Environmentally orientated research on solid household waste management in Khanty-Mansiysk Autonomous Okrug – Ugra

vorgelegt von
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Preface

On the request of Prof. Elena Lapshina from the Ugra State University in Khanty-Mansiysk/ Russia, a meeting was conducted between her, Prof. Berndt-Michael Wilke, Technische Universität Berlin, and me, the author of this thesis, in Berlin in November 2004. Prof. Lapshina wanted to establish this contact in order to discuss ecological problems of the Khanty-Mansiysk Autonomous Okrug - Ugra Region (KMAO), such as the increasing amount of solid household waste and the lack of waste management concepts which cumulatively result in environmental pollution.

Prof. Wilke and I first visited the Ugra State University in Khanty-Mansiysk in February 2005. The aim of this visit was to strengthen the relationship between both universities and to discuss possibilities of a co-operation. Based on the meetings with Prof. Lapshina and the visit to Ugra, we decided to create a bilateral project through two dissertations. In these dissertations, waste analyses were to be carried out to collect information on the quality and quantity of the solid domestic waste occurring in the region. The Russian company Ugra Service Ecology, which collects data of environmental parameters in Khanty-Mansiysk, supported the project with a scientist, Ms Tanja Kaz'mina. Ms Kaz'mina wanted to write a dissertation on waste management in the Ugra Region.
The title of my dissertation is "Environmentally orientated research on solid household waste management in Khanty-Mansiysk Autonomous Okrug - Ugra, Russia" and the main emphasis is on testing EU tools in Siberia in regard to developing a waste management concept. The topic of the dissertation by Ms Tanja Kaz'mina is the development and implementation of national environmental legislation for waste management concepts in Siberia. Waste analyses in the Ugra Region are the basis of both dissertations.

In December 2005, I visited the Ugra State University again to discuss the project in detail. We, Ms Kaz'mina and I, decided to take two important towns of the region as model cities and to start with the research there. Khanty-Mansiysk as the capital and Surgut as the biggest town in the region were chosen.

From April 2006 until July 2008 waste analyses were carried out in Khanty-Mansiysk. The waste analyses were subdivided into two series because a second company, the main disposal company, "M DEP" in Khanty-Mansiysk, started to co-operate with us only in Autumn 2007, and we thus had the opportunity to also analyse waste from other parts of the city. The waste analyses in Surgut were completed in one year's time, from Summer 2006 to Spring 2007. Ms Kaz'mina was mainly responsible for the implementation of the waste analyses in Surgut, while I principally did the analyses in Khanty-Mansiysk. Simultaneously, necessary background data were collected such as environmental conditions, population structure and its development, methods of waste collection, disposal methods, etc. In December 2006, we were able to make contact to the local authorities and therefore, it was possible to get more reliable data regarding the landfills, amount of waste in the past and present as well as plans for future waste disposal.

In May 2008, during the "3rd International Environmental Forum" of Khanty-Mansiysk Autonomous Okrug - Ugra in Nizhnevartovsk, a contact was made to the Perm State Technical University. Ms Yuliya Anfimova and Ms Natalya Slyusar as employees of the Environmental Protection Department from the Perm State Technical University also work on the development of a waste management concept for KMAO. A co-operation among the three universities was introduced in order to discuss the development of a waste management concept for Ugra, to exchange information, as well as to build up synergy effects.

Finally, I would like to mention that the implementation of the waste analyses was carried out without any financial support. All equipment was donated by private companies. The students of the Ugra State University and the employees of the waste disposal company in Surgut worked on a voluntary basis.

Julia Kaazke

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This dissertation is the result of a bilateral effort between the Ugra State University in Khanty-Mansiysk, Russian Federation, and Technische Universität Berlin, Germany. During the various phases of the dissertation I have been helped by a number of people both in the Russian Federation and in Germany.

I am greatly indebted to Prof. Dr. Dr. Berndt-Michael Wilke and Prof. Dr. Vera Susanne Rotter, for without them the study would not exist. They supported me in identifying and implementing the topic as well as in accompanying and coaching me throughout the entire time of the dissertation. Additionally, Prof. Dr. Dr. Berndt-Michael Wilke assisted me in raising funds and in managing travel to the research area in the Russian Federation.

I also would like to thank the people in Khanty-Mansiysk and in Surgut, Russian Federation. Let me especially mention Mr Yuri Reytov, Rector of the Ugra State University until 2008, and Prof. Dr. Elena Lapshina, Head of the Department for Foreign Affairs of the Ugra State University. They proposed the topic and supported the project *in situ*. I would like to express thanks to Liliya Kasatkina and Natalya Popova for their help in translating all my interviews, in supporting the waste analyses and their guidance and introduction to the Russian mentality. My particular thanks go to all the students at Ugra State University who gave up their leisure time in order to help me to implement the waste analyses as well as the questionnaires.

Furthermore, I would like to say thank you very much to the people of the local administrations in Khanty-Mansiysk and Surgut: Mr A.N. Kutscheravy, Mr Fedor Tomsha, Mr Alexander Burov from the Department of Municipal Communal Service, as well as Mr S.V Pikonow, Mrs Evgnya Kiseleva and Ms Tanja Kaz'mina from the Department of Nature Protection. All these people took time away from their work duties for my interviews in order to answer my numerous questions. Special thanks go to Mr J.A. Rybik, Mr S. A. Vsevolodovich and Mr G. A. Romanovich as the directors of the landfill site in Khanty-Mansyisk and as the directors of the company "Schistie Dom". They always supported me with information about waste disposal in Khanty-Mansiysk.

My special thanks to the Konrad Adenauer Foundation and the International Bureau of the Federal Ministry of Education and Research for funding my dissertation and travels to Khanty-Mansiysk and Surgut. Without the financial support of both institutions, an implementation of the research would not have been possible.

I am also greatly indebted to Mr Bertram Zwisele (ARGUS GmbH, Germany) as he introduced me to the correct implementation of waste analysis and always answered my questions regarding implementation and evaluation of waste analyses with patience.

Let me thank Mr Peter Beigl (BOKU - University of Natural Resources and Applied Life Sciences, Wie, Austria) and Prof. Montse Meneses (University Rovira I Virgili, Tarragona, Spain) for the support in becoming familiar with the software programs for waste prognosis and life cycle assessment.

I would also like to thank Mr Georg Hosoya and Mrs Karin Jakob-Deters from the Technische Universität Berlin, Germany, as well as Mr Marcus Schrenker of the Humboldt Universität

Berlin, Germany. They introduced me to the evaluation of questionnaires and the field of social sciences.

My special thanks to Ms Nadine Wersing, who proof-read my dissertation.

I also would like to mention and thank the “Kramer and Kramer” company which sponsored a lot of equipment for the waste analyses in Khanty-Mansiysk and in Surgut.

Last but not least, I would like to express my gratitude to my family and friends. I would especially like to mention my parents, who also sponsored equipment and advised me with ideas for equipment for the waste analyses, and Anika Lerche who answered my questions regarding mathematical issues patiently all the time. My sincere thanks to my friend Gerit Kulessa for her special help with the continuous question “Why?”, which truly lead to improve the content of my dissertation.

Thank you very much!

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Abbreviations

AB	Apartment blocks (a stratum within the waste analysis)
aeMBT	aerobic Mechanical-Biological-Treatment plant
anMBT	anaerobic Mechanical-Biological-Treatment plant
C.I.	Confidence Interval
C.L.	Confidence Level
EC	European Commission
ETC/ SCP	European Topic Centre on Sustainable Consumption and Production
ETC/ WMF	European Topic Centre on Waste and Material Flows
EU	European Union
KMAO	Khanty-Mansiysk Autonomous Okrug – Ugra (research area)
LCA	Life Cycle Assessment
LCA-IWM	The Use of Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies
OECD	Organisation for Economic Co-operation and Development
PST	Prognosis Software Tool
RDF	Refuse-derived fuel
SH	Small houses with garden (a stratum within the waste analysis)
SWA-Tool	Methodology for the Analysis of Solid Waste
UN	United Nations
UNCSD	United Nations Commission for Sustainable Development
UNEP	United Nations Environment Programme
WB	The World Bank

Units

Mg	Megagram (1Mg = 1,000kg)
$Mg\ a^{-1}$	Megagrammes per year
$kg\ c^{-1}\ a^{-1}$	Kilogrammes per capita and year
$kg\ c^{-1}\ w^{-1}$	Kilogrammes per capita and week
$kg\ c^{-1}\ d^{-1}$	Kilogrammes per capita and day
l	litre
WIE	World Inhabitant Equivalents

Definition of terms

Context-bound terms are used in the dissertation and are explained in the following paragraphs:

(Sampling) unit is the smallest unit of waste samples, such as a container size of $1m^3$ or a defined weight of waste (EC, 2004).

Coefficient of variation is defined as the ratio of the standard deviation to the mean (EC, 2004).

Commercial waste is defined as waste from small shops, enterprises or administration (EEA, 2008).

Confidence interval is an interval in which a test or measurement falls according to a set probability and demonstrates the reliability of a result (EC, 2004).

Confidence level corresponds with the set probability and represents how often the results of the measurements or tests lay within the confidence interval. For example, 90% confidence level means one can be 90% sure that one's results are within the confidence interval. The confidence level is the probability value associated with a confidence interval, often expressed as a percentage. For example, say $(1- \alpha)$, $\alpha = 0.10 = 10\%$, then the confidence level is equal to (1-0.10) = 0.90, i.e. a 90% confidence level (EC, 2004).

Degree of freedom of variance is equal to the number of independent scores (Bortz, 2005).

Domestic waste/ household waste is generated from private households only (EC, 2004).

Effect size supports calculation of the sampling size and has to be determined before the survey starts (Bortz, 2005).

Environmental assessment is the valuation of environmental resources (EEA, 2009).

European framework program is the key instrument to establish the European Research Area. The pre-condition for implementing projects within the European framework program is the co-operation of different countries (EC, 2007)

European research area has, among other key aims, the development of common principles and harmonisation of decision support tools for the international exchange of knowledge as well as the development of solutions for global issues (EC, 2007).

Inert waste has insignificant leachability and pollution content which will not require laboratory analysis (EEA, 2009).

Inference statistics has the aim to make a prediction/ a correlation about a characteristic between the total population and the researched population (Bortz, 2005).

Integrated solid waste management (ISWM) has been developed as a strategic approach towards a sustainable waste management. It includes not only the waste disposal but also takes into consideration all aspects of waste management such as waste generation, collection, transport and recovery in regard to the waste hierarchy: prevention, reuse/ recycling and environmental treatment. Furthermore, intentions of local authorities and interests of all stakeholders which are influenced by waste management should be taken into account within the development of integrated concepts (UNEP, 2009).

Life Cycle Assessment demonstrates the assessment of the environmental impacts of products or processes throughout their entire life (Baumann and Tillman, 2004).

Municipal waste is “Waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households.” (Directive 99/31/EC on landfill of waste, p. 0003).

Natural coefficient of variation demonstrates the *heterogeneity or variation* of waste and is to be determined by pre-investigation of the waste and stated as the natural variation coefficient (EC, 2004).

Public participation includes activities with a wide range of public involvement tools and processes, such as collaboration in steering committees, workshops, etc. (The World Bank, 2004).

Sampling level or level of sampling is the location where the sampling units are taken; for example, inside the household, directly from the kitchen, or outside from the waste containers (EC, 2004).

Sensitivity analysis is an identification and review of unverified data entered through testing the robustness of results by a systematic change of this data entered (Baumann and Tillman, 2004).

Significance tests evaluate whether a relationship could be due to chance (Bortz, 2005).

Stratification: Statistical subdivision of non-homogenous group of waste producers into more homogenous sub-group of waste producer in the research area which does not overlap, for example different residential structure (EC, 2004).

Stratum (sing.)/strata (pl.) is a homogenous sub-group; for example, residents of apartment blocks or residents of small houses with gardens (EC, 2004).

Two tailed tests examine an un-directed hypothesis. An Un-directed hypothesis means that there is no trend of correlation, differences or change (Bortz, 2005).

Waste analysis means the quantifying of different waste streams. It also records waste fractions as a proportion of the total waste stream and determines ways of waste disposal and waste practices (EC, 2004).

Waste prognosis is the calculation of waste amount and composition in a future time period, such as in 10 years (Beigl, et al. 2005).

Abstract

A continuous rise in waste volume produced has been recorded in the Russian Federation for several years. Therefore, the conventional methods of waste disposal have reached their limits. Additionally, there are gaps in the Russian legislation that complicate the development of integrated waste management concepts.

Based on agreements between the European Union and the Russian Federation regarding environmental protection measures in the Russian Federation, the question has arisen whether decision support tools developed within the European framework programme are transferable to Russia.

Decision support tools with an international approach have been developed in the European framework program based on co-operation between different states. This international approach was a precondition in the research proposal of the dissertation. It was assumed that such tools are more likely transferable to Siberian conditions. Consequently, several tools useable for the development of integrated waste management concepts were researched. Subsequently, their transferability to the Khanty-Mansiysk Autonomous Region – Ugra (research area) was tested. The point of departure was research which demonstrated that the following work steps and tools play an essential role for the development of an integrated waste management concept:

Guideline for the development of integrated waste management concepts:

- “Preparing a waste management plan. A methodological guidance note” by the European Topic Centre on Waste and Material Flows and commissioned by the European Commission DG Environment (EC, 2003)

Work steps for the development of integrated waste management concepts:

- Waste analysis: “Methodology for the Analysis of Solid Waste (SWA-Tool)” by the European Commission (EC, 2004)
- Public participation: “Toolkit. Social Assessment and Public Participation in Municipal Solid Waste Management” by The World Bank (2004). (This is an exception as the research demonstrated that there is no developed tool for a public participation within the European framework program.)
- Waste prognosis as well as life cycle assessment: “The use of life cycle assessment tool for the development of integrated waste management strategies for cities and region with rapid growing economies (LCA-IWM)” in the 5th EU framework (Project Coordinator TU Darmstadt, 2005)

A strength-weakness analysis of all tools in the research area in Siberia expressed that almost all tools are transferable with modifications. The LCA is not transferable. Recommendations for essential modifications are given in order to guarantee an optimal use at the local level in Siberia. The research also emphasises that these tools are used separately at the moment and hardly any correlations are recognisable. However, only interlinking these tools will lead to an integrated waste management concept. Therefore, the aim is to make be a better correlation among these tools in order to optimally develop an integrated waste management concept and to use synergy effects.

Zusammenfassung

In der Russischen Förderation ist seit einigen Jahren ein kontinuierlicher Anstieg der Abfallmengen zu verzeichnen. Die herkömmlichen Methoden der Abfallentsorgung stoßen daher an ihre Grenzen. Darüber hinaus existieren gesetzliche Unsicherheiten und erschweren die Entwicklung eines integrierten Abfallwirtschaftskonzeptes.

Basierend auf Abkommen zwischen der Europäischen Union und der Russischen Förderation wurde hinsichtlich des Umweltschutzes, vor allem in der Russischen Förderation, die Frage aufgeworfen, ob Instrumente, die im Europäischen Rahmenforschungsprogramm entwickelt worden sind, auf die Russische Förderation übertragbar seien.

