Research Project

Development of an Integrated Solid Waste Management System

Recommendations for the Ger-Settlement Bag7 in Darkhan | Mongolia

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I Abstract

Keywords: Capacity Development | Darkhan | Integrated Solid-Waste-Management | Mongolia | Waste Characterization | Waste Collection and Transport | Waste Recovery and Deposit

Solid waste management is a central issue for the prospective development in developing or emerging countries. Therefore, the following research project presents recommendations for the implementation of an integrated solid waste management system in a case study ger-settlement[1] Bag[2]7 in the Mongolian city Darkhan.
To develop an integrated approach - the work starts with a problem oriented analysis. This includes an analysis of the current institutional level of the solid waste management in Mongolia as well as waste characterization of the case study area Bag7 in Darkhan.
This analysis serves as the basis for the development of an integrated solid waste management system for Bag7 in Darkhan. The concept consists of three overarching components, namely collection and transport, recovery and deposit and capacity development. The point summary and outlook is a critical reflection about the implementation possibilities of the project presented here. The last sub section is a personal reflection of the authors' time in Darkhan, Mongolia.

1 Ger-settlements are informal settlements at the borders of Mongolian cities.

2 A Bag is the smallest territorial unit In Mongolia, which is comparable with smaller municipalities or boroughs in Germany (Sigel. 2012: 11).

II Acknowledgement

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In addition to the interviewees the help of the mongolian students was an invaluable part for the completion of our work. Especially the mongolian students were crucial to the data collection for the analysis part and they enabled us to get a deeper understanding of the current situation in Mongolia. Additionally they supported us in every manner in the daily life during our stay. The mongolian students are namely Kh. Otgonsuren, N. Otgonbayar, Kh. Gantulga, A. Oyunzul, Rosa M. Roza and A. Erdenechimeg. For all the support and the co-operation, we want to say, thank you to all mongolian students.

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Martin Böhm | Martin Lauckner | René Seyfarth

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1. Introduction

1.1 Thesis-Background

As one of the most sparsely populated countries in the world, Mongolia has a magnificent culture and landscape. There is an impression from the Western world, that Mongolia is a place untouched by the modern world. However it is only partly true. The mongolian state has undergone a far-reaching transformation since the collapse of the communist system. Until then, Mongolia was characterized by a unique cultural tradition as well as by a communist system. After the collapse of the socialist world - Mongolia struggled a long time to find its position in the world. Now, Mongolia is back on the world stage as one of the fastest growing economic systems in the world (Kirchner. 2012). Meanwhile, the fast economic development is placing new stresses and countless challenges upon environmental and social aspects. Apart from environmental problems like the negative impacts brought by booming mining industries and loss of the traditional way of life, urbanization is a core challenge for the further development of Mongolia.

The collapse of the political system led to a "De-economization" with a loss of the former economical basis, like the heavy industries supported by the Soviet Union. This in connection with the loss of the subsidies from the former Soviet Union resulted in social tensions within the country. The movement from the urban centers towards rural areas has increased significantly. The number of drovers went from less than 18 percent in 1990 to 35 percent in 1998 (Dore and Nagpal. 2006: 14).

But that was only a temporary effect. With the stabilization of the new political and economical system, the urban-rural migrations were stopped and a turnaround was reached. This incipient urbanization was supported by the removal of a law from communist times, which restricted the in-migration in urban areas (Dore and Nagpal. 2006: 14). Another central point, which supported the turnaround, were the natural conditions between 1999–2000 and 2000–2001. In these years the weather conditions in Mongolia were especially unfavorable with dry summers and harsh cold winters. The result of these catastrophic years was the death of 22 percent of the country's total livestock population. A lot of nomads lost their herds, their livelihoods and it led to an increasing migration of the nomads into larger urban centres (Dore and Nagpal. 2006: 12-15; Upton. 2010: 870).

This in connection with urban amenities like a "well" developed technical and social infrastructure led to a permanent migration from rural to urban areas (Sodgerel. 2010: 3). Especially Ulaanbaatar as the superior center of Mongolia was affected from this development. But even secondary cities like Darkhan and Erdenet recorded an increasing immigration (Dore and Nagpal. 2006: 12-15). As a result, 60 percent of Mongolia's inhabitants live now, at least most time of the year in cities (Ministry of Nature, Environment and Tourism of Mongolia and Korea Environment Corporation. 2011: 7).

The increasing urbanization process places new stress on the already fragile infrastructure of most Mongolian cities and has negative impacts in social, economical and environmental terms. It leads to an overload of the technical as well as the social infrastructure. This problematic development can be seen in the environmental impact, for instance the increasing air, water and soil pollution (Dore and Nagpal. 2006: 12). There is a need to rapidly adapt the infrastructure to the new conditions. William C. Clark from the Harvard University describes it in the following way: "The »battle for sustainability« [. . .] will almost certainly emerge as a battle to shape that rapid urbanization of smalltown infrastructure in ways that enhance both social and environmental liveability" (William C. Clark in Dore and Nagpal. 2006: 18).

One of the core problems of the urbanization,

apart from the insufficient water supply and sewage treatment, the lack of an adequate solid waste management (Dore and Nagpal. 2006: 12; Ministry of Nature, Environment and Tourism of Mongolia and Korea Environment Corporation. 2011: 8; Schuster. 2012: 8-9; UN-HABITAT. 2010: 18). The current solid waste disposal in Mongolia is inadequate for the rapidly growing number of inhabitants especially in the informal settlements. As in other developing countries, the rural poor in Mongolia tend to move into informal settlements, which have a particularly inadequate access to the urban infrastructure. In case of Mongolia - these informal settlements, in general called gers, are located in the peripheral areas of the city. It is necessary to adapt the solid waste management systems in the ger settlements to the new conditions and introduce an integrated solid waste management system (Dore and Nagpal. 2006: 12; Schuster. 2012: 8-9).

1.2 Goals and Limitations

The following research project contributes to a lack of an adequate solid waste management system in the Mongolian cities. The aim of this work is to develop a concept for an adequate waste management system in the case study area "Bag7" in Darkhan. Therefore, Bag7 is representative of the multitude of ger-settlements with similar conditions. As a result, the work focuses on a development of an integrated solid waste management system, which takes the local conditions into account and does not simply transfer German standards into the case study Bag7. It is not suitable just to transfer the waste management system from the economical developed world to the emerging or developing countries. To reach sustainable solid waste collection in the emerging or developing countries, it is necessary to adapt the systems and use appropriate technology. The used technology should be affordable, easy to operate and to maintain and spare parts have to be available in the region (UN-HABITAT. 2010: 8-12). Therefore, one goal of the work is to develop a system, which is adapted to the unique conditions of the Mongolian ger-settlements.

Furthermore, one goal of the research project is the development of an integrated approach. Integrated means, the development of an overarching concept with an emphasis not only on the technical terms. Even the local conditions, the development of a long-term perspective, the stakeholder constellation and the capacity development are crucial elements in the concept explained below.

Aside from these goals, there was also a need to take some limitations into account.

This work does not focuse on a complete analysis of the current situation in Darkhan or Mongolia in the case of the solid waste management. Such a kind of analysis is already given by Christian Schuster (2012) in his work "Description of Waste Management Systems in the City of Darkhan". His work is very detailed and so there was no need to repeat the whole analysis. Complements to the previously analysis by Christian Schuster and focuses only one some specific elements.

Furthermore, despite the work taking interfaces of the already existing system into account, it does not primarily aim to develop an integrated solid waste management system for the whole city of Darkhan. It is limited to the case study area Bag7.

What is more there is a need for another limitation in the work. During our stay in Darkhan, it was not possible to analyze the waste composition during the winter months and because of the lack of concrete statistics, we are not able to develop a concept for the whole year. Therefore the following concept has its focus on the summer months. To develop an approach for the whole year, there would be a need for further investigations.

1.3 Structure

The research project starts with an analysis of the current situation. The need for a new integrated approach is underlined in a problem oriented analysis. This kind of analysis investigates some problematic points of the current dealing process in a more thorough manner. The second subsection of the analysis part deals with the current institutional framework of Mongolia in case of the solid waste management. The question is, which public institutions are responsible for the solid waste management in Mongolia and in Darkhan. The goal is the identification of the crucial decision maker in the current Mongolian waste management system. The third subsection is a waste characterization of the household waste in Bag7. In order to develop an integrated approach, it was necessary to analyze the household waste in a more thorough manner. The reason for characterizing the waste from the ger settlements is, that former research in this field is not suitable for the concept presented here. Furthermore, the next subsection deals with the total waste arisings in Darkhan. This step is important in order to consider even large-scale reuse possibilities, which are not only limited to Bag7. For some reuse measures, the whole waste arisings of a city like Darkhan into account. The last subsection is dealing with a detailed analysis of the organic fraction of the household waste in Bag7. The goal of this part is to analyze the organic fraction according to certain criteria to determine various reuse possibilities.

This analysis serves as the basis for the development of an integrated solid waste management system for Bag7 in Darkhan. The concept consists of four overarching components, namely collection and transport, recovery and deposit, capacity development and development of an overarching model. All four topics are essential for the development of a detailed concept, which is not exclusively limited to a certain kind of activity. The four components are chosen according to their relevance for an integrated approach. The first subsection "collection and transport" is dealing with the introduction of a suitable collection and transportation system in Bag7. The next subsection deals with the recovery and disposal of waste. Therefore, seven utilization strategies were identified and described, namely the reuse of the organic material in a biogas plant, composting, the incineration of waste, the reused derived fuel system (RDF), landfill reclamation, the reuse of plastic materials and glass recycling.

Beside the technical solutions of an integrated approach, capacity development is even a crucial element. This subsection deals with the avoidance of waste and the capacity development by children.

The conclusion summarizes the main findings of the work. Furthermore, the work ends with an outlook on implementation possibilities of the concept presented here. Consequently, the outlook focuses on a critical discussion on a more general level.

1.4 Methodology

This work is a case study research witch uses different methods. The individual parts of the research project require different methodologies. The methods are chosen according to the relevance for the development of an integrated approach and are oriented towards the local conditions.

Basis for the development of an integrated system was a long term stay of the research group in Darkhan. The authors of this work lived almost two months in Darkhan. We lived in Darkhan to get a clearer understanding of the region, the problems of the current waste management and the possibilities aside from statistical data and the theoretical elaboration. In this context, we had meetings with representatives from the government and private institutions. We obtained

most of the information directly from the people, who have been dealing with the waste disposal in Darkhan for a long time. Furthermore, we went to Bag7 a few times in order to get a more thorough understanding of the current situation of the people and the existing approaches and possibilities.

In order to develop a detailed concept for a solid waste management, the research group worked interdisciplinary and consisted out of two environmental engineers and one urban planner. In addition, we worked together with Mongolian students and teachers from the Technical University of Mongolia and the Agriculture University of Mongolia. Both universities are located in Darkhan. Our project team sometimes consisted of 10 people and more. This was especially the case with the waste characterization.

The waste characterization was the first step of the work to understand the current situation in Bag7. Therefore, we did a primary research because of a lack of comparable or verified data. The exact procedure is described in the part “2.4 waste characterization”. In addition, we investigated the organic fraction of the collected waste in a more thorough manner. The exact procedure is described in part “2.5 Analysis of the organic fraction of the waste in Bag 7“. Aside from these initial projects, we started to work at a literature review at the same time. Handouts from lectures of the study programme environmental engineering at the Bauhaus-Universität Weimar were crucial sources. Especially lectures and handouts were suitable from the department “Biotechnologie in der Ressourcenwirtschaft” (former department "Abfallwirtschaft"), under professor Prof. Dr.-Ing. habil. W. Bidlingmaier and his sucessor Prof. Dr.-Ing. Eckhard Kraft. Even the department „Aufbereitung von Baustoffen und Wiederverwertung“ under the direction of Prof. Dr.-Ing. Horst-Michael Ludwig was a suitable source of information. Apart from lectures, even articles and works from the „Gesellschaft für Internationale Zusammenarbeit“ (GIZ) were an important source for the following work.

But despite the use of various literature sources, there is a lack of verified data in the literature about waste systems in Mongolia. There was a need to refer to local experts and to use their knowledge via the method of an expert interview. In order to understand the material better and to get a more thorough understanding one suitable measure is an expert interview. According to Meuser and Nagler (1991) experts are people, who are part of the examined field of activity and have an in-depth knowledge. The experts are directly involved in the research object (443). The experts in the case of the following work are all people, who deals with or have knowledge of the current solid waste management in Darkhan and especially in Bag7. The interviewees were persons from the Aimag and Soum administration in Darkhan, from PUSO and team members of the MoMo project. We conducted interviews with the following persons:

- » Mr. Tsendsuren Chimedsuren – current governor of Darkham Soum
- » The secretaries of the Tsendsuren Chimedsuren
- » Mr. Andrei - deputy chairman of the Building Development Department in the Aimag Darkhan
- » Mr. Nyam Ichuu – chief of the Public Utility Service Organisation Darkhan
- » Ms. O. Lkhamsuren – engineer at PUSO
- » Mr. Tserenadmid - current mayor of Bag7
- » Ms. Gerel Osor - employee of the MoMo project
- » Mr. Holger Schwarz – chief engineer in the Darkhan Thermal Power Plant
- » Ms. Ts. Enkhjargal - Leader of the local Non Governmental Organization " Eviin Khuch"

The interviews were face-to-face interviews. The language spoken was German,

which was translated into Mongolian by our translator Batchimeg Purev. Furthermore, the expert interviews were semi-conducted expert interviews. Dexter (1970) as a pioneer researcher in the area of communication skills argued in his book “Elite and Specialized Interviewing” that an expert interview should be an open interview. This would accommodate the expert and give him the chance to speak more freely about the research object (5). But in contrast to this more open way, there is need for a certain structure. Otherwise there is a risk of losing the plot. This method gives the researcher the freedom to expand on certain points which he thinks are important (May. 2001:123). This method was the most suitable for our interviews. The questionnaires are available in the appendix of this work.

Furthermore, we visited a lot of different firms and institutions in Mongolia during our stay in Darkhan. The protocols in the appendix show a short description of each field trip. We visited the following institutions and companies:

» Company “Mongolian Golden Oil” in Darkhan - possible other organic waste sources for the planned biogas plant
» Recycling company “San Orgiu” in Darkhan - current the only recycling company in Darkhan
» Darkhan Thermal Power Plant – a possible operator for a waste incinerator
» Restaurants “Altai- Mongolian Grill”; “Texas” and “Modern Nomads” – possible other organic waste sources for the planned biogas plant
» Slaughterhouse in Darkhan – possible other organic waste sources for the planned biogas plant
» Visiting of the local Non Governmental Organization " Eviin Khuch " - organization, which tries to improve the current solid waste management system in the ger-settlements

2. Analysis Part

2.1 Major Problems Referring to the Waste Management in Darkhan

Herewith are given a brief overview of the main issue. The following part focuses on the challenges and problems of the current solid waste management in the Mongolian city Darkhan as a representative example for the current situation of the solid waste management in other Mongolian cities. Despite Mongolia is an emerging country; the solid waste management has similar conditions and problems like most developing countries. These problematic conditions are present in every level of the state Mongolia, starting with the residents, companies, the Soum as well as the Aimag and are also represent in the national government. The major problems of the current solid waste management exist in the follwing fields: prevention, generation, recycling, transportation, collection and disposal.

Everywhere in Darkhan city or in outer areas, you will find wild deposited waste and people who burn their garbage on their plots. Open squares are often contaminated with waste because there is a lack of public bins. This type of waste disposal is cost-saving for the population but has a massive negative impact on the environment. The soil, groundwater and air are heavily polluted. This problem occurs with technical facilities. For example in Darkhan, there is a non sanitary landfill. Also you can call it an open dumping site because the landfill has no technical equipment like a multi barriers system, a cover, a treatment system for the leachate or a methane catching system. There is no need to talk about the dangers and problems of such a “legal” landfill because they are obvious. They start with a contamination of the groundwater and lead to health risks for humans and animals and the massive pollution of the air. In addition to this legal landfill there are many other open dumping sides close to the city.

In the Apartment area of the town there are some open collecting points. In an undefined collection frequency these are emptied by the municipal waste management company. This causes many problems, because these places are accessible to everybody. Therefore animals, like cows, dogs or insects, rummage in the waste and search for organic matter. Also waste pickers ransack the waste for some recyclable materials. The bins are not protected from wind and rain. Therefore, the smaller and lighter particles are carried away by the wind and leachate arises through precipitation. The same problems are given in the ger-settlements because the inhabitants store their waste on their Khashaas until the waste collection company picks it up.

> **Personal Experience**
> Darkhan has a massive waste problem. Especially the field trip to the landfill was „impressive“ in a negative way. The landfill is in a catastrophic state. The odour was horrible, a big part of the waste had been burned, cadaver and bones lay everywhere. Inbetween this horrible scenario were the workers of the waste company, scavengers and animals.

Another problem is that the waste management company picks up the waste only if the inhabitants call them and also there are no fixed collection points and regulated collection times. The waste disposal by company costs money, which leads to open dumping and illegal burning of the waste because not all inhabitants want to pay this fee.

Additionally, in general the waste

collection and disposal works very badly in the ger-settlements. Even if the inhabitants call the company, it often happens that the company does not come. So after a while, the inhabitants carry the waste away on their own take it to open dumping sides. Another obstacle is the very poor road conditions in Mongolia. This fact makes it very difficult to implement a reliable transport system especially in the winter.

Also the inadequate interaction between the different stakeholders in case of the solid waste management causes problems. For example the cooperation between the government and the companies is not the best. The system of the three powers, legislative, judicial and executive does not work well together. For example there are laws and regulations against illegal waste dumping and illegal burning of waste. But there is a lack of people who enforce these laws. As a consequence you can observe that in many places waste lies around and smoke arises from illegal incineration. But nobody controls the abidance by the laws. The government has demonstrated good will and support of the city with various programms to improve the waste management. Unfortunately these programs expired quickly and there will be no evaluation. Therefore, it is difficult to consider conclusions for future improvements.

Apart from these problematic circumstances, the existing system is also inefficient in economical terms. There is almost no reuse of the waste as a possible resource and the work processes of the local service providers are rather inefficient.

Lastly, another problematic issue is the lack of awareness of the waste problem. In a country like Mongolia people have far greater concerns than to take care of their waste. There always has to be an incentive or the possibility of a benefit to motivate the population. The Mongolian people do not look over the rim. Therefore most inhabitants do not have the will to change something. They do not see the reason behind the waste separation or why they should not dispose their waste at open dumping sides.

Altogether, the solid waste management system in Darkhan faces enormous challenges. The current system is not able to solve these core problems. The lack of an adequately working solid waste management system is a danger for the health and environment. In a long-term perspective, this system has to be adapted.

2.2 Institutional Frame Conditions

2.2.1 The Mongolian State Apparatus

To provide services in terms of a properly working waste collection, transport and disposal is a task of the public sector. Therefore, an inadequate working system is a failure of the government of a city, region or country (UN-HABITAT. 2010: 10). Because of this fact, it is necessary to analyze the current institutional situation of Mongolia and the practiced solid waste disposal more thoroughly. Hence the following part focuses especially on the state actors and institutions, because they are the central stakeholders in the solid waste management. Apart from them there are many other relevant private institutions or organisations. Examples are development aid organizations, the KfW Bankengruppe, non-governmental organizations or private recycling companies. They all have a central influence on the solid waste disposal in Mongolia. But despite this influence, the public institutions are still the most important with respect to solid waste management.

Mongolia is a unitary state with a central government. The state has three levels of local government under the national government (see figure 1). Currently, the state of Mongolia is divided in 21 Aimags (provinces) and the capital

city Ulaanbaatar as a separate unit. The Aimags are divided in 340 Soums (districts) and around 1.664 Bags, which are the smallest territorial units (comparable with smaller municipalities or boroughs). The capital has a special status in Mongolia and is divided into nine Districts and 121 Khoroos (Sigel. 2012: 11). According to the Constitution of Mongolia, the territorial units are organized through a combination of self-governance and state governance. The result is a dual system. The Mongolian administrative and territorial units have a governor as well as a local council. The capital, the Soum and the District has in each case its own Khural, which is the regional / local parliament (Government Service Council of Mongolia. 2008:24-25; Tortell et al. 2008: 13-14; Sigel. 2012: 11).

Since the collapse of the communist system in the 1990s - the national government started the decentralization of the administrative structure. Despite this effort to reform the existing system, the decentralization is still incomplete and a top-down hierarchy is still recognizable. The local governments, like the Aimags and Soums have some control over the local personnel, but the decision making power regarding cross-sectoral policies remains in the hand of the national government (Tortell et al. 2008: 13-14).

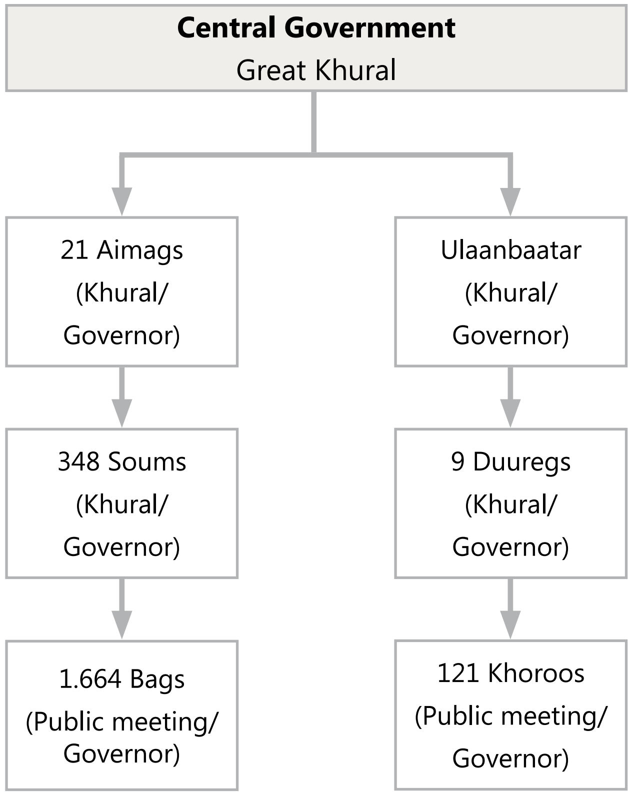


Figure 1: Territorial units in Mongolia (Sigel. 2012: 11)

Altogether, the resources to implement decisions are strictly limited to the Aimag and Soum level and the institutions are almost completely dependent on the national level. They are under a central fiscal control (Sigel. 2012: 14). To sum up, one can say that the national government has still the decision making power in Mongolia. As a result, the Aimag, Soum and Bag levels are responsible for the implementation of the decisions, which are decided at the national level. The own decisionsmaking power at the regional and local level is still strictly limited.

2.2.2 Waste Relevant Institutions at National Level

As already mentioned above, in fact the power is in the hands of the central government. This is noticeable in case of the solid waste management. The election in 2012 and the following change of the government structure led to a readjustment of the distribution of the responsibilities between the ministries. Ministers changed and ministries were divided. One example is that the former Ministry of Roads, Transport, Construction and Urban Development has been divided into the Ministry of Roads and Transport and the Ministry of Construction and Urban Development (Osor. 2012: Interview).

The figure 2 shows the connections and interactions between the different public institutions in relation to the solid waste management. The President of Mongolia appoints his government, which appoints the cabinet of each ministry. Each ministry deals with its field of responsibility like the urban

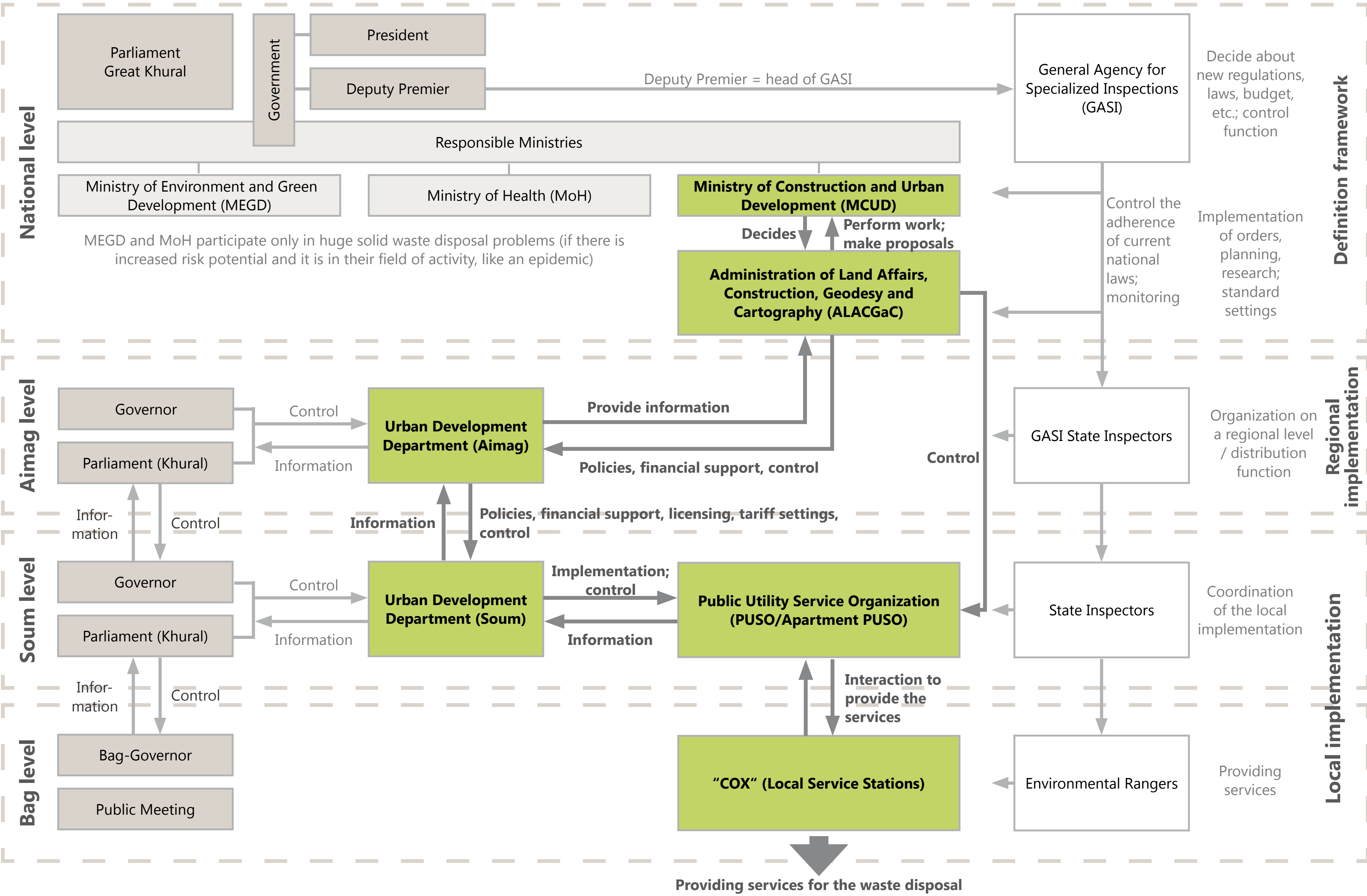


Figure 2: Institutional level of the solid waste management in Mongolia (Own figure on basis: ALACGaC. Undated; Osor. 2012; Sigel. 2012: 14)

development. The main actor in regarding the solid waste management is the Ministry of Construction and Urban Development (MCUD). Regarding the solid waste management the MCUD is responsible for the framework of the waste disposal. It introduces new regulations, national programs and regulates the distribution of the finances between the different resorts. Furthermore, it finalizes and chooses strategies for the further development in the field of urban waste disposal (Sigel. 2012: 34-35).

