percentage can be seen in Figure 33.

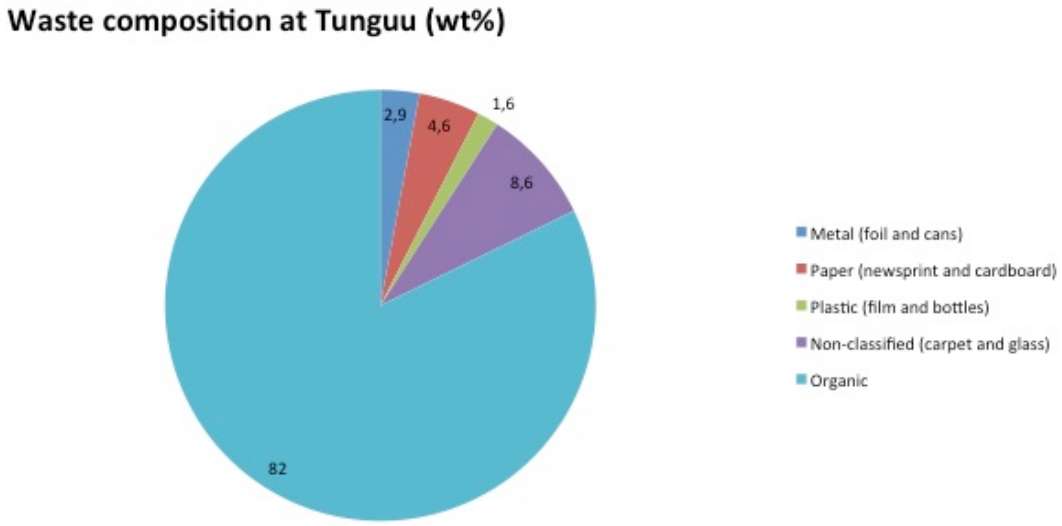

Figure 33. Waste composition in Tunguu estimated in weight percentage.

Hydrogeology, soil quality, ground and surface water quality

The bedrock in the area was formed during the Quaternary time, see Figure 34 and consists of limestone fragments and thin tropical laterite that is typically iron rich. It has potential to hold local aquifers. (Colbert et al., 1987) The soil is red and fertile and good for fruit and vegetable farming.

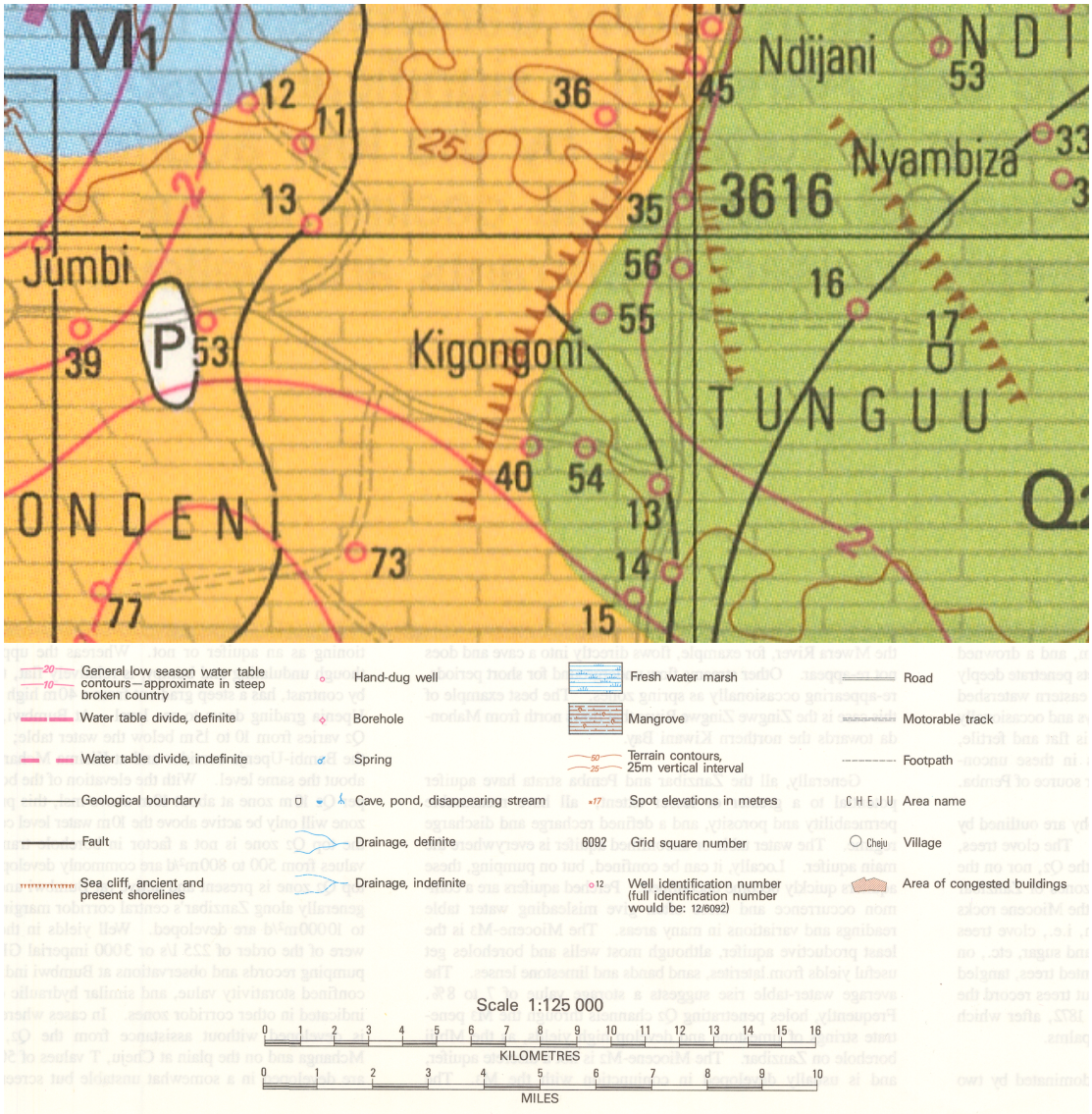

Figure 34. The hydrogeology in the Tunguu area. (Colbert et al., 1987)

The ground water table in the area varies between 1-2 meters, see Figure 34, and the shallow ground water level increases the risk of run-off affected by the waste to pollute the ground and surface water in the area. The area is at risk of seawater intrusion. (Colbert et al., 1987) The ground- and surface water quality was not tested in the Tunguu area due to limited time and resources.

Social and health impact

The waste dumping in the Tunguu area is very close to residential buildings, which increases its social and health impact. Vermin, such as flies, was observed in large quantities in the area where waste was disposed. Smells from the rotting waste also affect the neighbours in a negative way.

Using MSW as a fertilizer is a health risk, since there is no control of what is put on the plantations. During the field survey for instance batteries, hospital waste, paint bottles and electrical devices were observed in the waste on the plantations there is no way knowing if and how this is assimilated in the crops.

5 Result analysis

This chapter is based on the findings presented in the theory, background and result chapters. The analysis is made in order to answer some of the thesis questions and reach the aim.

5.1 Analyse of the waste collection point survey

The ocular examination concluded a daily increase of approximately less than 1 m^3 per day in the waste collection point surveyed. During 6 days the waste amount was estimated to increase with less than 5 m^3 in total. It is not known how much of the waste that was eaten by animals or collected by people. It is also hard to know how representative the surveyed days are compared to other days. However, since mainly villagers use the waste collection point, thereby making it unaffected by fluctuating tourist seasons, and since there were no extraordinary events (that could otherwise cause the waste amount to increase more than normal) it is a fairly good assumption that the waste amount generated during these days is representable.

The collection point chosen for the survey is one of the smallest of the four collection points in Paje and has not been renovated as some of the others have. This could be an indication that it is used less frequently than some of the other collection points. However, all collection points are believed to have about the same number of residents living nearby which could be an indication that they are used equally much. There has been no observations made of people throwing their waste in a collection point, therefor it is hard to know how waste is transported to them which in turn makes it hard to make assumptions of which ones of the waste collection points are being used the most.

Assuming that the four waste collection points in Paje gather the same amount of waste per week and that this amount is 5 m^3 the total weekly amount is calculated to 20 m^3. Also assuming that all household waste produced by the 3 000 residents in Paje ends up at one of the four waste collection points and that the density of the waste is 0.33 tonnes/m^3 (ZSDP2, 2005) the daily waste production rate is 0.31 kg/person. This figure can be compared to the daily waste production rate 0.45 kg/person estimated by the Zanzibar government in 2005 in Stone Town (ZSDP2, 2005) leading to the conclusion that the rough calculation is fairly good.

5.2 Todays waste composition on Zanzibar

In this chapter the most common waste fractions with recycling potential are discussed in terms of their historical distribution level, distribution level today and believed future distribution. The results from the waste composition analysis made on Tunguu are compared with the results in the waste composition study made in Stone Town, 2005 (ZSDP1, 2005).

The waste composition analysis from Tunguu is chosen for todays waste composition analysis since Tunguu dumping area is believed to have the waste composition most representative for the MSW generated in Stone Town today. Mwanakwerekwe does not receive MSW from Stone Town and Jumbi landfill has

not been operating since December 2011 and the waste on the landfill has been burnt.

Plastics

The most recent study of waste composition was made in Stone Town households in 2005. It showed that the household waste in average contains 0.8wt% plastic bottles and 3.6wt% plastic film, together 4.4wt%. (ZSDP1, 2005) The waste composition survey on Tunguu shows the Stone Town waste that ends up on a dumpsite today. The conducted surface analysis shows a plastic content (including both film and bottles) of about 35%, see Figure 32. A rough conversion of the waste distribution to weight gives 1.6wt%, see Figure 33. According to this survey the plastic waste fraction has decreased. This is however unlikely considering the increased income level and tourism which both are believed to contribute to an increased plastic fraction (UNHSP, 2010: POFEDP, 2011: AEO, 2011). Reasons for the decrease in plastic waste could be due to wrong assumptions leading to misestimations. It could also be due to that the waste composition study in Stone Town 2005 was made in households while our waste composition survey was conducted in a dumping area and plastic is a valuable that is likely to decrease through every step in the waste management system. Since the waste composition study in Stone Town was made a plastic recycling organization, ZASEA, has started in Stone Town that collects about a tonne of plastic bottles every day (Hamed, 2012). There is also a large informal second hand market for plastic bottles, which was illuminated during the plastic bottle survey. Part of the survey failed due to repeatedly thefts of the research material, in this case the plastic bottle collection.

Organics

The waste composition study made in households in Stone Town 2005 showed an organic content of 85.6wt% and organic waste is still believed to be the major part of the MSW on Zanzibar (ZSDP1, 2005). The waste composition survey conducted on Tunguu shows the Stone Town waste that ends up on a dumpsite today. The surface analysis gives an organic content of 36%, see Figure 32. Roughly converting the waste distribution to weight this is comparable to 82wt%, see Figure 33. It is reasonable to believe that the organic fraction is larger on a dumpsite than at the source (households) since valuables, such as metals, are removed in every waste management step. Therefore the organic waste fraction might have decreased even more due to increasing GDP and income level which leads to for instance more packaging material in the MSW (UNHSP, 2011: AEO, 2011).

Metals

Metal was a small waste fraction in the household study from 2005 where it only represented 0.2wt% (ZSDP1, 2005). At Tunguu metal covered 3.7% of the surface and this was estimated to represent 2.9wt%, see Figure 32 and Figure 33. This implies that the metal fraction in the waste have seen a real increase since waste disposed on a dumpsite likely contains a smaller amount of metal than at the source due to its relatively high second hand market value.

Paper and cardboard
Paper and cardboard represented 2.7wt% in the household study conducted in 2005 (ZSDP1, 2005). In the survey made on Tunguu it covered 13% of the surface and this was estimated to represent 4.6wt%, see Figure 32 and Figure 33. Due to fast decomposition of paper and cardboard it is reasonable to believe that the fraction is larger at the source than at a dumpsite, therefore the relative increase should represent a real increase. Paper and cardboard are in general rarely used materials in developing countries compared to in industrialized countries and is believed to stay uncommon due to its relative high cost in these countries (Rönnols, 2012).