Innerhalb des Rahmenforschungsprogramms der Europäischen Union werden, durch die Zusammenarbeit von Staaten in unterschiedlichen Projekten, Instrumente mit internationalem Ansatz entwickelt. Dieser internationale Ansatz war Grundbedingung im Forschungsansatz der Doktorarbeit, da angenommen wurde, dass solche Instrumente am ehesten auf die Konditionen in Sibirien anwendbar seien. Deshalb wurden einige Instrumente, die bei der Entwicklung von Abfallwirtschaftskonzepten Anwendung finden, ausgesucht und anschließend auf ihre Übertragbarkeit in die Region Khanty-Mansiysk Autonome Region – Ugra, Westsibirien (Untersuchungsgebiet) überprüft. Ausgangspunkt der Untersuchungen war eine Recherche und es zeigte sich, dass folgende Arbeitsschritte und Instrumente eine essentielle Rolle in der Entwicklung eines Abfallwirtschaftskonzeptes spielen und daher berücksichtigt wurden:

Richtlinie zur Entwicklung eines Abfallwirtschaftskonzeptes:

- “Preparing a waste management plan. A methodological guidance note” by the European Topic Centre on Waste and Material Flows and commissioned by the European Commission DG Environment (EC, 2003)

Arbeitsschritte und Instrumente für die Entwicklung eines Abfallwirtschaftskonzeptes:

- Abfallanalyse: “Methodology for the Analysis of Solid Waste (SWA-Tool)” by the European Commission (EC, 2004)
- Partizipation der lokalen Bevölkerung: “Toolkit. Social Assessment and Public Participation in Municipal Solid Waste Management ” by The World Bank (2004) (Das ist eine Ausnahme, da die Recherche aufzeigte, dass innerhalb des Rahmenforschungsprogramms kein Instrument zur Partizipation der lokalen Bevölkerung bisher erarbeitet wurde.)
- Prognose von Abfallmengen und -zusammensetzung sowie Ökobilanzierung: “The use of life cycle assessment tool for the development of integrated waste management strategies for cities and region with rapid growing economies (LCA-IWM)” in the 5th EU framework (Project Coordinator TU Darmstadt, 2005)

Eine Stärken-Schwächen-Analyse der Instrumente am Fallbeispiel der genannten sibirischen Region zeigte auf, dass mit Ausnahme der Ökobilanzierung- alle Instrumente mit Modifikationen übertragbar sind. Empfehlungen für notwendige Veränderungen wurden ausgesprochen, um einen optimalen Einsatz auf lokaler Ebene, spezielle im sibirischen Raum, zu ermöglichen. Deutlich wurde auch, dass diese Instrumente derzeit unabhängig voneinander angewandt werden und kaum Bezugspunkte zwischen ihnen zu finden sind, obwohl nur ein Zusammenwirken zu einem integrierten Abfallwirtschaftskonzept führen.

Ziel muss es sein, diese Instrumente zukünftig besser aufeinander abzustimmen, um auf bestmöglicher Art und Weise ein integriertes Abfallwirtschaftskonzept zu entwickeln sowie Synergieeffekte zu nutzen.

1. Introduction

Waste generation, including its treatment and international shipment, is one of the five global environmental key problems; the others being loss of ozonosphere and biodiversity, climate change as well as soil and water pollution (Woyke, 2004). Approximately 1.6 billion Mg municipal waste are generated worldwide per year at present (OECD, 2008). About 200,000 existing open landfills (UNEP, 2004) and improper and non-sustainable disposal of waste cause risks to human health and environment globally (OECD, 2008). Furthermore, the amount of global waste is still growing (ISWA, 2002), among other reasons due to the constant global demand and mining for raw materials as well as the increase of manufacturing of (industrial) products (OECD, 2008).

Dealing with waste was, is and will always be a task of everyday life. In times past, humans suffered from unhygienic circumstances and thousands of people in Europe died because of polluted drinking water. In the 19th century, the link between lack of hygiene and death was analysed and waste management was mainly undertaken in order to protect human health (Bilitewski et al., 2000). Today, further necessities than hygiene exist to deal with waste disposal: sustainability and environmental protection (ISWA, 2002). Since the second International Environmental Conference in Rio de Janeiro in 1992, waste management has gained a key role in environmental protection (ISWA, 2002). International agreements on waste management appeared at the end of the 20th and beginning of the 21st centuries, such as “The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal” (1989) and the Agenda 21, Article 20/21 (1992) (ISWA, 2008).
But waste policies alone cannot stop wrongful waste disposal and resulting environmental pollution; adequate waste management concepts are also essential as the impacts of waste concepts also play a significant role in climatic and natural resource protection as well as waste utilisation of waste as a second resource. According to the Organisation for Economic Co-operation and Development (OECD), waste management is one of the most important global challenges to deal with today (OECD, 2008).

Integrated waste management has been developed as a strategic approach towards sustainable waste management. It not only includes the waste disposal but also takes into consideration all aspects of waste management such as waste generation, collection, transport and recovery in regard to the waste hierarchy: prevention, reuse/recycling and environmental treatment. Furthermore, interests of local authorities and all stakeholders which are influenced by waste management should be taken into account within the development of integrated concepts (UNEP, 2007). Because of this complex approach, preparing and implementing integrated waste management concepts is difficult. Moreover, there are no internationally uniform regulations for preparing integrated waste management concepts and, therefore, the development of waste management concepts differs worldwide.
The European Union (EU) has already achieved an advanced standard in waste management concepts worldwide because of well-developed legislation (ISWA, 2002). In contrast to the EU, the Russian legislation does not offer a well-developed basis for preparing and implementing waste management concepts. In recent years, major growth of the Russian Federation’s economy and industry due to its intensive exploitation of natural gas and oil has started. The country’s growing economy results in a higher standard of living, production growth, and rising consumption. Consequently, mountains of waste have

appeared (BfAi, 2007). Therefore, waste management is one of the most complex issues that has to be dealt with in Russia today (GUA, 2005).

Khanty-Mansiysk Autonomous Okrug - Ugra (KMAO), the research area, has started to play a main role in the Russian economy since the mid-1990s because key oil and gas extraction is located in this region. Hence, a migration boom had started and the population increased from 33,000 inhabitants in 2000 to 70,000 inhabitants in 2007. As a result, the extension of infrastructure and higher incomes have been leading to an accelerated generation of municipal waste. An increase of solid household waste amount per capita from 140 kg c^{-1} a-^{1} in 2000 to 430 kg c^{-1} a^{-1} in 2007 was registered (Tomsha, 2007, pers. comm.). In the capital Khanty-Mansiysk the ***management of solid household waste*** is currently the biggest problem (Ivanovich, 2008a, pers. comm.) because waste disposal sites are almost full and illegal disposal occurs. In addition, these excavated holes which are either partly or entirely unsealed are used for deposition of all types of waste, including industrial waste. Furthermore, the landfills are frequently located in protected water zones and pollute the ground or surface water (Kiseleva, 2005, pers. comm.). Reliable data on waste quality and quantity as well as environmental impacts caused by waste disposal are hardly known because relevant data have never been collected. Research on sites that would be suitable for use as landfills has never been carried out. Current national legislation is insufficiently developed as, for example, the Russian legislation does not state in what way a waste management concept is to be developed (Ulanova, 2007). International standards of waste treatments are not applied in Russia. These issues result in the improper disposal of waste and cause environmental problems and risks to human health. It demonstrates the necessity of developing a sustainable waste management concept in the Ugra region that aims at reducing environmental pollution, achieving a minimised use of natural resources and protecting human health.

1.1. Aim of the dissertation

As Russia and the EU share a common border, ecological issues need to be handled in collaboration. Therefore, the EU has supported Russia in implementing several projects regarding environmental issues since 1995 (EC Delegation, 2008). Milestones are the ***"EU-Russia Common Economic Space road-map"*** (EC, 2005) and ***"EU-Russian Environmental Dialogue"*** (EC, 2006).

The "EU-Russia Common Economic Space road-map" was signed in 2005 and in this road map the agenda for the co-operation between Russia and EU are described and in which section 6 "Environment" plays a significant role. This topic was included because Russia also agreed on an "EU-Russian Environmental Dialogue". Therefore, a closer contact between the EU and Russian authorities as well as a new ecological dialogue between them has started. Main objectives of the "EU-Russia Common Economic Space road-map*"* regarding environment include building up ecological awareness, implementing international agreements such as the "United Nations Framework Convention on Climate Change", and introducing environmental responsiveness in all sectors of the government. In order to implement these aims, activities such as "Convergence of environmental legislation towards higher standards" are listed (EU, 2005).

In addition, the "EU-Russian Environmental Dialogue - Terms of Reference for establishing a dialogue on Environment between the Ministry of Natural Resources of the Russian Federation and the Directorate General for Environment of the European Commission" (ToR), in order to strengthen a partnership and to establish working groups, was signed in 2006. Objectives of the ToR are to encourage the development of environmental policies and management. This includes harmonising the environmental legislation between the EU and Russia, supporting transboundary ecological topics, raising public awareness, sharing of information etc. (EC, 2006).

Considering the aforementioned facts, the following questions have arisen: Is it possible to use European decision support tools such as guidelines and/or standardised tools for the development of solid household waste management concepts in Russia; i.e. Siberian regions? Which decision support tools can local authorities use for the development and implementation of an integrated solid waste management concept if no internationally recognised or national standards exist in Russia? Which information is crucial for the development of strategies for integrated solid household waste management, especially for Siberian regions, and need to be investigated in order to achieve a reduction of environmental pollution?

Many tools to develop an integrated solid waste management concept exist; for example, the EU has developed a guideline for preparing an integrated solid waste management concept within the ***European framework program***.

The European framework program is the key instrument to establish the European Research Area (ERA) which was introduced by the EU in 2000. Among others, key aims of establishing the ERA were the development of common principles and harmonisation of decision support tools for the international exchange of knowledge as well as the development of solutions for global issues. The pre-condition for implementing projects within the European framework program is the co-operation of different countries (EC, 2007); i.e. those developed tools within the European framework have an international scientific approach.

For this reason, I assumed that decision support tools which were developed in the European framework program of the EU are most suited to be transferred to the conditions for preparing a solid waste management concept in Russia; i.e. Siberian regions.

Therefore, the main objective of the thesis is to assess whether tools which were developed in European Union framework projects for preparing an integrated solid waste management concept are applicable in Siberian regions; i.e. transferable outside the EU.

Based on this starting point, the following objectives for the dissertation were formulated:

- to apply these tools to a particular case in Siberian regions,
- to identify their strengths and weaknesses ,
- to revise these tools for general use which should support the progress of international harmonisation, and finally,
- to develop recommendations for the most advantageous use of these tools in Siberia.

In order to achieve these objectives, at first a desk study was conducted to identify decision supporting tools recommended by the EU or developed within EU projects. Afterwards, they were tested in the research area. Finally, these tools were assessed as to whether they are applicable in Siberian regions.

Beyond the aim of testing the application of selected tools, first reliable data regarding waste management were collected for the development of an integrated waste management concept for two towns in Khanty-Mansiysk Autonomous Okrug-Ugra: Khanty-Mansiysk and Surgut.

1.2. Outline of the dissertation

Chapter 2 "Background information" gives a detailed overview of existing tools for preparing integrated waste management concepts on international and national level. It includes tools for development of a waste management, waste analysis, public participation, waste prognosis and environmental assessment. Furthermore, it describes briefly the European legislation as well as the Russian Federation and the research area Khanty-Mansiysk Autonomous Okrug - Ugra.

Chapter 3 "Methodology" is subdivided into the descriptions of implementation of each tool. The waste analysis and the survey of public participation were carried out and tested in KMAO. Therefore, their implementation is described thoroughly as execution is in part a research proposal of the dissertation.

Chapter 4 "Results and discussion" shows the results and a discussion of the waste analysis, survey of public opinion, waste prognosis and environmental assessment.

Chapter 5 "Applicability of tools in Siberian regions" represents the key chapter and reflects the research proposal of the dissertation. The sub-chapters to each tool are subdivided into monitoring the implementing as well as in identification and discussion of strengths and weakness of each tool. Finally, recommendations for an optimal application, especially in Siberian regions, are given.

Chapter 6 "Conclusions" summarises the results of Chapter 5. It also illustrates proposals for further research. Additionally, the relation between the development of integrated waste management concepts and other planning such as the regional planning is discussed briefly as waste management concepts can have an influence on other planning.

2. Background information

2.1. Desk study of decision support tools for the preparation of integrated solid waste management concepts

The literature study gives an overview of existing decision support tools for the preparation of integrated solid waste management concepts. The main emphasis of this study was to determine whether there are instructions by intergovernmental organisations, especially by the EU.

2.1.1. Strategies for preparing integrated solid waste management concepts

Several intergovernmental organisations have already worked on waste management strategies and manuals/guidelines as shown by the OECD (2008a). Based on this research, four international organisations were identified for providing guidelines for the preparation of waste management concepts: The World Bank, the United Nations (UN), the European Union (EU), and the Organisation for Economic Co-operation and Development (OECD). An overview of these manuals is given in Appendix – Chapter 2, Table A2.1.-1. In the following, these guidelines will be introduced.

"Strategic planning guide for municipal solid waste management" by Wilson et al. (2001) is the key recommendation by **The World Bank**. The aim is to improve the management of municipal waste in cities. The International Solid Waste Association (ISWA), the only association regarding waste operating worldwide, also recommends this guideline (UNEP, 2004). The planning guide was created in 2001, and the overall aim of the guidance is to promote efficient and sustainable municipal solid waste management in a city. The way from the initial to a final waste management concept is explained in seven steps. All steps have the same structure: user guide to this step, key messages, implementation of this step, and the time period for implementation of this step.
Step 1 "Mobilising" explains in detail the kick-off of preparing a waste management concept. Besides responsible bodies such as local authorities, all stakeholders (together with inhabitants) should be included in this part. It is recommended to create a "steering committee" where all key actors are represented in order to secure an effective continuous planning process and which is responsible for overall activities. Within the working groups (subgroups of the steering committee) all relevant topics have to be discussed, and they have the responsibility for different parts of the entire process such as the analysis of alternatives, for example, different types of collection systems. The aim of this step is to activate the planning process.
The next step, *step 2 "Defining the baseline",* is to determine all information needed for a waste management concept such as data on waste, management and regional background such as socio-economic data, land use, environment etc. Tools on how this information can be determined are also explained. The target is to characterise the current situation as well as to forecast demands of the future waste management concept.
Within *step 3 "Establishing the strategic planning framework"* a vision of future targets and objectives is supposed to be formulated which includes setting the scope of the future management concept, for example, to decide on the type of waste, time horizon etc.
Step 4 "Identifying and Evaluating options" describes the practical alternatives of each component of an integrated municipal waste management concept such as waste collection, transport and disposal. Technical solutions as well as costs are given for each part. In

addition, a part for promoting public awareness is demonstrated in order to include and inform the local population about the new management concept.

Step 5 "Developing the Strategy" includes the discussion of important issues for improving waste management and the development of a long-term perspective for the waste management concept.

Based on step 5, *step 6 "Preparing the Action Plan"* will be formulated. The aim of this step is to evaluate the vision of step 5 and identify the requirements for an implementation of the strategy. A pre-feasibility study is recommended for the technical options. This study also includes an environmental assessment via environmental impact assessment (EIA).

Finally, *step 7 "Implementing the strategic plan"* describes the move from planning to implementation as well as the monitoring of implementation. Capacity-building of the responsible staff, strengthening public awareness and improving cost recovery are key elements in the implementation process. An overall timetable and case studies regarding costs in different towns round off the guidelines (Wilson et al., 2001).