The central agency, which deals with matters of the urban development, on behalf of the MCUD, is the Administration of Land Affairs, Construction, Geodesy and Cartography (ALACGaC). ALACGaC was founded in the year 2000 under the name "National Center for Construction, Urban Development and Public Utilities". The organization is responsible for the implementation of the state policies at the Aimag, Soum and Bag level. Therefore, they provide information for the implementation as well as professional and technical support with regard to the development of new policies. The tasks contain:

» Develop and implement state policies, resolutions and orders in the fields of land affairs, geodesy and cartography, construction, urban planning and public utility
» Provide information like the establishment of a national spatial information infrastructure
» Ensure the adequate development and implementation of the urban master plans and strategic projects
» Research in field of the construction or production of building materials
» Development and implementation of the public utility policies
» Enhance development procedures in compliance with international standards (ALACGaC. Undated; Sigel. 2012: 35).

Therefore, the ALACGaC is responsible for the public utility service, which includes the solid waste management in Mongolia. The Department for Policy and Coordination of Construction and Public Utilities has thereby a central position regarding the solid waste management. It is responsible for:

» Formulation and implementation of the public utility policies
» Preparing the legal systems
» Planning of funding for the public services
» Management of design and research
» Coordinates and Control the Implementation
» Provide necessary information about the sector to citizens and organizations (ALACGaC; Sigel. 2012: 35).

Apart from the MCUD as the major ministry the Ministry of Environment and Green Development (MEGD) and the Ministry of Health (MoH) also have some competences with regard to the waste management. In general, they are not involved in concerns of the solid waste management. MEGD and MoH are only participating, when concerns of solid waste management affect their own fields of responsibility. One example is, when solid waste management problems lead to an epidemic. Then both ministries participate by removing the source of the problem. But they participate only in a short-term perspective to solve the problem, for example the removal of the waste, which had caused the epidemic situation (Osor. 2012: Interview).

But the ministries are not the only responsible institutions on the national level, which participate in solid waste management.

Another important institution is the General Agency for Specialized Inspections (GASI). GASI has been founded in 2002 and the Deputy Premier of Mongolia is the head of this organization. It is the main supervisory agency of the Mongolian government. The tasks of the agency include inspection and sanctioning of stakeholders and institutions by not keeping the environmental legislation. As a result, GASI has a control and enforcement function. GASI has approximately 1700 employees, who work as inspectors. GASI also has agencies in the local levels of Mongolia, namely the aimag inspection, the municipality inspection and the district inspections. Despite being the most powerful control unit in the area of environmental inspection, GASI has only limited power for example in scale of the possible penalties (Sigel. 2012: 34). In sum, GASI controls the adherence of the current national laws and monitors the developments. Therefore, they have representatives on all levels of the Mongolian state. But the decision making power with regard to the Mongolian waste management lies with the MCUD and the ALACGaC. Both interconnected institutions are the focal points in terms of solid waste management.

2.2.3 Waste Relevant Institutions at Regional and Local Level

Whereas the national level decides, the Aimag, Soum and Bag have to implement the decisions from the national level. Therefore they are to some extend the executive organs in the Mongolian state apparatus. Furthermore, the implementation is controlled by the GASI inspectors and also by inspectors from the ALACGaC. Thus, the implementation becomes more and more concrete, the farther one moves down onto local level.

On the Aimag-level, the local Urban Development Department is the institution, which is coordinates the implementation in the Soum and Bag levels. The ministerial level allocates the financial resources for the Aimag and the Aimag distributes the money to each Soum in the Bag. Therefore the Urban Development Department coordinates the solid waste disposal on the Aimag level and among the different Soums in the Aimag (distribution function). The Urban Development Department in the Aimag has a control function and is controlled by the ministerial level as well as GASI State Inspectors and by the Parliament/ Governor from the Aimag at the same time (Osor. 2012: Interview).

The Soum level works in a similar way. The Soum administration is extensively supervised by the upper levels, the State Inspectors and the own administration. But whereas the Aimag primarily has a distribution function, the Soum level is responsible for the implementation of a proper working solid waste management. Under the administration of the Urban development department in the Soum level lies the implementation by the Public Utility Service Organization (PUSO/Apartment PUSO). The PUSO as a state enterprise receives finicial support from the Aimag level to provide basic services in each Soum. In general each PUSO should cover the costs of their services. But not all PUSO in Mongolia are able to cover their costs. So they receive financial support from the upper levels of the Mongolian state institutions to adequately implement the task at hand. Apart from the own revenues, the local PUSOs also receive a financial support from the state (Osor. 2012: Interview).

Whereas some Soums are too small, PUSO has even the responsibility about other fields. For example it can also be responsible for the local housing. In that case PUSO is called Apartment PUSO. The main task of the company therefore is the waste disposal from the households, restaurants, hotels, shops, offices and the local

firms (Osor. 2012: Interview).

Because Darkhan is the second largest city in Mongolia, the housing department and PUSO are divided. In the first years since the collapse of the communist system, the services of the company were limited to the apartment areas in Darkhan. Untill 2004, there was no waste collection in the ger-settlements. This situation changed with the law on household and industrial waste 2004. PUSO completed a contract with the 16 Bag Governors and representatives of the Association of Apartment Owners for an overarching waste collection and transport in almost the whole Soum. This agreement covered 71 per cent of the households in the ger-settlements and 85 per cent of companies and enterprises. For the collection, transport and deposit of solid waste, a fee has to be paid by the waste generator (Schuster. 2012: 29-30).

Currently the PUSO in Darkhan has 185 employees and takes care of the following tasks:

» Cleaning of the public places as well as the streets

» Responsible for the solid waste disposal

» Maintenance of flood protection dams, water and sewers,

» Maintenance of streets and footpaths, and

» Responsible for the public green spaces (Schuster. 2012: 29)

In order to contain the tasks, the PUSO in Darkhan has a specific internal structure (see figure 3 on page 28). SPUSO employs 14 garbage collectors and 12 drivers for the collection vehicles. Furthermore they employ a similar number of debt collectors. Altogether, it is responsible for the direct collection and transport of the waste. Apart from these people, there are also engineers for the technical maintenance of the collection vehicles (PUSO. 2012).

With regard to the solid waste management, the PUSO in Darkhan collects and transports the waste to the local landfill Baraat. But to collect, especially in case of the apartment areas, there are local service stations called "COX". Employees from the COXs collects the waste from 4-5 apartment buildings every day and takes it to a central collection point within the collection area. When they have collected enough waste, they call PUSO. The PUSO comes and collects the waste from the service stations. But this is only done in one part of the collection area in Darkhan. In general the waste generator calls the PUSO, when they want the waste to be removed (Osor. 2012: Interview).

All in all, the Aimag, Soum and Bag level particularly have an implementation function. They have to provide the services for the inhabitants and have to follow the orders from the national level. In order to control this implementation, the ministries as well as GASI have inspectors in all levels of the Mongolian state apparatus. In consequence, the solid waste management in Mongolia reflects the general state structure of Mongolia, a top-down hierarchy with a small amount of a decentralized system.

2.3 Waste Characterization in Bag7

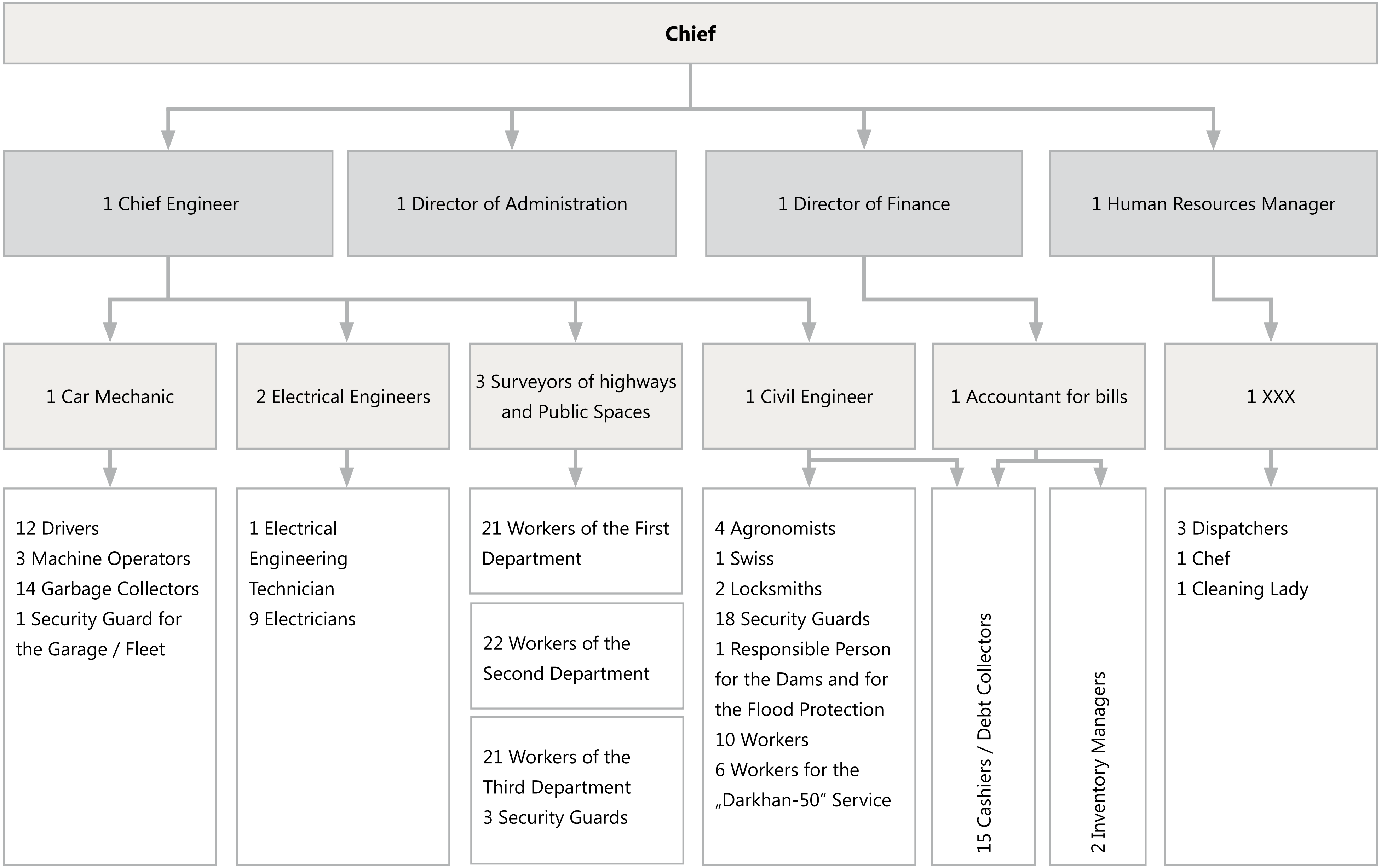


Figure 3: Organizational Chart of the PUSO in Darkhan (PUSO. 2012)

2.3.1 Procedure

The lack of verified data regarding the waste composition in Mongolian cities and especially in the ger settlements led to a need for own research in this area. There are a few studies, which analyse the waste composition and characterization in the city of Darkhan, for example a study from the Ministry of Nature, Environment and Tourism of Mongolia and Korea Environment Corporation (2011). But these works are only partially suitable for the further research. On the one hand, the scientific quality is doubtful. The formal settings as well as some descriptions and analyses are not adequately realized. On the other hand, there was a need to prove the data. With most studies the problem was that the methods used are not clearly comprehensible. As a result, it was necessary to carry out our own characterization of the waste composition in Bag7.

The realization of the characterization of the waste composition is based on a former work of a Mongolian student. The Mongolian student named Otgoo Huwhaltar (2011) did a waste collection during wintertime last year. She collected information including street name, household size of each family, weight and volume of the waste for over 60 Khashaas. This represents about two percent of the total population in Bag7. Her collection time amounted four days from Saturday to Tuesday. The results of this waste collection should be comparable with the new waste collection during summertime. In order to make the two studies comparable, a similar method was chosen in this work. But one problem of the realized study is that the student did not separate the waste in different fractions for further research. Therefore a lot of information was lost. As a consequence, the following research aims to generate data with more details like the weight of each fraction: plastic, paper, glass, metal, residual waste and organic matter. Furthermore, the organic matter of some families was stored in two separate containers, to make tests for a possible reuse in a biogas plant.

Beginning of the waste collection in Bag7 was the 14th August 2012. Every Khashaa received two plastic bags for the collection of their waste. These were in each case small white plastic bags with a volume of 45 liters and one bigger black plastic bag with a volume of 150 liters. In the white plastic bag, the inhabitants should collect the organic matter (kitchen waste). In the black plastic bag the inhabitants were supposed to collect plastic, paper, glass, metal and residual waste of her weekly waste. Instead of four collection days like the study of the Mongolian student, the decision was to enlarge the period to seven days from Wednesday the 14th of August to Wednesday the 22nd of August. Additional to the bags, every family received a handout for the correct use of the two bags. The handout showed how the inhabitants had to separate their waste (see appendix figure A1). Therefore a list, which included the different kinds of wastes explained where to put which kind of waste, was made. A plastic bottle should come in the black bag. Mongolian students were crucial team members, helping with the distribution and collection of bags. They explained the project to the conducted families and helped with the analyses of the waste. Furthermore, they were important team members because they have an in-depth knowledge of the local conditions. Without them, the whole waste characterization would not be possible.

> **Personal Experience**
> At the beginning of this waste collection one woman said: „Why we should collect the waste again? Waste is waste!" This statement shows the problems for a possible implementation of a solid waste management system

The waste was collected from the Khashaas seven days later on the 22th of August. Two groups with six people in each group visited the families. At the beginning, the collection of

the waste of the first family was done by both groups. It was used as an example to show the work processes. Every student had to know how the waste should be collected and separated. The materials of each group were:

» Weight scale
» Hand-shovel
» Bucket
» Face masks
» Rubber gloves
» Gauntlets

We analyzed the waste in Bag7 at the side of the street in front of each Khashaa (see picture 4). For that we had to sort the collected waste again. The reason for the resorting is, that most families did not separate the waste in the desired form. One of the major problems was the wrong collection. Many families put all of their waste in one plastic bag. Or they mixed the organic matter with plastic or paper. One family collected only one heavy plastic bag full of ash, which was not considered in this waste analysis. Another problem was that the most families do not understand the necessity of waste separation. Apart from the problem of a lack of understanding and the wrong collection, there was another problem with the waste collection. A massive problem was that in some bags medical equipment like injection needles were found. This was dangerous for the collection group and as a consequence also for the garbage collectors of PUSO. Therefore, the group had to be careful with the sorting of the waste.

After the analysis of the waste was done, the waste of each Khashaa was taken to central collection places within the Bag. After both groups finished the collection of the waste in the Bag, the PUSO were called to collect and dispose the waste. Subsequently PUSO took the collected waste to the landfill "Baraat".

2.3.2 Results of Waste Collection

The result of the waste collection during these seven days is shown below in table 5 and figure 6. All in all, the total amount of waste during these seven days is about 208 kilograms. Altogether the data of 175 inhabitants was gathered. This is 59.3 percent of the people asked and 2.8 percent of the total bag population. The major part of the waste is the residual waste with 42.7 percent and the organic matter with 25.1 percent. The organic matter often consists of bones and hair. For the use of the organic matter in the biogas plant, it is important to screen the waste and to separate all the impurities. Another organic material, which was found often, was potato peelings. Potatoes were consumed often at the time of collection in Mongolia. The reason was that August is the harvest time for potatoes.

The fractions metal and glass generate 11.9 percent of the total amount. During the waste collection it stuck out that metal and glass is picked up by waste pickers or collected by people, especially with low incomes. They collect these fractions separately in their Khashaa and sell them at special collection points. These facts have a negative impact on the quality of the research data and make it difficult to generate exact data for the whole ger-settlement. Paper is the smallest fraction with 2.1 percent and consists mainly of small pieces of wrapping paper. Newspaper or cardboards was found only in few waste bags.

In comparison to the waste analysis by the Ministry of Nature, Environment and Tourism of Mongolia and Korea Environment Corporation (2011) the results are different, especially the fractions paper, metal and glass (see table 7). Responsible for these big differences can be the influence of waste pickers and the number of requested people and as a consequence of this the amount of collected waste.

Despite the different results of the former waste analyses, the comparison between summer and winter seems to be representative. This is shown in table 8. Almost the same families in

Picture 4: Picture from the waste characterization (Own picture)

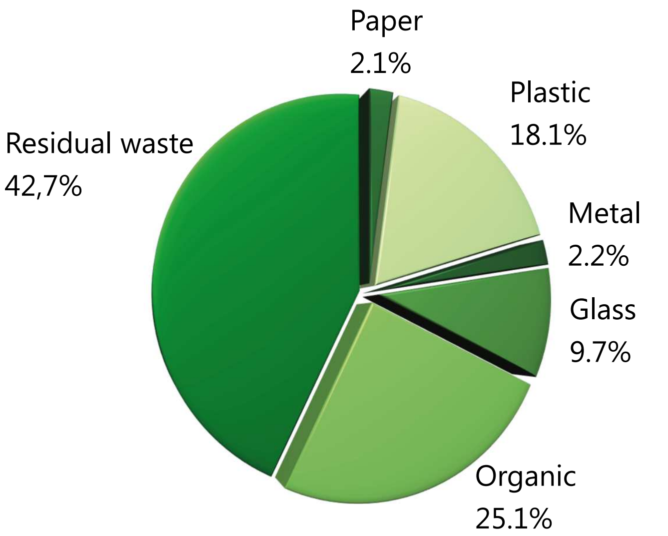


Figure 6: Results of the waste characterization [%] (Own results. 2012)

Fraction	Mass [kg]	Mass [%]
Paper	4.35	2.1
Plastic	37.75	18.1
Metal	4.53	2.2
Glass	20.28	9.7
Organic	52.30	25.1
Residual waste	89.00	42.7
Total	208.21	100.0

Table 5 Results of the waste characterization (Own results. 2012)

Fraction	Darkhan Bag7 2012 [%]	Darkahn ger-settlements 2010 [%]	Darkhan City 2010 [%]
Paper	2.1	6.0	8.2
Plastic	18.1	13.0	6.3
Metal	2.2	6.0	4.9
Glass	9.7	5.0	13.1
Organic	25.1	30.0	8.6
Residual waste	42.7	30.0	58.9
Total	100	100	100

Table 7: Comparison between the analysis presented herea nd the work from KECO (Ministry of Nature, Environment and Tourism of Mongolia and KECO. 2011; Own results. 2012)

winter and summer were asked to participate. First of all it sticks out that the generation of waste in winter is much bigger than in summer. In contrast to the amount of waste, the difference of the volume in winter and summer is almost the same with a little difference of 6.4 percent. The reason for this result is the influence of ash during wintertime. Coal is the most used energy supplier for heating the gers and houses in winter. This coal ash is also the reason for the higher waste density.

	Winter	**Summer**	**Difference**
Waste [kg/cap/d]	0.39	0.21	46.2
Volume [l/cap/d]	1.31	1.40	6.4
Density [kg/l]	0.30	0.17	43.3

Table 8: Differences in the waste composition during summer and winter months (Huwhaltar. 2011; Own results. 2012)

Table 9 shows the amount of waste in kilogram per capita and day for each fraction paper, plastic, metal, glass, organic and residual waste. The total amount of waste is 0.172 kg/cap/day. In comparison with the ger-settlements in Ulaanbaatar, the amount of waste is much higher with 0.956 kg/cap/day (in 2009). Also the parts of the different waste fractions are different and are shown below in figure 10 for summertime. During the winter months the generation of ash is about 49 percent of the whole amount of waste (Delgerbayar. 2009). Darkhan also has big problems with the ash in wintertime. This can be seen in the confrontation of the amount of waste in winter and summer with about 0.39 kg/cap/day in winter and 0.17 kg/cap/day in summer. The waste generation is more than twice as much in wintertime.

A comparison with other countries is shown in table 11. The amount of waste per capita and day in the ger-settlements in Darkhan is much lower than in the ger-settlements in Ulaanbaatar, the capital of Mongolia. Furthermore in comparison with other countries like Bangladesh, the generation of waste is always the same than in other parts. For example the organic matter is about 75 percent in Bangladesh. This high amount of organic matter is mainly based on the higher consumption of fresh vegetables than in Mongolia (Alamgir. Ahsan. 2007).

The mass indexes are shown in table 12. Especially the organic and residual waste looks plausible compared to literature. The mass indexes of paper and metal are limitedly representative because of the small amount of these two fractions in the household waste. It was difficult and not clearly to measure these fractions. The index of glass is higher than the index given in the literature. A reason for this variance could be the fact that the glasses in the waste characterization presented here was not broken, because the values from literature refer to waste in the container and not from the rubbish bag.

With the results of this waste collection it is possible to give an overview of the amount of waste for Bag7 and the other ger settlements around the city. This allows the construction of a functioning waste management system. This means the possibility to design optimal routes for the collection troops and to design the waste collection points. Furthermore it allows giving an overview over the possibilities for the reuse and the recycling of reusable and recyclable materials. And it also allows to compare the situation in Darkhan with other asian and mongolian cities.

Following of other previous waste

Fraction	Mass [kg/cap/d]
Paper	0.004
Plastic	0.031
Metal	0.004
Glass	0.017
Organic	0.043
Residual waste	0.073
Total	0.172

Table 9: Amount of waste per capita and day (Own results. 2012)

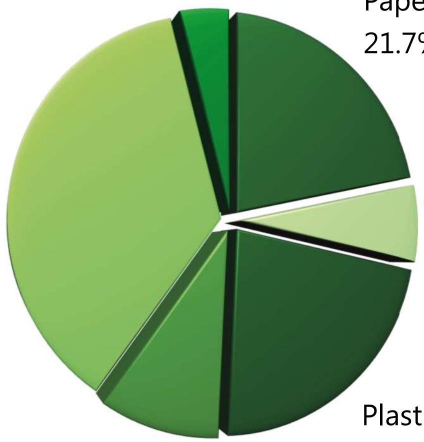


Figure 10: Amount of waste in Ulaanbaatar [%] (Delgerbayar. Undated)

Country / city	Amount of waste [kg/cap/d]
Darkhan ger-area (summer 2012)	0.172
Darkhan ger-area (winter 2011)	0.390
Ulaanbaatar ger-area (summer 2009)	0.956
Bangladesh total (2007)	0.387
Dhaka City (Bangladesh, 2005)	0.126
Khulna City (Bangladesh, 2000)	0.300

Table 11: Comparison with other regions (Ahsan et al. 2009: 101-108; Alamgir. 2007; Delgerbayar. Undated; Huwhaltar. 2011; Own results. 2012; Rahman et al. 2009: 255-263)

Fraction	Mass index [kg/l] our result	Mass index [kg/l] literature
Paper	0.1 (0.06)	0.1-0.2
Plastic	0.1 (0.06)	-
Metal	0.2 (0.18)	-
Glass	0.4 (0.35)	0.1-0.2
Organic	0.3 (0.27)	0.2-0.4
Residual waste	0.2 (0.17)	0.1-0.3

Table 12: Comparison own results with literature (Hädrich. 2009; Own results. 2012)

characterisations there are big differences between all of the characterisations. A major problem in this waste characterisation was to estimate an adequate count of inhabitants and with this an adequate count of waste. But the comparison of winter and summer time shows that our results are coherent. The waste amount is about 50% higher in winter time because of the very high use of ash for heating and cooking. And this issue conclusive to waste analysis in Ulaanbaatar (Delgerbayar. Undated).

2.4 Determining the Total Amount of Waste for Darkhan

In order to develop an integrated system, it is necesassary to know the total amount of waste arising for a ger-settlement as well as for the whole city. Four sources were used to determine the total amount of waste for the town Darkhan. The world health organization (WHO) in 2002 did an analysis of the amount and composition of solid waste. Unfortunately, the method of the analysis is not known (WHO. 2002).

The second source refers to a waste analysis in 2011. This analysis was performed by KECO, a Korean organization, in cooperation with the Ministry of Nature, Environment and Tourism of Mongolia. The analysis was performed on the landfill of the city.

Therefore, the waste was discharged on a flat area on the landfill. The size of the sample was adjusted as needed. But it is not clear how they determine the size of the sample because of a lack of suitable criteria. The vehicles were selected at random during each day of selection, because they collected waste from specific areas. The source for waste selection were the areas like ger -settlements or apartment areas or the type of generator like residential, ger-areas, commercial, street, or hospitals. After the vehicles had been loaded up, the bulldozer collected samples from 100 to 200 kg per sample from two different sections of the load. If the sample was on the flat ground, the sampling crew divided the mix in two halves. Afterwards, one half was collected. Accordingly the sample was separated by hand in different fractions and was collected in containers. The particles were also seperated into fine particles (< 2.5 cm) and big particles (> 2.5 cm). The big particles (the overs) were separated another time into the different fractions and the particles < 2,5 cm were added to the mixed waste or to the non-recyclable waste. After sorting the weight of the individual fractions were determined. Altogether a total of 15 samples were taken and analyzed. The quantity of the waste for one year was calculated using the number of the dumping trucks along with the bulk density of the various types of waste generated in Darkhan. The determination of the waste amount was only for summertime (KECO. 2011: 25-28).

The third source is a power point presentation, which is from the head quarter of the PUSO in Darkhan. The PUSO collected the generated waste from ger- settlements, apartment areas, shops, offices and from constructions from 2006 to 2010. The representative for the interior waste statistic is the engineer Lkhamsuren. For the determination of the amount of the waste the commissaries from PUSO counted the vehicles, which had collected the waste from apartments, ger-areas, offices and the waste from the streets. In this way they could extrapolate the amount of waste from the known volumes of the different collecting trucks.

For the comparison with the amount of waste in the ger-settlements the waste analysis of Bag 7 was used. It is assumed that the waste composition in ger-settlements is similar. Therefore, the emergence of waste of all ger-settlements was extrapolated by using a hand-out from Mr. Baast from the City Planning Department in Darkhan (see table 13). Unfortunately it was not possible to determine

the amount of waste for the entire city.