Electronic waste
Electronic waste was almost not observed during the field surveys to the landfills neither at the waste collection points or during the overall field study. However it is believed to increase and during the field study observations of a high usage of mobile phones were observed. Even the poorest people have a mobile phone, often they have several.

Import of electronic waste to developing countries has been going on for several years (NV, 2011). On Zanzibar this does however not seem to happen. During the field study no observations or references to organizations that import electronic waste have been made. It is though of importance to be aware of the challenge electronic waste will pose to the waste management system on the island when the fraction increases.

5.3 Environmental and social effects of Mwanakwerekwe dumpsite and Jumbi landfill

This chapter starts with a resume of the findings in the landfill investigation on Jumbi landfill and Mwanakwereke dumpsite presented in Table 5*. Some of the results are further analysed in the text below. Kisakasaka landfill is not analysed in this chapter since it is not yet an operating landfill and thereby has no environmental effects. It is however discussed in the next chapter. Tunguu dumping area is not analysed in this chapter either since it differs much from a general dumpsite. For instance the waste is not limited to a defined site but irregularly spread out over a wide area. Results from Tunguu are however analysed both in the previous chapter and in the next chapter.*

Table 5. Resume of results from the landfill investigations on Jumbi and Mwanakwerekwe.

	Jumbi landfill	Mwanakwerekwe
History	• Old limestone quarry	• Old sand quarry
Location	• 12 km east of Stone Town • Close to farming area with rice fields	• 6 km east of Stone Town • Next to a market and a wetland in a residential area
Appearance	• 2 hectares, 3 meters deep • Compacted • Burned	• In level with market • Uneven surface • Uncompacted
Accessibility	• Close to asphalted road	• Close to asphalted road
Dominating decomposition phase	• Undefined due to burning	• Methanogenic
Landfill gas potential	• Low	• High
Waste composition	• 45,5% gravel and ash, 36,5% plastic, 11% non-classified, 6,5% metal and 0,5% paper	• 66% organic, 12,5% plastic, 11,5% non-classified and 10% paper
Bedrock	• Limestone with high permeability • Partly iron-rich	• Dense and chalky with high permeability • May increase sulphates and chlorides in the water
Hydrology	• Mwera river passes by closely • Occasional flooding • Shallow groundwater level • Groundwater pollution recorded in a well • Risk of seawater intrusion	• Wetland and storm water channels nearby • Low-lying area and destination for lots of storm water • Occasional flooding • Seawater intrusion has been recorded
Water quality	• High conductivity • High salinity • High ammonium level in well located on rice field • High iron level in one well	• High conductivity • High salinity • High ammonium level in the surface water
Social and health impact	• Closed partly due to complaints of smell and burning • Might affect irrigation water	• Smell • Vermin • Burning that could lead to respiratory conditions

The main negative environmental impact from Mwanakwerekwe dumpsite and Jumbi landfill is their lack of siting and planning. They have for instance been located in areas that receive relatively much rain, which increases the risk of

flooding leading to high leachate production and the spread of waterborne diseases such as cholera (ACRA, 2012). Furthermore they have been sited in areas close to wetlands leading to an increased risk of surface and groundwater contamination through faster distribution of leachate (Lagerkvist, 1999: Kurian et al., 2008). Both Mwanakwerekwe and Jumbi are close to residential areas, which increases their social and health impact. One of the main social negative impacts is the smell that rise (or rose) from the areas. Smell was subject to many complaints on Jumbi before it closed. Also the impact from vermin increases with the closeness to residential areas. Both Mwanakwerekwe dumpsite and Jumbi landfill are of open dumpsite character meaning that they have no lining, no leachate collection system, no leachate treatment system, no gas collection system, lack an organized disposal system and have no cover.

The survey showed a large potential for landfill gas production on Mwanakwerekwe. Landfill gas emissions are one of the major contributors to global warming and therefore have a negative effect on the global climate. On Jumbi landfill, landfill gas is most likely not generated in any significant amounts since the landfill was regularly burnt while operating. However, the burning is likely to have had a negative impact on the air quality through release of toxic substances such as nitrogen oxides, sulphur oxides, dioxins, furans and heavy metals (Kurian et al., 2008).

The bedrock in the area of Jumbi landfill and Mwanakwerekwe is relatively unsuitable for a landfill due to its porosity (Colbert et al., 1987). It is however almost the same over the entire island and is a challenge that always has to be considered on Zanzibar, for instance through proper preparation of the underlying ground when constructing a new landfill. This has not been done on Jumbi landfill and Mwanakwerekwe and increases the possibility for negative environmental impact through leakage of pollutants to the soil and water.

Water quality was tested at both Mwanakwerekwe and Jumbi. The water quality at both sites is almost always acceptable according to the WHO standards for drinking water (WHO, 2011). Absolute conclusions about the water quality based on the tests cannot be drawn since only six water samples were analysed and many parameters were not tested. The results from the water sample collection are presented in Table 3 and Table 4 and are analysed in closer detail below.

Water analysis on Mwanakwerekwe

The water analysis on Mwanakwerekwe dumpsite showed conductivity levels exceeding WHO standards for drinking water in all water samples collected, see Table 3. High conductivity could be an indication of pollutants in the water but could also be caused by seawater intrusion common in the area. Since the conductivity was highest in the well believed to be unaffected by the dumpsite and lowest in the surface water next to the dumpsite it is reasonable to believe that the high conductivity is at least partly caused by seawater intrusion. This is also indicated by high salinity figures in all the water samples. Salinity varied between 99 and 126 ppm in the water samples. In comparison, mean salinity in the leachate from ten Swedish landfills is 8.3 ppm (SGI, 2011).

The ammonium level was significantly higher in the surface water sample than in the ground water samples and believed to be partly caused by leachate from the dumpsite. According to the Canadian guidelines presented in Figure 3 in the theory chapter the ammonium level should not rise above 0.767 mg/l when pH is 7.5 and temperature is 30°C if aquatic life is to be kept safe. (SGI, 2011) In the wetland beside Mwanakwerekwe the ammonium level is 0.221 mg/l at pH 7.5 and water temperature 29°C and therefore it does not indicate an acute threat to aquatic life. The measured pH between 7.2 and 7.5 indicate that the dumpsite is in the methanogenic phase (Lagerkvist, 1999).

Water analysis on Jumbi landfill

Conductivity exceeded WHO standards for drinking water in two of the three surveyed wells, see Table 4. This could be an indication of other pollutants in the water but could also be due to seawater intrusion. Salinity varied between 63 and 85 ppm in the ground water samples, which is lower than in Mwanakwerekwe but still high and indicates seawater intrusion. The seawater intrusion theory is strengthened by the fact that the well with the highest salinity level also had the highest conductivity level.

The ammonium level in one of the surveyed wells was significantly higher than in the other two, which is likely due to runoff from a fertilized surrounding rice field where the well is located. Using the Canadian guidelines the ammonium level should not rise above 2.1 mg/l when pH is 7 and temperature is 30°C if aquatic life is to be kept safe (SGI, 2011). In the current well the ammonium level is 2.5 mg/l at pH 7.1 and water temperature 28°C and therefore indicates a threat to eventual aquatic life, see Figure 3. However the magnitude of this threat is hard to estimate since the wells' connection with surface water is unknown.

The iron concentration in one of the wells exceeded WHO guidelines. This could be an indication that levels of other metals (not examined in the survey) are high but it could also be caused by the bedrock in the area, which is iron-rich (Colbert et al., 1987: Rönnols, 2012).

Waste composition on Mwanakwerekwe dumpsite

Mwanakwerekwes' surface consists to a majority of organic waste, which makes up 66%. Paper represents 10% and plastic stands for 12.5%. No metal was found.

The waste composition analysis was conducted on both horizontal ground and slopes with no noticeable difference in the waste distribution found. This is interpreted as an indication that the surface distribution is representative for the waste distribution further down. The interpretation is supported by the fact that the poverty on Zanzibar has been high during the dumpsites entire lifespan and is still significant (AEO, 2011). The surface waste distribution is assumed to be representative for the waste distribution further down based on the relationship between income level and waste composition (UNHSP, 2011). Therefore organic waste is believed to be the major fraction at Mwanakwerekwe. However, due to

decomposition a significant part of the organic waste further down is likely to have been transformed to soil.

Waste composition on Jumbi landfill
The major part of the surface consisted of gravel and ash, which made up 45.5% and the majority of the remaining waste was burnt plastic, which made up 36.5%. 6.5 % of the surface was covered by metal and 0.5% of paper.

The landfill has been operating for 16 years, and regularly burnt during this time. Based on the same reasoning regarding poverty, income level and waste composition in the analysis of the waste composition on Mwanakwerekwe, the surface waste distribution is believed to be representative for the waste distribution further down. Therefore gravel, ash and burnt plastic are believed to be the major waste fractions in the landfill.

6 General discussion and discussion of methods

This chapter is based on the findings presented in the theory, background and result chapters. It does not claim to cover the complex of problems entirely and is by necessity subjective to some extent.

Based on our findings in literature and during our field study we have made a rough SWOT-analysis regarding the waste management on Zanzibar, see Figure 35. The purpose of the SWOT-analysis is to answer our thesis aim and benchmark. Some of the listed strengths, weaknesses, opportunities and threats are discussed in this chapter.

Strengths	***Weaknesses***
• Local recycling initiatives • Zanzibar is an island • Cheap labour • A climate good for composting and biogas production	• Poor governance • Insufficient collection • Low public awareness • No legal landfills • Aid dependency • Zanzibar is an island • Hydrogeological conditions
Opportunities	***Threats***
• Improved landfills • Improved collection and recycling system • Compost • Small-scale biogas • Education • Tourism increase	• Population increase • Tourism increase • Increase of waste amounts • More hazardous waste • Climate change

Figure 35. SWOT-analysis regarding the waste management on Zanzibar.

6.1 Strengths

Local recycling initiatives

Local recycling initiatives such as ZASEA and Jamabeco are well known and have got credibility, which indicates a will of the people to handle the waste in a more proper way. One of the reasons for their credibility and the fact that they have been around for several years is probably their business idea. However an umbrella organisation for different waste management initiatives would probably benefit the government through better statistics as well as the organisations through improved possibilities for collaboration and competition.

These local initiatives are examples of the spontaneous and unofficial second hand market common in developing countries. A market that has both benefits and disadvantages. It benefits the people making a living on it as well as the environment through the material cycle it creates. Disadvantages are that when a government tries to create a proper MSW management system it can be hard to dimension due to bad statistics of waste fraction amounts caused by the large but erratic reuse market.

Zanzibar is an island

The fact that Zanzibar is an island means that its environment is relatively unaffected by neighbouring countries and an improvement of the waste management on Zanzibar means an absolute improvement of environmental parameters such as air quality, water quality and visual impact.

Cheap labour

Labour is available at a low cost, making it both economically efficient to use human workforce for collection and recycling instead of technical solutions.

6.2 Weaknesses

Poor governance

One major weakness regarding the waste management on Zanzibar is the corrupted government with low education level, lack of financial resources, poor governance and low credibility. These things together make it challenging to implement a proper waste management system. There is no national plan for waste management system on Zanzibar and the existing system only focus on Stone Town where a minority of the population lives. A national plan combined with financial resources distributed over the island is important in order to get credibility for governmental decisions. Today dumping continues on landfills/dumpsites closed by the government, a clear indication that governmental decisions are ignored. However the situation is not improved by the fact that part of the government (ZMC) dump waste at illegal sites.

The figures regarding waste on Zanzibar is based on surveys made in Stone Town and these figures are not representative for the whole island since waste composition differs between urban and rural areas. A lack of reliable figures is a major challenge when trying to create a proper waste management system. Accurate figures are essential when dimensioning a collection system as well as landfills.