"Waste management planning. An environmentally sound approach for sustainable urban waste management" was developed by **United Nations Environment Programme (UNEP)**/ **Division of Technology, Industry and Economics** in 2004. This guideline is subdivided into a description of the challenge of waste, waste management issues, especially in developing countries, as well as a brief guidance for preparing a waste management plan. The aim is to support countries all over the world to implement the waste targets set in Agenda 21 and to achieve sustainable development. Several parts from "Preparing a waste management plan. A methodological guidance note" by the European Commission (EC, 2003) are repeated because the authors are convinced it is also valid for non-European countries (UNEP, 2004). The precondition for a local or regional waste management plan is a national waste management plan as a legal framework with policy targets for the entire country. Three key steps are recommended for preparation of a waste management plan, taking action, implementation and public participation:

"Taking action" is subdivided into three steps:

1. The "Importance of waste management concepts" such as functional waste disposal is to be described.
2. The "Current situation" is to be analysed such as waste quantities, sources of waste, fraction of waste, treatment capacity, number of households and companies etc. Sorting test is one of the suggested tools for waste analysis. The result can be in statistical form and state an annual amount and its composition, and seasonal fluctuation.
3. In "Defining the scope and strategy" the main emphasis is on political objectives and goals within the waste hierarchy, i.e. promotion of clean technologies, recycling, education and environmental management system such as Life Cycle Assessment (LCA). Connections to other political guidelines such as scientific/technical, ecological and economic guidelines are demonstrated, and identifying measurable indicators with which to achieve targets and goals also plays an important role.

"Implementation" is also subdivided into three steps:

1. choice of a collection system,
2. choice of treatment plan, and
3. choice of the responsible body between the local authorities and industry.

"Public participation" is important when choosing the treatment plant, the type, capacity and location of the treatment plant, for they are the significant factors which will also have an impact on the inhabitants. Therefore, the inhabitants should be involved in this part of the

planning process. Furthermore, the education of the inhabitants in sustainable consumption in order to prevent waste is also important. Detailed explanations for development of waste management concepts and further links to websites for waste management are given in the appendix of the guideline and complete the manual (UNEP, 2004).

Furthermore, the **United Nations Environment Programme (UNEP)/ Division of Technology, Industry and Economics/ International Environmental Technology Centre** has recently published a new training manual in June 2009. The aim of this manual ***"Developing Integrated Solid Waste Management Plan (ISWM)"*** is to advise national and mainly local authorities of urban regions that have a waste management problem owing to fast economic growth. The training manual consists of four volumes:
Volume 1 "Waste characterisation and Quantification with Projections for future" gives an overview of tools for analysis of waste quantification, composition and waste characterisation. This volume describes tools for municipal, industrial and hazardous waste. UNEP (2009) refers to ways of implementing waste analyses from two companies "CASCADIA" and "Sky Valley Associates" from the U.S. (UNEP, 2009a).
Volume 2 "Assessment of Current Waste Management System and Gaps therein" focuses on the assessment of the existing waste management including policies, institutions, financing and technology. Work steps are recommended to collect the data on laws and acts, economic instruments etc. Suggested datasheets are given to prepare an overview of all collected data (UNEP, 2009b).
Volume 3 "Targets and Issues of Concern for ISWM" includes descriptions of ways for choices of objectives and setting targets. Furthermore, it describes the identification and participation of all stakeholders in the process of preparing a waste management concept (UNEP, 2009c).
Volume 4 "Integrated Solid Waste Management Plan" describes the entire planning process, which explains step-by-step the implementation of sustainable waste management from focusing on why a concept is necessary to institutionalisation of an action plan as well as monitoring and evaluating the concept. Each step is supported by a case study at the end of the chapter (UNEP, 2009d).
In contrast to the guideline about waste management planning by the UNEP in 2004, the new version describes all terminology such as integrated solid waste management and each decision support tool such as waste analysis thoroughly.

"Preparing a waste management plan. A methodological guidance note" by the **European Topic Centre on Waste and Material Flows** (ETC/ WMF[1]) and commissioned by the **European Commission (EC) DG Environment** was published in 2003. The aim of this manual is to provide a strategic tool for waste management planning at national level, but it can also be used by regional and urban authorities. In this case, the guidance note explains that the concepts should be more "action-orientated" (EC, 2003, p.7). Type of waste is not further subdivided. Before the development of a waste management concept is described, an introduction to the structure of waste management concepts and the EU legislation is given. The development of a concept is subdivided into three main parts: general consideration, status, and planning. In all three parts, several advice notes regarding the EU directives and examples of implementation are included and demonstrate the way from the beginning of a

[1] European Topic Centre on Waste and Material Flows (ETC/ WMF) was renamed into European Topic Centre on Sustainable Consumption and Production (ETC/ SCP) in January 2009 (ETC/ SCP, 2009).

concept to its finalisation. A revision after the implementation of the new waste management concept is recommended, but there are no steps included.
In the first part *"General consideration"* of the EU guidance note, mobilisation of the waste management process is described. It includes discussing the scope of the concept, how to include stakeholders, possible options for the required environmental assessment, the time scale, as well as the links to other policies.
In the second chapter, *"Writing the status report"*, the main emphasis is on the analysis of waste generation, type of waste, collection, treatment, as well as current funding. Finally, the current system needs to be assessed and problems have to be identified before new objects are developed.
Based on this assessment and the EU legislation, the *"Planning part"* starts (third part) and four steps are described:

1. Prognoses should be made; for example, about the changes in waste quality and quantity as well as accessibility of waste treatment facilities.
2. This step is to set objectives which can be monitored. For this process a template is given for objectives, measurable targets, measurable indicators, measures, and preconditions.
3. It builds up on the analyses in step 1 and the objectives in step 2 and considers possible solutions; for example, the collection system and the financing. In addition, possible measures for the implementation of targets should be identified. An example is public awareness because a new concept needs the understanding and support of its users. Information campaigns or other initiatives are possible instruments.
4. The introduction of long-term targets is also recommended at the end of this planning process. The example is given that such a waste management plan usually covers five years, but to run necessary treatment facilities, long-term targets are essential to consider the capacity of the treatment plant and its cost.

All three main parts, general consideration, status, and planning, have in common that they have a checklist with the main tasks of each step for the user at the end of their description (EC, 2003).

Usually, the **OECD** only develops policies, but there are a few exceptions such as the ***"Guidance Manual for the Implementation of the OECD Recommendation C(2004)100 on Environmentally Sound Management (ESM) of Waste"*** (Harjula, 2008, pers. comm.). The manual intends to introduce policies and technical information regarding waste management for governments in each OECD member state. The OECD identified the different level of standards regarding waste policies and treatment facilities in each of its member states as a problem. Therefore, the OECD would like to achieve a general awareness of waste management in each OECD member state. Three main targets were set with the guidelines:

- sustainable use of the environment in order to avoid risks to human health and ecology and to prevent waste;
- introduction of facilities with a high environmental standard in order to guarantee fair competition;
- creating incentive in order to promote progress for environmentally friendly waste treatment facilities.

The guideline supports a wide scope of waste management and for that reason, there is no subdivision of types of waste or treatment in order to include all aspects of waste management, with the exception of radioactive waste. All types of waste which are

generated, imported or exported -both from OECD members or non-OECD members- are included. All components of waste management, such as temporary or permanent disposal, landfill, incineration etc. are also covered by this manual.
The OECD manual is to ensure that all waste management options are implemented and competitive in an environmentally friendly way. Eleven recommendations were developed to strengthen the introduction of waste management policies and comparable standards of treatment facilities. Examples are that members should have suitable legislation and mechanisms to promote the development of environmentally sound activities (Recommendation 1), and they should have detailed knowledge about waste generation in order to prevent waste and to avoid risks in their countries (Recommendation 4). Additionally, the manual refers to six “Core Performance Elements” (CPEs) which describe measures for developing ecologically sound waste treatment facilities. One CPE, for example, recommends the implementation of an environmental management system (EMS) through “ISO 14001” Environmental Management or European Community Eco-Management and Audit Scheme (EMAS) or other national and/or regional systems. Advice on technical guidelines based on UNEP through the Basel Convention and EU legislation completes the manual (OECD, 2007).

Finally, four of the five guidelines described above, the two guidelines by the UNEP (2004/ 2009a-d), the guideline by the EC (2003), and the guideline by The World Bank (Wilson et al., 2001), have a comparable general outline: introducing the planning part, data acquisition, public participation, planning and implementation, all supported by work steps. However, the sequence of the work steps is different, which is most apparent when it comes to the question when to include the public. The OECD (2007) manual is different to the other four because of its basic idea: The main goal is not to prepare a waste management concept, but to implement the policies for preparing a waste management concept. However, since the manual by the OECD in parts describes the preparation of a waste management concept, it was also included (see Appendix – Chapter 2, Table A2.1.-1).
Waste analysis, ***public participation*** as well as ***prognosis of waste*** are key work steps in all guidelines (see Table 2-1). Differences exist in the level of detail of the description of these steps: Only the UNEP (2009a-d) new version and the guideline recommended by The World Bank (Wilson et al., 2001) specify in which way the steps could be implemented via tools thoroughly.
Although all guidelines recommend assessing new concepts in terms of their environmental impacts, the types of implementation also vary. The OECD (2007) refers to ISO 14000 series “Environmental management” which includes “Life Cycle Assessment” or “European Community Eco-Management and Audit Scheme” (EMAS). The UNEP version of 2004, among other proposals, also suggests “Life Cycle Assessment” (UNEP, 2004). The guidance note by the EC refers to the required “Environmental Impact Assessment” (EIA) for testing the impacts of a waste management concept according to EU legislation (EC, 2003). The guideline by The World Bank (Wilson et al., 2001) and the manual by the UNEP of 2009 (UNEP, 2009a-d) do not propose any specific tool for an environmental assessment of the integrated waste management concept. In contrast to tools for an assessment of environmental impacts such as EIA, ***Life Cycle Assessment*** (LCA) can evaluate an entire waste management concept or only single parts of the concept as well as identify waste treatment alternatives. LCA as a decision support tool has attained an important role in the evaluation of environmental impacts as part of the development of waste management concepts (Hauschild and Barlaz, 2007; Baumann and Tillmann, 2004; Guinée (Ed.), 2002).

Table 2-1: Overview of implementation of work steps as recommended by the manuals by intergovernmental organisations

Work steps \ Intergovernmental organisations	The World Bank (2001)	UNEP (2004)	UNEP (2009)	EC (2003)	OECD (2007)
Waste analysis	• enquiry from producer or transport firms • waste sorting • questionnaires	• enquiry from producer or transport firms • waste sorting • measurement of waste stream	• recommended by CASCADIA (2003, 2004, 2005) and SKY VALLEY ASSOCIATES (2003) • compiling data sheets	• enquiry of waste disposal companies • weighing of waste • calculation of waste amount based on the equipment currently used	• not considered
Participation	• creating steering committees	• information exchange between all integrated stakeholders • waste education • strengthens environmental awareness	• creating monitoring/ steering committees	• creating steering committees	• information exchange between producers, waste generators, waste managers and authorities
Waste prognosis	• formula is given	• not considered	• scenario-building approach	• formula is given	• not considered
Environmental assessment of ISWM	• not considered	• LCA	• not considered	• EIA	• ISO 14001 (including LCA)

Existing decision support tools for the implementation of waste analysis, public participation, prognosis, and LCA by intergovernmental organisations, and whether such tools exist especially for Russia were researched and will be described in the next chapters.

2.1.2. Tools for analysing amount and composition of solid household waste

Waste analyses are a crucial prerequisite of the development of waste concepts. Consequently, the selection of an appropriate tool for waste analysis is significant. Without knowledge about the amount and composition of waste it is not possible to develop a sustainable waste management concept. However, according to research by Dahlén and Lagerkvist (2008), there are 20 tools available globally to determine solid waste amount and composition. Additionally, I identified four further tools for waste analysis. All tools are mainly created on a national basis, but four international organisations have also developed tools for waste analysis (see Table 2-2).

Table 2-2: Overview of tools for analysis of waste composition and amount on international level

(Number of tools)	Tool	Reference/Institution
Intergovernmental organisation		
IEA (1)	Work in harmonising sampling and analytical protocols related to municipal solid waste conversion to energy	Scott (1995), International Energy Agency (IEA)
EU/ EC (2)	REMECOM-European Measurement for Characterisation of Domestic Waste	ADEME (1998), EU-Life-Program
	SWA-Tool, Methodology for the analysis of solid waste	European Commission (2004), EU-5th Framework Program
International organisation		
ERRA (1)	Waste analysis procedure. Reference multi-material recovery	ERRA - European Recovery and Recycling Association (1993)
ASTMI (1)	Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste	ASTM International (2003), American Society for Testing and Materials

The first approach for a waste analysis was already developed in Germany by the University of Stuttgart in 1956. Material proportions, particle size and heating value were analysed in different German towns (Zwisele, 2006). Since the 1960s, a methodology for waste characterisation has been developed in the US (Dahlén and Lagerkvist, 2008), and resulted in a “Standard Test Method for Determination of the Composition of Unprocessed Municipal Waste” by the American Society for Testing and Materials International (ASTMI, 2003). Additionally, nationally based research of municipal waste analysis started in the Netherlands in 1971. In 1981, the Luleå University of Technology in Sweden created a tool to analyse household waste generation and composition (Dahlén and Lagerkvist, 2008). Between 1990 and 2007, a multitude of waste analysis tools appeared in several countries and by international organisations such as the SWA-Tool by the European Commission in 2004. It seems that the most recent was developed in Great Britain in 2007. In spite of the different time periods of development and the different countries in which the tools were developed, many of these tools are linked and based on each other (Dahlén and Lagerkvist, 2008). Dahlén and Lagerkvist (2008) give a detailed overview of these tools including their sampling and components as well as the disadvantages and advantages of these methodologies. Generally speaking, all the tools have the same sequence from the preparation of a waste analysis, sampling, manual categorisation, to the assessment of data. Differences exist within the distribution of stratification, sample level, sample size and numbers as well as subdivision of the sorting catalogue. Finally, none of the waste analysis methodologies is internationally scientifically recognised, and different tools are available even in only one country (Dahlén and Lagerkvist, 2008).

Yu and Maclaren (1995) expanded the issue of waste analysis by comparing engineering (Direct Waste Analysis - DWA) and social approaches (questionnaires). The advantages of questionnaires are low costs in contrast to DWA. Similar results regarding waste quantity were obtained by DWA and questionnaire. Consequentely, the questionnaires could replace a waste amount analysis. Regarding waste composition, the results of DWA and questionnaires differ. Therefore, substitution by questionnaires is only recommended for analysing waste amount (Yu and Maclaren, 1995).

Within the framework of the development of a new set of guidelines for waste characterisation in Portugal, Martinho et al. (2008) compared internationally and nationally based tools of waste analysis. The *SWA-Tool* by the European Commission (EC), *EN 14899:2005* by CEN, *ASTMI D 5231 1992* by the American Society for Testing and Materials International (ASTMI), as well as *Remecon* by the French Environmental Agency and Energy Management (ADEME) are examples. The tools were compared regarding waste definition, sampling level, sample preparation, health and safety etc. Main differences are the time of development, definition of waste, sample level and waste categories. The first tool was developed by ASTMI in 1991, re-approved in 2003, and the last one by CEN in 2005. Regarding the definition of waste, solid and liquid waste are mentioned as well as residual solid waste from municipal solid waste, so the definitions of types of waste are different. The level of sampling also varies. A total of three types of sample collection are recommended: in households directly, from waste containers on the street, or from collection vehicles. The older tools recommend the analysis of waste in collection vehicles, the newer tools analysis of waste containers on the street. The numbers of waste fraction differ from methodology to methodology as well, but the main difference is the definition of fines (20mm or 10mm). Only the SWA-Tool by the EC (2004) and Remecon by ADEME (1998) include hazardous waste and complex products. It can be assumed that this is due to the fact of their growing significance in municipal waste. Martinho et al. (2008) also provides a detailed table of the six analysed tools. Based on this analysis, workshops and a case study, a new guideline was suggested mainly for Portugal which has a new definition of waste, sampling unit, and establishes statistical standards for the results (Martinho et al., 2008).