To compare all sources of waste for the city of Dakhan a table with different sources and different collection areas was rendered (see table 14). There is a difference between the seasons of collection time. So the sources of waste determination from the BUW and Korea study only show waste collection in summertime. This could falsify the results because every season has a different compositions and amount of waste. For example the waste from the ger-settlements concludes more ash from heating in wintertime than in summertime. Also there is a difference between the waste collection areas. In the waste determination from the WHO the street and construction waste was not included and in the determination from the Bauhaus-Universität only the waste from the ger-settlements was ascertained. Likewise the date of the studies fluctuates between 2002 (WHO) and 2012 (BUW). Because of the fast population increase of the town Darkhan it is advisable to apply more recent data. The results of the study from Korea and PUSO nearly show the same amount of waste. Therefore for an additional analysis it is advisable to use the values from PUSO, from Korea or to average these two sources.

The table 15 shows a statistic. It is based on the Statistic Office of the County Darkhan and shows the amount of waste for the whole

Bag, Nr.	Families	Inhabitants	Waste [kg/d]	Waste [l/d]	Waste [t/a]	Waste [m^3/a]
1	1 040	4 024	683.90	3 696.90	249.62	1 349.37
2	1 520	5 135	872.72	4 717.59	318.54	1 721.92
3	1 804	6 155	1046.07	5 654.68	381.82	2 063.96
6	1 377	5 048	857.93	4 637.66	313.15	1 692.75
7	1 598	6 200	1053.72	5 696.02	384.61	2 079.05
8	1 684	5 696	968.07	5 232.99	353.34	1 910.04
15	2 256	7 622	1295.40	7 002.43	472.82	2 555.89
Total	11 279	39 880	6777.82	36 638.26	2 473.90	13 372.97

Table 13: Amount of waste in the ger-settlements (Baast. Undated)

Source	Year	Summer (s) / win-ter (w)	Apart-ments [t/a]	Ger-areas [t/a]	Office, shops [t/a]	Street, construc-tion [t/a]	Total [t/a]
WHO	2002	-	3 182.8	1 540.0	677,4.0	-	5 400,3
KECO	2011	s	12 613.5	16 832.0	16 277.0	3916,6	4 9640.0
PUSO	2010	s + w	11 780.0	12 790.0	8 400.0	430.0	3 5830.0
BUW	2012	s	-	2 473.0	-	-	-

Table 14: Comparison from four different sources of waste analysis (Own figure on basis: KECO. 2011; Own results. 2012; WHO. 2002)

Content	Unit of measurement	Number
Collecting points	number of unit	7
Catchment area	hectare	21
Volume	1000* [m^3/a]	47 961
Volume ger-settlements	1000* [m^3/a]	13 358
Volume apartments	1000* [m^3/a]	12 013
Streets, public spaces	1000* [m^3/a]	7 389
Industry, business, commer-cial	1000* [m^3/a]	14 036
Waste of remeditation	[t/a]	62 190
Spaces of remiditation	hectare	36.7

Table 15: Waste analysis of the Aimag Darkhan (Statistic Office of the County Darkhan - Aimag. 2012)

county. It is differentiated into the sources of emergence and into the waste which is collected at the source of genesis or waste which was collected by the rehabilitation of contaminated sites. Unfortunately it is not possible to apply theses statistics to the generated amount of waste in the city Darkhan. It seems that this data is not comparable to the other statistics from PUSO, WHO or Korea, because the amount of volume is too big for the city. For example in the ger-settlemts there is an amount of 12 790 tons per year of mixed waste (PUSO), and appending there is a volume of mixed waste in the county of 13 358 000 m^3 per year which is too much for the weight.

2.5 Analysis of the Organic Fraction of the Waste in Bag7

In order to consider the different reuse possibilities for the different fractions, there was a need to analyse parts of the waste more thoroughly. This especially is the case with the organic fraction, because there is a large variance. The parts between different kinds of organic waste can differ wildly.

2.5.1. Sampling

In order to gain a representative sample, it is necessary to carry out the sampling precisely. Therefore the whole of the properties of the sample are shown. A sample is representative if it has the same characteristics as the whole sample.

Examples of typical characteristics:

- Mixing ratio
- Homogeneity
- Color
- Moisture content
- Particle size distribution

To obtain a representative sample, it is necessary to calculate possible mistakes (see figure 16). Mistakes could be done during sampling, measuring, or when dispersed into the analysis result. The volume of the sample is

representative only if it has the same grain size, distribution and material composition as the big sample. The characterization of the sampling could be done with the help of the following attributes:

» Maximum particle size of the sample
» Heterogeneity
» Analysis method

The First step is to take selected individual samples from the whole sample. Subsequently, the individual samples are combined into a composite sample. Finally, the aggregate sample is reduced to a laboratory sample.

The laboratory sample ideally should have an ideal order (see figure 17). The mass of the bulk sample can be designated by DIN EN 932-1 with the following formula (Linß. 2010a: 3-4)

$$M = 6 \times D \times \sqrt{bp}$$

M = mass of the sample [kg]
D = maximum size of particle [mm]
pb = bulk density [t / m³]
(Linß. 2010a: 19)

In order to undertake an investigation, there is a need for the use of different measures. As sampling devices blades or spears can be used (see figure 18 on page 38). If these tools

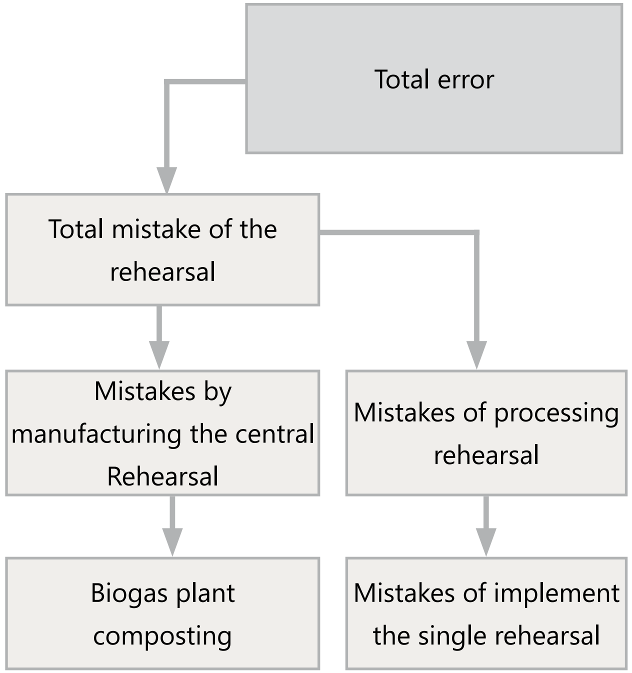


Figure 16: Components of the total error (Linß. 2010a: 3-4)

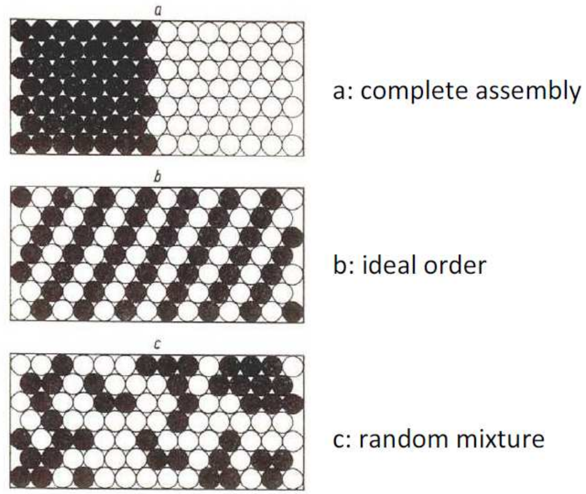


Figure 17: Blend states (Linß. 2010a: 3-4)

are not available also metal plates or wooden boards can be used. The sampling can be carried out from a stationary bed, or from a moving stream of material such as a conveyor belt. In order to achieve the required amount of analysis it is necessary to split the aggregate sample. The taper of the sample can be achieved by various errors. A riffle splitter has a lower error rate than the division cross. However, locally only simple technical possibilities exist. So a simple shovel was used to sample the accumulation in our project. Here are some examples of instruments for sample division:

» Division cross, split error ~ 2.5 - 4%
» Fixed riffle splitter, split error ~ 1.5 - 2%
» Rotating riffle splitter, split error ~ 0.5%
(Linß. 2010a: 29)

2.5.2 Comminution

Before analysis, the analysis sample has to be homogenized. This is necessary for the technical process as a pretreatment before the

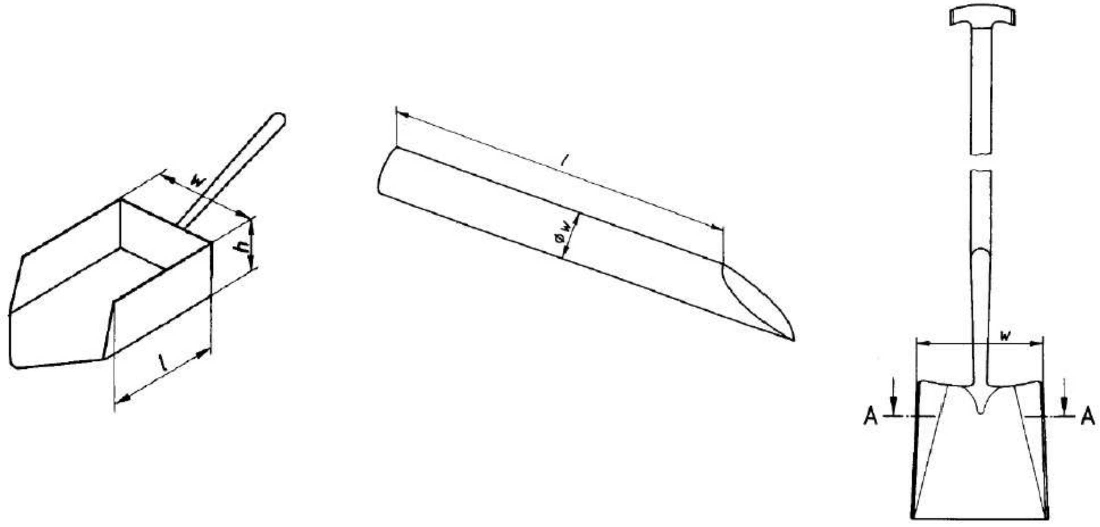


Figure 18: Tools for sampling (Linß. 2010a)

digestion. With the crushing of a solid body through stress by tensile forces and shear forces individual body parts will be created. These forces can be caused by tools or other items. A breaking point at first cracks on an imperfections on the body. Then the tear will widen over the whole particle.

For the analysis, it is necessary to homogenize the organic wastes after sampling. Impurities in the organic waste could be fibrous materials (wood, paper), plastic or bones. This must be crushed or sorted out before digestion. One possibility would be to break up the single rehearsal with a mixer or blender (Linß. 2010b).

2.5.3 Methods for Analysis

To determine the bioavailability of the organic waste various analytic methods can be used. A basic distinction could be done in chemical, physical, enzymatic, biological and stoichiometric processes. Listed below is a description of some core methods for a representative analysis for organic waste.

Physical-Chemical and Enzymatic Processes for Analysing.

The first method is the physical-chemical and enzymatic processes for dito. What is more it is possible to distinguish between the method of Chemical oxidizability, TOC (total organic carbon), GV (content of organic solids), Corrected GV and the Total Dietary Fiber in Food process.

The method of Chemical oxidizability is applied to DIN 38414Teil 9. The COD (chemical oxygen demand) provision is analogous to the methods of COD in wastewater. Oxidizable substances in sulfuric acid solution with potassium dichromate and silver sulfate are heated under defined conditions. Also they become oxidized. After that the mass is determined by oxygen, which is equivalent to the mass of potassium dichromate. However, in addition to the organic substances also nonbiodegradable components can become oxidized. This may affect the results. In addition the conversion of COD to carbon is difficult (Weitze. 2011/2012: 14).

Another method is TOC and it is applied in accordance with DIN EN 13137. In this method the sample is acidified. The sample will be burned in an oxygen flow by 900 to 1200°C. Then the released carbon is captured analytically. The following formula applies:

TC = TOC + TIC
TC = total carbon
TOC = total organic carbon
TIC = total inorganic carbon
(Weitze. 2011/2012: 15)

The next method presented here is GV. This method can be found in DIN 38414 Teil 3 or in the DIN EN 12879. The loss of ignition is a measure of the content of volatile organic compounds. A dry sample is annealed at 550°C. Subsequently, the mass difference of the unannealed to annealed sample is calculated. Here a problem similar to the TOC measurement occurs. They are also defined as nonbiodegradable substances (Weitze. 2011/2012: 16).

According to Soest the Corrected GV is also known as a modified material group analysis. This method is based on a gravimetric detection of biodegradable materials. For this the organic groups of substances will be extracted from the sample with acidic detergent solution, and sulfuric acid from the sample. Non-degradable materials (e.g. lignin) are deducted from the GV. This method is more accurate than the usual GV-determination. But this method is very time-consuming and expensive. (Weitze. 2011/2012: 17)

The last chosen method of the physical-chemical and enzymatic processes for Analysis is called the Total Dietary Fiber in Food process. This method seeks to determine the total fiber content. One can differentiate between soluble and insoluble fiber. This method can only be used with fat-free samples (fat content <10 percent) and requires special laboratory equipment (Weitze. 2011/2012: 18).
Apart from these commonly used methods are also other chemical and biological parameters do exist, which has to be taken into account. Furthermore in organic waste the nitrogen content (N in %TS), the ammonia content (NH4 in %TS), and the phosphorus pentoxid content (P_{2O5} in %TS) is measured. Also in biogas the C_{H4} contend in percentile should be measured (A. Schattauer. 2010: 93).

Biological Processes

The next kinds of methods are called biological processes for analysis. Therefore, the following methods are chosen for a further description: VDI Guideline 4630 (1), batch; VDI Guideline 4630 (2), continuously; EN ISO 11734; GB21 (DIN 38414 Teil 8).

Under the method of VDI Guideline 4630 (1), batch; the organic matter ferments. The temperature during digestion is selectable between thermophilic (50-55°C) and mesophilic (33-42°C). For this procedure, 0.5 to 2 liters digestion vessels are used. The seed sludge should be at least 50 percent organic dry (oTS) included. (Weitze. 2011/2012: 19)

The next method considered is called VDI Guideline 4630 (2), continuously. Digestion vessels of 5 liters to 2 m^3 are used here. This procedure needs different loading rates (oTS /m^3*d) and different residence times to be conducted. The degradation degree trough COD, oTS or a carbon balance can be performed. However, there are no standardized methods and the assessment of the biogas yield is very difficult (Weitze. 2011/2012: 20).

Another method, namely EN ISO 11734, is used to determine the complete anaerobic degradation of organic compounds in digested sludge. The implementation period is 60 days.

The temperature should be ~35ºC. The vessel size should be 0.1 to 1 liter. The pressure of the emerging gas in the reaction vessel is measured. After the end of the experiment the inorganic carbon (IC) is measured. Problematic for the trial are waste and materials with high solid content (Weitze. 2011/2012: 21).

The next method GB21 (DIN 38414 Teil 8) seeks to determine the fermentation behavior of organic substances. This test takes 21 days at a temperature of ~35°C in 0.5 liter vessels. The daily volume of gas is measured. This way one can determine the relative specific gas ratio to the dry mass. The results are easily reproducible. The

waste must be well prepared for this experiment (Weitze. 2011/2012: 22).

Stoichiometric Methods

If the elemental composition of the organic material is known, it is possible to infer the corresponding biogas yield. With a known weight of the fat, the proteins and the carbohydrates you an average elemental composition can be calculate (Weitze. 2011/2012j: 23).

Extraction Process by Microwaves

This procedure refers to a decomposition method of the energy of the microwaves, which consists of an electric and a magnetic field. The microwave causes, that heat is generated within the substrate. The optimal digestion temperature is 190ºC. The test takes 1 to 60 minutes. As development medium distilled water is used. As a result of the test the COD and DOC is calculated in mg/l (Weitze. 2011/2012: 24).

Quintessence

There are a number of tests which can be used for the characterization and the degree of biodegradability of organic substances. In order to find the right method it should be noted that chemical and physical methods are easy to perform and the reproduction is mostly good. Unfortunately, these methods are usually innacurate. Enzymatic methods are very accurate, but very expensive to carry out. Biological methods are generally only suitable for heterogeneous solids. In addition, these methods are very time- consuming and labor- intensive. The Microwave method is novel and exact. However, these methods can only be performed with the appropriate technical equipment.

2.5.4 Examination of the Organic Waste Fraction in Bag7

Based on the above steps for the sampling, the crushing and the analysis of the organic fraction of waste an analysis was performed. Unfortunately only minor technical possibilities are provided locally. Therefore we limited the analysis in addition to field samples, such as visual analysis and odor analysis. Also we measured the content of volatile solids (oTR).

The collected organic waste was transported in a plastic container to the treatment plant. On site the total mass of the bulk sample was determined with a vegetable weighing. This led to a total mass of 9.70 kg (M1).

To determine the necessary dimensions for the individual sample, the following formula was used. $M = 6 \times D \times \sqrt{pb}$

The determination of the biggest particle D was found to be about 50 millimeters. The average bulk density was calculated from the mass and volumes of all waste collected in the Bag7 (see appendix table A2).

The average bulk density was found to be 0.373 t/m^3 and the median of the bulk density to 0.317 t/m^3. Therefore the mass necessary for the aggregate sample is 15.85 kg (M2). Unfortunately, our sample weighed only 9.70 kg (M1) and therefore it was not exactly representative.

Then the organic waste was dumped on a heap with the help of a slide. Then with a hand shovel a single sample was taken from the debris. This was filled in again. The single sample was segmented until it corresponded with the size of the analyzing sample. The taper has been achieved with the help of the hand shovel and quartering of the debris. This step was repeated twice (see picture 19).

Subsequently, the analysis sample was crushed with a hand blender and mixed (see picture 20). The homogenized waste was then filled into a vessel and taken to the laboratory for analysis.

The segmented determination of the volatile solids was made in the laboratory of the treatment plant in Darkhan. First, the sample was filled in two ceramic vessels and weighed (see picture 21). Then both were preheated in a laboratory oven at 80°C for about 1 to 3 hours. Then the samples were stored in the laboratory

Picture 19: The segmented heap (Own picture)

Picture 20: The homogenized organic waste (Own picture)

oven for a night at 105°C to dry the sample. After that the sample was reweighed another time in order to determine the water content in the sample. After the sample had been cooled down, it was burned at a temperature of about 550°C for 2 hours in the oven. After reweighing the volatile solids can be determined in percent. Now the organics are burned up and only the mineral substance remains.

In table 22 on page 42, it can be seen that the sample contains 80.35 percent water. The water content is calculated as 100% - in dry matter (TS)in percent. For a wet fermentation, a water content of at least 90 percent is required. Or a maximum of 10 masspercentof dry substance in the sample (Kraft. 2009: 9). Therefore only wet digestion is possible if the material has been previously pulped. The loss on ignition showed that the dry sample contained 76 percent organic material. This leaves enough organic material for the fermentation process.

Compared to the biological waste in Germany there is only a small difference. For example, the organic waste of the city of Bottrop has a dry matter of 21.3% and a volatile solids content of 82.00% of the dry matter (TR) (Kraft. 2009).

Picture 21: Weighing the sample for analysis (Own picture)

	Dry matter	Organic dry matter
	DM (TS)	ODM (oTS)
Unit	% of whole rehearsal	% of dry matter
Organic waste	19.65%	76.00%

Table 22: The results of the dry matter analyze (Own results)

Substrat	TS [%]	oTS [%TS]	Biogas yield [Nm^3/t oTS]	Biogas content [%]	Biogas yield [m^3/t FM] (fresh mass)
Organic waste	40-75	50-70	150-600	58-65	80-120
Leftovers	(9-37)	80-98	200-500	45-61	50-480
Organic waste from market	15-20	80-90	400-600	60-65	45-110
Grease separator	(2-70)	75-93	700	60-72	(11-450)

Table 23: Handout biogas production and use (A. Schattauer, P. Weiland based on Federal Ministry of Food, Agriculture and Consumer Protection. 2010: 174)

Calculation of the Gas Formation Potential for Organic Waste

The following section is about the calculation of the gas formation potential of the organic waste, which was collected in Bag7 during the waste characterization. The calculation is based on a paper from the Bioenergie Verbund, Thüringen e.V.

According to A. Schattauer (table 23) 350 Nm^3/t oTS of biogas arise from a ton organic dry matter of biowaste:
1kg ODM (oTS) → gas 350Nl gas (table 23)

Methane content: 60% (table 23)

Account:
1kg ODM (oTS) → 210 NL methane

Conversion to fresh mass:
76% of the dry matter consists of organic dry matter
1kg ODM (oTS) → 1.32 kg dry matter (DM)

The fresh mass consists of 19.65% dry matter
1.32 kg TS → 6.72 kg fresh mass
Conclusion:
6.72 kg fresh →350 NL biogas
→ 210 NL methane

Information in standard liters of gas per ton of fresh weight:

1 ton fresh mass → 52083 NL biogas
= 52,1m^3

→ 31250 NL methane = 31,3m^3

As shown in figure 23 the biogas yield per ton of fresh mass (FM) with organic remaining materials varies from 11 to 480 m^3/t FM. The calculated values with the calculated dry matter levels indicate a biogas share of 52.1 m^3/t FM. This value is more in the lower range of the biogas yield spread. Reasons for this could be, that the biogas yield for the ODM with 350 NL

adopted too low or because of the volatile solids content, which is too low. Low organic dry matter content could be achieved, because the collected organic waste contained a lot of dirt and soil. These mineral components came perhaps from unwashed vegetable peelers. If other organic waste, such as leftovers from restaurants, were fermented too, a higher amount of biogas could certainly be achieved.
To estimate approximately how much energy can be generated by the biogas produced, the following calculation was performed. As you can see from 1 ton of organic matter from the ger-settlements, you can produce approximately 313 kWh power. For comparison an example for energy that is required for cooking is given. The cooking plates have 1000 to 2500 watt. A 2500 watt plate used for 15 minutes is 0,625 kWh (2500 W * 15 minutes * h / (60 min * 1000) for 300 days a year 187 kWh (NO WAR-Campaign. Undated). So you can approximately provide one to two families per year with the power for cooking from one ton of organic matter.

Calculate the energy output: (according to Bioenergie Verbund, Thüringen e.V.)

→ 6 kWh/m³ biogas (at about 1/3 share of CO_2) or 10 kWh/m³ methane
→ 91.5 m³ /52,1m³ biogas * 6 kWh/m³ = 312,6 kWh (biogas)
→ 54.9 m³/31,3 methane * 10 kWh/m³ = 313 kWh (methane)

2.6 Partial Summary

All in all, the current solid waste management system in Darkhan is insufficient. The problem oriented analysis has given a short overview of the variety of problems, which are related to the waste management in Darkhan. The in the moment not adequately working system causes a wide range of negative impact on environmental, social and health aspects. Despite these facts, it is also inefficient in economical terms. There is a need for a new system especially for the ger-settlements.

With the problems in mind, the next step was to find the crucial decision maker in terms of the solid waste management in Mongolia. The national level has the superior role in the case of solid waste management. The lower levels (Aimag, Soum and Bag) are the implementing organs of the mongolian state apparatus. But the power to change the solid waste system is in the hands of the national level. Especially the Ministry of Construction and Urban Development and the Administration of Land Affairs, Construction, Geodesy and Cartography must be mentioned here. Therefore, in order to implement an integrated solid waste system, the national level should support such new approaches.

With the waste characterization and the determination of the total amount of waste for the city of Darkhan were the first steps for an integrated solid waste management concept. The data was important for the design of a new approach to the solid waste management and also to the construction of the technical equipment. This also is the case with the detailed analysis of the organic fraction of the collected waste. Therefore, these different analyses were important for the development of an integrated approach. With these different analysis steps in mind the next goal was the development of a detailed concept for an integrated solid waste management concept as an alternative for the insufficient current system. This concept is shown in the following chapter.

3. Detailed Concept for an Integrated Solid Waste Management

After the analysis of certain perspectives on the current solid waste management practices is the next step is the development of an integrated system for Bag7. A waste disposal is characterized by different process steps. This starts by the gathering of the waste and goes further to the collection and transport. Important steps are the reuse of parts of the waste as well as the dumping of the residual waste. The following detailed concept takes this into account and has a focus on the part collection and transport (component 1) as a core element of every solid waste management system. Furthermore, the possible reuse and deposit systems (component 2) are taken into account and are described in more detail. In addition, also the capacity development (component 3) as an important factor has to be considered. Capacity development in this context describes the necessary awareness rising of the user of such a disposal system because without the willingness of the user to participate, even the most sophisticated system will fail.

3.1 Component 1: Collection and Transport

3.1.1 Methodical Introduction

The collection and transport of the waste are core elements of a properly working solid waste management. Especially the collection and transport forms a critical point because it requires 70 to 80 percent of the total expenditures of the whole waste management process. Additionally, the collection and transport have the greatest impact in terms of the environmental and the public health aspects in urban areas. Collection and transport of the waste include the storage of the waste at the production source, the loading, unloading and transfer of the waste and all phases of the waste transport until the final destination is reached (UN-HABITAT. 2010: 10:13). The central tasks of a waste disposal are:

» Gathering and Collection of all kinds of waste
» Transport of the collected waste to the waste treatment facilities and disposal facilities
» Separate gathering and transport of recyclable fractions (Bidlingmaier and Gallenkemper. Undated: 5).

The tasks include, apart from the extraction of the recyclable fractions or the "production" of energy, the treatment and deposit which include the necessary parts of collection, transport and deposit. Insofar, if there is no direct local recycling or recovery, there is a need to transport the waste to the recovering facilities. This can also happen in a larger scale (Bidlingmaier and Gallenkemper. Undated: 5). An integrated collection system should be designed and operated. Furthermore, the planning of a collection system has to take into account intersections with other parts of a solid waste management. All system elements have to be compatible with the other steps of an adequately working solid waste management (UN-HABITAT. 2010: 10-32). For an efficient implementation and an adequate organisation of solid waste collection and transport the following conditions are:

» Size of the areas of collection
» Social and economic factors
» Labor costs and unemployment
» Availability of spare parts
» Recycling and reuse like the performance of waste picker
» The habit of the inhabitants
    - Differences in lifestyle and therefore different waste composition

- Cooking and eating habits
- Attitudes to littering
- Environmental awareness

» Claims of the user
- Expected service level
- Cultural claims
- Emptying intervall

» Spatial situation
- Terrain section
- Site density

» Climate and geography
- Temperature
- Precipitation

» Architecture (housing situation)

» Choice of the suitable collection systems (Bidlingmaier and Gallenkemper. Undated: 10-11; UN-HABITAT. 2010: 15-25).