Insufficient collection
The waste collection system for MSW in Stone Town only has the capacity to handle about half of the waste generated in the town and the waste collection system is unreliable due to the lack of fixed collection routes. The skip trucks used in Stone Town can only transport one skip at a time and have to drive for about an hour to unload. The compressor trucks are not suitable for the typical waste on Zanzibar, which is wet and heavy due to the high level of organic waste and inert material. None of the truck types used in Stone Town are suitable for the narrow streets and sharp corners in the town. Furthermore the trucks are old and several are broken. Brimful skips and collection points is a common sight in the town and provides a good breeding ground for vermin. The conclusion is that the equipment used for collection in Stone Town is inefficient and unsuitable for the local conditions and the malfunctioning waste collection system is a health risk.

The areas outside Stone Town have no formal collection systems, which have induced uncontrolled and informal collection systems where waste amounts and way of disposal are unknown. The non-existing national waste collection system makes recycling harder, meaning that resources are not taken care of.

Low public awareness
Low public awareness affects the waste management system negatively since the knowledge is low regarding how to handle and dispose the MSW properly. Low public awareness also has a negative affect on the will to handle waste properly, which is shown through the disposal pattern where the waste is dropped on the spot and dumped at the beaches.

Furthermore collected waste is treated in environmentally and economically unwise ways. For instance waste is burnt in the backyards, dumped on closed landfills and used as fertilizers on plantations without any sorting. There is no insight in the health hazards that uncontrolled burning and waste fertilisation implies. The fact that farmers believe that all waste can be used as fertilizer is an indication of shortages in the information- and education system.

Recycling initiatives are also negatively affected by low public awareness since the understanding of the importance of sorting in clean fractions is limited. The willingness to pay for waste related services is limited by low public awareness in combination with low income.

No legal landfills
A proper waste management system requires a legal landfill, which is non-existing on Zanzibar today. It leads to waste being dumped and burnt in an uncontrolled way with no or little consideration to environmental, social and health effects. Informal dumpsites are not monitored and often not suitable for waste disposal leading to uncontrolled gas emissions, leachate release and potential spreading of diseases. Furthermore information regarding where dumping is allowed and where it is forbidden is poorly distributed and therefore dumping continues at informal areas such as Mwanakwerekwe.

Aid dependency
The waste management system on Zanzibar is dependent on development aid money in order to progress. There is however problems connected to aid projects for instance that they are often only active during a limited time and often lack an end-strategy with guidance in how to take over. For instance Zanzibar received help in 2005 to investigate and evaluate their waste management system, but none of the improvements presented in the report has been realised.

A feeling based on our experiences on Zanzibar is that people in power tend to sit and wait for money and projects to be presented for them. We find this attitude problematic since it shows a lack of initiatives and this approach tend to favour project based solely on money. This type of project might be maladapted to the country context like the incinerators built in Nigeria and the Philippines. But as long as there are aid organisations willing to pay for all the expenses of a project this approach is likely to continue.

Zanzibar is an island
The fact that Zanzibar is an island is also a weakness through its physical boundaries. For instance the unused space for future waste management facilities is limited.

Hydrogeological conditions
The bedrock on Zanzibar consists of coral limestone with high permeability, which is a weakness when pollutants from waste are released, increasing the distribution rate and the negative impacts on the environment. The big annual rainfall increases the amount of leachate and thereby the pollution distribution.

6.3 Opportunities

Improved landfills
Kisakasaka is planned to become the first controlled landfill on Zanzibar. Our landfill investigation shows potential disadvantages in the area such as residential resistance, bad quality of roads, located relatively far away from the place where waste is generated and the assumed large quantities of ground water in the area. Advantages include a large area with an estimated operating time of 20 years as well as no surface water in the area. Before deciding on making Kisakasaka into a landfill other alternatives should be investigated for instance the alternative to reopen Jumbi landfill and convert it into a controlled landfill. The decision should be based on economical, environmental and social aspects. If Kisakasaka is chosen it is of importance to make preparations before dumping starts, including at least proper lining, fencing, leachate control system and a plan for waste disposal. There is also great potential for landfill gas collection if the landfill is equipped with a gas collection system. A logbook where waste type, waste amount and dumping location on the landfill are recorded could be a way of keeping control of the landfill.

Improved landfills also include a proper closure of existing informal dumpsites which could include covering, monitoring of environmental effects, recycling of

easy accessible material for instance plastic at Tunguu and composting at Mwanakwerekwe.

Improved collection and recycling system
Clean fractions are of great importance in a recycling system and the easiest way to receive clean fractions is through waste separation at the source of generation. The biggest challenge for clean fraction that has to be overcome is the public awareness and concern about waste since it depends on their participation. A collection system that is easy to understand as well as it is reliable is crucial for engaging the public. To implement an improved waste collection system is expensive and ZMC does not have those financial resources and would need aid money. To make the collection system economically efficient it is favourable if the disposal site is located close to the waste generation source since human labour can be used instead of expensive trucks.

The fractions that might be recycled with economical and environmental profit on Zanzibar are plastic bottles and organic waste due to their abundance, value and relatively easy sorting and recycling. Organic waste can be converted into compost or biogas, which is described further down.

A big profit from plastic recycling is that it greatly reduces the volume of MSW ending up on landfills. Furthermore plastic is produced from oil and recycling reduces emissions of green house gases as well as toxic emissions related to the burning of plastic waste. However the informal second hand market for plastic bottles might be a challenge for the government if they are to implement plastic recycling.

Compost
Due to the high amount of organic waste in the MSW, Zanzibar has great potential to produce compost. The tropical climate makes the decomposition fast and there is potential for usage of the product (soil). Through composting Zanzibar could create a cycle of the nutrients and thereby lower the amount of artificial fertilizers, which would be of both economical and environmental gain. The landfill gas produced on a landfill is significantly reduced if organic waste is used for compost instead of being dumped. The study made on composting in Stone Town indicates that the compost can be of good quality as well as reducing the MSW ending up on the landfill significantly. A clean fraction, preferably sorted near the source, and good control about its content is of importance.

Both ZMC and local initiatives recognise the potential for composting on Zanzibar and on Matemwe dumpsite it is already going on. Water scarcity could be a challenge in some parts of the island and should be taken into consideration when choosing the site.

Farmers know that organic waste can be used for fertilization since they buy waste to improve the soil quality on their plantations and this might benefit a future market for compost. However it can also be a challenge that they are uneducated in the importance of using a clean organic fraction. There might be

competition between waste and compost if it is not made clear that fertilizing with untreated waste could be hazardous.

Small-scale biogas
If organic waste together with cow dung is digested in a controlled way it can be used to produce biogas. A big project regarding small-scale biogas is about to start at Zanzibar and in the future the cow dung could be complemented with organic waste. However there is a big educational gap to fill before this could happen. Biogas used for cooking instead of firewood lower the net level of carbon dioxide emitted to the atmosphere and decreases deforestation. Biologic digestion is preferable to composting since it produces both gas and a slurry but it is more expensive and complex than composting. In Zanzibar however there are challenges including lack of education and finances, water supply and locally adapted technique that can handle the air humidity.

Education
Public awareness and participation is of high importance in order to have a MSW management system that works properly. Jamabeco and the Danish Adventure School are good examples of local initiatives trying to increase public awareness regarding the waste situation and the environment through information in school etc. To improve the public awareness of MSW primary school is a good take-off point and the methods composed and used by Danish Adventure School and Jamabeco could be used as a model.

Newspapers, television and radio are not independent nor something that exists in every house and other information channels are preferable if possible. Information is better communicated through images and conversation than written text since a large part of the population is still illiterate. Substantial information and education focused on the positive effects for the public health it is more likely to be well received than information regarding for instance global warming that might be more elusive.

Tourism increase
The tourism on Zanzibar has increased during the last years and the governmental ambition is to attract more high-spending tourists. The tourism industry has already induced improvements of the waste management system on Zanzibar through for instance more frequent street-sweeping and collection in old Stone Town and cleaning of the beaches in Paje and Jambiani. Reports and interviews reveal that many hotel owners on Zanzibar see the profit in a well-managed waste collection system and are willing to pay for it. Hotels might also be a good take-off point to introduce biogas production. A better waste management system resulting in a cleaner island is likely to increase the arrivals of high-spending tourists on Zanzibar and this could be used as a motivation for governmental engagement. Furthermore an increased tourism and thereby nationally improved economy gives an opportunity to increase the waste management budget.

6.4 Threats

Population and tourism increase leading to increased waste amounts and more hazardous waste

An increase in population and income level will change the waste composition as well as increase the waste amount. A larger population means a higher pressure on existing systems and this needs to be taken into consideration when improving the waste management system. Most likely e-waste will increase and it could become a challenge to handle due to its complex and hazardous composition. Plastic is also likely to increase due to the use of more packaging material and since plastic contains environmental harmful additives it is also a future challenge.

Climate change

Zanzibar stands a risk for more heavy rains due to climate change, which might increase the amounts of leachate and distribution of pollutants.

6.5 Discussion of used methods for the landfill investigations

When the field survey was planned during the autumn of 2011 we had been promised funding from Zanrec Plastics for the research we wanted to do corresponding to an excavator, workwear and laboratory equipment. One month before we were leaving for Zanzibar we were informed that the research budget had decreased significantly. For instance we would not have access to an excavator and there were uncertainties to what extent we would get access to laboratory equipment. We started preparing for a field study with limited resources. After a month on Zanzibar it was clear that Zanrec Plastics would not be able to support the research with more than small expenses. During the whole field study we were in contact with Swedish waste experts discussing what methods to use with our constantly decreasing budget. In the end the landfill excavation for waste composition analysis became a surface examination using a wooden frame. The portable laboratory equipment for soil and water analysis became a limited water sample analysis conducted by ZAWA.

Our aim when arriving to Zanzibar was to examine the potential for landfill mining on existing landfills but during the field study this aim changed to become an assessment of some dumpsites. However some of the methods used were chosen based on the assumption that we were investigating recycle potential.

Data collection

Data collection proved a challenge during the field study since it became more and more evident that data is merchandise on Zanzibar and traded for other information or money. Some information was not received until the end of the field study, for instance the fact that the waste on Jumbi landfill was burnt on a regular basis when operating. If information would have been received earlier we might have changed our conducted examinations and our selection of dumpsites to investigate.

When investigating a landfill with limited recourses the dependence of already conducted studies is greater than when you have resources to conduct them on

your own. The paradox is that countries were the budget often is limited is also the countries with the least conducted studies. This is the case on Zanzibar for us, we were for instance not able to get data regarding air quality, wind and local climate. Data used regarding hydrogeology is from 1987 and most likely described conditions have changed, which affect the credibility of the data. This cause uncertainties in the study, but we argue that old data is better than no data in this case. We have tried to decrease these uncertainties through interviews and through reading more recent reports closely related to the subject.

For improved data on Zanzibar landfills you have to conduct most of the studies yourself, but they are costly, or you can spend time building up relationships with powerful persons. Zanzibar is a relationship-oriented country and information is only shared with people regarded as friends.

Waste composition analysis

The initial plan was to investigate the waste composition on the chosen landfill/dumpsites using an excavator, a large scale and lots of workforce but due to limited resources it became an analysis only of the surface waste composition.

We made the assumption that the waste composition on the surface was representative for the waste further down. This is a very rough estimation that had to be made due to limited resources and time. However these uncertainties are reduced trough investigation of the areas and interviews. Since we have made a lot of estimations both in the actual ocular examination and in the volume to weight-conversion calculation figures should only be seen as indications.

To improve the ocular examination a grid on the frame and a larger selection of measuring points could have made the estimations better. Division of the waste into more fractions would also have improved the data, for instance plastics could be divided into plastic film and plastic bottles to make data more comparable with data from former conducted studies. Another approach to collect more data concerning the waste composition at dumpsites would be to conduct an analysis of the waste on the waste trucks on their way to unload on a landfill. This research is currently very difficult to conduct on Zanzibar since there are no official dumpsites and the waste trucks dumps at random places.

Water sample analysis

Before arriving to Zanzibar we believed we would have a research permit giving us access to the areas we wanted to investigate. However, we never got this permit and therefore only had limited access to some of the areas in company with the environmental department.