In addition to the international tools described by Martinho et al., (2008), another tool exists: *Work in harmonising sampling and analytical protocols related to municipal solid waste conversion to energy* by Scott (1995) for the International Energy Agency (IEA). This project was supported by Denmark, Norway, the Netherlands, Great Britain, and the USA. The aim was to find a standardised tool for sampling municipal waste where the results not only show the quality and quantity of waste, but also how to convert it into energy. As part of the development of this protocol the differences between the tools of each participating country were identified. Variations were recognised in the range of sampling unit (between 0.5 and 12 Mg), sampling preparation (coning and quartering), sorting (manual or mechanical or combined) and waste categories (between 9 and 18 primary categories and subdivision into secondary categories). One result of this project was that without a harmonisation within sampling and analytic protocols, an international exchange of information and comparison of data are not possible.

In view of the manuals for preparing a waste management plan by the selected intergovernmental organisations, only the manual by the OECD (2007) does not offer any approach for waste analysis. The manuals by the UNEP (2004 and 2009a-d), EC (2003) and The World Bank (Wilson et al., 2001) recommend analysis of waste through sorting procedures. All four manuals have the approach of weighing the waste and, based on these results, calculating the annual quality and quantity of waste. The World Bank (Wilson et al., 2001) and EC (2003) do not refer to any of the waste analysis tools shown in Appendix – Chapter 2, Table A2.1.-2. In contrast to the EC (2003) and The World Bank's (Wilson et al., 2001) rough approach, a waste analysis tool by CASCADIA Consulting Group (2003, 2004 and 2005) and Sky Valley Associates (2003) is offered in the version by the UNEP of 2009a.
An overview of all decision support tools regarding analysis of waste composition and amount is given in Appendix – Chapter 2, Table A2.1.-2. Tools for analysing amount and composition of solid household waste that were explicitly developed for Russia do not exist.

2.1.3. Tools for public participation in an integrated solid waste management concept

Public participation plays an important role within an integrated waste management concept. It can support its success as knowledge about problems with recent waste disposal systems is available and similar issues in the new system can be avoided (Raje et al., 2000). Hence, a participation of all stakeholders in the development of a waste management concept assists the analysis of waste generation, verification of problems, transparency and better acceptance, as well as the implementation of the new concept.

The guidance note by the EC (2003) describes several tools of public participation and refers to the "Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters" (Aarhus Convention). The "Aarhus Convention" of the United Nations Economic Commission for Europe (UN/ ECE) entered into force in 2001 and states that every person has the right to participate in decision-making processes, because of the right to live in an environment which guarantees health. Suggested stakeholders are representatives of local authorities, experts, operators of treatment facilities, local population/users, and Non-Governmental Organisations (NGOs). The minimum approach is to publish the draft version of the future waste management concept and to expect comments from the inhabitants. A second option is to create an "advisory committee" that represents all stakeholders and should also be subdivided into working groups for defined topics. Workshops can also be carried out in addition to the working groups and advisory committee in order to collect additional information, but they should be organised later in the development process (EC, 2003).
The UNEP's training manual (2009a-d) and the strategic planning concept by The World Bank (Wilson et al., 2001) have a similar approach to the recommendations made in the EC manual (2003). All stakeholders should be included in the process through discussions and consultations from the beginning of the planning procedure. The aim is to include the stakeholders on the one hand and to raise environmental awareness on the other.
In the manual by the OECD (2007), Recommendation 4 describes an information exchange between all stakeholders in order to guarantee an environmentally sound management of waste. Examples for such a forum with the main emphasis on the exchange of information

between public authorities, operators and industrial sector could be journals and Internet websites. An example of the participation of inhabitants is not given.

The World Bank (2004) also developed a "Toolkit. Social Assessment and Public Participation in Municipal Solid Waste Management" as part of the development process of a waste management concept, in addition to its manual for preparing a waste management concept. The toolkit is subdivided into four parts: Social assessment, willingness to pay, public participation in facility siting, and social programmes for waste collectors/ pickers.
"Social assessment" is described as continuous activities within the development process of a waste management concept. Five entry points are mentioned, of which the identification of stakeholders and participation are two. The stakeholders' social backgrounds have to be analysed in order to guarantee a complete list of all potential representatives. Examples are representatives on national and/or local level, user groups, waste workers, vulnerable groups etc. The next step is participation. Different tools are offered to include stakeholders in the planning process; for example, a semi-structured questionnaire. The questionnaire should acquire detailed information about the waste generators/inhabitants regarding their social and economic situation as well as knowledge and satisfaction about the current waste disposal system in the region/town. An example of a "household questionnaire" is given in Appendix 1 of The World Bank's toolkit.
The level of *"Willingness to pay"* can be determined with a survey via questionnaire as well. Guidelines for developing such a questionnaire and a calculation for the determination of number of interviews are given in this part of the manual.
In the third part of this manual, different tools regarding *"Public participation"* are explained for *"siting a waste management facility"*. The basic idea for introducing this step is to inform the inhabitants on the one hand and to collect significant information about them on the other. The fourth part makes recommendations for the implementation of *"Social programs for waste pickers"*. Different alternatives for improving the work of waste pickers are given; for example, offering infrastructure (clean water) and including their work in recycling strategies (The World Bank, 2004).

Kobus (Ed., 2003), an environmental consultant to The World Bank, also created a practical guidebook for preparing a waste management concept in co-operation with the Bertelsmann Foundation. Comprehensive advice on the implementation of public participation, for example the organisation of stakeholder meetings, is given. In addition, an example of a questionnaire survey is provided for collecting data from inhabitants on matters such as satisfaction level with the current waste disposal system. The main emphasis is on compiling data for the *status quo* report which is the basis for developing the strategy for the waste management concept.

Plümer and Multhaup (1995) used questionnaires to determine the attitudes of inhabitants towards recycling, landfill and incineration in the cities of Dortmund, Germany, and Hamm, Germany. Besides research of attitudes, the awareness of environment and social background were also polled. A detailed description of the implementation and the questionnaires are given. These questionnaires were implemented for the development of an integrated waste management concept.

Raje et al. (2000) widened this approach and developed criteria in order to identify the satisfaction level of the inhabitants with the current waste management system and the relevance of these criteria, which are stated as an index. A questionnaire was selected as the tool. The case study was carried out in Delhi, India. He proved that the index can be used as a measure for determining the satisfaction level in a town; a well-designed sampling plan is the precondition.

Sharholy et al. (2006) determined the quality and quantity of solid household waste in Allahabad, India. Besides waste analyses, a questionnaire was also implemented based on the model by Raje et al. (2000) and Buenrostro et al. (2001). Data regarding daily disposal, collection frequency and satisfaction about the waste disposal were collected. The results were used to support the creation of ArcGIS-maps which provide all information required for a waste management concept and will be used to improve the current situation in Allahabad (Sharholy et al., 2006).

Matete and Trois (2007) also used a questionnaire in order to identify opinions about waste prevention and recycling in two research areas in South Africa. Based on the analysis of recyclable fractions in household waste and the results of questionnaires, a waste minimisation strategy was suggested.

Dahlén and Lagerkvist (2009) describe that many researchers used questionnaires to determine the recycling behaviour of inhabitants/users: the results of questionnaires regarding their willingness to recycle differs from the real picture. The actual rate of recycling is always lower than the willingness to recycle. This point has to be taken into account when developing a recycling strategy.
In summary, questionnaires are used to improve the social aspect of an integrated solid waste management concept as well as to get additional data on the current situation and inhabitants' views on types of waste management such as recycling possibilities.

Questionnaires for the participation of inhabitants to support the development of integrated waste management concepts in Russia were not found in the expert literature.

2.1.4. Tools for waste prognosis

Prognosis of waste quality and quantity is one of the most important tasks in developing a waste management concept but also the most problematic issue. Prognoses are essential for the type of future waste disposal, for the size of waste treatment plants as well as for the decision of utilisation of waste such as recycling. Several factors influence waste amount and quality, but these factors which include population growth, employment, environmental awareness and policies are difficult to predict (Sircar et al., 2003). Additionally, if there are no historical data the process of prognosis will be even more complicated (Beigl et al., 2005). International uniform formulas do not exist (Karavezyris, 2006), but large numbers of tools are available to predict the amount of waste and were developed in different contexts such as economics, engineering and administration (Beigl et al, 2005). However, tools for predicting changes of waste compositions are barely developed.

Beigl et al. (2005) and Karavezyris (2000 and 2006) give a detailed overview of existing waste prognosis tools. Prognosis tools can be subdivided into a quantitative, qualitative or combined approach. The anticipated time scale for the prognosis is a condition for choosing the right tool; short-term, mid- and long-term variations exist.

Quantitative tools are usually used for short-term (1 year) and/or mid-term (1-5 years) estimations and are based on statistical or econometric methodologies. The level of accuracy of these tools varies from linear extrapolation to more complex systems such as *Fuzzy Logic*. Chen and Chang (1999) as well as Dyson and Chang (2005) demonstrate grey fuzzy dynamics modelling and system dynamics modelling. The objectives of both methodologies are to offer solutions for short-term waste generation forecasting if hardly any historical data exist.
In contrast to the quantitative tools, a precondition of qualitative tools is that there are expected links between the waste generation and defined factors. Long-term estimations are possible. The *"Delphi method"* includes expert interviews with 50-100 experts regarding a specified subject, while the *"historic analogies"* require a qualitative judgement that is based on knowledge about historic development of, e.g. a product life cycle. An example for a combined approach is the *"scenario technique"*; trends, mainly in positive or negative development of the economy, are estimated. The results of each scenario have to be evaluated by another tool (Beigl et al., 2005).

Karavezyris (2006) explained two formulas on a European level:
1. A formula by the European Environment Agency (EEA).
2. A formula included in a waste prognosis software tool which was developed within an EU project.

The EEA is using a formula which depends on economic activities and time that also includes historical data of waste amount and economic activities. Instead of the latter factor, the number of inhabitants or workers of a certain area can be used (for a detailed description of this calculation compare Karavezyris (2000)).
This waste prognosis software tool was developed within the project "The use of life cycle assessment tool for the development of integrated waste management strategies for cities and region with rapid growing economies (LCA-IWM)" in the 5th EU framework (Project Coordinator TU Darmstadt, 2005). The aim was to create a software programme for forecasting waste composition and quantity in regions with a rapidly growing economy as well as to identify key information which has an impact on waste generation. Besides the numbers of current population and waste amounts, it also takes into consideration the gross domestic product (GDP), infant mortality rate, and employment in agriculture and services (Karavezyris, 2006). A prognosis for the generation of solid household waste of a region for 10 years is possible (Beigl et al., 2005). Advantages of this programme are that it is user-friendly as local authorities should be able to use this programme easily. Only little information needs to be entered by the user. A number of default data of different European countries exist in this programme to support the forecast of waste generation and composition in cities of these countries. Although the main objective was not an international applicability of the software tool, it is possible to forecast the waste generation in other countries. Especially the waste generation and composition of European countries which were not included in the project can be forecasted. The exactness of the results depends on whether the predicted data such as population growth and GDP in future and set as default data prove to be true. These data were offered for example by The World Bank and the OECD (Beigl, 2006).

Furthermore, Karavezyris (2006) described that future treatment technologies and other unpredictable occurrences, for example changes in ordinances, have an impact on the waste prognosis. Scenario approach, expert interviews and calculation with uncertainty are examples of expanding the prognosis. The aim is to narrow the gaps in the waste prognosis.

In regard to the manuals by the aforementioned intergovernmental organisations, the EC (2003) guidance note refers to the French Environmental Agency and Energy Management (ADEME) which recommends a tool to predict future waste volumes that multiplies the figures of future population and waste amount. The condition is that there is knowledge about population growth and the annual increase of waste volume. ADEME recommends assuming a minimum rate (low hypothesis) and a maximum rate (high hypothesis) of annual rise of waste between 0.6% and 1%, and in regard to population increases, between 0.4% and 0.9% in EU countries (EC, 2003). The strategic planning guide recommended by The World Bank (Wilson et al., 2001) also describes the same formula, but it does not give any guidelines about the possible increase of waste and/or population; the user of the strategic planning guide has to research these figures himself (Wilson et al., 2001). This kind of calculation used by EC/ADEME and The World Bank is the most common tool to estimate future waste amount (Karavezyris, 2006). Both manuals by the UNEP (2004 and 2009d) recommend a scenario-building approach although without a detailed description. The OECD manual does not offer any information about waste forecasting (OECD, 2007).

In summary, all these tools described are mainly to forecast waste amounts, but they are not internationally recognised. Furthermore, globally uniform tools for the estimation of future waste composition do not exist (Karavezyris, 2008, pers. comm.). No specialised tools for Russia were found in the literature.

2.1.5. Tools for Life Cycle Assessment of waste treatment

Integrated waste management concepts should achieve reduced environmental pollution and protect human health. Therefore, an assessment during the development of the concept in regard to future impacts is necessary. Several methodologies such as *Environmental Risk Assessment* (ERA), *Environmental Impact Assessment* (EIA) and *Life Cycle Assessment* (LCA) have been developed in order to evaluate ecological consequences. Only the latter includes the evaluation of a whole system, whereas ERA and EIA place their main emphasis on a single process or facility such as incineration (Hauschild and Barlaz, 2007). LCA follows the holistic approach, i.e. it was developed in order to evaluate the environmental impacts of products or processes throughout their entire life: from the beginning as raw material through production and use to disposal. It appeared in the early 1970s in the USA with the main emphasis on packaging and disposal. In 1973, the first oil crisis pushed the further development of LCA because the public dialogue started about wasteful lifestyle which was connected with the use of oil (Baumann and Tillmann, 2004). In the 1980s, the public interest in environmental impacts of products as well as the life-cycle awareness of products and processes grew (Hauschild and Barlaz, 2007). In 1997, the International Organization for Standardization (ISO) published the first standardised tool of LCA (Baumann and Tillmann, 2004), which is formulated in the "ISO 14 000 series". The implementation of LCA is written down in the "ISO 14 040:2006 series-Environmental Management-LCA-Principles and framework". Besides ISO, the Society of Environmental Toxicology and Chemistry (SETAC) and UNEP/ Department of Technology, Industry and Economics are international organisations supporting the use of LCA. "Code of Practice" for LCA developed by SETAC represents the forerunner of ISO's standardisation. UNEP's main emphasis is to promote the application of LCA, especially in developing countries (Guinée (Ed.), 2002).

"ISO 14044:2006 - Environmental Management - Life cycle assessment - Requirements and guidelines" is subdivided into four parts:

1. The goal and scope definition phase: The objectives and use of expected results as well as the main characteristic of the research are determined. This also includes the reason for the study and the target group.
2. The inventory analysis phase (LCI): The materials and energy flow are described regarding the object of the assessment. The result is an inventory list.
3. The impact assessment phase (LCIA): Supporting the inventory list and their results, the environmental impacts are estimated. Impact categories have to be defined.
4. The interpretation phase: This phase includes the evaluation of results and the formulation of recommendations. Sensitivity analyses can help in evaluating the robustness of results of the LCA (Guinée (Ed.), 2002).

Apart from the original objective of LCA -to assess the entire life of a product regarding its environmental impacts- it serves a further function (Guinée (Ed.), 2002); namely, outcomes of LCA can identify and select alternatives that are environmentally sound (OECD, 2008b). Therefore, its implementation has assumed an important role in assessing different waste management possibilities. The aim is to support the development of sustainable waste management concepts and prevent further detrimental environmental effects as well as to provide information about ecological consequences for decision makers (Thomas, 2009).