Especially the social and economical factors have a significant importance in the developing and emerging countries. In the area of development aid, an inadequate attention at these points led to the failure of a solid waste management project in a long term perspective. (UN-HABITAT. 2010: 15-25).

The removal of the solid waste from the place of generation to the point of removal is done according to a pattern:

1. The collection of waste in the relevant household or company
2. Allocation of the collection
3. Disposal of the waste with a collection vehicle
4. The transport to the collection points

In general, regarding to the first step, the waste generator is responsible for the waste. Already the second step is not anymore a clear area of responsibility for the generator. The disposal company may responsible for the allocation of the collection of waste with certain types of the collection system. For example in larger urban areas, it is common, that the collection company is responsible for this step (so-called full service). The garbage container will carried through the collecting labour from the standing point to the collecting point. The third step is an excessive responsibility field of the disposal company. The last step is also done by the company (Bidlingmaier and Gallenkemper. Undated: 13-14).

Therefore it is necessary to distinguish between the different concerns between the generator of waste and the collection / disposal company. The generator is concerned about the effort and time of collection the waste. If the generator thinks the effort and time is too much he or she will be unwilling to collect the waste. In contrast to that stands the collection company. The collection company has concerns about the costs, the access to the collection points and the access to spare parts. Inefficient planning results in an inadequate waste management for example when the containers are not emptied frequently. In the final consequence, the waste will be illegaly dumped everywhere. A proper working solid waste management has to communicate between the generator and the collector of waste (UN-HABITAT. 2010: 33-34).

Two basic methods for the waste collection are the curbside and bring system. The difference between both systems is the grade of involvement of the waste generator. In a kcurbside system the transport distance for the user is relatively low. The disposal company collects the waste directly from the generator. Consequently, the haul capacity for the user is low such a system. In contrast to the curbside system, the bring system requires a higher involvement of the waste generator. The collection container is several hundred meters away from the original waste source. The generator of waste has to take the waste to the collection station for example to a container. From this point, the disposal company takes the responsibility over the waste (Bidlingmaier and Gallenkemper. Undated: 15).

The removal of the waste can happen by using different systematic approaches: the

reloading system; the changing system, the one-way system and unmethodical removal. The reloading system is the most common process model for the waste removal. The wastes are collected in containers from the disposal company, which removes the waste in regular time periods. This happens through the transshipment of the wastes from the containers to the waste disposal vehicle. This is a typical process model in the Western world for most kinds of household garbage. In contrast to the reloading system is the changing system. In this case, the whole containers are collected from the waste disposal company. There is no transshipment from the containers to the disposal vehicles. The whole containers are collected. This changing system is used for larger amounts of waste for example building rubble. It is possible to replace the full container with a new, empty container and it is common, to use the emptied container again after that. Another process model is the one-way system. Here, the waste is collected in one-waypaper or plastic bags. These bags are provided by the disposal company for the collection. A typical example for the use of a one-way-system is the collection of plastic in some rural regions in Germany. This system is called "gelbe Säcke". Beside these common systems there is another one, the unmethodical removal which is used especially for voluminous waste. It is additional to the household garbage disposal and happens in certain time periods over the year. A typical example is the disposal of bulk waste in Germany. This means a collection of special kinds of wastes, which are too large for a normal waste disposal like furniture of the separate households which is not used anymore (Bidlingmaier and Gallenkemper. Undated: 15-17).

One central element of planning a collection and transport system is the decision for or against an accumulation bin system. It has wide wide-ranging consequences for the capital requirements in the future as well as for the work conditions and the overall costs. For the construction of an accumulation bins the following criteria should be taken into account:

» Economic efficiency
» Physical conditions of the labor
» Job safety
» Hygienic standards
» Spatial aspects
» Needs of the user

The following points have a crucial influence onthe dimension of the bins or containers:

» Supply rate [% of the user]
» Filling degree [% of the accumulation bin volumes]
» The weight of the accumulation in [kg/ m^3]
» Specific accumulation bin volumes [l/ cap]
» Removal frequency (l/week)
(Bidlingmaier and Gallenkemper. Undated: 19).

Even the divided gathering of reusable materials, rather before the disposal company treats the waste as one unit, changes the organizational and the technical system to collect the waste. The generator of waste has to separate the non-reusable parts of the waste from the reusable parts at the production place. Furthermore, this has to be collected in separate containers or bins. These separate containers for reusable items are installed either directly at the place of production (curbside system) or close to the place of the waste production (bring system). The containers or bins need to be emptied separately. In general the reusable parts are collected with separate collection vehicles. For a reuse of elements from the waste are in general dry matters like papers, cartons, glass, metals, plastics and textiles and the wet matter like organic kitchen and garden wastes.

Again one can distinguish between different systems for the removal organization:

» Integrated systems: collection of reusable material and of scrap happens together in one operation process in one split container or in multiple containers. In general the common collection vehicle for an integrated system is a multi-chamber vehicle.
» Partly integrated systems: The removal of the waste happens in periodic intervals; one vehicle collects different types of waste every time.
» Additive systems: The typical element for this kind of system is a separate collection and removal of waste. The waste is collected in different containers (Bidlingmaier and Gallenkemper. Undated: 31-32).

3.1.2 Application in case of Bag7 - General Approach

The basis for planning a properly working solid waste collection and transport is the waste analysis in Bag7. Various fractions of the waste has been studied. These fractions were: paper, plastic, metal, glass, organic waste and residual waste. Locally, the total volume and the mass of the fractions were determined. Based on this data, the volume of waste for Bag7 could be calculated.

Because in this bag live about 6200 people, it is difficult to collect all the garbage in a short time. If the fractions all were picked up individually, then one would need more vehicles and more staff.

Driving on Bag7 is very difficult due to poor road conditions and the narrow streets. Therefore it is seen as useful to introduce a bring system for waste disposal via communal containers in Bag7. This system has the advantage that it reduces the number of possible waste sources for the collection.

This system requires the cooperation of the population. Subsequently with the help of a CAD drawing (see figure 24) and an aerial image of Bag7 the collection points were identified. We decided to integrate six collection points in the entire catchment area. Research has shown that a small number of collection points in connection with for the users perceived far distances, led to the avoidance of the collection points. The result would be, that the waste generator throws the waste somewhere in the landscape (UN-HABITAT. 2010: 33-34). A walking distance of maximal 400 to 600 meters seems suitable for the Mongolian circumstances to avoid uncontrolled dumping (Hädrich, 2009. P. 17). Additionally, the communal containers should not stand too close to a dwell for example because of the possible odor from the containers (UN-HABITAT. 2010: 33-34).

To allocate the collection points we placed buffer zones with a radius of 300 meters around the collection points (see also figure 24). Then the Kashaas were assigned to the catchment areas. With the help of the population density the collection areas could be determined. All collection points should be specifically designed for each concept because of the different numbers of people who live in the six regions. Table 25 shows how many people live in each region (approximately) taking into account the low and high population density. Low population density means 40 inhabitants per hectare and hight density 100 inhabitants per hectare. Then, following a fixed collection frequency, the amounts of waste were determined. According to the volume of the various groups the container sizes were designed. For this the following points were considered:

» Decision on a bring-system
» Suitable gathering places to locate (accessibility, short distances)
» The design of the collection points (size, safety devices)
» The design of the container size for the respective catchment areas
» Development of a collection frequency
» Determination of the container sizes necesarry for the individual fractions

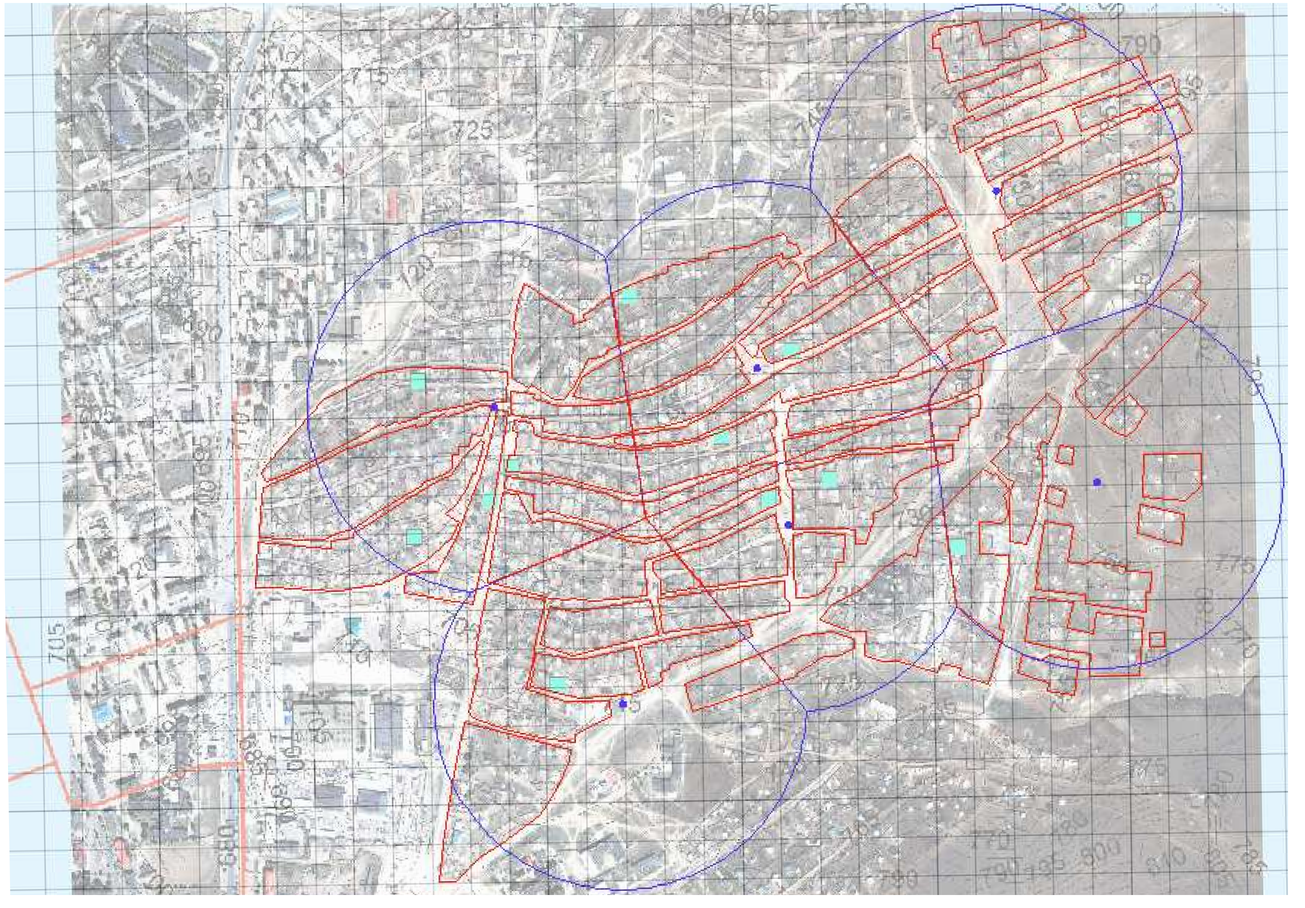


Figure 24: CAD drawing, waste collection in Bag7 with six collection points (Own illustration)

Region	Catchment Area [ha]	Inhabitants
1	17.9	1790
2	12.9	1290
3	12.9	769
4	12.1	1212
5	10.6	812
6	9.3	373
Total	75.7	6246

Table 25: Inhabitants per ha in the catchment area (Siegel,2010; own calculation of the catchment area)

After the parameters had been set and the locations of the collection points had been determined on the computer, the next step was a site visit in Bag7. The project group took a walk through the Bag and examined the individual collection points according to aspects of practicability. Furthermore, we checked the vehicle routes for their actual conditions because the investigation trough an aerial image is not suitable at all. The results for the final transport route and the final positions of the collection points are shown on the following two pages. Thereby, it should be taken into account that the quantity of collection points what we have planned should be higher after a successful implementation of the system. The first six collection points are only the first step to implement the system. Because of the high population density in some areas in Bag7 the routes from the Khashaas to the collection points are to long. Additionally there should be build more smaller collection points.

Figure 26: Concept for the route planning (Own illustration)

Collection Station 1 and 2

Both collection points are centrally located in each sector of the bag. The accessibility is given for the possible collection vehicles. Furthermore, there is enough space to locate the collection station not too close to the adjoining property of the inhabitants. Collection point two even has an already existing concrete bottom plate, which can be used prospectively.

Picture 27: View of the possible collection point **1** (Own picture)

Picture 28: View of the possible collection point **2**

Collection Station 3 and 4

The third and fourth possible collection points are characterized by rugged, vacant land. Both collection points are easy accessible, despite beeing on two opposite hills. The points are located on relatively frequented streets in Bag7. That is because the collection and transport should be possible even in the winter months.

Picture 29: View of the possible collection point **3** (Own picture)

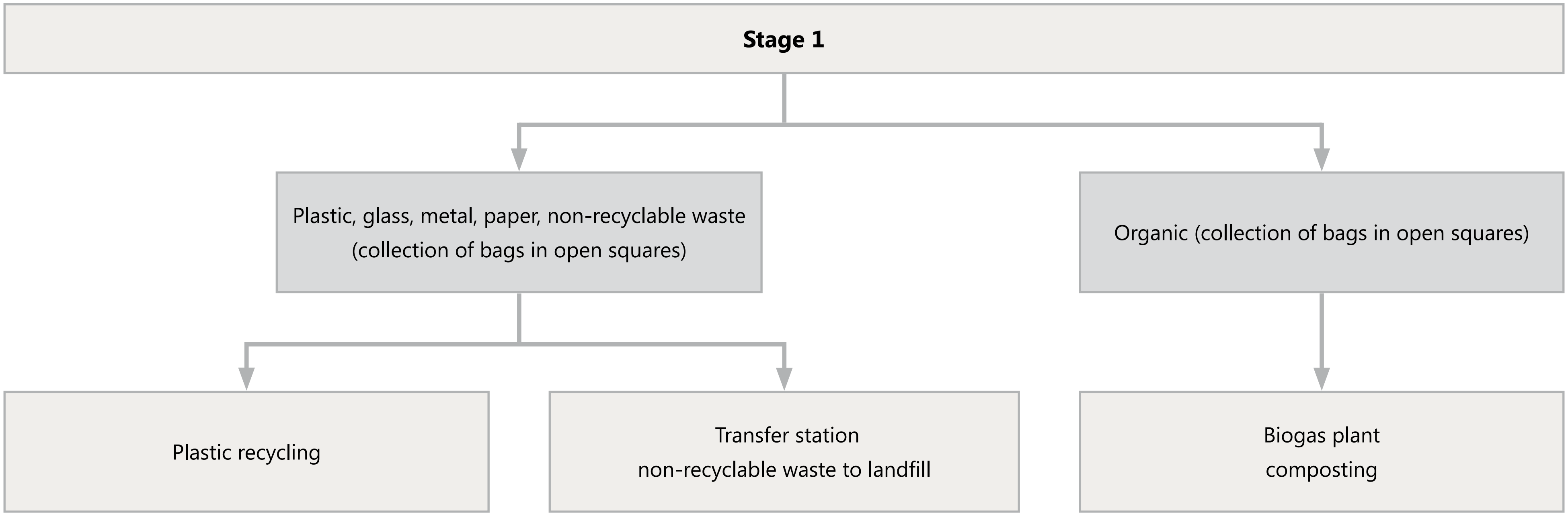
Picture 30: View of the possible collection point **4** (Own picture)

Collection Station 5 and 6

The last two collection stations are characterized through enough space for the installation of two collection stations. Close to point five is a water kiosk. Additionally, there is a deserted garage, which can easily be used as the collection point. in contrast collection point six is directly at the main street of Bag7 and therefore easily accessible.

Picture 31: View of the possible collecting point **5** (Own picture)

Picture 32: View of the possible collection point **6** (Own picture)



Procedural steps

Plastic, glass, metal, paper, nonrecyclable waste → collection of bags in open squares → waste sorting at the recycling factory

→ recycling of the plastic waste
→ transporting the nonrecyclable waste to the landfill (transfer station)

Procedural steps

Organic → collection of bags in open squares → transport with the pick up truck (e.g. iPiT Truck) to the biogas plant

→ composting of the digestate

Figure 33: First stage of the presented collection system (Own illustration)

3.1.3 Three Stage Collection

On 27th August was a meeting with the mayor of Bag7. There we presented our project. He supported our approach and has assured his cooperation. However, drew our attention to various problems with the current garbage collection in Bag7. He mentioned the problems with dogs and the waste pickers. He also made us aware, that it will be very difficult to convince the people of Bag7 for waste separation. The raising awareness of the inhabitants by the approach to the own waste is a central task to implement and to keep the waste system running in a long term perspective. In order to reach a "capacity development", we decided to plan the collection system and the transport system broken down into three phases. It should be an incremental approach that the inhabitants slowly get used to a separation of the waste. This system is for the people of Bag7 to make it easier to use a waste separation system. Only after the former stage is working in an adequate manner, the next stage will be implemented. From stage to stage the separation will be more complex.

As already mentioned, the waste generator has to bring the waste to a collection station (bring system). This collection station will be expanded from stage to stage to adapt to the new conditions. From stage to stage, the collection station becomes more and more advanced with improved materials and a more sophisticated collection system. In the end, all important waste fractions should be collected separately. Therefore, the approach presented here is an additive system. The three stages are described in detail on the following pages.

The technical design of the collection points is illustrated below at collection point one. This is the biggest collection point with the most people using it. For every region, there are different dimensions for the collection points. The population density at the Khashaas which are situated at the border of Bag7 is much lower than the other Khashaas. Because of this the space for the collection points is much smaller at the border regions at the same carriage frequency. As a result, the different collection points differ in their technical design and the collection point one shown here is only a representative example.

3.1.4 First Stage

During the first stage the organic matter should be separate from the residual waste (see figure 33). The separation of only one fraction is important in order to acclimate the people who live in the ger-settlements because they do not know how to separate the waste in the right way. Furthermore, the other steps should be implemented only if the previous step works well.

In case of the first stage, there are two possible approaches to operate the collection and transport system. It is possible, that the USAG deals with the organic waste and the PUSO with the nonrecycable fractions. USAG can use the organic waste in a biogas plant. But before that USAG has to build such a biogas plant. The remaining waste can be collected and transported to the local sorting plant. In the sorting plant the waste is separated into the different fractions. Recycling companies like San Orgiu are possible purchasers of the recyclable waste. The unusable fractions could be taken to a landfill or burned in a waste incinerator by the local waste disposal company. Another approach is that a local recycling company like San Orgiu is the operator of the collection station. After the collection of the waste, they would take it separately to a sorting plant and resell the redundant fractions. This system may be suitable for a recycling company, if the collection and separation costs are lower than buying the materials needed from a sorting station.

The first stage serves as an experiment. Therefore, only simple materials should be used for the construction (see figure 34). The bottom plate is only straightened and secured against erosion with concrete boards. The wall structure

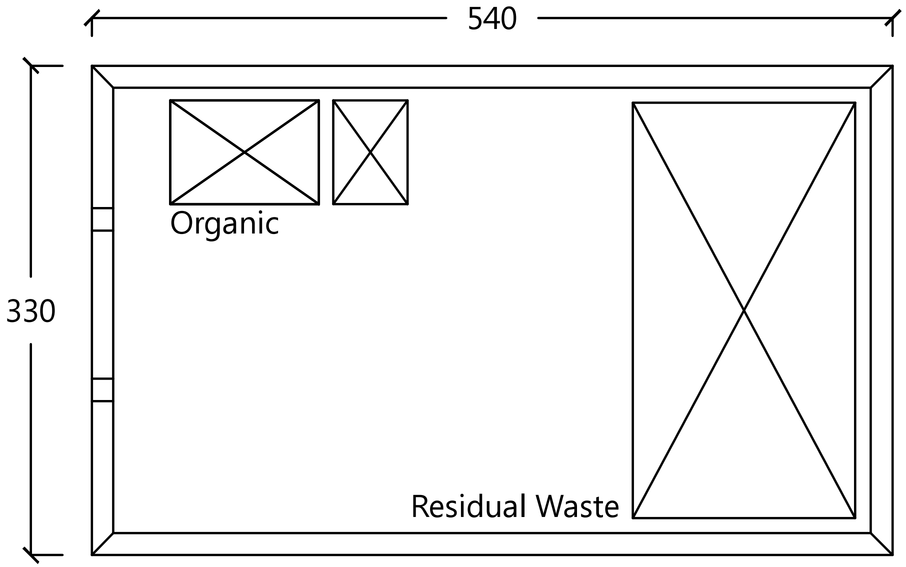


Figure 34: Ground outline first stage (organic waste is separated) of the collection station region 1; dimension in cm (Own illustration)

is built entirely of wood planks. There a gate should be built in the middle of the short site. Thus, a garbage truck could easily dock with the station. The door should be secured with a lock. It is possible to collect the separated fractions into containers. As an alternative, it is possible to work without containers in the first stage. This means that there would be only two open areas for the collection of garbage bags. They are open to one side. The collection point is 540cm long, 330cm wide and 220cm high. It should be covered with a metal mesh. This metal mesh protects against illegal waste deposits and the removal of waste by waste pickers.

The main reason for the design of the collection points is to build cost-efficient constructions. Also safety aspects like the problem of waste pickers and animals need to be considered. Especially dogs are the main reason for a closed construction.

The recommended materials are wood and steal. Steal is only used for the stake, to build a safe base for the whole construction. These buildings also have a roof. On the one hand, it is a rain and storm cover and on the other hand it is used against uncontrolled waste dumping. The roof is scarped to lead the rainwater away. Wire mash or corrugated sheet iron can also be possible construction materials for the collection points.

For ger-settlements it is much better to build non-permanent collection points. First, a non-permanent system is more adaptable to the potential dynamic development of the settlement in the future. Second it is only the first step of the proposed implementation of the three-step-collection and serves as an experiment, as already mentioned. These reasons also explain why the choise of materials and buildings with brick or concrete constructions is unfavorable. But the use of concrete for the bottom depends on the composition of the ground. In Bag7 it is important to build a concrete bottom which helps against soil erosion. With the wood construction described it is very easy to extend the collection houses longitudinally.

The first stage includes the separation of the organic matter. Because of the amount of organic waste (kitchen waste), the pick-up frequency of this waste should be once a week. During winter it may be that the generation of organic waste is much lower than in summer. For example in Ulaanbaatar, the organic matter drops down from 35.7% to 22.7% (Delgerbayar. Undated). This is a reduction of about 36%. That

implies for the first region at the first stage that one container will be empty in wintertime. But this empty container can be used for the collection of ash. During the first stage of the waste management implementation it is important to use the existing vehicles. The organic matter can be collected from the MoMo-collection group, which picked up the feaces from the iPiT's. The limitation factor of this vehicle (Kia Bongo) is the vehicle load capacity. Therefore the payload is not so important because the maximum weight of 5 m^3 of organic waste is about 1.500 kg (0.3 kg/l mass index).

The residual waste can be picked up by the local waste service company and should be collected twice a week because of the high mass of this kind of waste. Residual waste should be collected with the Russian ZIL-130, which is also available. All in all the ger-settlement should be connect to the city-wide system, in order to use the existing competences of the local waste service companies. Interfaces between the settlement and the city can be the planned waste collection points (see figure 35).

Apart from smoothly functioning interfaces, the main limitation of such a system is a stable and efficient structure in the city and also the settlement levels. Furthermore, fees should be corresponding with a functioning system and cost recovery (GTZ. 2005a: 29 et seqq.).

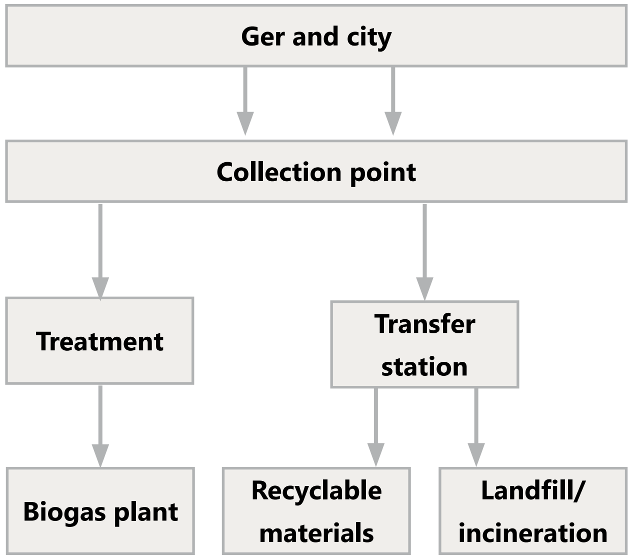


Figure 35: Interface between ger and city (Own illustration)

In general there are important and necessary conditions for the sustainable implementation of a waste management system and these have to be taken into account:

- » Interested users support the waste management activities
- » Users should have access to all information about waste management
- » Cooperation between public sector and community based organizations
- » Transparent rules for collection and fees
- » Technical standards and solutions should be attuned to with user needs and financial capacities
- » Stable organizational structures
- » Capacity building

(GTZ. 2005a: 43)

Possible problems will be wrong waste collection and along with this wrong separation of the organic matter. To minimize these problems we decided to open the collection points at regular hours and to employ workers who work at the collection points. Their job is to control the whole collection. Because of the high number of inhabitants in some collection regions, the houses should be open at several days at regular hours. But there is no need to open one collection station the whole week. So the workers should work according to a rotation principle. It means, that a collection station only opens during certain time in the week. After this collection station is closed, the worker goes to the next one and opens this station for a certain time.

During the first weeks of the implementation of such a system it is also possible to teach the people at the collection points. This can happen with a poster on the walls and simultaneously with an extra supervisor. The supervisor can be employed by the local government and this person can also go to the schools and teach the pupils there.

One further observation which we have made during our stay in Darkhan was that in general the children are responsible for the waste disposal in the ger-settlements. So, if you reach the children and motivate them to bring the waste to the collection station, the probability of a long-term establishment of such a system would increase significantly. So the willingness of the children to collect and separate the waste would probably increase even in a long term perspective. As a consequence, the whole system would work better. But again, first of all is the capacity development. In that case it means, to teach the children safety aspects and also to teach the parents that they should collect the hazardous waste separately. Safety aspects are essential, especially in case of children.

Cooperation between the government and private companies and stakeholder is important for the overall system. It is several for the implementation of such a system and of course for it to work well. For the financing part, the government can help existing private companies to build up new businesses and new companies as well. A private-public-partnership (PPP) is one option for operating.

PPP describes a joint of public and private actors in context of infrastructure and other services like telecommunication. Public actors are ministries, departments and municipalities. Private partners may be companies and also organizations like NGOs (non government organization) or CBOs (community-based organization).