We had no information regarding to what extent leachate was produced on Zanzibar during dry season and during our field study it turned out to be almost non-existing. Therefore ground water in wells was tested instead. We depended on the environmental department and ZMC for access to the areas and for knowledge about the sites. This knowledge proved to be quite limited and in retrospect we would have made another selection of wells if we had known what

we know today. For instance we would have made sure that we tested both upstream and downstream wells, we tried to secure this during the survey but it is still unclear if this was made. The planning of what wells to test had to be left to the environmental department since we lacked access to the area. We also lacked hydrological and topographical maps despite persistent attempts to get this information. Furthermore the information about what wells to be tested was not given to us beforehand and it turned out that the choices were made on site.

The water samples were collected in water bottles, which was the best option since proper plastic containers for water samples could not be found on Zanzibar. The water samples were analysed at ZAWA in a portable spectrophotometer from 1992 and we were not given information about how it was calibrated or how the tests were made partly due to language barriers. This is however the laboratory where Zanzibar drinking water is analysed and under the conditions the best option.

We had to make a selection of which parameters to test since we did not have money to test them all and ZAWA was unable to test all parameters, for instance BOD and COD. It is preferable if BOD and COD can be tested in a landfill investigation since they can give much information about the status of the landfill. According to WHO standard all tested waters qualify for drinking water in most parameters. However, bacteria in the water have a major influence on drinking water quality and since bacteria tests were not made no conclusions should be drawn regarding the drinking water quality of the water in the wells tested. Generally a list of about 50 parameters is tested when investigating leachate, and naturally more conclusions could have been drawn if all these were tested. However, the parameters selected were the ones believed to provide the most information and are probably not the major limiting factors in the thesis.

An improvement of the water quality tests would be to collect more samples and collect them during different times of the year i.e. wet season and dry season since the water quality depend on seasonal fluctuations.

6.6 Limitations and sources of error in the study

A lot of information was gained through active part taking in everyday life, informal conversations and observations. All observations made are subjective to some extent and made from our western perspective which affect the selection of information mentioned in the report and the presentation of the information gained.

Not many studies are done at Zanzibar and to find information regarding any topic can be a challenge. For instance no national census has been made since 2002 and our impression is that no one really knows how many people live on the island. Different persons give different answers regarding concrete subjects such as figures and we had to discuss and evaluate which answer to use. We have for instance tried to evaluate the credibility in different reports and interviews and compared them to each other. However this is a significant uncertainty in our study but our discussions hopefully have secured that the

information presented in the report is as accurate as possible under the circumstances.

Plastic bottle- and waste collection point surveys
In order to get more information about todays waste composition on Zanzibar surveys on amounts of plastic bottles used by tourists and waste disposed at a collection point were made. These methods were chosen based on their simplicity and cheapness.

An overestimation of the amount of plastic bottles generated by tourists could have negative consequences on an eventual future recycling initiative. Therefore we decided to conduct the plastic bottle survey in a way that would make the result an understatement. It does for instance not include plastic bottles consumed in restaurants or other places outside the hotel/house and the assumption that tourists in general stay one week on Zanzibar is also believed to be an understatement. According to our experience tourists visiting Zanzibar in general stay two weeks and it is very uncommon that tourists stay only for a weekend.

The result from the waste collection point survey is based on an ocular analysis of photographs and is a very rough estimation. However since waste is disposed in a scattered pattern it is very difficult to conduct the study in another way. The method we used is probably the best given the circumstances.

The waste collection point was only visited once a day and full day observations could have given information about disposal patterns and how waste is scattered or scavenged. However this type of investigation could have had an affect on our credibility among the local people and affected our chances for interviews. It would most likely have been seen as strange and locals might have doubted our intentions. Due to language barriers this would have been hard to communicate.

The waste collection point survey was only conducted during one week, and a longer survey that were to be repeated during a year in order to get the seasonal fluctuations would probably have given better information. A longer survey was not possible due to time limitations.

We were promised to be contacted when the collection points in Paje were to be emptied but this never happened. It would have been an opportunity to verify the information regarding Paje collection system as well as a possibility to better estimate the volume of waste generated in Paje.

7 Conclusions
The conclusions refer back to the aim and questions of the master thesis. In the end recommendations for the first steps when improving the waste management on Zanzibar are given. Suggestions of further research topics of interest are also given.

- The results in the field study concerning the waste composition on Zanzibar correlate closely with the findings in a study conducted on Zanzibar in 2005. Like many other developing countries Zanzibar's waste

composition is mainly made up by organic waste (85.6wt% in 2005) and plastic (4.4wt% in 2005). Plastic is however a significant part both volume wise and visually and covers about 30% of the surface in the conducted waste composition analyses.

- The field study shows that there is no functioning waste management system on Zanzibar today. Today Zanzibar lacks a national plan for waste management, a nationwide waste collection system and a proper and legal landfill able to deal with all waste generated on the island. MSW is to a large extent burnt in backyards, which affects human health and the local environment negatively. Indiscriminately disposal of waste for instance in storm channels cause flooding and is a breeding ground for diseases. Furthermore the working conditions for the waste collectors are unsatisfactory.

- Even with limited resources a landfill investigation can be made that gives some direction and knowledge of its environmental and social impact. But since it has to rely on already made reports, figures and maps some information might be old and hard to get which increases the uncertainties in the investigation. When resources are limited it is recommended to reflect on when is the best time for sample-taking and to collect them when impacts are expected to peak.

- Based on the landfill investigation Jumbi landfill, Mwanakwerekwe dumpsite and Tunguu dumping area have environmental and social impacts mainly through their bad siting, odour, vermin and closeness to surface- and ground water. The waste composition analysis on the sites together with the water quality analysis shows limited environmental impact from the sites due to high organic content in the waste and low content of hazardous materials. However, the impact is believed to increase during rain season.

- The first step to improve the waste management system on Zanzibar is to stop fertilizing plantations with waste from Stone Town. This is of high importance since the it is unsorted and contains hazardous waste and the potential negative effects from the fertilization are likely to intensify over time since the hazardous waste fraction is likely to increase.

- One of the first steps in improving the waste management on Zanzibar should be to establish a controlled landfill. Before starting it an environmental impact assessment should be conducted with the purpose to reveal the best siting for a landfill. However, since this is unlikely to happen, and since there are already plans concerning Kisakasaka, the advice is to build it as a controlled landfill including for instance proper lining, gas collection and leachate treatment.

- Another first step in the waste management improvement is composting. Composting could be a good option for treatment of the high amount of organic waste both from an economic and environmental perspective. Composting both reduces the volume of waste disposed on a landfill and creates a recycle circle. When siting the facility it is of importance to investigate the water access (since parts of Zanzibar suffer from water scarcity dunging periods of the year) and the market for compost in the area. Small-scale biogas production from organic waste could be an option in the future but is considered too advanced at the moment.

- Education to raise public awareness regarding waste is essential to be able to implement the first steps in an improved waste management system. A good starting point is to use methods from already existing waste education projects.

- If the improvements of the waste management system are going to be realized, major obstacles that have to be overcome are the poor governance and the corrupted government with small resources. To increase the benefits from aid projects, both economical commitment and active part-taking from Zanzibar government is to prefer. In the long run this could hopefully result in more effective and lasting aid projects and hopefully inspire to less corruption and better governance.

There are many questions left to answer regarding the waste management system on Zanzibar and how to improve it. A continuation of the master thesis could include a composting study and/or an extended study of the recycling potential of dumped waste on landfills, dumpsites and dumping areas. It would also be interesting to investigate the governmental organization behind the waste management system. A more detailed research regarding the effects of the landfills and dumpsites with sample-taking conducted over several years could also be of interest.

8 References

ACRA: ACRA- Cooperazione Rurale in Africa e America Latina, Italian NGO since 1968, *EuropeAid/132128/C/ACT/Multi – Annex A – Grant application form*, 2012.

Adewole, A. Taiwo, *Waste management towards sustainable development in Nigeria: A case study of Lagos state,* International NGO Journal Vol. 4 (4), pp. 173-179, April 2009.

AEO: African Economic Outlook 2011, *Tanzania 2011*, accountable of AfDB, OECD, UNDP, UNECA.

BP: Juma, Mzee K. & Fariborz, Kia, *Businessplan 2010-2011*, Zanzibar Municipal Council, 2011

C. L. Nahonyo et al: C. L. Nahonyo, L. B. Mwasumbi, S. Eliapenda, C. Msuya, C. Mwansasu, T. M. Suya, B. O. Mponda and P. Kihaule, *Jozani - Chwaka Bay proposed national park biodiversity inventory report*, Department of Zoology and Marine Biology University of Dar Es Salaam 2002

Colbert et al: Colbert, G, Wagner, B, Pinther, M, United Nations Department of Conference Services. Cartographic Unit, *Hydrogeological map of Zanzibar : including the islands of Zanzibar and Pemba, the United Republic of Tanzania*, United Nations, 1987

Golder: Golder Associate, *Zanzibar urban services project, Hydrology report for proposed Zanzibar urban services project*, report no. 12574-9575-9, Feb 2010

Gössling, S, *The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania*, Journal of Environmental Management (2001) 61, 179–191, 2001

Hoornweg et al.: D, Hoornweg, L, Thomas, L, Otten, *Composting and Its Applicability in Developing Countries*, The Urban Development Division, The World Bank, Washington DC, 2000.

ISWA1: International solid waste association (ISWA) Working Group on Landfill, *International guidelines (1) for the evaluation of the status of municipal waste landfills for economically developing countries*, 2011

IVL, Svenska Miljöinstitutet, *Vad vet vi om farliga ämnen vid materialåtervinning i plast?*, 2012

Knödel et al: Knödel, K, Lange, G, Voigt, H-J, *Environmental geology – Handbook of field methods and case studies*, Bundesanstalt für geowissenschaften und rohstoffe, Springer-verlag Berlin Heidelberg, 2007.

Kurian et. al: Centre for Environmental Studies Anna University, Chennai, *Dumpsite Rehabilitation Manual*, Kurian, J, Nagendran, R, Thanasekaran, K, Visvanathan, C, Hogland, W, 2008.

Lagerkvist, A, *Landfill technology*, Report 99:1, Division of Landfill Science & Technology, Luleå University of Technology, 1999.

Lagerkvist, A *Landfill Technology*, Report 2003:15, Division of Landfill Science & Technology, Luleå University of Technology, 2003.

Lundsor, Elisabeth, ACRA, *Hotel waste management in Zanzibar*, 2011.

NV, Naturvårdverket, *Recycling and disposal of electronic waste -Health hazards and environmental impacts*, 2011

Ogwueleka, T. Ch., *Municipal solid waste characteristics and management in Nigeria,* 2008.

RGZ: Revolutionary Government of Zanzibar, *Zanzibar Food Security and Nutrition Policy*, 2008.

Salustro, Jean Luc, *Sustainable solid waste management for the priority regions of Recomap*, Regional programme for the sustainable management of the costal zones of the Indian ocean countries, 2009

Sandec: Sandec Water and sanitation in developing countries, Eawag aquatic research, *Global waste challenge – Situation in developing countries,* Collaborate Working Group on Solid Waste Management in Low- and Middle income Countries, April 2008.

Scheinberg, Anne, *The Development of a Recycling Processing Centre in Dar es Salaam -A case study in using the ISWM Methodology*, 2005.

SGI: Statens geotekniska institut, Rihm, Thomas, *Underlag för vägledning beträffande inventering, undersökning och riskklassning av gamla deponier - Lakvatten och deponigas*, 2011.

SMOLE1: Sustainable Management of Land and Environment in Zanzibar, SMOLE II, *Terms of Reference (ToR) International Expert and Local/Regional Expert, Solid Waste Sector Analysis*, 2011.

SMOLE2: Sustainable Management of Land and Environment in Zanzibar, SMOLE II, Revolutionary Government of Zanzibar, Fredrik Alfredsson, *Discussion material for solid waste management on Zanzibar – For identifying & develop pilots*, 2011.