LCA is mostly implemented via software programmes as due to its holistic approach, it requires a large volume of data for the evaluation of possible environmental impacts.
In addition, the software programme can aid to develop scenarios, to subdivide the entire process into different parts and hence, to present the results of the individual parts or the whole procedure. The main reasons for using a software tool are the possibility to compare the different options and, subsequently, the option to decide for the best alternative. The research field of LCA software is very well developed; innumerable programmes exist but not all are useable for the assessment of waste management concepts (Unger et al., 2008). The *International Expert Group on Life Cycle Assessment for Integrated Waste Management* listed several software tools: ARES, IWM (2), ORWARE, DST, UMBERTO, WISARD, EASTEWASTE, LCA-IWM and WRATE (Thomas, 2009). UMBERTO was not specially developed as a waste management assessment tool but can also be used for evaluating waste management concepts (Winkler, 2004).

Winkler (2004) described and analysed the differences between ARES, EPIC/CSR, IWM (2), ORWARE, DST, and UMBERTO in depth. He tested the tools regarding inventory analysis, the results of impact assessment as well as user-friendliness. He used one case study in order to compare these different software tools and found that the results of all these LCA software tools differ from one another. Reasons for this problem can be the multi-layered development of a waste management concept. In contrast to the linear approach of the LCA software, the complexity of the reality can not be reflected. All programmes have their advantages and disadvantages, and the choice of the right software programme depends on the aim and scope of the research. However, it is important to continue the research of LCA software programmes and instead of a continuous development of the existing models, Winkler (2004) suggested developing a best-practice model by using all experiences of all models.

Hansen et al. (2006) also compared IWM (2), ORWARE, DST, UMBERTO and EASTEWASTE in regard to the assessment of organic waste treatment. Although there are also differences in the results, these tools are usable for the assessment of waste concepts.

Additionally, Emery et al. (2006) demonstrated the use of WISARD in a case study of municipal solid waste management in Wales. The conclusion was that the use of WISARD shows that an integrated approach to a waste management concept leads to less environmental impact, and the software programme assists the development of environmentally sound waste management. He also explained that LCA should not be used as a substitute for a decision; it can only support a decision regarding waste management concepts (Emery et al., 2006).

Schubert (2006) used the software tool UMBERTO as the basis and entered different modules for the impact assessment phase for the different impact categories. He also used these different modules for sensitivity analysis. For example, photo-oxidant formation was tested with the modules by Heijungs et al. (1992), Anderson-Sköld et al. and Derwent et al. (in: Guinée (Ed.), 2002) as well as Stern (in: Ifeu-Institute, 2002). He demonstrated that sensitivity analyses led to results about impacts with the categories global warming, acidification and eutrophication. In contrast to these results, the sensitivity analyses for human and eco-toxicity as well as photo-oxidant formation came to very different results, and an impact on the environment could not be proven. Preconditions of sensitivity analyses are higher expenditure of work and demands on the user of LCA software tools. Finally, an entire assessment of impacts through a LCA software tool should not be expected; the main emphasis should be to discover weaknesses of the waste management (Schubert, 2006).

Finally, Erikson et al. (2002) also described ORWARE in detail and demonstrated that LCA models differ from one another depending on the data entered as well as the results of simulations, referring to LCA models from Sweden, the United Kingdom and the United States of America. Regional conditions are always included in the default data of each model, and therefore an assessment outside of this region can not be easily implemented (Erikson, 2002).

In addition to the LCA software programmes described above, a further programme exists. The *LCA-IWM Assessment tool* was developed as a part of the project “The use of life cycle assessment tool for the development of integrated waste management strategies for cities and regions with rapid growing economies (LCA-IWM)” within the 5th EU framework (TU-Darmstadt, 2005). It not only validates the crucial environmental assessment of new waste management treatments, it also includes a social and economic evaluation. The aim is to support decision-makers regarding the development of waste management concepts in regions with fast economic growth. Default data for different countries, such as Ukraine, Poland, Germany, etc. are available in this programme and differ in this respect from the other LCA models which usually offer a data set of one country only.

In conclusion, all default data in the software programmes for LCA have a close link to the region where the programmes were developed, usually to North America or Western Europe, and they are mainly developed in and for industrial countries (Winkler, 2008, pers. comm.). Only LCA-IWM offers default data from different countries, including countries with changing economies such as Lithuania or Ukraine.

Table 2-3: List of relevant LCA software tools for assessment of waste management systems according to IEGLCA (Thomas, 2009, pers. comm.)

Level of organisation (number of tools)	**Name of LCA software tool**	**Institutions**
Intergovernmental organisation		
EU (1)	LCA-IWM	Project Coordinator TU-Darmstadt, Germany
National Organisation		
Germany (2)	ARES	WAR Institute, Technical University of Darmstadt, Germany
	UMBERTO	ifeu - Institute for Energy and Environmental Research Heidelberg GmbH, Germany
United Kingdom (2)	IWM (2)	Procter & Gamble, Oxford, United Kingdom
	WRATE	UK Environment Agency, Bristol, United Kingdom
Sweden (1)	ORWARE	Swedish Royal Institute of Technology, Stockholm, Sweden
France (1)	WISARD	Ecobilan – PricewaterhouseCoopers, Neuilly Sur Seine, France
Denmark (1)	EASTEWASTE	Technical University of Denmark (DTU), Copenhagen, Denmark
USA (1)	DST	North Carolina State University and Research Triangle Institute, Raleigh, NC, U.S.A.

During the research and since Winkler (2004), Cherubini et al. (2008), Schubert (2006) tested and compared different LCA software tools and the results of their LCA software tools always support the waste hierarchy, the following questions appeared: Is an LCA appropriate to assess environmental impacts if the only result is a confirmation of the waste hierarchy? What is the validity of LCA software tools if it seems that all LCA software tools produce the same result?

The advantages are that an LCA software tool is scientifically supported and includes databases which are scientifically determined. In the event that proposed scenarios are similar or different opinions are held by the steering committee, results of LCA software tools can support a decision. Another reason for using an LCA software tool is when new technology of waste treatment plants is introduced and is to be included in the waste management concept. A simple comparison with the former technology for waste treatment is possible (Björklung, 2009, pers. comm.). Another advantage is the flexibility of the LCA software tool. LCA software tools can assess the entire strategy of a waste management concept or only parts such as collection or treatment of integrated waste management concepts. Therefore, waste management concepts can be combined with the best alternative of each part of waste management concepts by testing the different alternatives of each part of a waste management concept via LCA software tool (Hauschild and Barlaz, 2007).

Winkler (2004), Cherubuni et al. (2008), Schubert (2006) and Emery et al. (2006) described in detail the advantages and disadvantages of different LCA software tools. They agreed on one point: further research is necessary and LCA can not provide a complete assessment of a waste management concept as the reality is so complex. However, LCA can support - not make - the decision for an environmentally sound waste management concept.

Again, only the manual by the OECD (2007) refers to ISO 14001 (including LCA) and UNEP's (2004) first version to LCA for assessing the environmental impacts of a newly created waste management concept. EC (2003) guidance note refers to EIA required by the legislation of the EU. Neither UNEP (2009a-d) new version nor guideline which is recommended by The World Bank (Wilson et al., 2001) explains a tool for the assessment of environmental management systems.
In the scientific literature, specialised LCA software programmes for Russia were not found.

2.2. European legislation regarding waste management

The Framework Directive on Waste ***Directive 2008/98/EC*** is the key directive of European legislation regarding waste management. It also describes the European waste hierarchy with its five principles. The waste hierarchy of the EU has become a cornerstone of sustainable waste management as well serving as a useful framework for European countries. This hierarchy classifies waste management strategies according to their desirability, defines the order of waste treatments based on their environmental impacts, and how they should be considered in waste management.
Besides the EC manual (2003) for preparing waste management concepts, the manuals by the OECD (2007) and UNEP's first version (2004) also refer to this European legislation and hierarchy regarding waste management and disposal.

The principles in order of favourite to least favourite option are:
1. Prevention includes instruments/methods which have to be considered before materials or products have become waste.
2. Preparing for re-use includes operations to prepare waste such that it " […] can be re-used without any other pre-procressing" (Directive 2008/98/EC, p.10). Waste can be products or product materials.
3. Recycling includes any recovery operations except energy recovery. Waste is reprocessed into materials or products, whether for the original or other purposes.
4. Other recovery includes any other recovery operations such as energy recovery. The main aim is to replace other material or products with the prepared waste.
5. Disposal includes any operation without recovery such as deposition of waste on landfills (Directive 2008/98/EC).

Further Daughter Directives of the Framework Directive also play an important role for preparing waste management concepts, for example ***Directive 94/62/EC on packaging and packaging waste*** which includes a recycling quota, and ***Directive 99/31/EC on landfill of waste*** which states that only inert waste can be disposed of on landfills (Kobus, 2003).

The Russian Federation and KMAO will be described briefly in the next chapters in order to provide historical, social, economic and ecological data.

2.3. The Russian Federation

The Russian Federation was founded in December 1991 after the collapse of the Soviet Union. It is the biggest country in the world, covering an area of 17.1 million km^2. It has a population of 142.2 million and its capital is Moscow. In a global comparison, Russia is first as concerns territory, natural gas deposits, wooded areas, iron ore deposits, and supply in surface water; in second place in regard to nature reserves as well as deposits of oil, coal, nickel and potash salts, and in third place in terms of its agricultural area (Brade et al., 2004). Russia has been the top oil-producing country worldwide since 1998 (Starobin, 2008).

Since 2004, two departments have existed to regulate environmental affairs: the Ministry of Natural Resources and Federal Service for Environmental, Technological and Nuclear Supervision. Waste management and disposal is a task of the latter (OECD, 2006). Between 1991 and 2000, the most important laws in regard to environmental matters were developed. Examples are the "Law on industrial and municipal waste" in 1998 (OECD, 2006) and the "Law on the Protection of the Environment" in 2001 (Oda, 2007). Russia also signed several international conventions and protocols regarding environmental protection. There are three key ratifications:

- Kyoto Protocol to the UN Convention on Climate Change, ratified in 2004 (Thus, the Protocol came into effect.) (UNEP, 2008)
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, ratified in 1995 (SBC, 2008)
- Convention on Biological Diversity, ratified in 1995 (SCBD, 2008).

The environmental situation is precarious in Russia; many problems have emerged recently such as pollution of rivers and the countryside, in part due to wrongful waste disposal as well as high air pollution in cities (Gumpel, 2006). Environmental pollution is the leading cause of death and illnesses in Russia (Gumpel, 2004). One key problem is the disposal of (hazardous) waste. Gas and oil pipelines are often leaky and contaminate the environment, and there is hardly any control of the construction of pipelines (Gumpel, 2006). In addition, more than 3-4 billion Mg of waste arise per year (Ulanova, 2007), including 36 million Mg domestic waste (BfAi, 2007), and the usual waste treatment plants can not cope with these amounts (Ulanova, 2007). For example, 11 incineration plants exist in Russia but their capacity is insufficient, and 80 million Mg domestic waste have accumulated for incineration only (GUA, 2005). 20,000 km^2 of land are covered by waste, and a further 6,000 km^2 of land by sludge from industrial production (Ulanova, 2007).

Outdated and insufficient technologies and infrastructures as well as a rapidly growing number of motor vehicles increase the amount of untreated wastewater, air pollution, generating even more industrial and municipal waste and intensifying the ecological issues (OECD, 2006).

In fact, Russia is in "a state of environmental crisis" (Oda, 2007). Lacking political awareness of environmental issues as well as an absence or deficit of legislation and measures for environmental protection support shadow economy and economic losses (OECD, 2006). The will, knowledge and culture to protect the environment are extremely underdeveloped (Oda, 2007).

2.4. The research area - Khanty-Mansiysk Autonomous Okrug - Ugra

The research area Khanty-Mansiysk Autonomous Okrug - Ugra (KMAO)[2] is located in Western Siberia in the Russian Federation (see Figure 2-1).

Figure 2-1: Location of Region Ugra (Administration of KMAO, 2008)

The capital of the Okrug is Khanty-Mansiysk and is located where the rivers Ob and Irtysh flow into each other. Samarovo, the original town, was founded in 1637 and is a part of Khanty-Mansiysk today. At the end of the 19th century and the beginning of the 20th century, the Ob-Irtysh North's economy and life were characterised by natural conditions such as severe climate and a low population (Administration KMAO, 2005). It had an estimated population of a mere 800 (Levko, 1995). Because of the climatic conditions, the main industry was a simple fish canning factory and cattle breeding.

Due to a Russian Decree, the Ostyako-Vogulsky National Okrug was founded in 1930. In 1940, it was renamed to Khanty-Mansiysk National Okrug. In 1977, during the constitution of the Soviet Union, it was developed into Khanty-Mansiysk Autonomous Okrug and received the status of an autonomous region. In 1993, the Autonomous Okrug joined the Russian Federation as an equal member and was re-named Khanty-Mansiysk Autonomous Okrug - Ugra in 2003 (Administration KMAO, 2008). KMAO is one of the 10 autonomous Russian districts and is part of the federal district Ural (Brade et al., 2004). The key law is "The Charter of Khanty-Mansiysk Autonomous Okrug - Yuga", and it has its foundations in the Constitution of the Russian Federation as well as the Federal Legislation (Administration KMAO, 2008).

The Okrug Ugra has a north-south length of 900 km and a west-east length of 1,400 km. The size of the area is 534,800 km^2, which is one and a half times larger than Germany (357,021 km^2). The population of the autonomous region Ugra was approximately 1.4 million in January 2006, and 80% of the population live in the region's 16 cities. The capital and the

[2] There are several synonyms: Ugra, KMAO, Ugra region, Okrug Ugra

administrative centre is Khanty-Mansiysk (Administration of KMAO, 2005). The population of Khanty-Mansiysk was estimated at 70,000 in January 2007 (Tomsha, 2007, pers. comm.).

The climate is almost continental with an average temperature between -18℃ and -24℃ in January and 15.7℃ and 18.4℃ in July. Spring and autumn can be as short as only one day. Temperatures below zero degrees Celsius and snowfall are recorded for seven months per year, from October to April. 50-80cm's snowfall can occur in the winter period. The average rainfall rate is 400-500mm per year in the Ugra Region. 15% of this annual average alone can be recorded in July (Administration KMAO, 2008).

Plains, hills and lakes characterise the landscape in Ugra. There are more than 290,000 lakes with a size over one hectare and the river system of Ob and Irtysh. The territory is covered by approximately 40% forest, 35% swamp lands, 20% peak lands with forest, and 4% river meadow. Towns and villages account for only 1% of land area (Lapshina, 2008, pers. comm.). Therefore, the region is not suitable for agriculture and agricultural products have to be imported from other parts of Russia (Administration KMAO, 2008).

Ugra is the leading oil production region in Russia. Oil and gas were already found in the Ugra Region in 1934. In 1951, oil was drilled, but industrial exploitation only began in 1964. One million Mg per day were pumped in the 1980s. As a result of the development of the oil industry, the population started growing, new cities were founded, and infrastructure developed, including the construction of roads and pipelines. In the 1990s, market reforms caused a decrease of oil extraction volumes until 1996 (Administration of KMAO, 2005). Today, oil production is constant and an important factor of the Russian oil industry, and the Autonomous Okrug is one of the most important producers of oil and gas as well as of electric power generation in Russia (Administration KMAO, 2008).