In the past PPPs have become very popular. In developing countries, PPPs initially were especially in telecommunication and energy sectors. The main sectors include infrastructure, manufacturing and services (Jamali. 2004: 2) Partnerships in water and sanitation are much smaller than in other sectors (1.9 billion US-Dollars in 2004). The volume of investments increased many times since the 1990s. In 1997 there was one high peak of investigations of PPPs in developing countries with about 131 billion US-Dollars. Prosperous PPPs were realized especially in road building, dock building and mobile telecommunication (Thönen. 2005). In 2005, the total investments in infrastructures in developing countries accounted for 96 billion US-Dollars.

To satisfy the interest of public and private actors, some points are necessary:

- » Technical issues
- » Legal,regulatory and policy framework
- » Institutional and capacity status
- » Commercial, financial and economic issues

Furthermore the inclusion of stakeholder interests is a critical issue for a successful PPP because all too often the stakeholders are not adequately involved in the process. Figure 36 shows an example of different stakeholders and their interests.

The operating times of PPPs are very different. For example a service contract has a duration of one to three years and contrary to this a lease contract has a duration of 10 to 15 years. For waste management services in ger-settlements it is probably better to implement a short time contract. People from the government of Darkhan think that the ger-settlements will looks exactl the same in 20 years as it is now but the country and of course the main cities likes Darkhan are changing all the time. Because of this fact it is not safe to say whether and how the ger-settlements will change and a long term contract involvesa high risk level. Favored PPPs options are the service contract and management contract. In service contracts, the investments and responsibility go to the public sector. Private companies receive orders to do services for a defined time period and agreed costs. A special feature of this service contract is the development of local private companies. In contrast management contracts shares the operation and maintenance responsibilities to the private sector. This generates more private

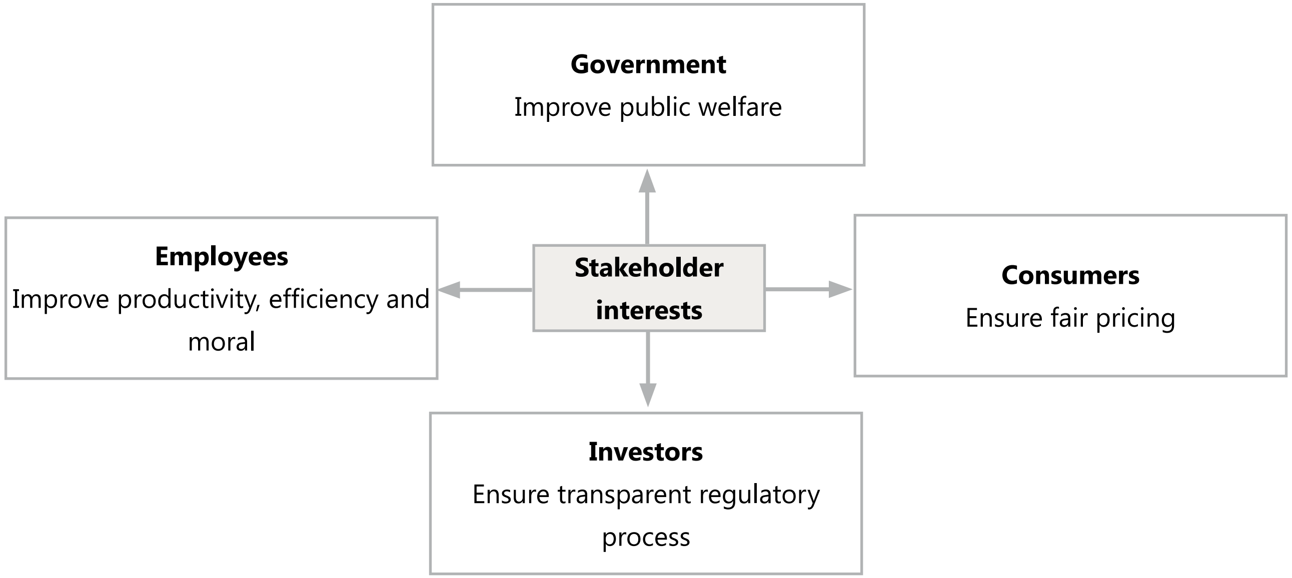


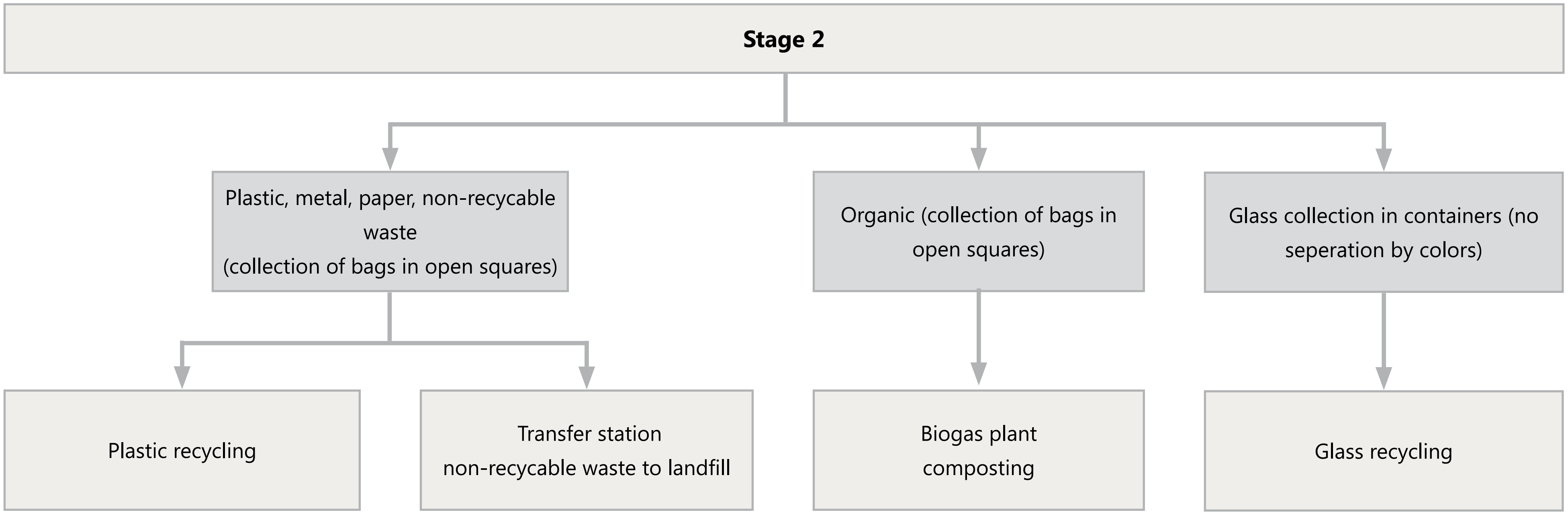
Figure 36: Interests of the different stakeholders in case of PPPs (ADB. Undated)

participation as a service contract. The risk level of these two contracts is minimal (ADB. Undated).

For privatization there are more options available. Apart from service and management contracts there are lease contracts, build-operate-transfer (BOT) models, concessions and joint ventures. The most popular PPPs in Asia are service contracts with 33.3%, BOT with 26.7% and concessions with 17.1% (ADB. Undated).

For this project, there are two general solutions for proposed the operating model of the waste management system in Bag7. This is only a broad view on the allocation of responsibilities. First, the whole waste is collecting by PUSO. After collected they sell the recyclable waste to companies like San Orgio. The proceeds of these recyclable fractions can be used for maintenance and operation of the system. Taxes for the households should be avoided, to motivate the people to bring their waste to the collection points.

Second, every company collects their waste for themselves. PUSO is responsible for the collection point service and the non-recyclable fractions. The useful recyclable fractions like the organic matter, plastic and glass are picked up by the respective companies. Parts of the costs for transport and manpower will be transferred to the recycling companies. All in all the financing of the whole system rested on the selling and processing of the recyclable materials.



Procedural steps
Plastic, glass, metal, paper, nonrecycable waste → collection of bags in open squares → waste sorting at the recycling factory (transfer station)

→ recycling of the plastic waste
→ transport the nonrecycable waste to the landfill

Procedural steps
Organic → collection of bags in open squares → transport with the pick up truck (e.g. iPiT Truck) to the biogas plant

→ composting of the digestate

Procedural steps
Glass → collection in containers (no Separation by colors)

→ transport to a glass recycling factory

Figure 37: Second stage of the collection system presented (Own illustration)

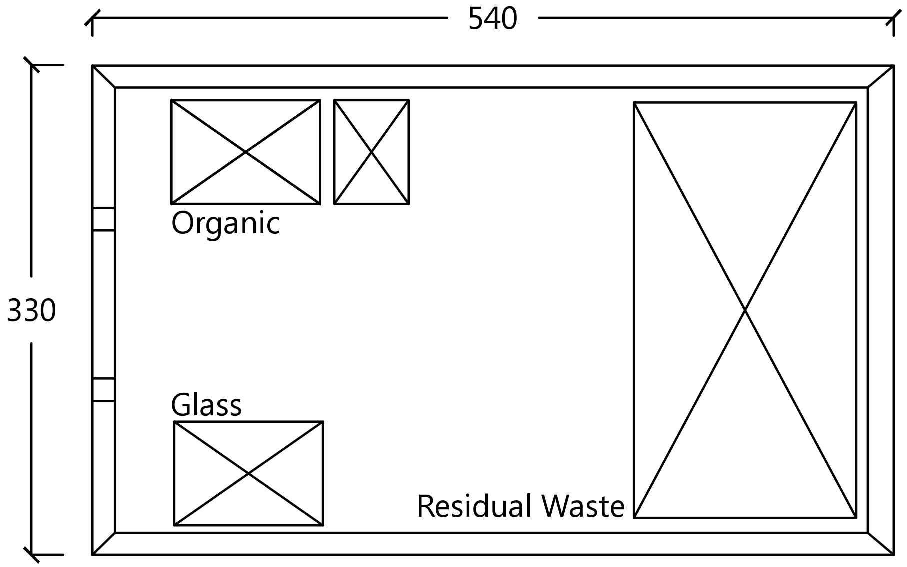


Figure 38: Ground outline second stage (three fractions) of the collection station region 1, dimension in cm (Own illustration)

3.1.5 Second Stage

In addition to the organic wastes, the glass fraction will be separated in stage 2 (see figure 37). The glass should be collected in containers. The glass should not be divided into green glass, white glass and brown glass. Moreover, it is possible to introduce a system for reusable glass bottles (Take back system). This would reduce the production of glass bottles and save energy in production and in recycling.

The operator system would be similar to the first stage system. The USAG still collect the organic fractions. Either the PUSO will be responsible for the waste collection and transport to the sorting station with a following sale to the recycling companies or the recycling companies will collect the waste directly from the collection station. For example a glass recycling company will collects the glass fractions directly from the collection station in Bag7 so that they don't have to buy it. Before this system is implemented, it is necessary to have a glass recycling company.

The second stage will only be built if the first stage works well. The second stage is built solidly (see figure 38). The base plate is made of concrete pavement or concrete slabs. The bottom plate is enclosed by concrete boards. The plates should be at least 10 - 15 cm thick and be reinforced with steel. Steel hooks should also be installed in order to be able to install the panels with a crane. Metal columns are embedded in the foundation. Metal fence is attached to these columns. The collection point is also backed with a cover. The place itself is 540cm long, 330cm wide and 220cm high.

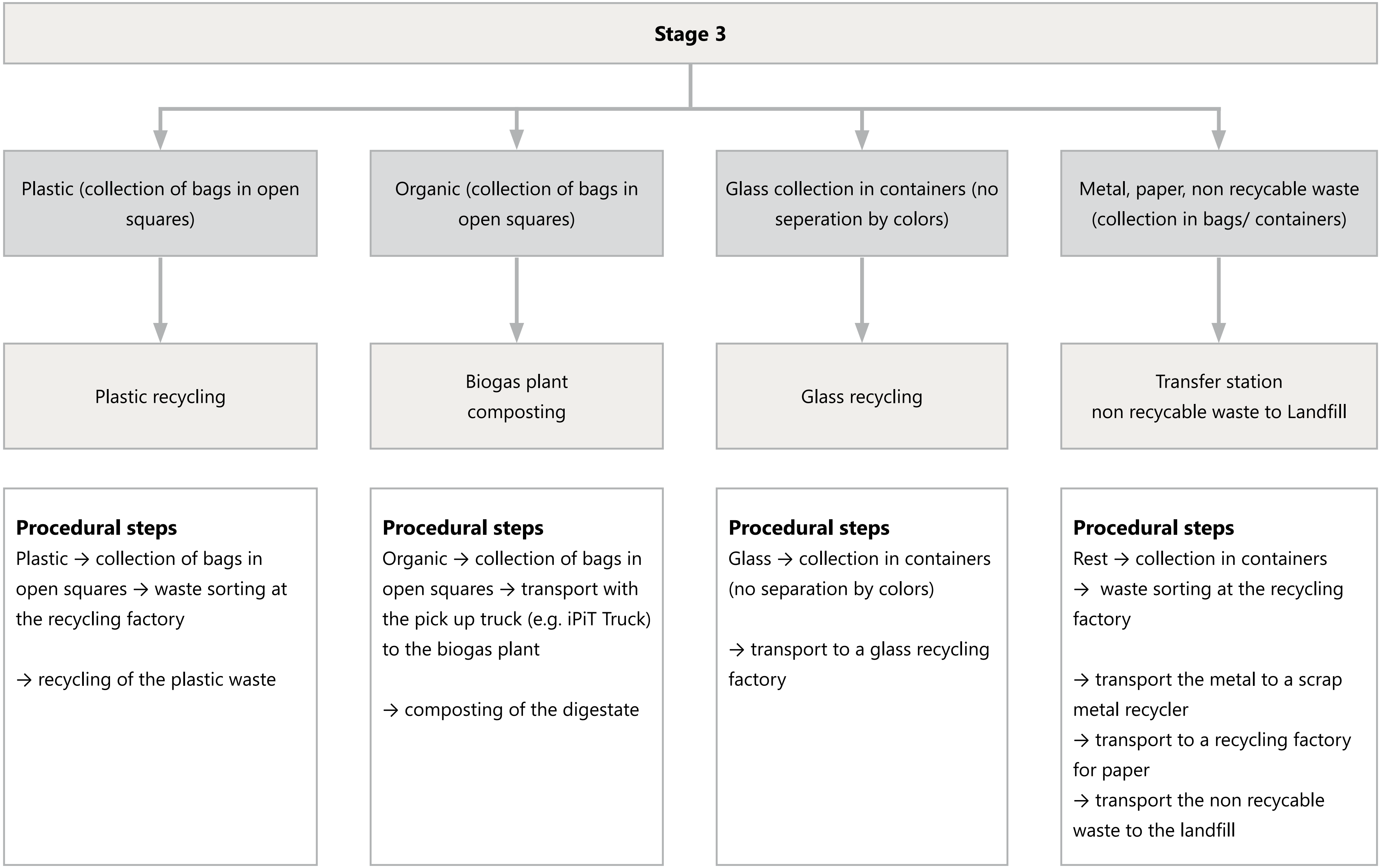


Figure 39: Third stage of the collection system presented (Own illustration)

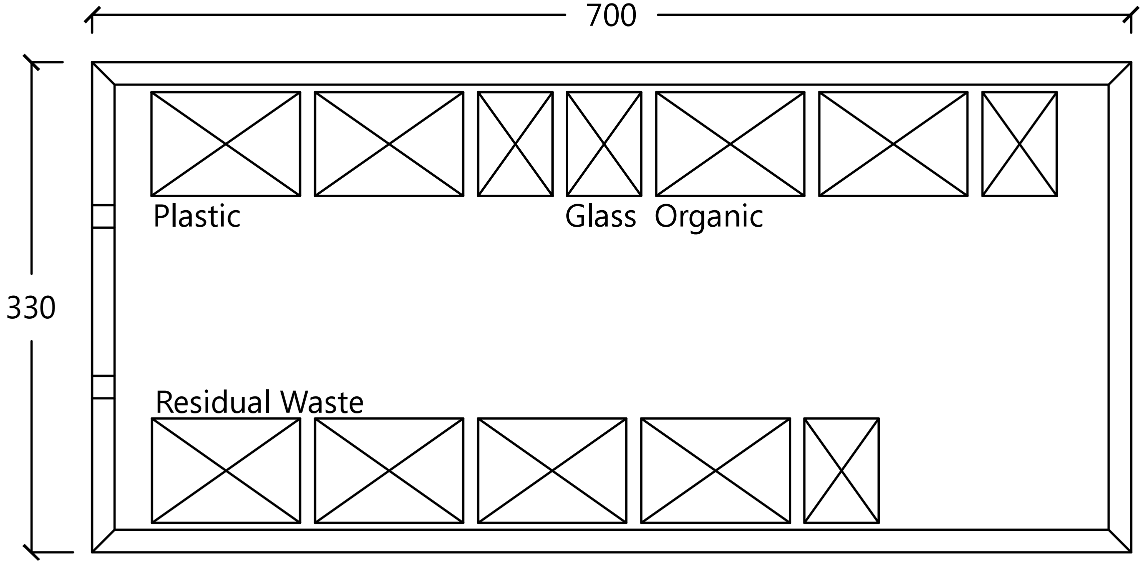


Figure 40: Ground outline third stage (five fractions) of the collection station region 1, dimension in cm (Own illustration)

3.1.6 Third Stage

The third stage of development is the last and the most sophisticated system. It can be realized only, when Level 1 and Level 2 work adequately. At level 3, plastic is collected in a separate container (see figure 39). This system requires a lot of educational work among the inhabitants. Even in developed countries such as Germany, this system does not always work without problems. In this system, plastic continues to be processed by the residents` recycling company. The organic waste can be fed to the biogas plant. Glass can be recycled. Metal and paper are included in the container with the residual waste because the percentage is much too low for a local seperation. Therefore it would not be suitable and would only result in a high effort. In general, the inhabitans sell metal waste or waste pickers take it with them. This happens similiarly in case of paper.

But the implementation of such a system is only possible with the support and the development of some local recycling companies. The possible operator systems will be almost the same as in the second stage, only that it is extended. The residual fraction is transported to a transfer station and later moved to the landfill or an incinerator.

During the third stage the waste fractions are all collected in containers (see figure 40). Therefore, the collection site is also big enough. Draining has to be realizable easily. The containers must be freestanding in order to move them. The container needs to be moved to the gate without problems.

The structure of the collection station is essentially the second stage. But the gate is disposed on the left side for all three stages (see figure 41, 42 and 43 on page 62). The collection point is 700cm long, 330cm wide and 220cm high. Unlike stage 2 no cover is provided. Also should the collection site should not be closed with a gate.

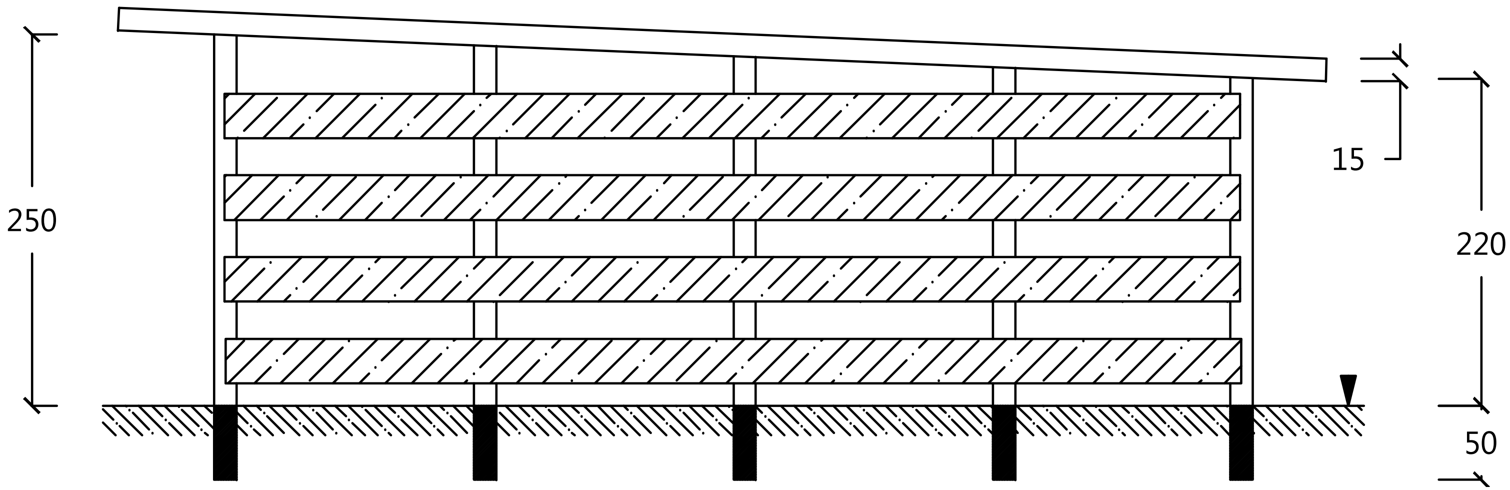


Figure 41: Side view third stage of the collection station region 1, dimension in cm (Own illustration)

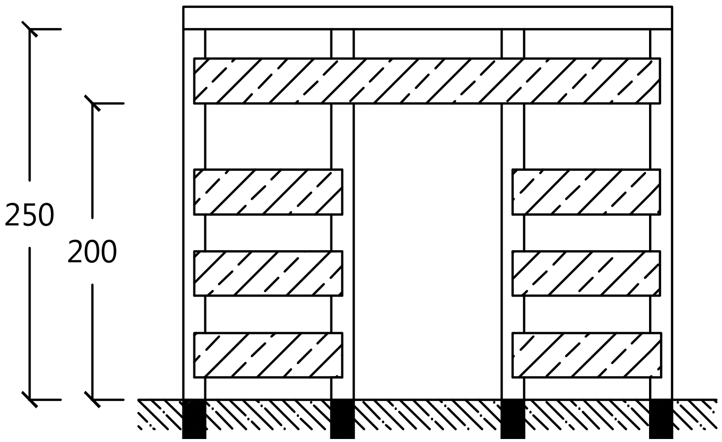


Figure 42: Front view third stage of the collection station region 1, dimension in cm (Own illustration)

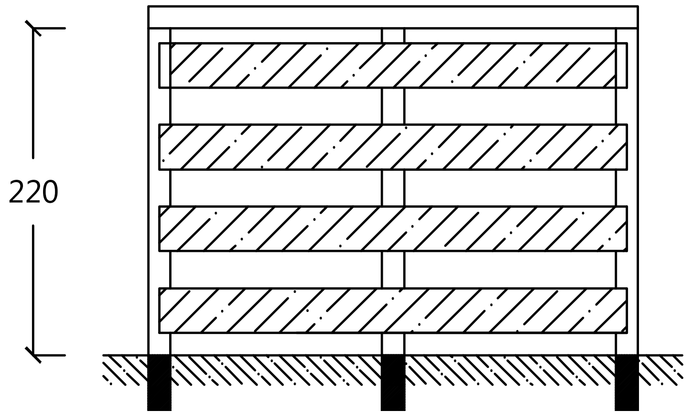


Figure 43: Rear view third stage of the collection station region 1, dimension in cm (Own illustration)

3.1.7 Urgent Measures for Improvement of the Waste Situation

But in spite of it all, it will take some time to implement the three stages. This even is the case for the first stage. Therefore there is a need to improve the situation immediately. The urgent measures should be arranged in three groups, namely tasks for inhabitants, for companies and for the public institutions. Each of these groups can make a contribution to improving the situation. It is not always the big things that can make a difference. One can also achieve a lot as an individual. Whether mayor or residents, anyone can participate. It does not always take big machines or a lot of money to change something.

As the first link in the chain of waste treatment, the inhabitants have a central task in the waste prevention. They can already be careful when buying something so that they minimize packaging material. Furthermore, the inhabitants can take their own shopping bags to the market. So there is no need for further plastic bags, which are usually only used once.

It is important that the pollution of the environment by throwing the waste to every free place stops. Open dumping can contaminate the soil and the ground water. Thus if the inhabitants collect their waste a properly they should follow the rules of separating. This has a lot of advantages for them. First they could sell the plastic waste and other reusable materials to recycling companies and get money for it. It is also necessary for their safety to separate the healthcare waste, because there are sometimes syringes in the waste. Also the people from the garbage collection could be infected with these syringes. One possibility for the separated organic waste is self-composting on the Kashaas. So the inhabitants could reduce the size of their waste and can also get a good humus product. With this they could improve the soil on their Kashaa and plant some fruits for their personal requirements.

But even the companies, which have to deal with waste, can improve the situation dramatically with small changes. First and foremost it is the duty of PUSO to change something. It starts already with health and safety measures for the manpower. The people who work in a garbage company should protect themselves. Therefore they should wear suitable protecting clothes like goggles, protective gloves, strong boots and jackets.

Probably a better arrangement of the manpower from the waste collection companies should save time, manpower and money. For example on a collecting truck from PUSO there are three persons at the moment, one driver, one who collects the waste and one who is collects the taxes. So in most cases one person is working hard and the others are just waiting. A suggestion is that only two persons are on one truck. One person loads the truck and in the meantime the other person, maybe the driver, collects taxes. Another way to save time and transport costs is to collect the waste in the Bag during fixed times. At the moment the inhabitants of the bag call the waste company and then the waste is picked up. But if there would be fixed times for collection the truck could define fixed routes for collection. As a first step before the implementation of a designed collection point the inhabitants could bring their waste to a temporary collection point. So the truck must does not need to stop in front of every Kashaa.

If children bring the waste to the collection points or to the collection truck someone could give them little presents, for example sweets so that the children would be glad to do this work.

In the past some programs to improve the waste management of the city took place. One of these programs was called „Darkhan clean city". For programs like this it is hard to find some results. Therefore the companies could corporate a standard report to use the result for implementations. This would help to find out where the problems are and what could be improved.

Beside the inhabitants and PUSO, the public institutions have a significant influence

on improving the situation. The city government has great choices. They could make regulations and guidelines. However, the government must continue to work with the citizens, because only a government which deals with problems properly, has the chance to be re-elected.

At the moment there are certain enactments and regulations and punishments for illegal waste disposal, waste dumping and illegal waste incineration. Nevertheless garbage is located or rubbish is burned everywhere. The reasons for this are varying. A major problem is that the executive is expanded too poorly. Therefore there are not enough law enforcement officers on the road, which control regulations. If there are not enough officers the government could introduce civil guards. Those would report if someone violates the rules. This could save jobs and the problems would regulate themself.

n the one hand, there is the need to control regulations more strictly. But on the other hand, the public institutions should support "Bottom-Up" initiatives more. One example is an NGO in Bag6, which tries to improve the current situation step by step. One already existing solid waste management project of the NGO was introduced in the year 2009 and claims to improve the current situation in a small scale perspective. In the current state, 75 families are directly involved in the project. The major parts of the families come from Bag6, but also families from Bag7 do participate. In the beginning 40 families were part of the project. At that state, the project was financed by the World Health Bank. In 2012, the project was expanded and further 35 families were included. Since 2012 it is financed by the National Mongolian Government. Apart from these official "project families" approximately further 75 families, participate voluntarily outside the actual project (Enkhjargal. 2012: Interview).