Tobisson et al: Tobisson, E, Andersson, J, Ngazi, Z, Rydberg, L and Cederlöf, U, *Tides, Monsoons and Seabed: Local Knowledge and Practice in Chwaka Bay, Zanzibar*, Ambio Vol. 27 No. 8, Dec 1998.

TWB2: Da Zhu, P. U. Asnani, Chris Zurbrügg, Sebastian Anapolsky, Shyamala Mani, *Improving Municipal Solid Waste Management in India - A Sourcebook for Policy Makers and Practitioners*, The World Bank, 2008

UD: Utrikesdepartementet, Regeringskansliet*, Mänskliga rättigheter i Tanzania 2007*, 2007.

UNEP1: United Nations Environment Programme, *Training module – Closing an open dumpsite and shifting from open dumping to controlled dumping and to sanitary land filling*, 2005

UNEP2: United Nations Environment Programme, Njoroge G. Kimani, *Environmental Pollution and Impact to Public Health; Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya*, 2007.

UNEP3: United Nations Environment Programme, *Developing integrated solid waste management plan – training manual, Volume 1, Waste Characterization and Quantification with Projections for Future*, 2009.

UNHSP: United nations humans settlements programme, UN-Habitat, *Solid waste management in the world's cities – Water and sanitation in the worlds cities 2010*, 2010

Visvanathan et al: Visvanathan, C, Tränkler, J, Basnayake, B.F.A, Chiemchaisri, C, Kurian, J, Gonming, Z, *Asian regional research programme on sustainable solid waste landfill management in Asia*, Sardinia, Tenth International Landfill Symposium, 2005.

Vuai, Said Ali Hamad, *Characterization of MSW and related waste-derived compost in Zanzibar municipality*, Waste Management & Research 2010: 28: 177–184, Dodoma, Tanzania, 2010.

WHO: World Health Organization, *Guidelines for Drinking-water Quality – Fourth edition*, 2011.

ZSDP1: Zanzibar Sanitation and Drainage Program Phase II, The Zanzibar Municipal Council, H.P. Gauff Ingenieure, *Feasibility study on solid waste volume I*, 2005.

ZSDP2: Zanzibar Sanitation and Drainage Program Phase II, The Zanzibar Municipal Council, H.P. Gauff Ingenieure, *Feasibility study on solid waste volume II*, 2005.

Zurbrugg, Chris, *Solid waste management in developing countries*, SANDEC/EAWAG, 2003

Electronic references

AED: African elections database, *Elections in Zanzibar*, retrieved 120326, http://africanelections.tripod.com/zanzibar.html,

Brunner: Paul H., *Goal oriented waste management: why and how?*, Vienna University of Technology, retrieved 120508, http://www.iswa.org/uploads/tx_iswaknowledgebase/p101.pdf

CTZ: Commission for tourism Zanzibar, *Terrestrial Wildlife*, retrieved 110921, http://www.zanzibartourism.net/terrestrialwildlife.php

EABW: East African Business Week, *Zanzibar bans use of plastic bags*, retrieved 111025,http://www.busiweek.com/11/news/tanzania/1652-zanzibar-bans-use-of-plastic-bags

Garfi, Marianna, Bonoli, Alessandra, *Waste Disposal In Developing Countries And Emergency Situations. The Case Of Saharawi Refugees Camps*, DICMA, University of Bologna, retrieved 111212, http://www.iswa.org/uploads/tx_iswaknowledgebase/15-384paper_long.pdf

MANZ: Ministry of agriculture and natural resources Zanzibar, *Environment*, retrieved 110921, http://www.kilimoznz.or.tz/departments/environment.html

NB: National Bureau of Statistics Ministry of Finance, The united republic of Tanzania, *Tanzania in figures*, 2011, retrieved 120326, http://www.nbs.go.tz/takwimu/references/Tanzania_in_Figures2010.pdf

NE: Nationalencyklopedin, Zanzibar, retrieved 110920, http://www.ne.se/lang/zanzibar/349598?i_whole_article=true

POFEDP: President's office Finance, Economy and Development Planning, *Promotion of Sustainable*, last updated April 5 2011, retrieved 110920, http://www.mofeaznz.org/index.php?option=com_content&view=article&id=116&Itemid=164

SACMEQ: Southern and eastern Africa consortium for monitoring educational quality, *Country profile*, retrieved 110920, http://www.sacmeq.org/index.htm

SIDA: Swedish international development cooperation agency, *Urban Solid Waste Management*, retrieved 111212, http://sidapublications.citat.se/interface/frmoptimaker3.asp?doctype=3&order=createdate DESC&departmentid=298&topheight=55&headerheight=23&fotheight=0&leftframewidth=300&width=820&stylesheet=sida.css&frameout=0&language=11&login=True&username=sida&passwh

SOPOR: Naturvårdsverket, Avfall Sverige, El-kretsen and Förpacknings- och tidningsinsamlingen, *Avfallsmängder*, retrieved 120322, http://www.sopor.nu/avfallsmangder.aspx

SZ: Ministry for Foreign Affairs of Finland, *Sustainable Zanzibar*, retrieved 120516, http://sustainablezanzibar.utu.fi/Study_Sites_Menu.htm

TDN: Daily news – the leading online new edition in Tanzania, *Zanzibar bans plastic bags*, retrieved 111025, http://www.dailynews.co.tz/home/?n=22572

UI: Utrikespolitiska institutet, Landguiden, *Tanzania*, http://www.landguiden.se/Lander/Afrika/Tanzania, retrieved 120326

UNEP5: United Nations Environment Programme, *Global partnership on waste management – background*, retrieved 111214, http://www.unep.or.jp/ietc/SPC/activities/GPWM/background.asp

ZP: Zanrec Plastics, *About*, retrieved 111011, http://www.zanrec.com/?page_id=2

ZPRP: The Revolutionary Government of Zanzibar, Zanzibar Poverty Reduction Plan, *Poverty in Z*, retrieved 111025, http://www.hakikazi.org/zwp/poverty_in_z.htm

ZTC: Zanzibar tourist corporation, *General information about Zanzibar*, retrieved 110920, http://zanzibartouristcorporation.net/zanzibar.htm

Verbal references

Alfredsson: Fredrik, Alfredsson, CEO at Zanrec Plastics, interviewed repeatedly between September 2011 and may 2012, +46 709 147 237, e-mail: Fredrik.alfredsson@switch-rv.se

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Hogland: William Hogland, Professor in Environmental engineering at Linnaeus University, Doctor of Science in Civil Engineering and involved in Waste Management and Recovery since 1988, interviewed in November 2011, e-mail: william.hogland@lnu.se, phone number +46 705858352

Juma: Mzee K. Juma, head of division of Sewage-Drainage and Solid Waste in the Zanzibar Municipal Council, interviewed several times between 23rd of January and 16th of February 2012, e-mail: mkju61@yahoo.com, phone number: +255 777 41 30 43

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Luca: Abel Luca Mtui, co-manager at the Danish Adventure School and the hotel Blue Lagoon, interviewed 26th of January 2012.

Kwatcha: Abu Kwatcha, the village eldest son and member of the Paje village committee, interview 27th of January 2012.

Kirknæs: Jesper Kirknæs, involved in the DANTAN biogas project on Zanzibar, interviewed via e-mail between 11th and 26th October 2011, e-mail: jesper@safi.dk, phone number: +45 38 10 01 10

Mwinyi: Abdul Mwinyi, member of the Paje Village Committee, interviewed 26th January 2012.

Okala: Mohammed Okala, member of the NGO Jamabeco, interviewed 26th of February 2012, phone number +255 773 15 16 51, e-mail jamabeco@yahoo.co.uk

Othman: Saad Othman, civil engineer and project coordinator at MCAEE, interviewed 24th of February 2012, e-mail: saad_othman2000@yahoo.com

Retzner: Charlotte Retzner, former employee at Nordvästra Skånes Renhållnings AB, NSR AB, and teacher in Environmental and Energy System Studies at Lund University, interviewed several times between September 2011 and May 2012, e-mail: charlotte@retzner.se, phone number +46 702107563

Rosqvist: Håkan Rosqvist, Civil engineer and consultant in waste management and landfill management through his company Rosqvist Resurs, former head of R&D at NSR AB and former head of the regional office of SGI, Statens Geotekniska Institut, interviewed several times between December 2011 and February 2012, e-mail: hakan@rosqvist-resurs.se

Rönnols: Eric Rönnols, works for NSR AB and Avfall Sverige as a consultant on waste management, interviewed several times between November 2011 and February 2012, e-mail: eric.ronnols@avfallsverige.se

Tobisson: Eva Tobisson, anthropologist and East Africa expert on the Swedish Ministry of Foreign Affairs, interviewed on 21st of November 2012, e-mail: eva.tobisson@nai.uu.se

Appendix 1 – Waste composition analysis – basic data

Tunguu dumping area

Waste fraction (%)/Site	Metal (foil and cans)	Paper (newsprint and cardboard)	Plastic (film and bottles)	Non-classified	Organic
1	5	15	30	5	45
2	10	30	50	0	10
3	5	5	30	10	50
4	0	5	45	25	25
5	0	5	25	0	70
6	5	5	75	0	15
7	5	10	40	5	40
8	0	15	30	5	50
9	5	0	20	0	75
10 (2nd site)	10	10	40	5	35
11 (2nd site)	5	15	30	20	30
12 (2nd site)	0	30	30	30	10
13 (2nd site)	0	30	35	5	30
14 (2nd site)	5	10	20	20	45
15 (2nd site)	0	10	30	50	10
Average	3,666666667	13	35,33333333	12	36
Median	5	10	30	5	35

Volume to weight conversion, Tunguu

Figures for density estimate in pounds per cubic yard are collected from the reference "UNEP, 2009". The conversion from pounds per cubic yard to kg/m^3 is done through multiplication with 0,59328.

Tunguu	Metal (foil and cans)	Paper (newsprint and cardboard)	Plastic (film and bottles)	Non-classified (carpet and glass)	Organic
Density estimate (pounds/cubic yard)	(175+850)/2	(400+50)/2	(23+35)/2	(305+600)/2	1443
Density estimate (kg/m^3)	304,1	133,5	17,2	268	856
Surface percentage	3,6	13	35,3	12	36
Relative weight	1094,76	1735,5	607,16	3216	30816
"Total weight"	37469,42				
Weight percentage	2,92	4,63	1,62	8,58	82,2

Jumbi landfill

Waste fraction (%)/Site	Metal (foil and cans)	Paper (newsprint and cardboard)	Plastic (film and bottles)	Non-classified	Gravel and ash
1	10	0	30	10	50
2	0	0	50	10	40
3	10	0	0	15	75
4	0	5	30	0	65
5	0	0	50	0	50
6	15	0	35	25	25
7	10	0	10	15	65
8	5	0	75	20	0
9	10	0	75	5	10
10	5	0	10	10	75
Average	6,5	0,5	36,5	11	45,5
Median	7,5	0	32,5	10	50

Mwanakwerekwe dumpsite

Waste fraction (%)/Site	Metal (foil and cans)	Paper (newsprint and cardboard)	Plastic (film and bottles)	Non-classified	Organic
1	0	0	15	0	85
2	0	0	15	85	0
3	0	0	5	0	95
4	0	5	25	0	70
5	0	20	5	5	70
6	0	10	10	0	80
7	0	5	10	15	70
8	0	30	30	5	35
9	0	20	5	0	75
10	0	10	5	5	80
Average	0	10	12,5	11,5	66
Median	0	7,5	10	2,5	72,5

Appendix 2 – Interviews held on Zanzibar

Interview with Rashid Ali Juma and the secretary of the minister of internal affairs on Zanzibar

23rd January 2012, meeting with Rashid Ali Juma, Director of Zanzibar Municipal Council, ZMC, and with the secretary of the minister of internal affairs on Zanzibar.

There is no way to handle solid waste on Zanzibar today. Plastic is good, you can not just ban it, in a land that wants a brighter future you need it, but there has to be a waste system able to handle it and it should be sorted at the source.

I want Zanzibar to set a good example to the entire world; in the future it should be called “the green island”.

It is good that the private and public sector collaborate in arranging a waste management system.