The economy of Ugra in 2007 consisted of:

- industrial production (including oil and gas production): 92%
- electric power industry: 5%
- machinery and metal-working: 2%
- logging and woodworking industry: 0.4%,
- production of building materials: 0.4%
- food industry: 0.2% (Administration KMAO, 2008).

Along with the recent growth of the economy, average income has also increased from 20,053 roubles per month (approximately 542€[3]) in 2004 to 26,900 roubles per month (approximately 727€) in 2006 (Administration of KMAO, 2008). In comparison, the average income in Russia was 6,832 roubles per month (approximately 185€) in 2004 (Administration of KMAO, 2005). The unemployment rate is under 2%. The population is also growing. The population increased by 4% between 2001 and 2006. 123 nationalities live in the Ugra region, but only 1.5% are native Khanty, Mansi and forest Nenets (Administration of KMAO, 2008).

As a result of the second boom of gas and oil extractions as well as rapid population and economic growth, new environmental problems have arisen in Western Siberia as well as in

[3] exchange rate: 1€ = 35roubels, Date: December 2008

the whole of Russia. Outdated and broken pipelines cause environmental disaster; between 2% and 20% of the oil gets lost on the way to refineries. More than 29 larger rivers and more than 120 smaller lakes are extremely polluted. 8,000km^2 of Khanty-Mansiysk land is also damaged and can no longer be used for grazing. Furthermore, oil piping technologies use a high amount of water to increase the pressure in the pipelines. This results in water shortages and water pollution. Additionally, oil production accessory gas burns freely day and night. Those torches that pollute the air are even visible from space (gfbv, 2006). Almost 3,000 accidents involving oil pipelines are recorded in Khanty-Mansiysk Autonomous Okrug every year. 6,000km pipelines would have to be repaired each year in order to avoid these accidents, but in fact, only 1,500 to 2,000km pipelines are repaired per year. There is also environmental damage done because of the construction of roads which are needed to supply equipment to the oil platforms (Gumpel, 2006).

Last but not least, waste disposal is a further problem. Many cities do not have an organised sewage and waste disposal structure. Untreated sewage is discharged into rivers, waste is burned uncontrolled and causes air pollution (Schuldt, 2008, pers. comm.) or is disposed of at indiscriminate dumps. According to local authorities, 36 officially sanctioned landfills have been constructed to receive a quantity of 140kg c^{-1} a^{-1} of municipal waste in towns. In fact, an increase of the amount of waste from 250 to 350kg c^{-1} a^{-1} was calculated in Khanty-Mansiysk in 2004 (Kiseleva, 2005, pers. comm.), and approximately 430kg c^{-1} a^{-1} of waste was already recorded in Khanty-Mansiysk in 2006 (Tomsha, 2007, pers. comm.). Additionally, cities in KMAO are recording high rates of population growth, but the current disposal systems were not designed for the current amounts of waste or sewage.

3. Methodology

3.1. Terminology and scope of the dissertation

Solid household waste/domestic waste is the only type of waste analysed within the dissertation. It is defined as waste generated from only private households (EEA, 2008).
Only household waste in towns was selected as the waste origin because:

- It is the biggest problem due to the extreme migration wave to towns in the Ugra region, especially to Khanty-Mansiysk and Surgut, experienced at the moment;
- The aim was to achieve statistical accuracy of the results of the waste analysis as recommended in the SWA-Tool: The selected tool for waste analysis "Methodology for the Analysis of Solid Waste (SWA-Tool)" by the European Commission (EC, 2004) offers the sorting procedure for <u>residual solid household waste</u> or <u>mixture household and commercial waste</u> or <u>commercial waste</u>. An analysis of mixture of household and commercial waste or only commercial waste requires a higher number of sampling units than of the analysis of only household waste in order to reach statistical accuracy. As also described in the *Preface*, the implementation of the waste analysis was not financed. Therefore, statistical accuracy needs to be reached with fewer analysed units.

Khanty-Mansiysk and Surgut are the pilot study areas because they are the most rapidly growing towns in the Ugra region, and it was assumed that most of the region's solid household waste is generated there.

All results determined within the dissertation, i.e. of the waste analysis, waste prognosis etc. are mainly discussed in terms of their environmental impacts. Nevertheless, social impacts and economic conditions also play an important role in the development of an integrated waste management concept. However, to consider all these aspects would go beyond the scope of this dissertation.

3.2. Preparation of an integrated waste management concept

In the literature review, no specific tools for developing a waste management concept in Russia were identified. The approach of this dissertation is to use decision support tools which were developed within EU framework projects or recommended by the EU, and these tools were tested as to whether they are applicable for Siberian regions (compare Introduction).
"Preparing a Waste Management Plan. A methodological guidance note", which was developed by the European Topic Centre and Material Flows in May 2003 (EC, 2003), is the basis for the development of integrated waste management concepts. However, as the guideline does not suggest tools to use for the implementation for each work step such as waste analysis, forecasting, public participation and environmental assessment, it was necessary to research those and decide which tool would be most suitable to apply. An overview is given in Table 3-1.

Waste analysis

The literature study showed that there are two tools for waste analysis of waste amount and composition at the EU intergovernmental level:

1. REMECOM-European Measurement for Characterisation of Domestic Waste (ADEME, 1998) and

2. The Methodology for the Analysis of Solid Waste (SWA-Tool) (EC, 2004).
REMECON (ADEME, 1998) and SWA-Tool (EC, 2004) deal with similar content such as sorting of samples. In addition to REMECON, the newer SWA-Tool describes a unite type of sample-taking, sorting of samples and stratification (Zwisele, 2006). Because SWA-Tool (EC, 2004) is more current and more comprehensive it was used to analyse waste amount and composition. Data of waste amount and composition are among the essential factors for developing a waste management concept.

Participation
Based on the literature study, questionnaires are a common tool for public participation. However, questionnaires as a tool for public participation in the development of a waste management concept were neither offered by the EU nor developed within an EU project. The intergovernmental organisations, UNEP (2004 and 2009) and OECD (2007), do not offer tools or questionnaires for public participation within their manuals for the development of integrated waste management concepts either (see Chapter 1). Only The World Bank (2004) worked out an extra "Toolkit. Social Assessment and Public Participation in Municipal Solid Waste Management". Prepared questionnaires are the key recommendations in the toolkit for public participation. Therefore, I selected questionnaires created by The World Bank.

Waste prognosis
As demonstrated in the literature study, within the EU there are three main tools to predict the amount of waste:
1. The European Environment Agency uses a formula which requires historical data (Karavezyris, 2006).
2. The guidance note by the EC (2003) recommends a formula based on number of inhabitants and waste occurrence.
3. A formula within a prognosis software tool was developed within the EU 5th framework project "The Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies (LCA-IWM)". The formula requires various information, including gross domestic products (GDP) and infant mortality rate (Project Coordinator TU Darmstadt, 2005).

Because of lacks of historical data in the Siberian region, the first calculation could not be used. Only the two last tools could be used for the prognosis of the amount of waste and the composition thereof.

Karavezyris (2006) also recommended expert interviews to narrow the gap in differences within the forecasting of solid household waste generation. Russian experts for waste management were interviewed in order to compare their prognoses with the results of using the formula and software tool.

Environmental Assessment
Within the EU 5th framework the project "The Use of Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies (LCA-IWM)" developed an LCA software programme (Project Coordinator TU Darmstadt, 2005). As this is the only LCA software whose programme was created within the course of EU projects it was used for assessing environmental impacts of waste treatment scenarios in Khanty-Mansiysk and Surgut.

Literature studies, Internet research and interviews with local authorities were also carried out in each work step in order to gather the required information.

Table 3-1: Work steps for a waste management concept and main tools of their implementation

Work step	Content/ Aim	Tool
Waste analysis/ Data acquisition	▪ Scope of investigation ▪ Information on the region ▪ Documentation of the current waste disposal system ▪ Waste analysis	▪ SWA-Tool by European Commission/ SWA-Tool Consortium, 5th framework of the EU (EC, 2004) ▪ Literature studies ▪ Interviews with local authorities
Public Participation	▪ User participation	▪ Empirical survey/ questionnaires as recommended by The World Bank (2004)
Waste Prognosis	▪ Waste Prognosis	▪ LCA-IWM, Prognosis Tool, Project Coordinator TU Darmstadt, 5th framework of the EU (Project Coordinator TU Darmstadt, 2005) ▪ Recommendation of guidance note by the EC (2003) ▪ Interviews with experts
Environmental Assessment	▪ Development of scenarios ▪ Decision of treatment facilities	▪ LCA-IWM, Assessment Tool, Project Coordinator TU Darmstadt, 5th framework of the EU (Project Coordinator TU Darmstadt, 2005)

3.3. Analysis of solid household waste

The selected waste analysis follows the model of the "Methodology for the Analysis of Solid Waste (SWA-Tool)" by the European Commission (EC, 2004) as described above. A "user version" and a "long version" of this tool exist. The "long version" was used because the implementation of a waste analysis is described more thoroughly.
In compliance with this tool, it is necessary to take random but also representative samples of waste, as it is not possible to analyse the whole determined research area such as a town. Random samples allow the estimation of the entire quality and quantity of waste of a research area. It is required to define criteria in order to get representative random samples. This tool describes several decisive factors for a standard waste analysis:

- background information
- type of waste sampling
- stratification
- level of sampling
- type of sampling units and their size
- generation of random sampling plan
- duration of a waste analysis and
- sorting catalogue.

In order to be able to compare the results in Khanty-Mansiysk and Surgut both analyses were carried out in a similar way. Therefore, the type of sampling waste, the level of sampling, the sampling units and their size, as well as the sorting catalogue are the same. However, there are differences between Surgut and Khanty-Mansiysk, regarding stratification, generation of sampling plan and duration of waste analyses, which owe to the different conditions in the towns. Eight waste analyses were carried out in Khanty-Mansiysk between May 2006 and August 2008, and four analyses were implemented in Surgut between August 2006 and June 2007. All results presented refer to this research time period.

Background information

Investigation of the survey area and identification of factors that may have an impact on waste amount and composition are the crucial information required for the status report. All these data were mainly collected by interviewing the local authorities, through literature research as well as with the help of a questionnaire which will be described later. The description of the background information follows the recommended description in the case studies (see Chapter 4.1.1). These case studies are given in addition to the explanation of implementation of waste analysis in the SWA-Tool (EC, 2004).

Type of waste sampling and stratification

The recommended *stratified random sampling method with defined stratification criteria* was used as the type of sampling. This analysis tool achieves a higher accuracy with fewer sample units. According to the suggested stratification criteria*, waste origin, residential structure, and seasonality* were selected.

As waste origin solid household waste was chosen as the biggest problems regarding waste in both cities are caused by the extreme population growth (see Chapter 3.1).

Within the factor *residential structure* two main structures exist in ***Khanty-Mansiysk***: "apartment block settlements" (> 2 floors) and "small houses with gardens" (1 floor) (see

Appendix – Chapter 3, Photographic documentation). The main emphasis is on the difference between these residential structures in regard to amount and composition of waste, especially the amount of organic waste. One assumption was that people with gardens compost their organic waste and that they would therefore produce less waste (see Appendix – Chapter 3, Map I for investigation area).

Since May 2006 waste analyses have been conducted *seasonally* in spring, summer, autumn and winter. The analysis needed to take certain weather conditions into account. Seasonal analyses are important as it can be assumed that people change their living behaviours at different times of the year depending on the season and weather. Furthermore, the heating period plays an important role because ash can have an impact on the results of the waste analysis. For this reason, temperature was also an important condition and determined when the waste analyses were carried out.

In ***Khanty-Mansiysk***, the seasonal analyses were subdivided into four analyses of the residential structure "apartment blocks" and four analyses of the residential structure "small houses with gardens" between Spring 2006 until Summer 2008. As opposed to Khanty-Mansiysk, in ***Surgut*** all analyses were conducted from Summer 2006 till Spring 2007 (see Appendix – Chapter 3, Table A3.3.-1 and Table A3.3.-2).

According to the SWA-Tool, a matrix is recommended within the distribution of inhabitants to the residential structure. It also shows the ratio and therefore the importance of the single stratum. Calculation of such a matrix for Khanty-Mansiysk poses a big problem due to the fast growing population. In January 2006, at the start of the preparation of the waste analysis, the population was approximately 59,600 (Tomsha, 2007, pers. comm.). In August 2008, at the end of the enquiry, that figure was estimated at 79,400 (Ivanovich, 2008a, pers. comm.). That means while the waste analyses were carried out, the number of inhabitants could have risen by 19,800. Registration is not mandatory and thus the numbers of inhabitants are only an estimation by the local authorities. For these reasons, fast-growing population and the non-existence of exact numbers of inhabitants, it was necessary to use a mean: 70,000 inhabitants.

Fact is, there are 3,675 *small houses with gardens* in Khanty-Mansiysk (Tomsha, 2008, pers. comm.); the number of persons per household in this residential structure is unknown. As a result of the questionnaires, approximately four persons per household live in the residential structure "small houses with gardens" (see Chapter 4.2.1). That means approximately 15,000 inhabitants live in small houses with gardens.

The number of inhabitants per households for *apartment blocks* as well as the average number of households for apartment blocks are unknown (Kaz'mina, 2008, pers. comm.). Based on the assumptions of 70,000 inhabitants in total for Khanty-Mansiysk and 15,000 inhabitants for the residential structure "small houses with gardens", 55,000 inhabitants for the residential structure "apartment blocks" were estimated. Approximately three persons per household produced an average of 18,350 households for apartment blocks in Khanty-Mansiysk as an average of three persons per household in apartment blocks was the result of questionnaires which were carried out in Khanty-Mansiysk (see Chapter 4.2.1).

15,000 inhabitants for small houses which also represent the smaller proportion in the residential structures, and 55,000 inhabitants for apartment blocks; that is, 70,000 inhabitants in total, provide the basis for all results of the waste analyses (see Table 3-2).

Table 3-2: Distribution of residential structure in Khanty-Mansiysk (Tomsha, 2007, pers. comm.)

Residential structure	Number of households	Number of inhabitants	Proportion of residential structure
Small houses with gardens (1 floor)	**3,675**	15,000*	21 %
Apartment blocks (> 2 floors)	18,350*	55,000*	79 %
Total	22,025*	70,000*	100 %

Note: (*) means estimations based on results of questionnaires and interviews with local authorities.

In agreement with the Ugra State University as well as “MDEP” and “Schistie Dom”, the supporting waste disposal companies in Khanty-Mansiysk, representative areas were chosen. These areas match the criteria of the apartment block settlements and small houses, and the cooperating waste disposal companies operate here.

In ***Surgut***, I mainly focussed on apartment block settlements (> 2 floors) because it is the biggest proportion in the residential structure (see Appendix – Chapter 3, Photographic documentation and see Appendix - Chapter 3, Map II for investigation area). In contrast to Khanty-Mansiysk, figures on number of inhabitants, households and buildings were available (see Table 3-3).

Table 3-3: Distribution of residential structure in Surgut (Kiseleva, 2008, pers. comm.)

Types of residential structure	Number of buildings	Number of households	Number of inhabitants	Proportion of residential structure
Small houses with gardens (1 floor)	441	441	1,192	0.4%
Apartment blocks (> 2 floors)	1,489	108,140	289,927	99.6%
Total	**1,930**	**108,581**	**291,119**	**100%**

Together with one waste disposal company, two areas for apartment blocks and one area for small houses were chosen (see Appendix - Chapter 3, Photographic documentation).