The main goal of the project is to improve the current solid waste management in the ger-settlements. They try to improve the situation through provision of information. They want to show possible reuse measures. Therefore, the first step was the seperation of the waste. They installed five small containers next to each family or Khashaa for the separation of the waste. The separately collected fractions are:

» Ash
» Bones
» Plastic
» Manure from animals or biological waste
» Residual waste

For each fraction, the NGO shows different possible uses or offers possibilities for the disposal of the waste. In case of the ash this means that the people can take the full container with ash to the NGO and the NGO disposes it afterwards. The same procedure happens in case of the bones. But for both fractions, a reuse of the materials was the original intention. But in the end, it did not work. As a result of this, the NGO agreed to dispose these materials. In case of the plastic disposal, the procedure is different. There exists a co-operation with San Orgio. The participating families take their waste to 30 collection stations in the Bag, where they can dispose of their waste for free. San Orgio as a plastic recycling company uses the waste for its further production. In case of the manure from animals the reuse by the residents has priority. The NGO shows how they can dry the manure and what reuse possibilities they have. If the families do not have animals, they can throw their organic waste into the container. Then the NGO shows the families, what they can do with the organic waste (for example composting, feed to the dogs, etc.) Through these different measures, the families are able to reduce the residual waste significantly. Therefore, the residual wastes are usually disposed by the PUSO. But because of the large reduction, it is cheaper for the residents. The fractions glass, metal and paper are not taken into account because they are barely produced or the families sale it by there own (Enkhjargal. 2012: Interview).

This project of the NGO experiences a high acceptance under the people of the bags. That is already shown that more families are participating then only the “chosen one”. More than the half of the actual “project families” and the voluntaryily participating families do a good job. The minor part of the families is participating more or less effectively in the project (Enkhjargal. 2012: Interview). In the moment this is a successful step in the right direction. But despite seeming to be successful, there are doubts about the long-term applicability and the large-scale applicability of such an approach. But despite the doubts, initiatives like the local NGO in Darkhan are necessary. They are able to improve the situation in a short-term perspective. Of course in a long term-perspective, there is a need for a centrally organized waste management system. But at the moment, with a certain support, they are able to change something immediately and therefore, they are in general able to change something without a large capital investment. “Bottom-Up” initiatives are able to reach the local inhabitants and are most capable to reach the population. They stand close to the inhabitants and are able to change local behaviour. The local government should support local initiatives. This can happen financially and with manpower. But an idealistic support is also important. This support would even bring the government closer to the inhabitants. Overall, public relation is an important task. Apart from the support of such initiatives the city should also involve the media in their work. They should offer information sessions and build billboards. Thus the population will always be included in the ongoing work.

3.2 Component 2: Recovery und Deposit

The organization of a collection and transport system is a crucial step for the development of an integrated solid waste management system. But after the waste is collected and transported, the question: “What should we do with the waste?” is of central importance. The following subsection of the work deals with this topic of waste reuse and waste disposal. Therefore, the consideration of waste as a resource is a central idea behind the following part.

This idea receives even more importance in the current planning of the Aimag Darkhan. In an interview with Mr. Andrei, an urban planner from the Aimag Darkhan, it could be detected that it is one goal of the future development of Darkhan. Darkhan should become the recycling center in Mongolia in the near furture. This plan is rather new, so the Aimag is still working on it. But in general, they want to develop a large-scale recycling industry in Darkhan. Also other cities should bring certain fractions of waste to the city for the further processing.

Furthermore, the Aimag promotes the development of a waste incineration plant, which should be operated jointly by the three cities Ulanbaatar, Darkhan and Erdenet (Andrei. 2012: Interview). In this context, the following part focuses on various reuse and deposit measures and they are presented and applied in the case of Darkhan. The part refers to the entire city as well as to our initial point of our considerations, namely Bag7.

3.2.1 Anaerobic Digestion

Anaerobic digestion is one reuse possibility for the organic waste. Biogas plants can process both solid and liquid organic waste. This could be for example wastewater, kitchen scraps, animal excrements, agriculture waste or residual waste from food processing. The biogas plant has two main tasks. On the one hand, wastewater is neutralized and on the other hand it produces biogas for energy production and is used as valuable fertilizer for soil improvement. A biogas plant is especially

efficient, if a mixture of components with low carbon and nitrogen contnent (e.g. feaces) and components with high carbon and nitrogen content (e.g. garden or kitchen waste)is used. For the anaerobic process, temperatures of 30 to 35°C are particularly adaptable. The process is managed by microorganisms, which produce in mainly methane gas and some carbon dioxide in four steps. After composting the solid residues can be used as a fertlizer (GTZ. 2005b: 84).

Procedure of a Biogas Plant

The process of an anaerobic digestion consists of four parts. The first step is the assumption. Part of the assumption is the delivery. In case of the delivery, it is necessary to control the substances. It should be checked that there are no toxic substances or other pollutants in the waste. In addition, the materials should be weighed e.g. on a truck scale. During this step, the first foreign matter will be removed. After this procedure, the organic waste should be stored in a bunker. There are different types of storage spaces, e.g. Flat bunker, Deep bunkers and tanks. The bunkers are dimensioned for the annual amount of waste. To avoid any unpleasant smells, the air has to be cleaned out before it gets out of the bunkers. Air purification can be achieved through a biofilter (see figure 44).

The next step is the preparation. This is

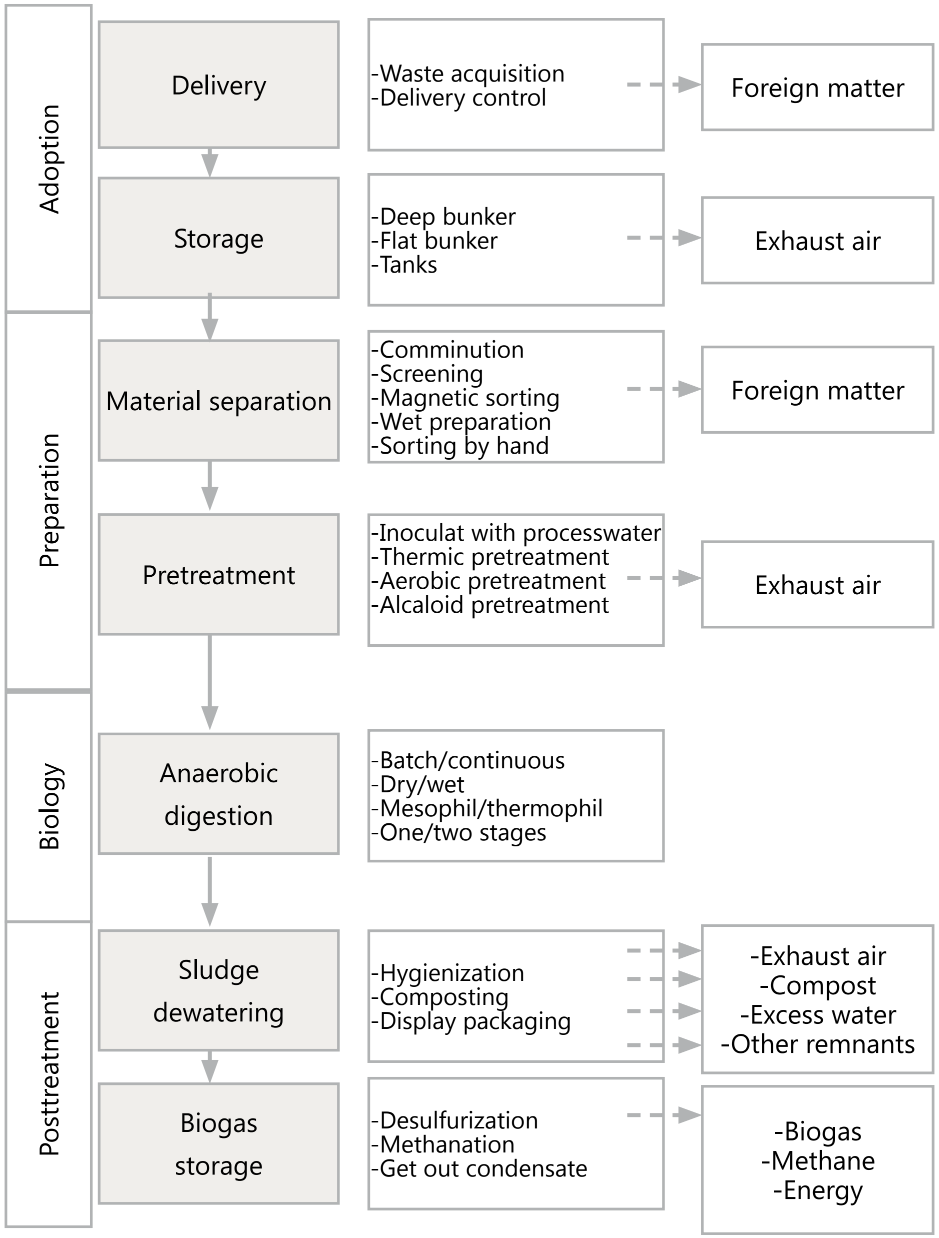


Figure 44: Process sequence of the anaerobic digestion (Kraft. 2009: 22)

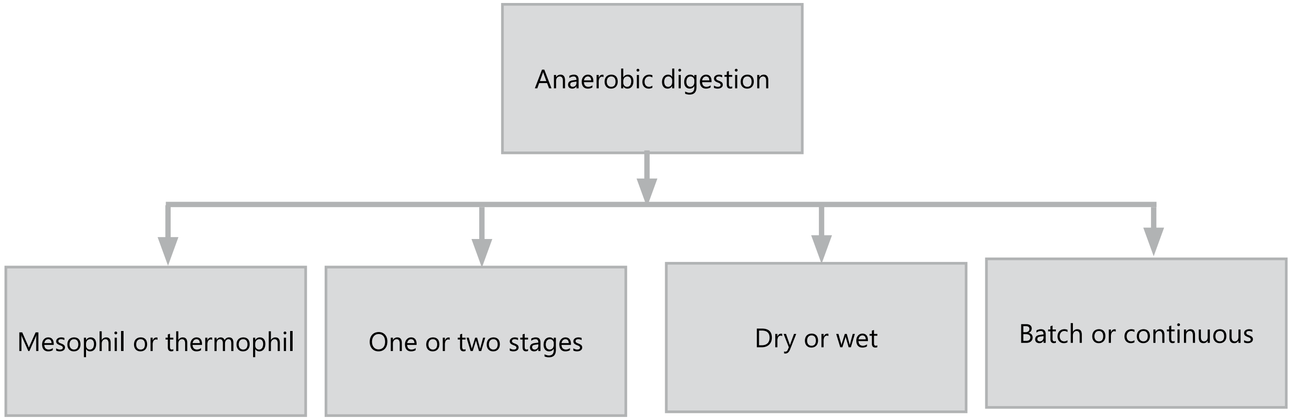


Figure 45: Kinds of anaerobic digestion (Own illustration)

described in detail in the next point. The treatment consists of two components. During the first step the material is separated and impurities are read. This can be done either by hand or by machine. The other component is the pre-treatment. It serves as preparation for the digestion process. In the pretreatment the material is inoculated with the process water. This allows the process to run faster. Also the material can be thermally pretreated, alkalined or aerobically pretreated. Therefore, the digestion process is optimized.

The third step is the actual biological process, the digestion. There are several major classes of digestion. A digestion could consist of one or two steps. Also the temperatures and processes may be different (see figure 45).

The last step is the post-treatment. The digestates from the digestion are treated. The digestate can be packaged, sanitized and composted. Composting makes sense. The compost can be used to improve the soil. A hygienization is necessary to kill the germs in the material. At the same time, it creates process water in the digestage. Process water has to be treated or may be used to inoculate. The exhaust air has to be cleaned. Biogas is a product of the digestion. Before biogas can be used to generate electricity, it needs to be treated. For example, sulfur and condensate has to be removed. Even, the methane biogas can be accumulated.

Preparation for the Biogas Plant

Depending on the requirements, the aggregates are selected for the specific case. The waste composition depends on various parameters for example, if people separate the waste or the various components of the waste. The organic waste from Bag7 is composed largely of potato peels and vegetable scraps. But also ash, soil, bones and plastic particles are present (see picutre 46 on page 68).

Plastics, bones and wood parts are contaminants that may inhibit the process. These substances can also destroy parts of the machine. Therefore, it is necessary to sort out the contaminants. This can be done by screening or by hand.

To get out the dirt and the ash of the material a sand trap or a air classifier is used. The dirt mostly comes from the vegetable bins (e.g. carrots or potatoes). This dirt must be removed so that no machine parts, such as pumps, will break. In addition, soil and mineral ash can not be digested. A magnetic separator is not necessary, because there are no metal parts in the organic waste.

For an optimal use of the materials in the digester, they need to be homogenized. This reduction can be done with shredders, hammer mills or homogenizing machines. Depending on the kind of digestion, the mashing of the substrate is necessary. In a wet digestion at least 90% water content are necessary. In a dry digestion, 65% water content is enough in general (Kraft. 2009:

9). Aggregates that may serve for the treatment of biological waste are:

- » Mashing
- » Crushing
- » Screening
- » Sort of contaminants
- » Magnetic separation
- » Sand trap
- » Windsifting
- » Solid-liquid separation

Possibility for a Co-digestion in Darkhan

In the MoMo Project, there is a new kind of an ecologically beneficial sanitation system used. This toilet system is named iPiT (integrated Personal innovative Toilet). The toilets are installed on different Kashaas (accommodation units in the ger-settlement) and the feaces are collected in containers under the toilet. In order to emty the container, a truck transports the feaces to the biogas plant on the area of the sewage plant. There, the feaces are digested together with primary sludge from the inflow to the sewage plant. Currently this biogas plant is just a test construction to show how such an installation and the appending equipment works in this special area under extreme conditions like very cold temperatures. If the project works well it is possible to create a technical biogas plant for the digestion of different input materials. These materials could be primary sludge or excess sludge from the sewage plant, the feaces from the iPiT– toilet system and also biological matter from organic waste or from carryovers from the industry. Such companies which are considered for a co-digestion in Darkhan could be for example the abattoir, the vodka distillery, the cooking oil company or the tannery (Kraft. 2011). A co-digestion has various advantages but also some disadvantages which you can see in figure 47.

Picture 46: Composition of the organic waste (Own picture)

3.2.2 Composting

In developing countries, more than 50% of the total household waste consists of organic matter (GTZ. 2005b: 44). In Mongolia, especially in Bag7 there is only 25.1% organic matter (see appendix, table A2). Anyhow, it is a lot of organic matter. Therefore composting can significantly reduce the amount of organic waste. The organic fraction has a higher density than the other fractions. For this reason it is much heavier than the other waste and transport is not so easy. Also composting produces valuable fertilizer that can

Advantages	Disadvantages
Use of available infra-structure	sediments on parts of the construction and on the equipment
No follows for on-going operations	Bad smell
No pretreatment of the substrates neces-sary	Bad sludge dewate-ring conditions
Continued high quali-ty of the sludge	
No foam on the liquid substrates	

Table 47: Advantages and disadvantages of a co-fermentation (Kraft. 2011: 35)

Picture 48: Plantation on a Kashaa (Own picture)

be used for gardening or agriculture. The soil in Darkhan is not very fertile. So if the inhabitants of Bag7 can use the humus to improve their soil it is also possible that they can plant some fruits for their personal requirements in their Khashaa. So, in many emerging countries, is not yet common to sell compost as a product. But this fact can be helpful to initialized the personal use of compost as a fertilizer. To demonstrate the usage of the fertilizer, it could be helpful to show the positive effects of humus.

Composting can be done both individually on the Kashaa (see picture 48) or in a central composting station. The advantage of composting at home is that organic waste compounds can be separated at their source. Therefore there are not so many components of other waste in it, which could effect contamination. Furthermore, there is no need to transport it to long distances. But a central composting allows a more optimized working. Also it is easier to regulate some parameters which are important for the composting process. Such parameters could be the humidity, temperature, the level of bacteriology and the quality of the compost. A disadvantage for a central composting is that all the waste has to be transported. Also there is a high need of manpower and machinery such as motorized shovels, drum sieves or shredders (GTZ. 2005b: 44).

Composting is an aerobic process, which involves the absorption of oxygen. To enable the necessary oxygen to get to the compost, you need a mixture of organic waste with low fibre content and waste with a higher fibre content. This material is known as structure material

and could be green cut or pieces of wood for example. Large compost pits should not be deeper and wider than 3m because air can only reach 1.5m into the pit (Kraft, 2011). During the composting process, the arising temperature kills pathogens and other vermins. At the peak of the process, the temperature can rise up to 65°C. A drop in temperature could be an indicator for the transmission from an aerobic to an anaerobic process. If this happens, it is necesarry to drop of the heap to get oxygen into the heap. Another important factor is humidity, which is needed for the activation of the bacteria. A very easy factor which can control the composting process is the moisture content (GTZ. 2005b: 45). The control of the moisture content can be easily done by a cane, which is stuck into the pit. It is also possible to take some of the material into your hand and feel how wet it is. The percentage of water inside the heaps should be 40 to 60%. The duration of the decay depends on the region and the climatic conditions. During the first two months, the process is initialized. This is called the main rot. After that there is the follow-up rot. This could take two to four months or more. After the rot, the compost has a consistency like humus soil (GTZ. 2005b: 45).

The composting on the Kashaas can be done for instance in plastic compost bins or in cradles of wood. The plastic bins can be made from recycled plastics from San Orgiu. The central composting is mostly done in form of conical large heaps. In other cases which are more specialized or in most industrial states the compost is ventilated or rotated in drums.

Simple composting processes can be done with little equipment and little operation expenses. But basic knowledge about the handling and the biological process is important. Operators therefore have some experience and knowledge. The knowledge could be act by agents. These agents could be NGOs, local specialists or teachers. Likewise in many countries the composting initiative can be built on the knowledge of tradition and society and can be disseminated by neighborhood committees and self-help groups.

3.2.3 Glass Recycling

Apart from the two reuse options for the organic waste, the other fractions of waste also are resources. One example is the reuse of glass. In poor settlements like the ger-settlements in Mongolia glass recycling is not so important. Usually intact glass bottles and containers are sold rather than thrown away. In our waste analysis, a lot of broken glass was found. The major part of bottles were alcoholic bottles (see picture 49). 9.7% of the whole waste was glas (see also appendix table A2). For this reason, there are just two options for glass recycling. The first option is to sort and condition the scrap glass with the intention to sell it to a fabric, which is produces glass products. The second option is to process new glass in small manufactures (GTZ. 2005b: 58).

Picture 49: Waste analysis, collected glass bottles of a Kashaa (Own picture)

Sorting, Conditioning and Processing of Glass

During the second stage of the recycling system presented here, glass is also separated. But there is no separation according to colors like in some industrial states. The reason is that it is to expensive to use three different containers for brown, green and white glass. After the collection,

the glass is sorted into pieces of similar size. An investment for machines is not necessary but there is a need for protective clothes for the workers, like gloves, shoes and safety goggles. Some basic tools for the workers are hammers for breaking the glass and shovels for loading. The sorting should be done on the floor or other clean areas. The careful separation by colors will be important for the later marketing. For example, it is very important to get clean white glass to get no aesthetic pollution.

Processing in local manufactures requires a melting furnace. This furnace could be heated up to a temperature of 1200 to 1400°C (GTZ. 2005b: 58). Other equipment could be hand-blowing forms, cutting and grinding tools. For the final processing step may be needed a reheating furnace to heat treat the glass. Certainly it could be very difficult to implement such a system in Darkhan because it requires knowledge, investment, technical skills and the recycling of glass needs a lot of energy.

Maybe, there is the possibility to introduce another system like a reuse system that does not require as much energy in a long-term perspective. This system would save capital, labor for processing and valuable resources. For all these improvements a lot of restructuring work is necessary. One would have to introduce the take back system in the production, in shops, in transport and in the households. A lot of educational work would be necessary. But if this system were successfully implemented, it would save energy and resources.

3.2.4 Plastic Recycling

In poor urban settlements in emerging countries plastic waste is the third important fraction of the household waste (GTZ. 2005b: 52). In Darkhan there is the same situation. 18.1% of the whole waste is plastic. Usually, the amount of waste increases with the wealth of the population. In non-indutrial areas with a poor population the amount of waste fluctuates. On a small scale of industrial level, there are various processes for the recycling of plastic materials. But in urban poor settlements, they have not been tested in a larger scale (GTZ. 2005b: 52). A reason for this is, that the recycling for plastic only makes sense if there is a real market for recycled products. Furthermore, technical equipment and capital have to be available.

Mostly found in common household waste are plastic bags out of polyethylen (PE), containers and moulded objects made from polypropylene (PP), tubes and other items made of polyvinylchloride (PVC).

Basic Properties

Synthetic materials are materials of high molecular, organic compounds. There are fully synthetic materials derived from oil, coal, natural gas, limestone, salt and water. Another fraction are semi-synthetic materials made from natural substances such as cellulose, rubber or protein. Recycled synthetic materials are materials, that at least have undergone one processing step. The main components of plasctics are carbon, hydrogen and oxygen. Plastics have certain characteristics. They are predestined especially for the sectors, packaging, construction, electronics, adhesives, vehicles, furniture and household (Müller. 2010: chapter a) Typical physical properties of plasctics are:

» Low density 0.8-1.5 g/cm^3
» Low thermal conductivity
» High thermal expansion
» Low electrical conductivity
» Rather high tensile strength
» High elongation at fracture
» Low modulus of elasticity
» High durability against water and aggressive fluids
» Becomes brittle at low temperatures
» Not dimensionally stable at high temperatures (Müller.2010: chapter a)

There are several options for the recycling of plastic waste. During mechanical recycling the macromolecules survive. The processing is either one type or a mixture. Granules or mixed plastics will arise. When feedstock recycling, the macromolecules are degraded. During hydrolysis or pyrolysis waxes, oils or gases arises. With the utilization of energy the macromolecules are burned. This creates energy that can be used for heating or for the production of power (Müller.2010: chapter c). The plastic waste can be divided into three types:

» Wastes from the manufacture. These can be products of poor quality. These wastes are mostly sorted clean.
» Wastes from the processing. These wastes are also clean.
» Waste from the consumption or use. This plastic waste is not clean, and mixed with other substances. Mostly these wastes are not in one location (Müller.2010: chapter c).

The Mechanical recycling of plastics requires at least the following steps:
» A grain size reduction by shredding
» Cleaning by washing
» Sorting out the impurities and sorting of plastics (see figure 50).

Application Possibilities in Darkhan

During the first stage of the waste collection, only the organic waste is separated. The other groups are gathered and need to be separated in a sorting station. The plastic garbage can be picked up and processed by the plastic recycling company. There the plastic can be reused after a down-cycling, upcycling or recycling. During down-cycling, an original product ibecomes an inferior product. During recycling the original product is reprocessed to the initial material. During upcycling a higher-quality product is produced (Müller.2010: chapter d).

A plastics recycling company named San Orgiu is located in Darkhan. It recycles all types of plastic waste. The company has been operating since 2005. As a worker from the company said on 20th of August, that San Orgiu was the first company of this kind of business in whole Mongolia.

The plastic materials are processed in a into garden benches[3]. All types of plastic (plastic bags, soda bottles, etc) are melted and pressed in a thermal process. The plastic waste is bought for 150 to 200 Tugrik per kilogram. For this, the residents bring their waste to the recycling center where it is processed further. During the first step the collected or delivered waste is

3 The garden benches can be purchased at a price of 85 000 Tugrik; 1 US$ = 1392 Tugrik (Date: 06.03.2013)

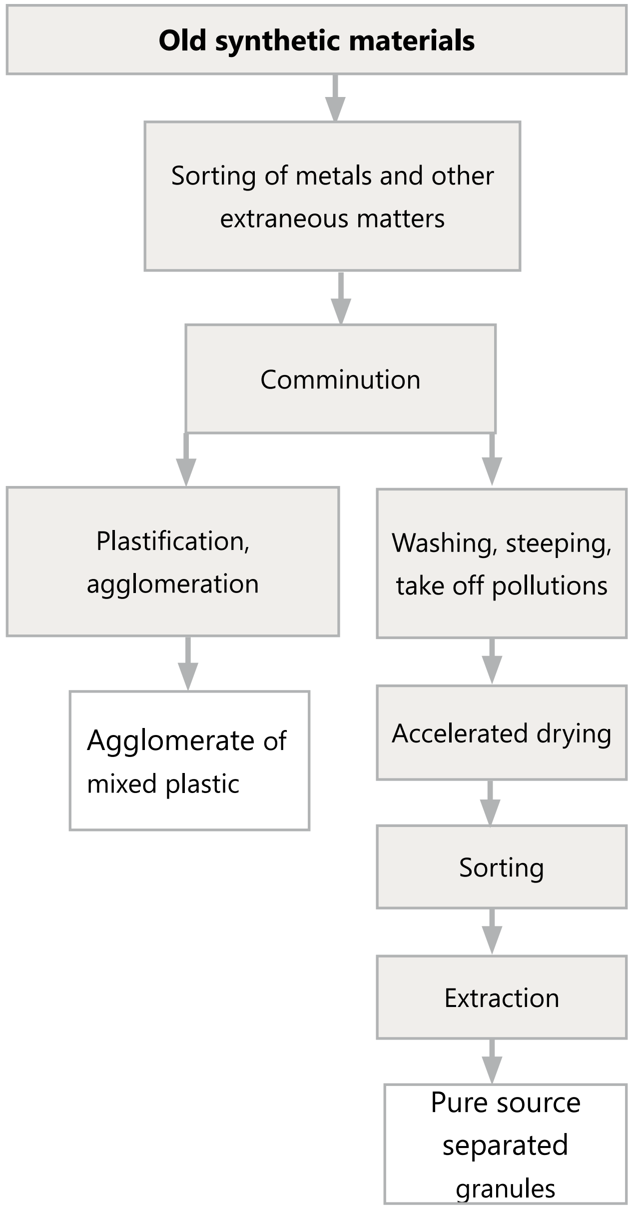


Figure 50. Flow sheet for the production of plastic pellets (Müller. 2010)

discarded. Impurities can be sorted out and it is separated into various types of plastic. In three different machines the waste is heated, melted and pressed. The plastic is compressed to form ingots. In an assembly room the plastic parts are glued and screwed.