Interview with Abel Luca Mtui

26th of January 2012, meeting with Abel Luca Mtui, co-manager at the Danish Adventure School and the hotel Blue Lagoon in Paje.

Today there is three collecting points in Paje. also known as ”Taka-taka-stations”. All of them are designed and built by students at the Danish Adventure School. Originally there were eight collecting points, all made of wood. However some of

the wood was stolen by villagers and that opened the collection points up for the animals who eats and spread the garbage. Some of them burn down due to waste burning. Today two of the collecting points have been rebuilt and are made out of concrete and bricks. One is made out of both wood and concrete.

The new garbage stations, made out of concrete, are designed for two waste fractions, one fraction to burn and one not to burn. The fraction not to burn was supposed to be used for compost. However the villagers didn´t sort properly and the garbage collectors only visited randomly so the collection points were overloaded and villagers continued to leave the garbage outside the collecting points.

The Danish Adventure School arrange "Taka-taka-days" each year for the local schoolchildren where they teach them about waste and make a walk through the village and collect waste by the "streets".

Today the hotels pay for the collecting system through donations. Every hotel is supposed to pay a smaller amount of money each year to the village committee so that the collecting points can be emptied. One of the villagers, Abu Kwacha, owns two or three trucks and he is paid to collect once a month and drive the waste to a dumpsite in Stone Town.

The hotels waste is sorted, glass and plastic bottles are separated and brought to Stone Town where the plastic bottles are sold and the glass is dumped. The remaining waste is burned on regular basis. The Taka-taka-stations are used only by the villagers and were built to keep the beaches clean. Earlier the villagers left their garbage at the beaches to be taken out by the tide, however the beaches got filthy and meant bad business for hotel owners. The villagers' garbage consists in very small amounts of cans and bottles, this waste is mostly generated by tourists at the hotels.

There are 20 members in the village committee. The committee is divided into subgroups, for instance water, waste and forest. It also has a chairman.

One hotel on the way to Jambiani dump their garbage in the forest.

Interview with Abdul Mwinyi

26th of January 2012, meeting with Abdul Mwinyi, member in Paje Committee responsible for collecting waste-fee from the hotel owners.

December 1st 2011 the Paje Committee, the hotel owners, the kite centres and the shop owners met to discuss the problem with overloaded waste-stations. They all agreed to pay a monthly fee to the committee so that they could hire a truck and personnel to empty the stations once a month. So far there has not been any money collected.

The hotels are supposed to pay 50 000 shilling per month. The kite centres agreed to pay 5 USD per kitesurfer.

Mr Jan at the adventure school started the waste project. He called Paje committee, the elders and the women that work at the seaweed centre to a meeting and convinced them not to put waste in the sea.

We have about 3 000 villagers and we have two strong waste stations built in concrete now. We would need 6-7 in the village and they need to be emptied once a month.

Our problem is that we need about 4 new waste stations and we need someone to clean them. When we have collected money from everyone we will bring it to the secretary of the village and look at which waste station is full. Then we will bring the garbage where the government tells us to put it.

Our elders know about the waste problem. It is no problem to talk to them about it. All hotels tell us not to put waste in the sea. It is bad for all people, not just for divers.

Waste is a very big problem and it is forever. We use things and make waste every day. It is also bad for tourism. The wind is a problem since it spread the waste. The biggest problem of waste comes when the rains come it causes flooding. It's smelly and people get sick in their stomach.

To empty a full waste station and bring it to the landfill between Paje and Jambiani costs about 250 000 shilling. This price includes the truck and the personnel. It would be better if we had a truck ourselves.

We tried to put locks on the waste stations, but the people who entered the stations removed them. It is a problem because now the animals and the children gets in and eat the waste. I have seen one animal die from eating plastic.

The villagers are poor and you can not ask them to pay for waste collection. If the waste stations aren't emptied, maybe they will start putting waste in the sea again. The hotels make the most waste, some hotels take it to the dump, but most don't.

We take most waste to the landfill, but some waste is from the tree (paper) and this we burn. The plastic we take to the landfill.

There might be a recycling place in Makunduchi in the future.

Interview with Abu Kwacha

27th January 2012, meeting with Abu Kwacha, the village eldest son and member of the Paje committee responsible for the waste collection.

For 7 or 8 years we didn´t have waste stations, then people threw the garbage everywhere. Back then the beach was not clean.

We empty the waste stations twice a month and bring the garbage to Hakunamajewi. This dump started 5 years ago. Now we want to take waste to Makunduchi because there are many hotels in Hakunamajewi.

We have a problem with the surfers and the kite surfers, we want them to pay 5 USD each to finance the waste stations. We want approval from the government to collect that fee. To collect the fee from the hotels, we have to show them how much we clean, how much we empty and how much we pay people. One empty cost 40 000 shilling (200 kr) and we have to do it 3 times.

The last time there was a money collection at the hotels many didn't pay.
The problem was that after the collection in December, there where no information about how the collected money was used. The hotel managers wanted to know how the money was spent and on what.

We use my truck to empty the waste stations (there are also some small trucks in town). My truck can take 7 tonnes. During the 1-15 in a month we only clean the waste stations. Between the 15-30 we empty. If the waste station is full we have to go back and forth 3 times to empty it. The big waste station at Supa Duka takes 5 times back and forth to empty. We have 4 waste stations.

The villagers agreed to bring their waste to the stations, it's easier now – they don't have to go so far. The beach area is now clean and nice.
Every year the adventure school organise a waste-day in the school and everybody goes out and collects waste to clean the village.
The government is not prepared for the waste situation. They place dumps where people live and they get ill. I think a recycling centre is a good idea but there are many people who come here and say they will do it but nothing happens.

The separation at the waste stations works. We burn part of the waste and use the ash to fertilize the crops.

There are caves before and after the dump in Hakunamajewi and according to water tests done two years ago the water is good.

(There is some sorting going on at Hakunamajewi, PET-bottles are separated from the rest of the waste and put in big bags and according to Abu Kwacha they are waiting for ZASEA to come and collect it.)

Interview with Eddy

27th January 2012, field trip to dumpsites and waste collection points with Eddy, the taxi driver, as a guide.

There are many farmers close to Jumbi landfill. Now Jumbi is closed. A lot of people liver nearby and they complained of the smell. There is also several rice fields clos to Jumbi. Now there is no water but in the rain season they will be flooded and so will Jumbi landfill be. It takes 12-15 hours for the water to leave Jumbi landfill when it is raining. During the rain season, which lasts for 3 months,

it sometimes rains the whole day, sometimes a few minutes and sometimes there is no rain for a whole week.

Before the dumping started this was used for sand extracting by the government.

Farmers buy waste from Stone Town and make compost of it. They grow pineapple trees, lime trees, orange trees, mango trees, banana trees and coconut palms opposite of Jumbi landfill, about 30 metres in to the forest. They use garbage as a fertilizer since 7 months or one year.

For a long time there were no dumps in Zanzibar, people dropped the waste on the streets.

In the shehias outside of Stone Town people throw garbage in baskets made out of braided coconut. Then they pay a guy with a cart drawn by cows to come and collect it and bring it to the dump.

Interview with Salum S. Hamed
30th January 2012, meeting at ZASEA, an NGO that operates a recycling centre, with Salum S. Hamed, Manager of ZASEA.

ZASEA are currently unable to recycle hard plastic, plastic bags and glass but they aim to do so in the future.

Recycle bins attract pests because of the availability of left over food in cans and bottles.

Pricelist (what ZASEA buys different waste fractions for):
Plastic bottles: 200 TSH/kilo
Aluminium: 500 TSH/kilo
Stainless steel: 500 TSH/kilo
Electrical items, appliances, car batteries: 400 TSH/kilo
Cast iron and steel: 200 TSH/kilo
Steel containers and scrap: 100 TSH/kilo
Aluminium (soft and cast): 600 TSH/kilo
Copper and brass – price differs.

Zanrec plans to fill up a 20 tonnes container with PET in flakes and sell it to China for 450 Euro (about 550 USD). They want to make pellets of PP and flakes of PET.

ZASEA sells 1 tonnes of PET for 1 million TSH.

Today they get between 500 kg and 1000 kg plastic each day. They have a capacity to handle about 2 tonnes plastic/day.

35 people work for the NGO ZASEA. It is a youth project where all participants are under 32 of age.

One bag (1,5 x 4 m) with plastics (delivered from Matemwe) weighs about 45 – 60 kg.

Nicolas Mollel from Denmark works for UN-habitat and research how young people are trying to make their future better in Zanzibar. He has studied both ZASEA and MCAEE - Matemwe Control Aids, Environment and Education, in Matemwe. MCAEE are starting up a project that will work on turning organic waste (coconut shells for instance) into chicken food.

Streetboys bring plastic to ZASEA (conflict –they could have been in school but on the same time they need the money to be able to go to school). Also the dumpsite in Matemwe compresses plastics and brings it to ZASEA.

In Tanzania there is a problem with stolen goods from railroads for instance. That is not a problem in Zanzibar since there are no railroads or other material of value to steal.

Interview with Fiki

20th of February 2012, Fiki and Ali took us for a study visit with a skipper truck. Fiki drove and was also the one who talked.

It is a hard job, in the nights I am very tired. I work both day and night. We have 4 skipper cars but 2 are broken. Our cars are to few, we have to work in the night also.

If I had a new car I would be done at 12 o clock. I can not drive fast with this car since it is 15 years old.

I have worked here for 3 years. I go back and forth to Stone Town 7-11 times a day to collect containers. I start at 5 o'clock and I work every day.

There are 35-36 skippers. Many of them are broken. Then the tippers have to collect the waste instead. There are 2 tippers today, but only one works.

The car uses about 200 litres petrol in 3 days.

Everybody wants the garbage. They use it for growing bananas. They grow very fast when you pour waste on them.

The farmers pay 5000 TSH for one container of garbage if they have money. Everybody can not pay since they have to little money. They get it for free.

The car broke down this Sunday. Since it was a Sunday the office was closed and Fiki had to fix the problem himself. It took from early morning until 11 o'clock to fix it. There was no air in the compressor. Then he had to drive until 2 o'clock in the morning to finish the job.

Fiki tells us that dumping has been going on in the farm areas on Zanzibar for several years. He has worked for 3 years and it has been going on at least during that time.

Interview with Saad Othman

24th February 2012, meeting with Saad Othman, civil engineer and project coordinator at MCAEE (Matemwe control aids, environment and education). We were supposed to start in January but the work has been delayed. We plan to start in June.

MCAEE has existed since 2007 and I have been working here for one year. We work with poverty innovation.

In the project that I am coordinating we will use organic waste and convert it into chicken feed. We will use fish waste and fruit waste that include for instance banana peel, orange peel and coconut leftovers. We will collect the food from the markets and collaborate with ZMC. They will provide special bins containing special black plastic bags. ZMC will collect these plastic bags when they are full and bring it to us and we will pay for the gas.

In Matemwe we will collect coconut leftovers. We will buy a machine that can make oil from this and then we will feed the chicken with the oil to increase the production.

The youths involved in the project have to apply and to be allowed to apply you have to be between 15 and 32 years old. You should not go to school and you should not have a fulltime job and you must have a place to keep the chickens. There will be 11 youths involved in the project at the same time. So far there has been a large interest to participate and we have received 27 applications. Nicolas and me sent a letter to the three shehias in Matemwe and told them about the project and that we needed youths. Then we had a meeting with youths.

I will also employ 5 people to run the oil machine and about 15 people for processing the waste.

We will give them chickens and chicken food and they will breed them for 6 weeks and then sell them. After this the project start all over again. They will go through this four times and after this the idea is that they will have enough money to either start their own chicken farm or to start another enterprise.

I have made a survey of the amounts that will be possible to collect in the markets. I paid people working at the market for their waste during a week. The results I got and the amounts I expect to be able to collect from the Dalajani market, the Mombasa market, the Malindi market and the Mikanguni market are as follows:

Fish waste: 200 kg/day
Fruit waste: 1000 kg/day (because bread fruit makes a lot of waste)

In Matemwe we will send a bin to the hotels in which they can sort out organic waste. The benefit for them is that we come and pick it up. We take care of their waste for free. I think the best solution is to offer this service for free because then I give them incitement to sort. Hotels are a good starting point because it's easier to explain the waste sorting to managers, who are often from other countries where they already sort waste. Here many people think that sorting waste is a waste of time.