Level of sampling and type of sampling unit

The external waste containers (see Appendix – Chapter 3, Photographic documentation) in front of the apartment blocks and small houses were the chosen sampling level, as they represent the suggested level in the methodology. This level has a minimum of disadvantages compared to taking samples from a waste collection vehicle or internal waste bins which can increase the statistical sampling errors.
As sampling unit (u), the bin volume was taken in both Khanty-Mansiysk and Surgut. Two containers with a volume of 0.5m^3 each equal 1 unit of 1m^3.

However, during the winter analysis for apartment blocks one unit is only 0.5m^3 in ***Khanty-Mansiysk*** in January 2007. The analyses were carried out *in situ,* and therefore there was no protection from the weather. The temperatures ranged between -25°C and -30°C, making it impossible to work outside for very long. Thus it was necessary to reduce the size of a unit

from 1m^3 to 0.5m^3. The temperature while carrying out the waste analysis for small houses was higher in December 2008, so 1m^3 could be collected again.
In conclusion, two units for apartment blocks (four containers) and one unit (two containers) for small houses were usually analysed in order to reflect the distribution of residential structure.
In ***Surgut***, spring is an exception; one unit is only 0.5m^3 because there was less help for implementing this waste analysis.
Therefore, both these analyses do not achieve statistical accuracy as the recommendation is that 1 unit is 1m^3.

Calculation of sampling size
There are two key criteria to determine the sampling size:

1. The *heterogeneity or variation* of waste is to be determined by pre-investigation of the waste and stated as the *natural variation coefficient*.
2. The value of *relative accuracy* also plays a key role. The SWA-Tool allows a scope between 10% and 30% of maximum allowance for random sampling errors for the total results. The recommendation is 10% of random sampling error based on a 95% confidence level and under the assumption that the natural variation coefficient for household waste is about 30%.

The number of necessary samples, also called (sampling) units, can be calculated as follows (EC, 2004):

$$n = \left(\frac{t_{\alpha;n-1} \cdot \mathrm{var}\,coeff\,(x_i)}{\varepsilon_{\theta,r}} \right)^2 \quad \text{for } f = \frac{n}{N} < 0.05$$

n:	number of sampling units
$t_{\alpha;n-1}$:	confidence coefficient (from tabulated- t-distribution with error probability α and n-1 degrees of freedom)
varcoeff(x_i):	variation coefficient of single values from the sample
ε_{Θ},r:	maximum allowance for random sampling error
Θ:	estimate value for the wanted parameter in the parent population
N:	number of survey units in the parent population
f:	sample proportion

While the relative accuracy has to be established with a view to the aim of accuracy for the waste analysis, the variation/ natural variation coefficient has to be determined via pre-investigation.

Organisation and implementation of waste analysis, especially analysis of samples, require equipment, human labour and financial support to secure accuracy. Also, the more samples are analysed, the higher the accuracy. All waste analyses had to be carried out without any financial support and with volunteers of the Ugra State University. Therefore, it was not possible to reach the suggested number of sampling units of the SWA-Tool; 45 sampling units for a first waste analysis in a town when the natural variation coefficient is unknown.
For the waste analyses in Khanty-Mansiysk and Surgut, the confidence level was cut back to 90% with a minimum of 20% statistical accuracy. Based on the recommendations and experiences from ARGUS GmbH, a 30% of natural variation coefficient for household waste was assumed in both in Khanty-Mansiysk and in Surgut. ARGUS GmbH was one of the

members of the consortium for the development of the SWA-Tool (Zwisele, 2006, pers. comm.).
For the reasons of the project as aforementioned, it was only possible to analyse 10 units per one seasonal survey/week. Based on the assumption of a natural variation coefficient of 30%, these 10 sampling units mean a sampling error with 16% on a confidence level with 90% per seasonal analysis.

It is also recommended to analyse 1m^3 of waste containers for one unit as well as a minimum of 6 units per stratum as this guarantees a secured result. However, the waste analysis period was only 5 days per season, from Monday till Friday. 6 units could not be equally subdivided into 5 days; consequently, the decision was made to take 5 units; i.e. one unit per day per stratum as a minimum.

In ***Khanty-Mansiysk***, 5 units per seasonal analysis were analysed in the residential structure “small houses with gardens” and 10 units per week for the residential structure “apartment blocks” as the ratio between both these residential structures, 21%:79%, is to be reflected in the units analysed. The 10 units of apartment blocks were sorted and listed together as these containers stand together; therefore, they corresponded with 5 units. This means 10 units in total per seasonal analysis and a random sampling error of 16% per waste analysis.
630 inhabitants are registered for the research area “apartment blocks”. 12 waste containers are available. 105 persons per unit (2 containers) were calculated.
The number of persons per household and/or per waste container is/was unknown in the research area “small house with gardens”. Through questionnaires a mean of 4 persons per household was extrapolated (see Chapter 4.2.1). Between 25 and 27 small houses with gardens share two containers. 105 persons per unit (2 containers) within the residential structure “small houses with gardens” were taken as the average as it is for “apartment blocks” as well. A seasonal distribution of sampling size for Khanty-Mansiysk is given in Appendix – Chapter 3, Table A3.3.-3.

In ***Surgut,*** only one key residential structure, apartment blocks, was analysed. 105 persons per unit were given by Kaz’mina (2006, pers. comm.) as the basis for all statistical calculations. Only between 6 and 8 sampling units per seasonal analysis were analysed per each waste analysis as the support was sparser in Surgut than in Khanty-Mansiysk. A matrix in regard to Khanty-Mansiysk was not developed as two decisive residential structures do not exist. Between 17% and 20% is the sampling error, based on a 90% confidence level.
Small houses with gardens (1 floor) were also analysed but only to check whether there are big differences in the waste amount and composition. Because of the small sampling size of analysed waste in small houses, only 0.5 m^3 each waste analysis, the results were not included in the final calculations (see Appendix - Chapter 3, Table A3.3.-4).

Generation of a random sampling plan
In regard to the multi-stage random selection within the town ***Khanty-Mansiysk***, two residential areas were defined for the stratum residential structure, as mentioned above. In the second stage, random streets within these areas were chosen, and in the third stage, containers in these streets were randomly selected. Six collection sites in total were selected (see also Appendix - Chapter 3, Figure A3.3.-1).

With a percentage of 99%, apartment blocks take up the main part of the residential area in **Surgut**. Therefore, two different areas with apartment blocks were selected (first stage). Additionally, streets were randomly chosen (second level) with different container places (third stage). Additionally, one container site in the area of small houses was chosen (see Appendix - Chapter 3, Figure A3.3.-2).

Sorting catalogue

For the analysis in Khanty-Mansiysk and Surgut the primary categories of the SWA-Tool sorting catalogue were used. In addition, some primary categories were extended by second categories to collect more detailed information as the waste analysis had been the first one in Khanty-Mansiysk. Eventually, 17 categories were used for the waste analysis in Khanty-Mansiysk and Surgut (see Table 3-4).

Table 3-4: Waste categories and examples used in the sorting analysis

	1st Categories	2nd Categories	Examples
1	Organic	Organic (kitchen)	Bread, vegetables, fruits, fish, meat
2		Organic (garden)	Flowers, grass cuttings, animal remains
3	Wood		All kind of wood
4	Paper/cardboard		Catalogue, newspaper, cardboard
5	Plastic		Plastic bottles, plastic packages for cakes, bin liners
6	Glass		Juice, beer and wine bottles
7	Textiles		Trousers, pullovers, jacket
8	Metals	Ferrous metals	Ferrous tins for beverages or groceries
9		Non-ferrous metals	Non-ferrous tins for beverages or groceries
10	Hazardous waste		Batteries, paints, (household) chemicals, medicines
11	Complex products	Complex packaging	Packages which cannot be separated, for example milk packages made up of cardboard and aluminium foil
12		Electronics	TV-set, stereo system, electronic iron
13	Inert		Soil, stones, ceramics
14	Other categories	Miscellaneous waste	Waste which does not fit in the former categories
15		Sanitary waste	Toilet paper, sanitary towel, tampons, nappy
16		Shoes	Shoes
17	Fine		Full vacuum cleaner bags, ash

Duration of a waste analysis

The duration of the waste analysis depends on several factors such as the design of the waste analysis, the number of sampling units and their size, as well as frequency of waste collection. For a daily collection, a one-week analysis with five working days is recommended by the SWA-Tool.

The waste disposal company in ***Khanty-Mansiysk*** offers a daily service, also on Sunday and bank holidays. The waste disposal company in ***Surgut*** only offers a daily service from Monday till Saturday. There is no service on Sundays and bank holidays. According to the recommendation by the SWA-Tool, one waste analysis in Khanty-Mansiysk and in Surgut should cover five days, from Monday till Friday. In Surgut, there was not as much support for the project as in Khanty-Mansiysk, and therefore a waste analysis covers between three and four days.

In the end, the separated waste was weighed and disposed of. The time lapse between the last emptying of the container by the company and the waste analysis was 24 hours. The reason was to not only check the quality, but also the quantity of the waste. 24 hours were chosen because of the daily service schedule of the waste disposal companies in Khanty-Mansiysk. Moreover, the same time difference between the daily waste analyses guaranteed a comparable waste quantity. The inhabitants were not made aware of the waste analyses to avoid changing their behaviour and, consequently, the waste composition and amount. The analysis followed the same system in all seasons.

Evaluation of the results

Regarding the SWA-Tool, the mean, the standard deviation, the variation coefficient, the confidence coefficient, the confidence interval and the composition were determined for each waste category, seasonal analysis as well as for the annual/total result.

For ***stratification***, the results of each single stratum have to be combined and the mean of the total result has to be calculated as the ***weighted mean*** of all strata based on their ratio; i.e. in the case of the dissertation, from two strata in Khanty-Mansiysk: small houses with gardens and apartment blocks, based on the ratio 21%:79%.

The evaluation follows the description within the SWA-Tool. Beside the formulas within the SWA-Tool for seasonal calculations, formulas for the calculations for natural variation coefficient and the confidence interval (mean) are given by Mr Bertram Zwisele, ARGUS GmbH (Zwisele, 2006, pers. comm.) and Zwisele (2005). These formulas are not included in the SWA-Tool, although both factors play an essential role for calculating the sample size as aforementioned. Formulas are given in Appendix - Chapter 4. Based on the 10 units planned per seasonal survey, a confidence interval of 7.8% for Surgut and 11.0% for Khanty-Mansiysk at 90% confidence level could be calculated.

Table 3-5: Overview of starting point of annual statistical evaluation

	Sampling size [m^3]	**Natural variation coefficient** [%]	**Sampling error at a 90% confidence level** [%]
Surgut (planned)	40	30.0	7.8
Khanty-Mansiysk (planned)	20*	30.0	11.0

Note: (*) - Because of weighting of the results of both strata in Khanty-Mansiysk, there are only 20 units for the annual calculation instead of 40 units.

Finally, more than ***6 Mg of waste*** were collected, sorted and weighed in Khanty-Mansiysk and Surgut altogether and is the basis for all calculations regarding the described parameters (for detailed calculation see Appendix - Chapter 3, Table A3.3.-5).

3.4. Public participation through questionnaires

The tool chosen for public participation was an oral standardised questionnaire adapted to questionnaires suggested by The World Bank (2004) in its “Toolkit. Social Assessment and Public Participation in Municipal Solid Waste Management”. Although The World Bank recommends questionnaires, implementation and evaluation of questionnaires is not explained.

Within the preparation of questionings, the following factors play a key role:

- the type of questions
- the type of questionnaires
- the implementation of questionnaires
- the sampling and sampling size and
- the evaluation (compare Atteslander (2008); Kromrey (2002); Bortz und Döring (2006), Lamnek (2005); Diekmann, 2008).

Type of questions

Most questions had suggested answers and the people interviewed had to decide for one answer given; so called “closed-ended questions”. These answers given in the questionnaire were mainly dichotomy answers. The questionnaire (see Appendix - Chapter 3, Text A3.4.-1) included questions regarding social situation, dealing with waste such as organics and electronics, satisfaction with and payment for waste disposal, attitude to recycling, and statements for the future waste management concept.

Type of questionnaires and implementation

The questionnaires were standardised questionnaires, and the interview was structured. The aim of such standardisation is to enable comparability of results (Diekmann, 2008).

People taking part in the survey were directly interviewed via door-to-door survey, and if they did not want to answer or did not answer, this was understood as “no statement”. The requirements were that interviewees should have lived at least one year in Khanty-Mansiysk and no students living in dormitories were to be asked. These conditions were set to guarantee knowledge about the local waste disposal system. A test run of the questionnaires was implemented with teachers of the Ugra State University.

Volunteer students from the Ugra State University carried out the survey. The students went from house to house and asked people to fill in the questionnaires in Khanty-Mansiysk. The interviews were carried out in September 2006 and May 2008.
The empirical survey was only completed in Khanty-Mansiysk. It was planned to also carry out this questionnaire in Surgut. As mentioned in *Chapter 3.3*, there was less support for this project in Surgut than in Khanty-Mansiysk; i.e. there was no possibility to put an enquiry into practice, and therefore interviews could not be carried out in Surgut.

Type of sampling

The type of sampling for the survey was an *ad hoc* stratified sampling. The stratification criterion was again the residential structure as for the waste analysis: apartment blocks and small houses with gardens. Arbitrary apartments and houses were chosen for gathering answers (*ad hoc* sampling).

Originally, it was planned to carry out surveys in the area where the waste analyses were not carried out. The aim was to collect additional data and to compare the results with the results of the waste analyses. However, the number of inhabitants of small houses per one waste container within the waste analysis area was/is unknown. Therefore, an enquiry was necessary to get an estimate of this figure, and surveys were also conducted in areas of small houses where waste analyses were carried out.
That is why the survey was split into interviewing people:

- from apartment block houses, but not in the waste analysis area of apartment block houses, and
- from small houses with gardens in the waste analysis area of small houses with gardens.

Sampling size
Regarding the sample size, the toolkit by The World Bank (2004) does not offer a number of questionnaires for the questionnaires regarding attitude and daily behaviour as concerns solid household waste. Different researchers offer a variation of sampling size:

- The World Bank (2004) offers another questionnaire “Willingness to pay survey”, and according to this questionnaire, a table with sampling sizes based on sampling error. For example, a 10% sampling error with a 95% confidence level means *96 sampling sizes*.
- Bortz and Döring (2006) recommend *87 questionnaires* for determining frequency of categories based on the 95% confidence level and a medium effect size.
- Kobus (2003) recommends sending out 300 questionnaires as a sufficient sample size. He also assumed a return of 30% and thus, *90 questionnaires* can be expected for analysis.
- According to Plümer and Multhaup (1995), between *81 and 421 questionnaires* were collected during a survey of public opinion regarding incineration and landfill as well as the recycling system in the city of Hamm, Germany.

Based on these recommendations and experiences, I decided to get 100 interviews per stratum, so as to also ensure a statistical evaluation according to Bortz and Döring (2006). Therefore, the sources of information from the users are 200 questionnaires in total in Khanty-Mansiysk: 100 answered questionnaires for apartment blocks and 100 for small houses with gardens.

Evaluation of results
There are two aims of the questionnaire:

1. to gather more information (explorative research) for the status report of the integrated waste management concept and
2. to correlate the data of the researched population with the total population, which is also called as demographic description survey (see Figure 3-1).