Since 2012 San Orgiu has also set up containers in the city. There, residents can throw their garbage in the containers and they should seperate the waste in recycleable and non-recycleable materials. If the containers are full, San Orgiu picks the recycleable waste up, brings them to there recycling center and process it further. The non-recyclable waste will be removed through PUSO. Currently this system is still in a test phase (see picture 51). A total of 35 containers were distributed in the city. Thereby, the containers were only placed in parts of New Darkhan. The idea for this campaign came from the mayor himself, according to an employee of the company. The mayor heads the campaign and is responsible for informing the public. Should this campaign be successful, San Orgiu will expand further.

Picture 51: Containers of plastic recycling company in San Orgiu (Own picture)

3.2.5 Incineration

Fundamentals of Waste Incineration, Toxics and Gas Cleaning

Incineration is the burning of combustible components of atmospheric waste for the purpose of the reduction of the volume of waste by using the energy contained and accompanied by the compaction of the remaining amount for further recycling or land filling (Diaz. 2012: chapter 12).

Incineration can be classified in a number of ways: by the type of waste, by the throughout capacity, by the state in which residue emerges and by the shape of the furnaces. Also there are different types of Incinerators, modular, large-capacity stoker and fluidized bed reactors. Modular Combustion Unit is used mostly for residential and commercial waste and for selected industrial waste. The physical process for incineration is the pyrolysis. Therefore, organic matter is broken down at a high temperature in the absence of oxygen. Depending on th operating conditions the products may be

gaseous, liquid or solid. Similar processes are the thermal gasification and the liquefacation. The pyrolysis is an endothermic reaction. Therefore, it needs an external source of energy. It is necessary to start the fire. Another option is a co-incineration with primer fuels like coal (Diaz. 2012: chapter 12).

In the future, the use of waste in plants will gain importance as a waste management option. The object of co-incinerating high-calorific waste as a substitute fuel in production, power plants and industrial boilers is the substitution of regular fuel and the reduction of energy costs. Therefore, the calorific values of the solid waste in different countries and cultures are quite different and this has to be taken into account (see figure 52). The climate-relevant emissions of a waste incineration plant are made up of a proportion to be allocated to the wastes contribution to the thermal output and that of the remaining regular fuel. Therefore, a proportions calculation needs to be carried out in order to determine the proportion of those climate-relevant emissions, which result from the co-incineration of the waste (Johnke et al. Undated: 458)

From a waste management perspective, merely dividing the total CO_2 load produced by a waste incineration plant into carbon compounds of fossil origin is too simple. It fails to take into account the waste of biogenic origin. It includes

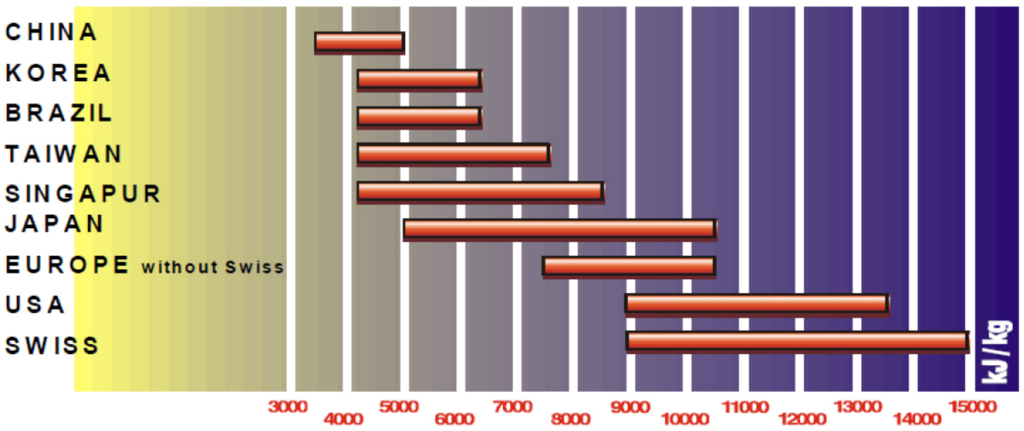


Figure 52: Calorific values of municipal solid waste in other Countries (Martin GmbH. 1997: 5)

a fossil component from the product life-cycle. This component stems from manufacture and transport and needs to be allocated and charged to the waste fraction as climate-relevant. However, these emissions are included in the energy sector and should therefore not be included in the waste emission (Johnke et al. Undated: 458).

Emissions from Waste Incineration

The incineration of municipal waste involves the generation of climate-relevant emissions (see table 53). These are mainly emissions of CO_2 (carbon dioxide) as well as N_2O (nitrous oxide), NOx (oxides of nitrogen) NH_3 (ammonia) and organic C, measured as total carbon. CH_4 (methane) is not generated during the waste incineration process by the normal operation. It only arises in particular, exceptional cases and to a small extent. Therefore in quantitative terms CH_4 is not to be regarded as climate-relevant (Johnke et al. Undated: 455).

The gases which are formed during the combustion of the waste must not escape untreated into the atmosphere. Therfore they must be cleaned and an incinerator exhaust gas purification is essential. The flue gas cleaning system consists of different filter systems. For example, electrostatic precipitators, coke filters or other catalysts (see figure 54 on page 76).

Pollutant	Control methods	Typical reduction (%)
NO_2 (oxides of nitrogen)	» Selective catalytic reduction » Flue gas recirculation » Combustion control	10 to 60
SO_2 and HCL (acid gases)	» Wet scrubber » Dry scrubber » Fabric filter » Electrostatic precipitator	50 to 85 (SO_2) 75 to 90 (HCL)
CO (carbon monoxide)	» Combustion control	50 to 90
Heavy metals	» Dry scrubber » Fabric filter » Electrostatic precipitator	70 to 95
Particulates	» Fabric filter » Electrostatic precipitator	95 to 99.9
Toxic organics (including dioxins and furan)	» Combustion control » Combustion of dry scrubber and fabric filter	50 to 99.9

Table 53: : Air pollutants from solid waste incineration and methods of control (Diaz. 2012: chapter 12)

Expansion of the Power Plant in Darkhan to a Waste Incineration Plant

The compound structure of the power supply in Mongolia consists of four systems (see table 55 on page 76). The central energy system in Mongolia includes the heating power stations in Darkhan, Erdenet and Ulaanbaatar. 94.5% of the total energy of Mongolia are generated by these power stations. Moreover, 0.47% of the whole energy stem from hydroelectric power, 0.57% from diesel generators, 0.01% from renewable sources and 4.36% from other energy sources (Schwarz. Undated).

The heating power plant in Darkhan was first connected to the power network in the year 1965. For its time, the power plant was completely oversized. Since 1993 there is a cooperation between Germany and Mongolia. Successfully implemented projects are for example:

- "Darkhan-1 and Darkhan-2" boiler rehabilitation at the power plant in Darkhan (1993 to 1997)
- "Energy sector Program 1" (2005)
- „TC project“ Training of plant personnel (2005 to 2009)
- "Energy efficiency Program-1" (2011-2013) (Schwarz. Undated).

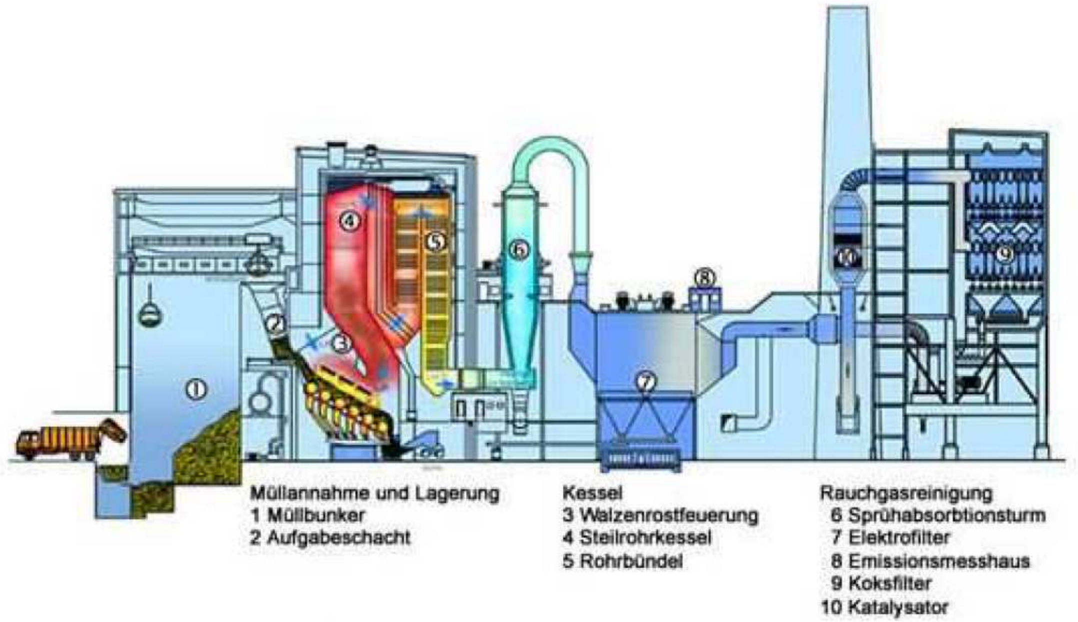


Figure 54: Schematic of a waste incineration plant, with delivery and storage, boiler and gas cleaning system (Stadtwerke Düsseldorf. Undated)

Power station	**Number**	**Installed power [MW]**
Cogeneration plant	5	814
HKW- 2		22
HKW- 3		148
HKW -4		560
Darkhan HKW		48
Erdenet HKW		36
Hydropower	13	5.25
Renewable energy	27	2.38
Total	45	821

Table 55: Installed capacity of power plants in Mongolia (Schwarz. Undated)

The program „Darkhan-1 and Darkhan-2" has been successfully implemented for the rehabilitation of the power plant. A loan of nine million DM (Deutsche Mark) was granted for the program by the KfW Bank. The background for the program were the production difficulties at the power plant. This was to the transformation to a market economy, the collapse of the price policy in the energy branch and investment downtime for repairs. Therefore, in 1993 the distribution of electricity decreased to 57.7% and the heat distribution dropped to 37.9% (Schwarz. Undated).

For the TC project training centers and workshops were built. For example, welding workshops, electrical engineering laboratories workshops for pipe insulation and workshops for lining. In addition, the project has trained workshop leaders. From 2006 to 2009, 70 employees had been trained (Schwarz. Undated).

„Energy efficency Program-1" is responsible for the rehabilitation of a turbine. For this purpose two old turbines are switched off and a new turbine will be built. These turbines were built in 1964 and have a capacity of 12 MW. The new turbine will have an installed capacity of 35 MW and a greater efficiency. The contract was

signed on 12/21/2007 between the Mongolian government and the KfW bank. The construction acquires the Russian firm „Asen Moscow". Completion is scheduled for the end of 2013 (Schwarz. Undated).

Other planned modernization measures are retrofitting the boiler to a "Kohlestaubdirektfeuerung" and equipping the control center with modern technology.

The power plant is supplied with hard brown coal from three mines in the country. The coal is delivered by freight trains. The annual consumption of brown coal is about 350 000 t/a. The calorific value of the coal is approximately 3 000 to 4 000 kcal. These are approximately 12 500-16 500 KJ/Kg[4]. The plant produces about 350 million kWh power per year. This means that around 100 000 people have power. The electricity is fed with 110 KV, 35 KV and 6 KV.

The hot water is supplied only in the apartment complexes and not in the bags. Of the 350 000 t/a coal about 2.5 % fall to ashes. These are about 8 700 t/a ash. The ash is conveyed with water in ash ponds. The ash ponds are covered with sheets. When the ash ponds are full, they are covered with soil. The water for the plant is drawn from nine groundwells. In the summertime the water for district heating has a flow temperature of 70 °C and in wintertime of 110 °C. The district

Picture 56: : Heating power plant in Darkhan (Own picture)

heating pipes have a diameter of 0.8m. Currently, renovation works are in progress. The district heating system will be converted from an open system to a closed system. About 50% are already converted. The plant has its own chemical water treatment plant for process water. The process water in front of the turbine has a pressure of 40 bars and a temperature of approximately 440°C.

The power plant includes nine heating boilers. During summertime only two boilers are fired. The coal is crushed prior to the processing in coal mills and pulverized later. The power plant does not have a cleaning system for emissions. Only the solid components of the exhaust gases are bound by water. The solids from the exhaust gases come down about 30km away from the city. Therefore no emission cleaning system would be necessary (Schwarz. 2012: Interview).

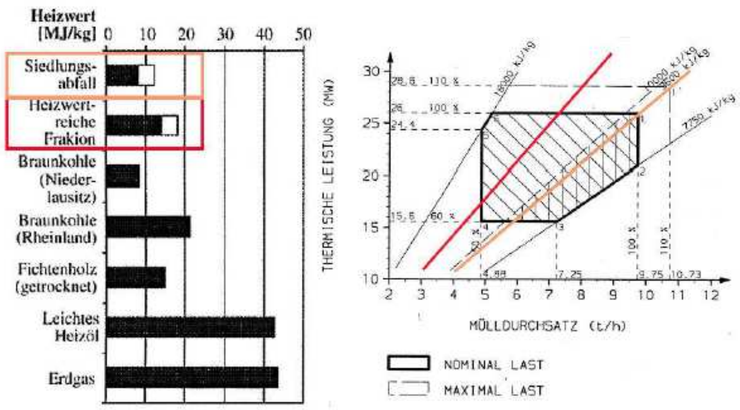
In order to find out if the power plant in Darkhan is suitable for waste incineration, a visit of the plant took place on 09/13/2012 (see picture 56). The power plant engineer Holger Schwarz looked after us. Mr. Schwarz drew our attention to various problems. The first problem is that the waste does not have the same calorific value as brown coal. The calorific value of hard brown coal from surface mines in Mongolia approximately has a calorific value of 12 500 kj/kg

4 Joule = 0,2388459 Kalorien

to 16 500 kj/kg (Schwarz. 13.09.2012, Interview). The municipal waste has a calorific value of 9 000 kj/kg to 13 000 kj/kg (see figure 57). However, the waste can not be burned together with the coal because during an incineration the waste can not be burned in boilers. The waste must be burned on a grate (see also figure 57).

For these reasons it is unsuitable to retrofit the plant completely. The construction of a complete process line is necessary. This would also require the installation of a complete exhaust gas cleaning system.

In order to increase the calorific value of the waste, it is possible to win the calorific fraction from the garbage. For this it is necessary to build a mechanical-biological treatment plant to get the RDF (Schwarz. 2012: Interview).



Picture 57: Calorific value of different fuels (Arnold. 2008)

The RDF is made from urban waste. Generally the RDF has a high concentration of paper and plastics. The consequence of this is that the RDF has a higher heating value than raw waste. Generally two distinct subsystems are required, namely the “front-end” and the “back-end” system (see figure 58). A typical function of “front-end” systems is to accept waste and separate the material into two fractions. These fractions are combustible and non-combustible waste. Front-end separation produces feedstock for several “back-end” systems. Such systems that recover a combustible fraction from mixed waste generally use size reduction, screening and magnetic separation. Other designs have used screening, followed by a size reduction and reversed the previous layout. The design depends on the waste composition, quality of the finished product and other factors. Other unit operations can include manual sorting, magnetic separation, air classification and pelletization (Diaz, 2012: chapter 11).

Pre-processing provides the means for the recovery of a high-quality fuel fraction. Various qualities of the RDF can be produced. Table 59 on page 80 shows some of the main characteristics of the RDF.

The RDF can be used as fuel or as a supplement. It is fired in a mobile grate furnace or in a boiler with a grate. It can be co-fired with pulverized coal in a suspension and the RDF can be used for other thermal systems like pyrolysis and fluidized bed. Although the RDF has a high concentration of paper and plastics. Contaminants of the RDF can have a high concentration of ash and chlorides and also some kind of metal or glass can show up in the RDF. Theses small particles are difficult to remove due to their size and aerodynamic characteristics. Theses contaminants deposit on heat transfer surfaces of the boiler. For beneficiation the improvement in heating value, ash and moisture content is

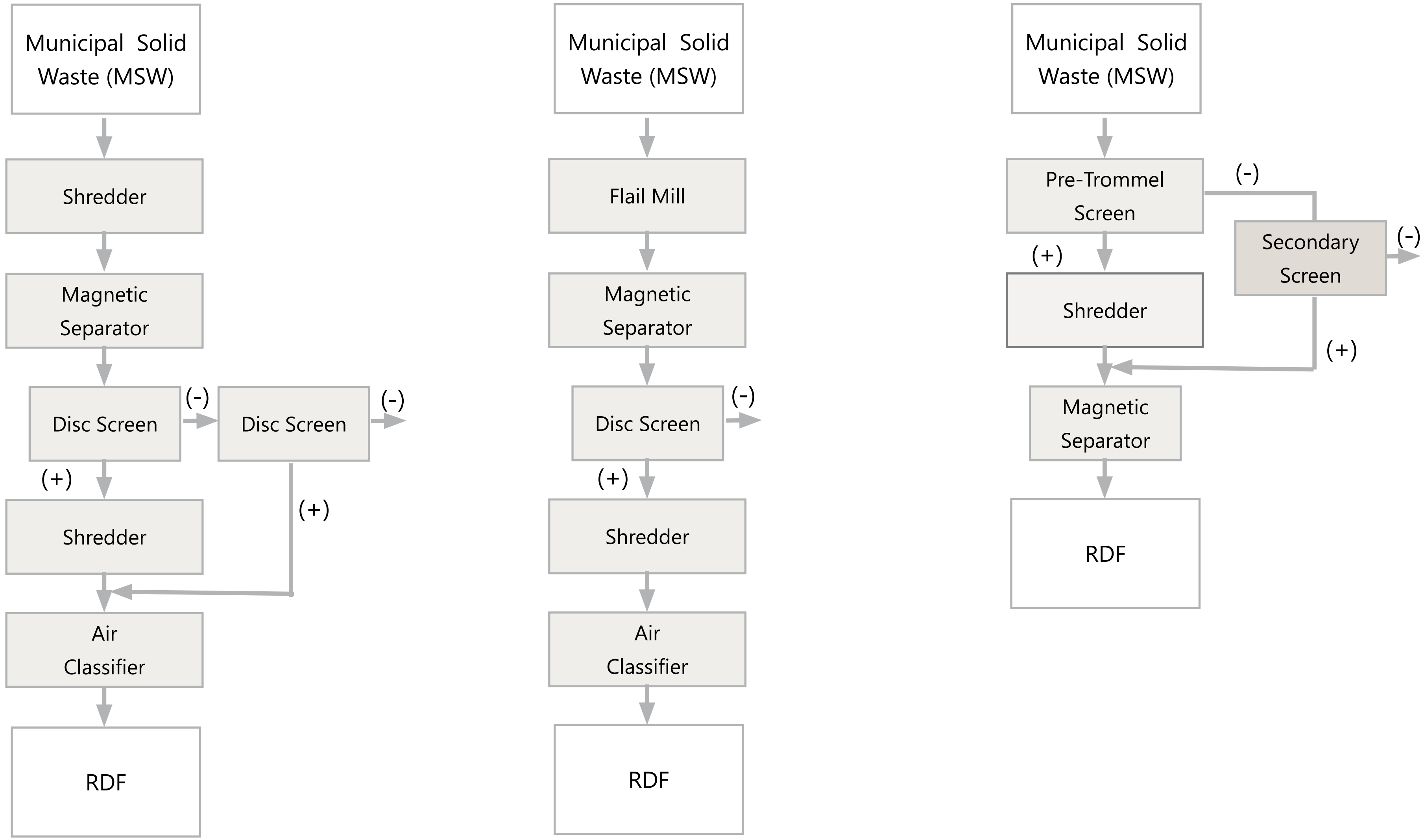


Figure 58: Examples for front-end configurations that are used for the production of the RDF (Diaz. 2012: chapter 11)

	Heating value [j/g]	Moisture content [%]	Ash content [%]
RDF	12 000 to 16 000	15 to 25	10 to 22
Coal	21 000 to 32 000	3 to 10	5 to 10
Mixed waste	11 000 to 12 000	30 to 40	25 to 35

Table 59: Important fuel properties of the RDF (Diaz. 2012: chapter 11)

necessary. Theses can be accomplished trough proper processing and screening. There are some precautions that must pay attention to for example the proper design. The differences between raw solid waste and feedstock used in other industries must be considered. Equipment has to be designed specifically for the municipal solid waste (Diaz. 2012: chapter 11).

To summarize the use and production of the RDF in emerging countries like Mongolia one can say that the RDF can be used in the coal-burning facility. But the use of a grate is required to ensure complete combustion. A modification or an addition of ash handling equipment is necessary. Therefore the ash could not be flushed to ash-lakes like this happens normally in Mongolia in the moment. As well a purgation of the exhaust gases is necessary. There is a need for a new bin location or a bunker for the waste and the compatibility of the existing equipment with the new RDF incineration should be considered.

For developing countries, it is necessary to install such a system. But it is unsuitable because they have much bigger problems, with which they are struggling at the moment. But this is only partly the case in Mongolia, because it is already an emerging country and has the possibilities to implement such a system. Thereofre it is a good option for the generation of energy and for the reduction of waste.

On reflection, it is not the best option to install the machinery for the production of the RDF near the heating power station because of the space, the bad odors, the waste pickers and some animals. Another option is to install the RDF production directly on the landfill site. A disadvantage is that the landfill is on the other site of the city than the heating power plant. An option to eliminate this problem is that the waste trucks transport the municipal solid waste to the landfill and on their way back, they could transport the product from the RDF production directly to the heating power station. With this alternative, it is possible to reduce transport routes significantly. Another possibility is the use of the waste from the existing landfill directly on the landfill site. It is called landfill reclamation.

There are different reasons for the consideration of landfill mining and reclamation for example the cleaning of industrial disposal sites. Also the remediation of landfills entail environmental impacts. Theses impacts could be the ground water contamination or the contamination of the soil. Another reason is to save storage place for the waste. If there is no sanitary landfill as it is the case in Darkhan, it is necessary for a landfill reclamation (Diaz. 2012: chapter 15). There are a lot of factors that make such a dismantling in Darkhan necessary. Every fraction is dumped on the landfill. There are a lot of scavengers who pick up the valuable materials and bring them to the recycling factories. Also you can see a lot of fires in the waste because of self heating processes (see picture 60).

Before doing a landfill reclamation some studies need to be carried out. For example an environmental analysis like soil borings, water or leachet quality analyses, waste characteristics,

Picture 60: : Landfill „Baraat" with a waste truck, burning waste and a scavenger (Own picture)

preliminary processes or site surveying. Even economic analyses like capital, operating costs, revenues and net costs have to be taken into account. Equally, a health and safety consideration has to be done so that you can find some potential risks for the general public. These risks could be sharp, dangerous and hazardous wastes and pathogens (Diaz. 2012: chapter 15).

All in all, a landfill reclamation only makes sense if a lot of factors are complied. But with the right engineering, economical and environmental planning it is a good option to be resource-efficient and to protect the environment.

3.3 Component 3: Capacity Development

3.3.1 Education and Awareness Rising

The importance of the involvement of the public and to ensure public cooperation and a satisfactory service is often underestimated. But in order to have a realistic chance to implement a project, you have to devote considerable effort to informing, involving, consulting and persuading the actors.

In solid waste management, there is often a three-way partnership (see figure 61). Theses partners are the local government, which imonitors, pays and penalizes the private sector or the contractor. The contractor gives a service to the government and provides and informs the customers, who are the waste generators. The customer is in a co-operation with the contractor and pays the fee to the government. The local government also is the contact person for the costumers and raises awareness and receives complaints. But you should consider that some of these functions may vary from case to case and can not be applied in every situation. Especially in Darkhan, the three partners of this constitution are the local government and the governor of Bag7, the inhabitants of Bag7 and for the private sector the waste disposal company PUSO or local recycling factories like San Orgiu.

Such a private sector participation often depends on a high level of participation in fee payment by the households and the business people. The government may apply measures like environmental laws to ensure the payment of fees. In most cases, it is better to convince the inhabitants to pay the fee or taxes by raising their awareness, rather than trying to force them to pay by penalties or threats because penalties or threats often result in opposition, evasion and non-cooperation. That is why one should include awareness and explain the project and

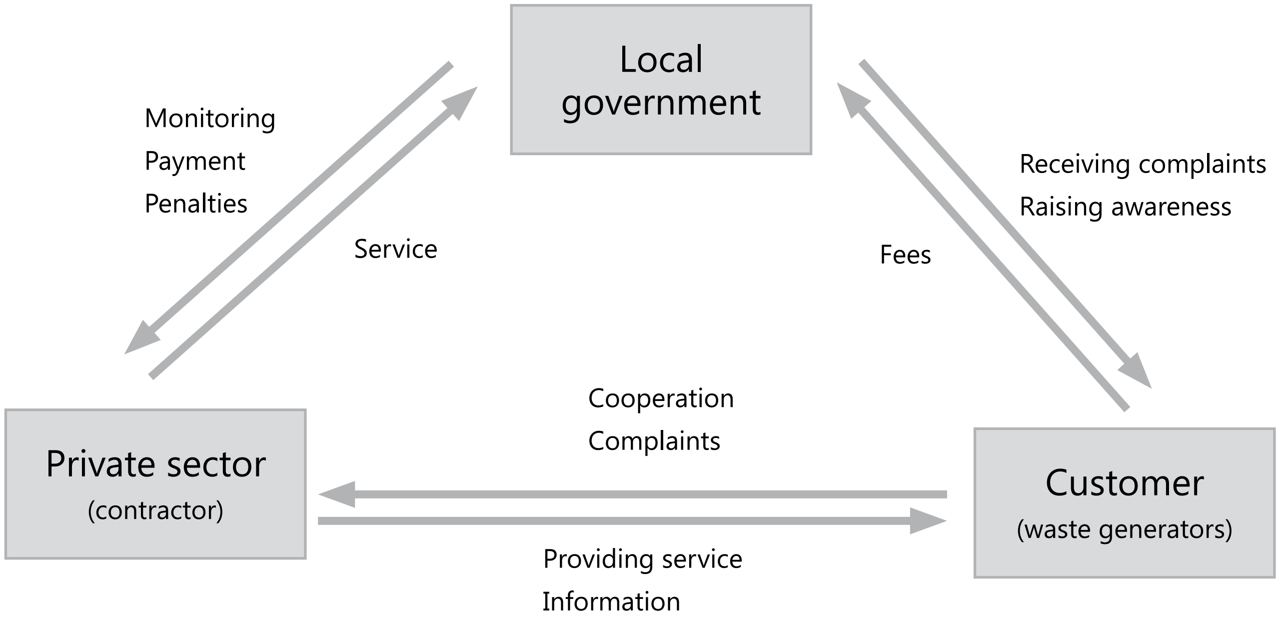


Figure 61: The three- cornered public-private-costumer partnership (GTZ 2005b: 75)

the reasons for costs and fees to all participants (GTZ. 2005b: 75-76).