I have my own livestock company that I run parallel with this project. During my time in this company I have researched the possibility to feed chicken with organic waste. You have to know what livestock feed contains. During my research I have found out that a lot of organic waste can be used as feed (I have sent it for analysis). I have places extra focus on researching the possibility to use breadfruit since this cultivation does not compete with human needs. In Tanzania the chicken farmers breed their chicken with corn and this conflicts with human needs (since they also eat corn). In five years time my plan is to have my own breadfruit tree plantation. I have to apply for land for this plantation with the government. So far they don't know me and I have not gotten the land.

The big cost when breeding chicken is the chicken feed. This stands for 70 % of the costs:
<u>100 chickens:</u>
Buying the chickens: 100 chicken x 1400 TSH/chicken = 140 000 TSH
Chicken feed: 6 bags of 10 kg feed x 47 000 TSH = 282 000 TSH
Medicine for the chickens: 20 000 TSH
Total: 450 000 TSH

Selling 100 breeded chickens:
100 x 4700 TSH = 470 000 TSH

The difference (470 000 – 450 000) means that 6 weeks work gives the chicken breeder 20 000 TSH. This is what Saad wants to change through providing cheap chicken food from organic waste.

I have two goals with the chicken feed production. Firstly I am cleaning the environment and minimizing the waste on the landfills. Secondly I will lower the price on chickens through lowering the price of chicken feed.

Now I am going to Dar es Salaam to buy machines that I need for the production of chicken feed. For instance I need a drying machine. UN Habitat have given me the money I need for the first investments in the machines but I will have to wait until June when the second payment comes before I can buy all machines needed. My father has also contributed to the project through providing the land needed for the factory.

The major challenges for this project are to make people understand that waste is valuable. The initial cost for the machines is also challenging. In the future I think we will make revenue but in the beginning it will be tough to manage.

In the future I want to do good meat processing. There is currently no good meat processing facility on Zanzibar. The chickens here are good because people don't treat them with medicine. The problems are that there is no good place to store the meat and that the feather picking is time consuming. The industry would gain from a big processing plant that they (small producers who breed 100-200 chickens) could sell the chickens to.

People here wants to work but they do not have the means. They complain that they don't have any money. Now I am solving that issue for them.

I know the NGO who runs the Matemwe landfill, Mutallah. We corporate and when I start the project I will call him and see if we can help each other.

There is a big market for chickens on Zanzibar. One hotel buys about 200 chickens every 10 days.

In the future I want to make briquettes from paper waste and coconut husk. But this will be in another phase.

The major problem with the waste situation on Zanzibar today is that we have disease outbreaks (diarrhea) because of the limited waste management. There is also a problem with malaria due to this. The problem is worsening in the rain season because then people throw waste in the drainage channels.

Interviews with Mr Mzee K. Juma

Mzee K. Juma, head of division of Sewage-Drainage and Solid Waste in the Zanzibar Municipal Council, interviewed several times between 23rd of January and 16th of February 2012

2012-01-23:
Mr Mzee does not believe in the plastic recycling plant since he thinks that the plastic waste is already minimized because of the ban on plastic bags.
He thinks that a waste composition analysis is needed because new waste fractions have increased, such as e-waste, since the last analysis was made in 2005.

He is worried about how to finance the new collecting system. He does not want to see it funded by fees, taxes or producer responsibility.

2012-02-01:
Today we dump in the forest. This is a very big problem.

Tunguu is not designed for dumping, but trucks are going there.

During the dry season we used to burn Jumbi landfill every day. Now Jumbi is closed due to complaints from the community about flies and smoke from the fire.

2012-02-16:
The amount of skips, in Stone Town used to be 8, but now there is less. Several have been destroyed or damaged. The collection in town is limited to skips, concrete slaps and neither skips nor slabs (illegal dumpsites).

The municipality have 6 garbage trucks today but only three of them are working. They are all very old. There are 2 working skip trucks and 1 working compressor truck.

Jumbi landfill has not been used the last 3-4 months. Before that it was burned every day during dry season. The compactor broke down recently.

The collection is organised in routes. Workmen using a waste waggon maintain the roads in Stone Town. The skips are emptied every day to every third day depending on the amount of waste produced in the area. At markets the skips are emptied twice a day. The number of skips needs to be doubled according to Mr Mzee.

To be able to start dumping on Jumbi again about 85 million TSH is needed for cover material, a bulldozer, daily maintenance and a front loader etc. A bulldozer alone costs about 3,5 million TSH.

Mr Mzee believes that the depth of Jumbi is less than 3 meters.

Collected waste is transported to farm areas at different places in the surroundings of Stone Town.

Mr Mzee wants a new waste composition analysis to be made because the population has increased since 2005. He estimates that nowadays the waste production in Stone Town area is about 230 tonnes and about 45% of the waste is taken care of by the municipality. The daily waste collection he estimates to 99 tonnes but it could be as much as 110-115 tonnes per day.

Kisakasaka is a15 hectares big area that the municipality wants to convert into a new dumpsite. It's the only good place for a landfill even though is near communities and to raise the awareness among people living nearby is needed before you start to build it. The new landfill would provide new job opportunities, as the plan is to have sorting on the landfill. The advantages of Kisaksaka are that the land is government owned, there is enough space for a compost plant and a recycle plant (mainly plastic) and there is land for the wastewater. However the road leading to the area needs to be improved, there should be a workshop for the waste trucks, the methane gas from the landfill should be flared (because then they will earn carbon credits and raise the revenue). The area is rocky so it's good for the farmers if compost is produced in the area.

Mr Mzee thinks that due to low public awareness sorting of waste is hard to do at the source. In order to start sorting at the source, the public awareness regarding waste need to increase.

There is a problem with the society in Kisakasaka regarding the landfill. Today they complain that there's no place for a school and that maybe they want to build a hospital in the future.

Today's situation:
The situation is not good, the municipality do not have the capacity to manage the need, at least 80% should be collected by today it only 45%.

Local strengths are:
* Communities organise themselves and cooperate with us.
* Municipality have the awareness to understand that others can organize cleaning
* Municipality are willing to support and contribute (to a more developed waste management)
* Municipality knows about the problem and what to do, they have the basic information.

Challenges are:
* Equipment is needed
* The urban area is hard to manage
* The service can not cooperate with the activities such as population growth.
* A policy is missing and a policy would be a good tool.
* To collect everything.
* To update the database in order to make it function better.

Technology
* 80% of the waste is organic, municipality want produce compost from the organic waste, which will minimize the cost of a landfill.
* Municipality want to involve both the communities and the private sector.
* Plastic should be recycled.

Responsibility
* For the solid waste everyone is responsible, some people don't understand it's not only the municipality.
* Everybody should try to fix the waste management in his or her community.

Priorities
* The waste composition analysis is old – it should be updated to how it is now.
* Electronics are a new type of waste and proper technique is needed to take care of it.
* Trust in our own abilities, update the database and customers should pay for "what you get is what you spend".

In one year
* We should have a proper landfill at least have updated the old one
* Have a waste committee
* Not dump waste everywhere, raise people's awareness and have no illegal collection points

* Have enough collections points so that all waste is there, have the proper techniques.

It's all about money. You have to pay for services!

Interviews with Dr. Aboud Jumbe

Aboud Jumbe, PhD in environmental science, head of Policy, Planning and Research Unit at the Department of Environment on Zanzibar, interviewed several times between 30th of January and 7th of February 2012.

2012-01-30:
There is no national policy regarding waste management. It's done ad hoc today, but it does not solve the issue.

To dump in Marahoubi (by the Portuguese baths) was forbidden by the environmental department. But the people went on dumping anyways because they saved fuel by going there.

Outside town the districts of the shehias decide where you are allowed to dump but there is no law enforcement. No one gets convicted for illegal dumping.

Before this issue was small, now it's magnified because of the growing economy and the population growth. There is a vast rate of population growth in Zanzibar, especially at the west fringe. Land is also an issue, there will soon be no land left.

What happens when diseases break out? When you have water contamination? People here have a hard time understanding that the garbage will eventually reach the water and contaminate it.

We are only ethically interested. The responsibility is ZMC:s.

The Seychelles and Mauritius have programs regarding post closure management and monitoring of landfills. Post closure is one thing we really need to research in Zanzibar.

In 1985 Zanzibar didn't have an issue of waste. I came back in 2010 and I see a country on the tip of environmental disaster.

In South Africa fishes downstream die because of toxic waste.

I believe there will be heavy metals and POP:s in the leachate from the dumps in Zanzibar, but I don't know.

Persistent organic compounds can be tested on the Zanzibar food and drugs authority. They have a spectrophotometer. The state university of Zanzibar also has a machine but it is not installed so they send their samples to Dar es Salaam.

They have found heavy metals in soil samples collected around Dar es Salaam. The soil was polluted by irrigation water. In Dar this problem is acknowledged and discussed but not on Zanzibar.

Zanzibar is now preparing for climate change management. They are not in the cyclone area but stand a risk for more heavy rains and maybe tsunamis.

2012-02-01:
Jumbi used to be a surface quarrel for murram (a mixture of stone and rock). It is about 1-5 meters deep.

If you dig deeper than 5-10 meter anywhere on Zanzibar you risk punctuating aquifers.

Kisakasaka used to be a surface quarrel as well.

The biggest concern for landfills on Zanzibar is the shallow groundwater level. There are cases of visual evidence of water contamination.

There is a contamination issue on Zanzibar today with salinity. The seawater penetrates the groundwater. This is most frequent on Pemba. The changed weather pattern with erratic rainfall could be the cause. When the freshwater levels are low, the seawater moves in.

There have been findings of salinity in some of the wells surrounding Jumbi landfill, which is mentioned in a report from ZAWA written 93/94.

2012-02-07:
In Zanzibar Forestry Act you will find endangered and threaten species, mostly plants but also some red listed animals, for instance the Jozani frog, the Red Colobus monkey and a funny looking deer.

Mwanakwerekwe market was built 15 years ago. The dumpsite started expanding after this.

Sateni was the first dumpsite on Zanzibar and was built about 20 years ago. It is now closed and houses have been built over the entire former dumpsite.

GW1 is built in the former dumpsite of Mwanakwerekwe. It is a pretty deep well and therefore runs a risk of being polluted. The well has no filter, just a pump.

The inlet and outlet of Mwanakwerekwe wetland is dry and the pond is overgrown by water lettuce.

The soil in the area surrounding Mwanakwerekwe is a mixture of clay and sand, a sandy soil. It is a fertile area. However, the soil degrades when we build houses and roads. The roads are sandy and when the rains come they wash away the soil. There is a big problem with soil degradation on Zanzibar today.

The soils where "created" during the Miocene and Quaternary time on Zanzibar. There are 6-7 soiltypes on Zanzibar.

GW2 is most likely affected by the domestic area that surrounds it. Before it was used for drinking purposes, nowadays the have municipal water and the water in the well is only used for washing.

The sparrow is less and less common. This could be because of the increased air pollution that attracts predators (craw) who eats sparrows.

The diversity of butterflies have decreased the last years, they where more common in the seventies. Nowadays many of the species can only be seen in butterfly parks.

Frog diversity is also declining.

There is a stream in the Jumbi area that goes from Mwegera towards the south, close to Jumbi landfill.

In the Jumbi area the soil is loamy. This is a good soil for rice cultivation. Coral stone and plain make up the bedrock. (Bedrock plain is a low relief with a horizontal to slightly sloping surface. It may include small patches of sedimentary plains or inselbergs. Typically found in association with sedimentary plains.)

Interview with Gerard Hendriksen

Gerard Hendriksen is an engineer who works as a rural and energy advisor for the Zanzibarian government, interviewed 17th of February 2012, at the restaurant Archipelago in Stone Town.