Mostly there are two separate streams of input into a solid waste management system. The engineering stream and the sociological stream. Sometimes conflicts characterize their connection and they will not understand the actions and opinion of the other side. Engineers often are technology-minded. They calculate, design plans and estimate costs. Sometimes they ignore the human element and the society. The other stream, which are the sociologists do not pay attention to equipment, technical processes or costs. Certainly both groups are needed but the main factor is, how they work together and how this is regulated by the regional administration (GTZ. 2005b: 76).

3.3.2 Motivation and Cooperation with the Public and the Inhabitants

For a successful implementation of a solid waste management system, a cooperation with the inhabitants is necessary. To motivate the citizens, it is necessary to understand the benefits of a new waste management system. For a functioning system, there is a need for capital. Therefore one should encourage the citizens to pay the fees. For this, the public should be informed about their role in the whole system. For example they should cooperate with the provider and reduce pollutants for environmental protection. The public should be integrated if there is any change in the system that will affect them directly. This could be a change of the methods of collection or a change in fees. Likewise to inform the public about financial and environmental consequences of their bad habits could help to sensitize the public ownership. Examples for bad habits especially in Darkhan are the illegal burning of waste, the junking of the waste on the streets, the groveling in containers to get recyclable material or the unintended use of waste containers. These practices often lead to a financial burden for the government. Of course the government can not pay for it itself that the inhabitants have to pay for it in the end. One the one hand the money could be used for the repair of containers or collection points and for cleaning the environment. On the other hand, well structured awareness- raising programs are essential. With programs to inform the public about the consequences of their bad practices is a reduction of service costs and a cleaner environment is likely (GTZ. 2005b: 76).

Development of public education campaign:

- » Close cooperation with professional who are knowledgeable about local conditions
- » Use all methods of communication that are popular in the specific area (TV, radio, church, school)
- » Work together with children, be present in school
- » Conduction step by step
- » Use a simple language, use local dialect as needed
- » Occur with equal rights

Demonstration programs:

- » Demonstrate the good growth of plants which are fertilized for example with feces
- » Use local plants
- » Arrange tours and visits to sites

Technical training:

- » Basic training by knowledgeable professionals
- » Train community leader on key aspects of the systems used
- » Monitoring of the process
- » Arrange for workshops or training sessions (Diaz, 2012: chapter 7)

3.3.3 Communication

A really effective education of the public that leads to changes in habits requires clear messages. Mostly it is not enough to print a handout or to do a short presentation. But there are some really effective ways to sensitize the citizens, for example to work with school children and to do a kind of learning puppet show, house to house visits, provision of information in hospitals or public constitutions. For presentations, you should not only use handouts, but also Powerpoint, other audiovisual presentations or posters and campaigns. To get feedback for your program, you should evaluate each tool that you have used by surveys or interviews. New campaigns should be conducted before they start. In this way, the population would be included and it increases the probability to accomplish a change in the local habits. If the program, for example the collection service, starts there should be an intensive campaign to explain the residents how the system works and what they have to do (GTZ. 2005b: 77).

In order to improve the public relation you can use feedback to improve the public service and the relationship with the citizens. If you accept the facts of the feedback and if you try to find a solution the citizenship will reclaim trust. It is important, that not only problems and negative feedback are in the media, but also successes and new developments should be broadcast to the public. For this reason, feedback is not the only item that the inhabitants hear about. It is always important to inform the public about the program and the proceedings to improve the relationship between the service provider and the citizens. Information for the inhabitants should be as accurate and explicit as possible. For example you should inform about the type of service that is being planned and about the necessary actions for implementation, about waste collection routes, collection points and how to separate the waste correctly. Also information about the time of collection is important so that the people know, when they can take their waste to the collection stations. Some general information about the most important elements of a solid waste management system should be given to the affected inhabitant. If they understand the whole system and the associated costs, it increases the probality that they accept the fees and pay them. Information about how to deal with special types of waste, such as hazardous waste, demolition waste, unwanted furniture or bones should be published everywhere.

Summarizing the capacity development is very important for a good co-operation. You should also cultivate a good relationship with the press and the media because through the media can speak to the public. But unfortunately false

information or information that is given too early could break up the whole program or system. Likewise, it is not recommendable to give false promise to the government or to the citizens because in this way you will lose all the faith, when the system cannot meet the requirements. Such inaccurate information can raise unrealistic expectations. If they are not fulfilled the public acceptance of private waste services will be reduced. It is necessary to inform the citizens through the local government authority because the inhabitants are convinced by the official status of the government rather than the private sector (GTZ. 2005b: 78-80).

3.3.4 Own Contribution for an Improved Communication

We have tried to build different types of communication, which we introduce briefly below:

» Patronized contact to the government
» Meetings with the governor of Bag7 and the governor of Darkhan (see picture 62)
» Workshop with specialized representatives from different areas
» Presentation of the MoMo Project on the immatriculation party
» Interviews in the local TV
» Give some urgent measures
» Use of the internet for publication of current information
» Handouts for inhabitants of Bag 7 about waste separation
» Include children, give them some cookies or sweets

This was mainly addressed to the local government but also to local firms and residents. We have tried to be always on hand and we tried not to plan only on maps and to have a closer look on the local conditions. Before we wrote down a decision, we tested it again on site or let it be confirmed by the mayor. Consequently we have built trust and were certain that our results and ideas were accepted. Furthermore, we brought forward new proposals for some urgent measures so that the responsible persons could start to change something promptly, because it takes a lot of time to implement a whole new waste management system.

The companies in Darkhan have to provide the waste collection, recycling and disposal of the waste. That is why we also have contact with the PUSO or other local companies. To get an overview of the work of the PUSO, we took part in a rubbish collection in Bag7 . This gives us a better understanding of the work and we could make suggestions for improvements easier.

In the analysis of the waste generated in Bag7, we distributed small flyers (see also appendix figure A1) so that the families know exactly what they should do. In order to strengthen the trust of the people of Bag7, we gave some cookies or other sweets to the children. Unfortunately the advice which is given on the handouts was ignored and the garbage was collected separately in very few cases. To get a better cooperation between the German students and the Mongolian students, we held a short speech at the matriculation ceremony of the new first-year students. One has noticed that the German students are not only students for the Mongols because we were representatives for the MoMo project. We were also respected by the mayor and other city officials, and they worked together with us in most cases. The MoMo Projekt was even presented on TV by our supervisor Jürgen Stäudel and Grit Rost. Thus we were able to establish large-scale contact with the population. As another form of media communication, the Internet was used.

To increase the interaction between the government, the customers and the private sector, it is necessary to build trust between the partners. But to built up trust, it takes a lot of time and it can also be destroyed very fast. Trust can be lost, if one partner excludes the other partner from important decisions or if one partner fails

Picture 62: Meeting with the mayor of Darkhan (Own picture)

to give information about changing processes like in waste collection. Another reason could be if one party unjustly blames the other for a failure without talking about the problems. It is a big risk, if there is a loss of trust between the citizens and the contractor or the government. The collaboration of the public administration and the society is an elemental factor for the successful implementation of an efficient system (GTZ. 2005b: 80). The integration of the citizens into decisions that are being made is a important part of the system. The businesses and residents should always be asked about decisions and issues that relate to them. The first step is to build up a proposal for a waste management system and then before the implementation you should contact the private sector and the customers to let them make some suggestions to improve the system. Then you should present it another time and only if there is a consent between all parties concerned you can try an implementation. Currently the waste management project for Bag7 is a in the first step, the first proposal. To ensure our ideas we presented our advance nearly every week to the government. So we feel assured to be on the right track with our system, because the mayor mostly had the same estimation as we had.

4 Summary and Outlook

The country Mongolia as an emerging country faces huge challenges, which show themselves in social, economical and ecological changes. Therefore a central problem for the future development of the country is the unsuitable solid waste management in Mongolia. This need for change was the starting point for this work.

In order to introduce an integrated approach to a solid waste management system, it was advisable to limit our focus to the case study Bag7 in Darkhan. After an analysis of certain perspectives of the current solid waste management system and its conditions, an integrated solid waste management system was developed. The procedure and the developed integrated system are shown in figure 63 on page 89.

Therefore, the overarching concept for Bag7 especially takes the local conditions of Bag7 into account. This is the case with the planning for the transport and collection system as well with the capacity development. But at the same time, the approaches presented here are transferable to other ger-settlements in Darkhan and in Mongolia. But the integrated system also takes the whole situation of the city into account. This is the case especially with the reuse possibilities. In general, for most centrally organized reuse possibilities, there is a need for a larger amount of certain fractions of waste. To collect only the waste in one ger-settlement would be unsuitable. A suitable reuse system has to take the whole structure into account. For instance for a reliable and realistic waste incineration system, Bag7 does not produce enough waste. The total amount of waste of Darkhan has to be taken into account. Therefore the integrated approach connects different levels and layers, which are important in terms of the solid waste management.

The development of an integrated approach did have priority in our work. But apart from that, there is a need to reflect the work critically. The following outlook focuses on a critical reflection. Therefore, it was important to compare different solid waste management systems with the integrated approach developed here. In the following table 64 on page 90, you can see the benchmarking of the three steps and the German system as well. We want to give an overview of the efficiency of the three-step-system and the German system for a direct comparison. The decision was to compare and benchmark the systems in relation to costs, transport and acceptance with two different scenarios (see tables 65 and 66 on page 91). Most of these points have detailed evaluation criteria. The criteria „costs" includes investment costs, operating costs, labor costs and the return of costs. Return of costs will be estimated twice as much as the other costs because of the ratio of the four cost criteria. With this measure the criterion „return of costs" became 40% of the total costs instead of only 25%. The other three cost criteria get a proportion of 20%. Furthermore the transport criteria include the complexity and efficiency with a proportion of 50% for each criterion. Acceptance will be proportion with 100%. The two different scenarios will demonstrate how the benchmarking switches if you rate the three main criteria in different ways.

Without any exposure of the criteria, System 1 and 3 (the first and third step for the new system for the ger-settlement) have the highest ratio. System two and the German System are following.

Scenario one shows a ratio with 70% costs, 10% transport and 20% acceptance. The criterion „costs" is the main factor for benchmarking the four systems. The result shows that system one and three are the best solutions for ger-settlements. System two is following and the German system is the system with the lowest ratio. The high ratio of the third system can be described by the higher ratio of "return of costs" in comparison to the other systems.

The second scenario simulates that the

costs will be rated 40%, transport 20% and acceptance 40%. The criterion „acceptance“ is an important value because the users have to accept and understand the system and the need for this. But the costs are also an important value because of the low income of the inhabitants in the ger-settlements. In this scenario, the results reflect our assessment because the system two and three got the highest ratio. The German system got the lowest ratio. This scenario shows that the systems two and three (second and third step) are the best solution for the ger-settlements in comparison to the German system. System number one also is a better solution than the German system but not the best – it is the midway. In system one the return of costs is much lower than in the other systems. The results of these scenarios are shown in table 65 and 66 on page 91.

The comparison between the existing waste management system and the newly proposed system is much clearer. Five main criteria show which system is better than the other system. These criteria are costs, efficiency, environmental aspects, acceptance and health and hygiene. This is also shown in table 67 on page 92. For each evaluation criterion the positive and negative preferences are displayed. The benchmark indicates the system that has more advantages as opposed to the other system.

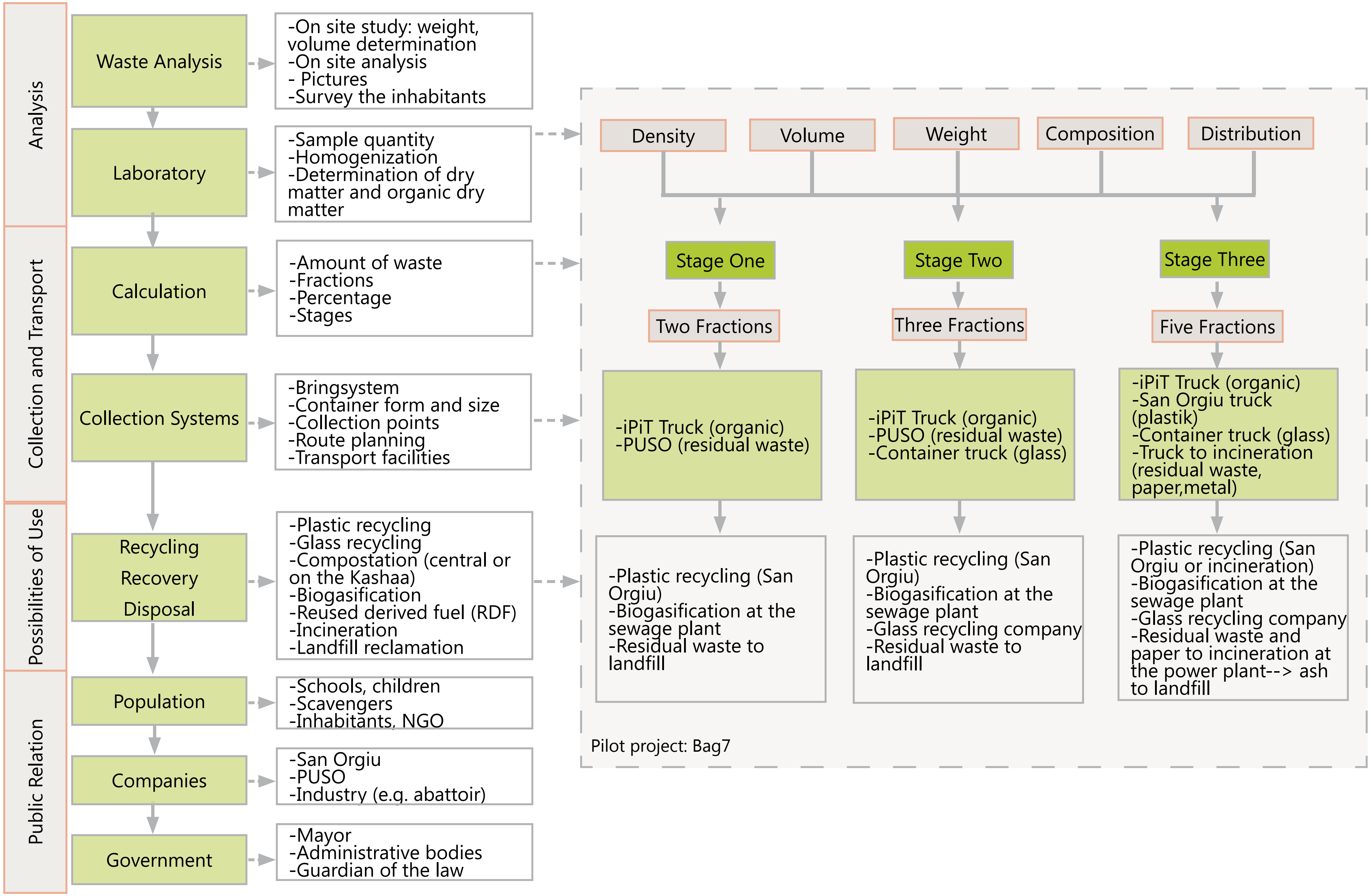


Figure 63: Structure of the whole waste management system (Own illustration)

Evaluation criteria	System / step	Benchmark	Statement of grounds
Investment costs (including building costs, technology)	1	5	Collection points: cheap materials, simple construction; container: only organic fraction; 2 vehicles
	2	3	CPs: cheap materials, simple construction; container: organic, glass; 3 vehicles
	3	3	CPs: cheap materials, simple construction; container: organic, glass, plastic; 4 vehicles
	G	2	CPs: massive construction, expensive materials; Container: different versions, expensive and complex constructions; special vehicles for each fraction
Operating costs	1	5	Low costs for maintenance; low energy costs (fuel)
	2	4	Increasing of maintenance because of number of vehicles
	3	4	Analogical to step 2
	G	2	Complex and expensive vehicle technic
Labor costs	1	5	Little man power because of only 2 fractions and associated with this only 2 vehicles
	2	4	Increasing costs because of more vehicles and transportation troop
	3	3	Increasing costs because of more vehicles and transportation troop
	G	3	Analogical to step 3
Return of costs	1	2	Return of energy via recovery of organic in biogas plant
	2	3	Increasing resource recovery (organic, glass)
	3	4	Increasing resource recovery (organic, glass, plastic)
	G	5	Extensive and hight quality resource recovery
Transportation - complexity	1	5	Little complexity because of less separation of fractions
	2	4	Increasing complexity because of more fractions and more transportation troops
	3	3	Analogical to step 2
	G	3	Hight complexity but optimized technique
Transportation - efficiency	1	3	Optimize route planning; open scares are inefficient because of use of space and time for collection
	2	3	Analogical to step 1
	3	4	Optimize use of collection points (use of space, container)
	G	5	Optimize route planning and vehicle capacities (computer-assisted)
Acceptance	1	2	Implementation of new system; elucidation of citizens
	2	3	Increasing of acceptance because of education and (well) working of the system
	3	3	Analogical to step 2; more work for waste separation
	G	1	No/little acceptance; the necessity will not be identified (probably)

Figure 64: Benchmarking of the four systems (Own illustration)

Benchmark Matrix									
Criteria	**Exposure**	**System 1**		**System 2**		**System 3**		**System G**	
		Cleared value	Measured value	Cleared value	Measured value	Cleared value	Measured value	Cleared value	Measured value
Costs	70%	3.8	2.7	3.4	2.4	3.6	2.5	3.4	2.4
Transport	10%	4.0	0.4	3.5	0.4	3.5	0.4	4.0	0.4
Acceptance	20%	2.0	0.4	3.0	0.6	3.0	0.6	1.0	0.2
Result			3.5		3.3		3.5		3.0

Figure 65: Benchmarking of the four systems (prioritized values) - Scenario 1 (Own illustration)

Benchmark Matrix									
Criteria	**Exposure**	**System 1**		**System 2**		**System 3**		**System G**	
		Cleared value	Measured value	Cleared value	Measured value	Cleared value	Measured value	Cleared value	Measured value
Costs	40%	3.8	1.5	3.4	1.4	3.6	1.4	3.4	1.4
Transport	20%	4.0	0.8	3.5	0.7	3.5	0.7	4.0	0.8
Acceptance	40%	2.0	0.8	3.0	1.2	3.0	1.2	1.0	0.4
Result			3.1		3.3		3.3		2.6

Figure 66: Benchmarking of the four systems (prioritized values) - Scenario 2 (Own illustration)

Evaluation criteria	Existent system	Benchmark	New system
Costs (running, personnel costs)	+ No operation buildings + Low priced dumping + Payment for waste collection	– + – – –	- Collection points (building, building extension, upgrades and controls) - Employees for service at collection points + Profit via resource recovery
Efficiency	- Inefficient division of tasks - Capacity of vehicle is under-worked - Collection time periods are not continued	– – – – +	+ Steady collection points with defined holding capacity + Regular collection time periods + Optimized collection routes for the vehicles
Environmental aspects	- Dumping at unsafe landfill - Wild waste dumping - Open waste burning in Khashaas	– – – – +	+ Resource recovery + Generation of energy with kitchen waste + Less organic waste at landfill
Acceptance	- No alternatives at this time + Successful pilot projects	– – + – –	- Elucidation of the citizens is indispensable and needs much time + Children will learn playfulyl and regularly at school
Health and hygiene	- Insufficient protection for collection troops - Open dumping – dogs ripping the waste	– – – + –	+ Waste is unapproachable for dogs and waste pickers + Contamination with pathogenic agents will be minimized

Figure 67: Benchmarking of the existent and the new waste management systems (Own illustration)

5 Personal Reflection

This project-work was part of a research project at the Bauhaus-Universität in Weimar. Students and professors of the professorship "Urban Water Management" worked in various areas. The sub-areas range from waste management to municipal wastewater treatment to agriculture. The development of our projects was only possible trough the support of our supervisors, our translator and the help of Mongolian students and faculties. Sometimes the collaboration was difficult because the communication was mostly not easy and the work attitude between the Mongolians and the Germans was a bit different. Nevertheless, many Mongolians who worked with us directly were very reliable and helpful. It was especially helpful for us to work with the faculty and students of the University, but also the support of the government of the city and the mayor was very important for us. The mayor of Darkhan and the mayor of Bag7 were very interested in our work and supported us as far as possible. Also we did several excursions in the industrial areas. The companies welcomed us and allowed us to have a look at their buildings and their production. A familiarization was necessary to adjust to the structural and infrastructural realities of Mongolia. You had to combine the mind of a German ingenier with the existing conditions to form a beneficial product.

Nevertheless, Mongolia is an emerging country and we have always tried to work as both, innovative and with the simplest technical and local resources. Simple tools, such as shovel or bags were purchased on the local market. But the market also has a variety of other things for daily use, from food and clothing to building materials, which have been recognized for our application projects like the iPiT- toilets. The adaption to local conditions e.g. to the local food or the climate, caused some difficulties. We still settled in quickly in Darkhan and the communal life in our apartment was mostly unproblematic. We quickly had become accustomed to power outages and other problems. The cooperation in the project group was not always easy. The division of tasks and the work presented a few problems. This was mainly due to the different views between engineers and urban planners. After an acclimatization period, the project team was well coordinated and all tasks were solved easily. The cooperation with other students went really well. For bigger tasks, such as the repair of the iPiT toilets or in the waste analysis, all students helped each other. Not only in the professional part also in the private sector all got on well together and some new friendships were created. Apart from project work, there were many trips and tours which helpt to learn more about country and people and to get a different perspective on Mongolia. Mongolia is a spectacular country. People are generally hospitable and open-minded and nature has many unspoiled landscapes. One notices that Mongolia is a land of tradition and modernity. The Mongolian foster their traditions like the yurts, costumes and festivals such as the Naadam. But due to the weak economy conditions in the country, many modern goods from other countries like Korea, China and Russia are imported, which characterize the cityscape. We believe that Mongolia, despite the onset of industrialization and rapid urban growth still has the opportunity to protect the environment. Therefore, programs to promote the industry, the infrastructure and the environment like the MoMo project are very important and should be pursued in the future. The involvement of students in such programs is also very important because young people represent the future of the countries. Our project group can recommend a stay and work in Mongolia. We have learned many new things and we hope that we can help the Mongolians a little bit with the development of their country through our projekt work.

Therefore, Thanks.

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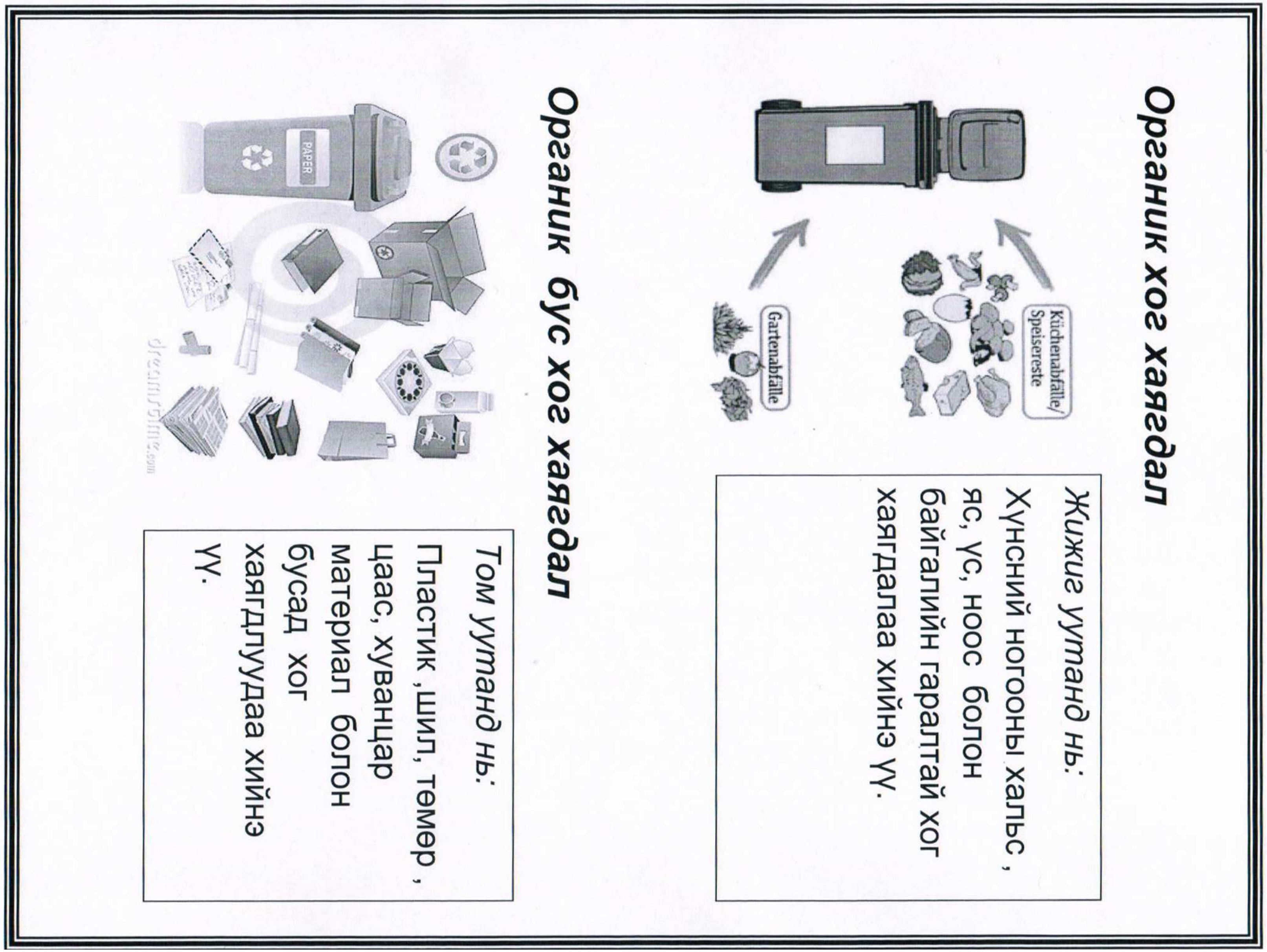
VI Appendix

VI.I Attached Content

Appendix Figure A1: Guiding handout for the waste seperation (Own illustration)

Appendix Table A2: Own waste analysis of Bag7 (Own results)



Appendix Figure A1: Guiding Handout for the waste seperation (Own illustration)

Appendix Table A2: Own waste analysis of Bag7 (Own results)

VI.II Statutory Declaration

We declare that we have authored this research project independently, that we have not used other than the declared sources / resources, and that we have explicitly marked all material which has been quoted either literally or by content from the used sources.

B.Sc. Martin Böhm | B.Sc. Martin Lauckner | B.Sc. René Seyfarth

"Don´t stop the power... MoMo!"