Gerard has lived in East Africa since 1977 for example in Kenya, Rwanda and Tanzania but have also been working in Bangladesh. In 1977 he studied at the University of Zambia. He has a degree in mechanical agriculture.
Now he lives in Stone Town, Zanzibar and works as an advisor to the government. "I support the government offices with knowledge."

The big difference between Africa and Asia, according to Gerard, is the scale of the production and volume of the waste, mainly due to high population in Asia.

Gerard pays 10 000 TSH each month for waste collection, his bin is supposed to be emptied three times a week but often it's only once a week. He pays the "west municipality" the waste-fee. This fee is less than half of the fee he paid in Kigali, Rwanda for less service (where they collected twice a week). He thinks that the low fee is a problem because there is now way as he sees it that the municipality can make a profit while maintaining these low levels. Kigali in Rwanda sticks out in Africa from a waste perspective, being very clean. Rwanda has a stronger government and is more regulated.

Waste management is not for the rich as some people think, it's for everyone. Biogas works better when it's warm and on Zanzibar it's warm both day and night all year. High temperature reduces the retention time (which normally is about 40 days). A good place to start discuss and communicate about the waste problem might be in school?

Biogas could be very efficient on Zanzibar due to the temperature and climate. On Zanzibar and the detention time in a reactor would approximately be 40 days.

The Zanzibar government (ministry of agriculture?) is now focusing on a new biogas project and have the aim to have installed up to 400 plants in the next 5 years. This project is hosted by SNV and another Dutch organization (who helps with the funding). These plants are supposed to cost about 1,2 million TSH each and have a volume of 6 m^3. This type of plant should be able to produce enough gas for a family of 6 persons, but the family might still need to use some wood/charcoal. 2-3 cows in needed to produce the right amount of gas.

So far it's only DANTAN who has built 14 small-scale biogas plants in Zanzibar (two of these does not work). These biogas plants where of a more advanced model (for instance they tried to increase the dungflow with a gasflow) compared to the ones that is usually installed in east African countries and therefor more expensive (about 3 million TSH each). Gerard thinks these plants are too complicated and that it's not worth paying three times the price for something that is harder to manage. DANTAN was financed by DANIDA (the Danish SIDA) but is now closed.

There is a problem getting farmers in Zanzibar to invest in a small-scale biogas plant. A good cow costs about 1 million TSH and a regular one about 600 000 - 700 000 TSH and the farmers tend to think that investing in a cow instead of biogas is a better affair. The farmers can directly see the profit from one extra cow, milk can be sold directly, and it's difficult to see the direct profit from a small biogas plant since. It takes a few weeks before you have enough gas for cooking and the gas replaces something that you otherwise would get for free (firewood for cooking). Furthermore gas instead of fire wood/charcoal for cooking only helps women and children (reducing there time in the kitchen) and that also has a negative effect the interest to invest. Biogas is seen as luxury.

In other east African counties there is a health factor that influences the amount of biogas plants. For example in Rwanda and Kenya most of the cooking is done inside the house and burning inside is bad for the health, gas provides a much healthier way to cook. In Zanzibar most of the cooking is done outside due to nice weather and therefore the health aspect is not so strong here. Furthermore the price of wood is lower on Zanzibar than on the mainland and therefore they have not started buying more advanced cooking stoves on Zanzibar yet, while

When it comes to use organic household waste in the biogas plants Gerard says that you have to start from the basics, biogas from cow dung or chicken manure is easy, it´s when you start to put other things in the reactor it gets complicated and sometimes goes wrong. First you have to know how the system works. Start

at an easy level then you can start to experiment with other things but you have to be careful. The biogas plant must work and be stable before you should try to add other material than cow dung.

SNV is a Dutch government-sponsored organization that supports biogas projects in Africa and is present in for instance Rwanda, Kenya and Tanzania.

It can be hard to get aid-money for biogas project since they don't help the people who are the poorest. Therefor you need the locals to buy the plant themselves and thereby stimulate the market.

A small-scale biogas plants requires that the farmer keeps his cows tied up, he has to be able to easily collect the dung. This is a problem on Zanzibar since many cows walk around as they please. In the central parts of Zanzibar the cows are tied up, but in the east and south parts they walk freely. For this reason the focus of the planned biogas project will be on the central parts of Zanzibar.

The security issue of biogas is quite big since it is quite dangerous to store. It needs to be used when it's produced. Liquefied gas is compressed under 3-5 bars and contains much more gas but to liquefy biogas is impossible (is too expensive?). If a biogas project goes bad, the rumour spreads and that can destroy the market. The stakeholders have to be aware and careful when implementing a new system of what can go wrong.

Gerard explains, from his experience, that a difference between the governments in Zanzibar and Rwanda is that Rwanda has a much stronger government. In Rwanda the people who works for the government are more educated, more "well aware", further ahead and has better knowledge in questions "regarding the world". The war in Rwanda created a movement as people who once fled, got educated during their time in exile, and then came back. Rwanda also has a long history of being organised. Already in the 1930:s they planted tree to slow down deforestation.

Gerard thinks that Zanzibar is 25-50 years behind environmentally. They should be much more forward but instead they are late with everything. As the government wants new advanced technology there is a risk that it's too advanced (due to skipping a lot of steps?) and might only destroy for the future.

In Zanzibar 85-90% of the energy is used for cooking – make biogas and reduce the energy consumption, make the energy more environmentally friendly and limit the deforestation that's happening on the island. The Zanzibarian government have announced that they want to use less firewood for energy and thereby decrease the deforestation. Gerard says that if the government wants fast improvement on this issue, they should buy the advanced cooking stoves. They reduce the energy consumption by 50%.

PTD - plastic tube digester
In Kenya there is a biogas project where they use big, tube-shaped plastic bags as biogas reactors. It has been going on for 5-6 years and is a private sector

initiative that is fully commercial. The advantages are that it's easy for the farmer to get, he can go straight to the store and buy it and there are no contracts. They are cheap (about 500 USD in Kenya), easy to install and light. The disadvantage is that they only last about 5 years. In Kenya the government and people are more aware of the environmental problem in their country due to the population density, which makes the environmental issues bigger.

ARTI is located in Dar el Salaam and is run by a Canadian guy called Dennis and they focus on solar energy, biogas, carbon bricks and stoves. They have developed a cheap small-scale biogas plant, which also can be run on food waste.

Gerard thinks that the first step in a working MSW on Zanzibar should be to get the collection system working. One of the challenges on Zanzibar is that there is a lack of law enforcement and people reckons that the waste is not there problem. Therefore education and raised public awareness are needed regarding the waste. People need to realize that waste is everybody's problem.

He believes that the air pollution issue is still small on Zanzibar since there are few industries and cars.

A big environmental issue in placing a landfill is the groundwater, since the groundwater level is quite high. Kisakasaka has for instance a lot of groundwater.

He believes that Zanzibar has no problem with water scarcity. Instead the issue is the water distribution. In the middle of Zanzibar there is good access to water, but in the beach areas the freshwater is more limited.

For small-scale biogas plants the water is no issue since you collect both cow dung and urine.

Gerard thinks that hotels (for instance the Archipelago) could successfully invest in making small-scale biogas from food waste if they wanted to market themselves as green and environmentally friendly (minimizing the waste) and if they gained enough knowledge. He does not believe in bigger scale projects for the time being on Zanzibar, making streetlight for instance. He thinks that the level of knowledge is to low.

When you start putting waste in the biogas unit you have to hygienize. With cow dung this step is not needed since cow dung is a clean product.

One problem with biogas is the log return time of the investment. You save time and firewood but you it takes 5 years until you get the money back. On Zanzibar such a long payback-time does not work. They only invest if the payback-time is less than 3 years. The payback-time is shorter here than in Sweden.

Gerard thinks that the way to do biogas is the way the TDBP does it (Tanzania Biogas...).

Gerard thinks that the reason of the frequent power cuts on Zanzibar is that electricity is too cheap on the island. The government sets the price so low that it becomes unprofitable to provide electricity.

On Kisakasaka the UN made a combined solar energy and biogas project that didn't work. The cows walk freely so a person needs to collect the dung by hand force. Furthermore the project is too complicated; they put solar on the roof and tried to make batteries of the solar energy and the biogas. The technique is too advanced for Zanzibar. Gerard also questions why you make electricity out of the biogas when you lack gas for cooking. Today firewood constitutes 74% of the total domestic energy consumption by fuel type on Zanzibar and 85% of the energy on the island is used for cooking. Therefore that is the market where you should place your focus.

A local woman (missionary) outside Stone Town on the way to the airport has built an underground system for biogas. She also facilitates a quite advanced irrigation system. There is also a guy in Machui that has built an underground biogas system. Both built it with help from people in Arusha. The advantages with the underground system are that it takes less space, is hard to destroy and that you don't have to loft the cow dung high from the ground.

Interview with Mohammed Okala

26th of February 2012, meeting with the NGO Jamabeco in Jambiani. Mohammed Okala, member of the NGO and chairman in the beginning. Abdul, member of the NGO and chairman last year.

We started in 2001 with 7 members. We recognized that the environment was destroyed and had an idea about cleaning up the environment. I am in the tourism business and I talked to a lot of people from other countries where solid waste was already an issue. We also began to see that the waste was starting to become an issue for the marine wildlife. First it was about making Jambiani clean. The last years we have also met with people from other villages and are discussing collaboration with ten other communities, mainly in the east coast of Zanzibar. We want to find a solution for the waste in the east coastal area including among others Makunduchi, Paje and Jambiani.

We were registered as an organization with the government in 2005. Now we have 35 members. We have rotating leadership. Recomap funds us.

We collaborate with the schools, the nasars (kindergarten) and the madrassas and arrange competitions for the children. The one who collects for instance the most batteries or the most plastic bottles get a prize. Usually we give away uniforms, books or pencils for prize. It is hard for many children to get a good uniform. Schools and nasars also have cleaning days and cleaning projects where they bring the waste to us.

We have collected ton and ton of waste. The problem is that we have no place to put it. Before we brought it to Jumbi but now it is closed and we have no solution. ZASEA buys plastic for 200 TSH but it is difficult for us to bring it to them and

they wont come here to collect it unless we have more than 5 ton. We used to send the plastic, non-compressed, at the roof of the Dalla Dalla's to them. We can not claim an area big enough to hold 5 ton here in the village, even though the plastic bottles don't smell. At the moment we use land that is the property of our relatives.

Now we want to buy our own recycling centre but we need help from engineers to find a suitable place. We discussed with some Italian guys who promised to help, but for different reasons they won't come so we are looking for a new partner. We need more knowledge, people with ideas who can show us how to do it.

Tourists make a lot of waste. We do not drink wine or beer or water from plastic bottles.

At the moment there are so many empty beds at the hotels and it has been like this for about 10 years. Tourists won't come because they think that the environment is too polluted. Now the government are talking about ecotourism. The problem is that the government didn't research the benefits and disadvantages of tourism in the beginning. They just welcomed it.

The solid waste situation on Zanzibar today is very bad. Especially when you go to the farms around Jumbi landfill. They use the waste to fertilize the crops and we think that will be a big problem in the future. There is also a problem with plastic waste on the beach, which is a danger to the marine wildlife and the coral reefs.

I think that all of us are responsible for the waste and to find a solution.

We need a sustainable solution, for instance to reuse materials for construction of school benches. There is also a need for recycling in general.

We hope that solid waste management can give local people jobs.

We have started a survey of the hotels in Jambiani. We ask the guests how much water they drink and then we ask the hotels how many hotel rooms they have. Then we can calculate the amount of water bottles available to collect.

We have only small problems with people stealing our collected plastic bottles. There are some doctors, herbalists, which take a few bottles and put medicines in them and sell them. Children also take plastic bottles and use them for swim training, to stay afloat. When they are done playing with them they just leave them at the beach.

Abdul: We realized that the environmental destruction must affect us and then we started this organization. Lack of education of the environment is the biggest issue and also the solution to the waste situation on Zanzibar as I see it.

The plastic bottles in the hut next to Okala's restaurant have been collected for less than a month.