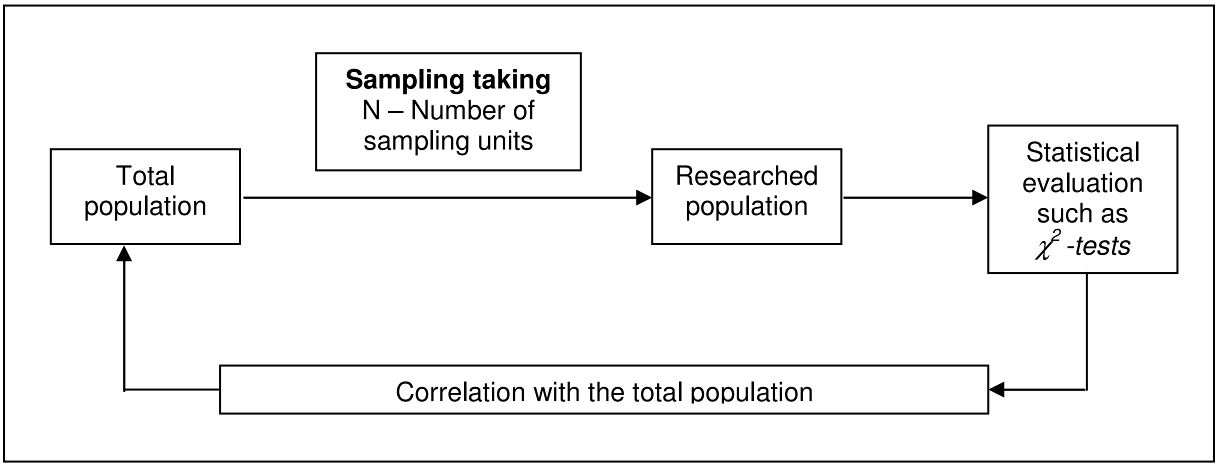

Figure 3-1: Correlation between sampling and total population (modified after Schnell et al., 1995)

In order to prove such correlations, the social sciences use hypotheses and significance tests to determine such links. The significance has to be tested in order to determine whether researched frequency is not random. This statistical evaluation is also called statistical inference (Bortz and Döring, 2006).

The first step is to describe and summarise the determined results. As the main type of answers means a category (nominal data), the absolute frequency (f) of the analysed categories is to be counted (Bortz, 2005); i.e. the answers of each question was counted. This frequency of answers is given in the text in *Chapter 4.2.1* in brackets, in which “AB” means the answer from people from apartment blocks and “SH” from small houses with gardens.

In the second step, the statistical significance was determined. Frequency is analysed by *χ^2 – tests*. As the most answers in the questionnaires are dichotomy answers, a 4-fields-*χ^2-test* was used (Bortz and Döring, 2006):

$$\chi^2 = \frac{N * (ad - bc)^2}{(a + b) * (c + d) * (a + c) * (b + d)}$$

N: total number of sampling units
a, b, c, d: absolute frequency of characteristics

For testing the significance of rank data (cardinal data), the *median test* was consulted. It also based on the *χ^2-test.* Instead of the absolute frequency, the median of the rank data was used. The aforementioned formula was taken as well (Bortz and Lienert, 2003).
The result, *χ^2,* is a number which has to be compared with critical numbers of defined tables which are already described by the social sciences, on a significance/confidence level of 95% (significant) or 99% (very significant). Only the significant result, on a 95% confidence level ($p = 0.05$), is stated in the evaluation of the results. The implementation of questionnaires was the first survey in Khanty-Mansiysk and only a significant result was aimed for. The critical number of *χ^2-texts* for a significant result, regarding frequency or median, is: $\chi^2 > 3.84$ (significant). Preconditions are the so-called degrees of freedom (df error) which is always “1” for *χ^2-texts* with dichotomy answers and “two tailed” tests (Bortz, and Döring, 2006).

In the third step, the effect factor, also called correlation factor, between different characteristics was calculated. The effect factor is described as follows (Bortz, 2005):

$$\Phi = \sqrt{\frac{\chi^2}{N}}$$

Φ: Effect factor
N: total number of sampling units

This correlation factor can only be between *"zero - no correlation"* and "*one - perfect correlation*" (Schrenker, 2008, pers. comm.). The effect factor plays an essential role for calculating the sampling size (compare Bortz (2005), Bortz and Döring (2006) for detailed explanations of significant tests).
Therefore, a significant result of *χ^2-texts* or *median test* means that there is a correlation between the researched characteristics (Bortz, 2005), and the determined results (frequency or median) can be correlated to entire population as well (Diekmann, 2008). For the case in Khanty-Mansiysk the correlation between apartment blocks and small houses with gardens regarding one question/ characteristic was mainly researched.
The description of the results of the significance tests in Chapter 4.2.1 follows the recommendation by the American Psychological Association (2001). The general format for χ^2-text is:

χ^2 ([df error], N = [total number of sampling units]) = [χ^2 obtained], p= [p-value]

In the fourth step, the results of the questions were interpreted and the meaning for the integrated waste management concept was worked out.

3.5. Prognosis of solid household waste

For the prognosis of ***waste amount*** in Khanty-Mansiysk and in Surgut, two key tools were used:

- the formula which is included in a *prognosis software tool* (PST) that was developed as part of the project "The Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies (LCA-IWM)" (Project Coordinator TU Darmstadt, 2005), and
- the formula for *trend analysis* which is recommended in "Preparing a waste management plan. A methodological guidance note" (EC, 2003).

The necessary information for the formula recommended by the EC (2003) and the software tool such as waste amount, population size, gross domestic product were collected via waste analysis, Internet research and by interviewing the local authorities. The annual waste amount was extrapolated from the results of the waste analyses, and the population size was given by the local authorities.
While researching the data that were to be entered in the software tool, different figures were stated by the United Nations/ Department of Economic and Social Affairs for current life expectancy (65.5 years and 68.1 years), future life expectancy (65.8 years and 69.1 years) and current national/ urban infant mortality rate (16.6% and 16.8%). As the same reference lists two different figures for the same characteristic, *two data sets* were created, data set 1 and data set 2. Data set 1 assumed a lower life expectancy as well as a lower infant mortality rate. Data set 2 supposed a longer life expectancy but also a higher infant mortality rate. Both data sets were entered into the waste prognosis software tool in order to check whether there would be differences in the results (of the waste prognosis). All figures entered in the prognosis software tool for data set 1 and data set 2 are given in Appendix - Chapter 3, Table A3.5.-1 to Table A3.5.-3.

Additionally, the experts with experiences of waste management concepts in Russia were asked to forecast the quantity of solid household waste:

- Ms Slyusar from the Perm State Technical University/Environmental Protection Department, Russia, who is also involved in the development of a waste management concept in Ugra (Slyusar, 2008, pers. comm.)
- Dr.-Ing. Olga Ulanova from the University Duisburg/ Waste Technology and from the Technical University Dresden/ Waste management, Germany, who is working on a waste management concept for the Baikal region (Ulanova, 2008, pers. comm.).

Finally, the results of both formulas and prognosis by the experts aforementioned for forecasting the waste amount were compared with each other. On the one hand the aim was to identify whether there are differences among these prognoses, and on the other -based on the recommendation by Karavezyris (2006)- the uncertainty of waste prognosis was to be reduced.

In contrast to the prognosis of waste amount, formulas for forecasting the ***waste composition*** do not exist. However, the software tool can calculate future waste composition. In order to estimate future tendency of waste composition, it was assumed that the composition of solid household waste will become more and more similar worldwide because of the effects of globalisation. In addition to the results of the prognosis tool, the composition of waste in Khanty-Mansiysk and Surgut was compared with Berlin's and Helsinki's waste composition. Both are cities in highly developed countries. Helsinki also has similar climatic conditions as Surgut and Khanty-Mansiysk, which is important as climate conditions have an impact on the waste composition (Zwisele, 2008, pers. comm.). Furthermore, the experts mentioned above were also interviewed to forecast the waste composition. These diverse tools were used in order to estimate the future waste amount and also to demonstrate the differences between them.

Historical data can support waste prognosis (Beigl et al., 2005). Neither Khanty-Mansiysk nor Surgut has historical or reliable current data of municipal waste generation. So, only domestic waste could be predicted based on the solid household waste analyses implemented from 2006 to 2008. Because of a lack of information about the waste amount and composition in the research areas as well as their modified factors such as lifestyle and gross domestic product (GDP), only a five-year prognosis was chosen. Therefore, all forecasts are calculated for the year 2012.

In addition, sensitivity analyses are essential parts of testing the results within complex models such as software programs (Drechsler, 1998; Helton et al., 2006; Cariboni et al., 2007; Irving, 1992; Saltelli et al. 2006). A sensitivity analysis is defined as “determination of the contributions of individual uncertain analysis inputs to the uncertainty in analysis results” (Helton et.al, 2006, p. 1175). The prognosis software tool requires many data which are uncertain such as number of local population, waste amount etc. These uncertainties can have an impact on the accuracy of results.

Three sensitivity analyses for testing the robustness of the results regarding *waste amount* were implemented through the software tool:

1. The discussion of the annual amount in *Chapter 4.1.4* demonstrates there are uncertainities in the calculation of the annual amount. Based on this discussion, different annual waste amounts were estimated. These different results were entered in the prognosis software tool.
2. The number of inhabitants was changed with a range by ±1% in Surgut based on the recent population growth. The number of residents was changed with a range of almost ±7%, also based on the recent population growth.
3. All figures required in data set 1 and data set 2 such as GDP and current life expectancy were changed with a range of ±10%.

Regarding the *waste composition*, sensitivity analyses were also implemented with the following two factors:

1. All figures in data set 1 and data set 2 were changed with a range of ±10% likewise for the sensitivity analysis regarding waste amount.
2. Current seasonal waste compositions of residential structure “small houses with gardens” of Khanty-Mansiysk were entered in the PST in order to check whether there is a significant difference between the seasonal waste compositions and the original input in the prognosis software tool. Only these compositions were chosen because they demonstrate noticeable deviations among the seasons.

Finally, which of these factors has the main impact on the results of future waste amount and composition were identified.

All formulas for waste prognosis and changed data for the sensitivity analyses are given in Appendix - Chapter 4.

3.6. Proposed scenarios for solid household waste treatments

Based on the results of the waste analyses, prognosis and questionnaires, eight scenarios for possible solid household waste treatments for ***Khanty-Mansiysk*** and for ***Surgut*** were developed. The aim of all these approaches to waste treatment is to achieve a reduction of environmental contamination in the Ugra region.
For developing the scenarios, the European legislation, i.e. waste hierarchy, the type of waste disposal/ treatment plant, and the daily behaviour of the local population were taken into account. Each scenario is based on the situation described in the previous one but is more complex and meets a more desirable standard of waste treatment.
Regarding the European legislation, the waste hierarchy was taken into account as it demonstrates the cornerstone of sustainable waste management (see Chapter 2.2 European legislation regarding waste management).
Aerobic Mechanical-Biological-Treatment plants (aeMBT), anaerobic Mechanical-Biological-Treatment plants (anMBT) and incineration plants were selected as they can treat mixed solid household waste.
Additionally, recycling of waste necessitates educating the local population and changing their daily behaviour in regard to waste disposal. It also requires different and more waste bins as well as waste collection trucks. Thus, the scenario with recycling is more challenging than a scenario without recycling.

In all scenarios “collection and transport” occur in almost the same way and for that reason they have a minor impact on the assessment of the scenarios. The waste is transported to treatment plants and/or to a landfill via disposal trucks. This landfill is not equipped with a gas or leachate collection system, which reflects the local conditions in Khanty-Mansiysk and in Surgut.

Scenario 1 describes the current situation: All mixed solid household waste is disposed of on the landfill. Only principle 5 of the Framework Directive on Waste Directive 2008/98/EC is implemented. The local population does not have to change their daily behaviour regarding waste disposal.

While Scenario 1 describes the status quo, all the following scenarios explain possible future waste management in Khanty-Mansiysk and Surgut:
Options are to treat all mixed domestic waste in an aerobic Mechanical-Biological-Treatment plant (aeMBT) as in **Scenario 2**, or in an anaerobic Mechanical-Biological-Treatment plant (aeMBT) as in **Scenario 3**. Rejects of treatment plants in both scenarios are disposed of on a landfill.
These scenarios were selected because recovery of energy is possible, and the 3rd principle in the European waste hierarchy is implemented. Less amount of waste after treatment and only inert waste need to be disposed of on a landfill, and the condition of Directive 99/31/EC on landfill of waste is thereby also met.
The difference between Scenarios 2 and 3 is the technique of biodegradation. Scenario 2 only includes an intensive rotting and stabilisation. In contrast to Scenario 2, Scenario 3 includes, besides the intensive rotting and stabilisation, a fermentation process in order to produce biogas. The local population does not have to change their daily behaviour with regard to waste disposal in either scenario.

Scenario 4 states that all mixed waste is burned in an incineration plant. Rejects of incineration are disposed of at a specialised ash landfill. The local population does not have to change their behaviour regarding waste disposal.

Scenario 5 to Scenario 8 describe that 20% of paper/cardboard, glass, plastic, metals and electronics are collected separately and recycled. Besides the Framework Direction, the Directive 94/62/EC on packaging and packaging waste has also been applied to developing the scenario. It sets targets for recycling and recovery quota.

The results of the waste analysis demonstrated that 43.3% of the annual waste composition in Khanty-Mansiysk and 50.3% of the annual waste composition in Surgut consist of these five waste fractions - paper/cardboard, glass, plastic, metals and electronics. These fractions are very suitable for recycling. In addition, based on the results of the questionnaires it can be assumed that there will be an increase in the amount of electronics.

A 20% recycling rate was chosen because the data from Lithuania demonstrate that introduction of a recycling rate within 5 years is possible (Eek, 2004). Lithuania and Russia share a common history, and Lithuania has been a member of the European Union since May 2004. Lithuania needs to reach an overall recycling rate between 55 % and 80% by 2012 (Directive 2005/20/EC). Therefore, the current recycling rate of Lithuania was transferred to the scenarios for Siberian regions.

The current daily behaviour (no recycling) of the local population has to be changed for Scenario 5, 6, 7 and 8, which means the local population has to dispose of their waste separately.

The difference between Scenario 5, 6, 7 and 8 is the treatment of residual waste.

In ***Scenario 5***, the residual waste and the rejects of the recycling procedure would be disposed of on a landfill. In ***Scenario 6***, the difference to Scenario 5 is that residual waste goes to an aeMBT. Rejects of aeMBT and the recycling procedure will be disposed of on a landfill. ***Scenario 7*** follows the same procedure as in Scenario 6 but with an anMBT. In contrast to Scenario 5, Scenarios 6 and 7 aim to reduce the waste amount for landfilling and to treat the waste until it is inert through treatment in an aeMBT or anMBT. ***Scenario 8*** includes the incineration plant but with a previous recycling quota of 20% of paper/cardboard, glass, plastic, metals and electronics.

Table 3-6: Overview and summary of all scenarios

Name of the scenario	Content of the scenrio
Scenario 1 “landfill”	All mixed solid household waste is disposed of on a landfill (*status quo*).
Scenario 2 “aeMBT”	All mixed solid household waste is treated in an aeMBT. Rejects of aeMBT are disposed of on a landfill. Recyclable materials are treated in further treatment plants. Refuse-derived fuel (RDF) is sold as “recovered energy” to a cement kiln.
Scenario 3 “anMBT”	All mixed solid household waste is treated in an anMBT. Rejects of anMBT are disposed of on a landfill. Recyclable materials are treated in further treatment plants. Recovered energy can be sold. RDF is sold as “recovered energy” to a cement kiln.
Scenario 4 “incineration”	All mixed solid household waste is burnt in an incineration plant. Recovered energy will be sold.

Name of the scenario	Content of the scenrio
Scenario 5 “landfill and recycling”	20% of electronics, glass, paper, plastics, metals are recycled; residuals and rejects of recycling are disposed of on a landfill.
Scenario 6 “aeMBT and recycling”-	20% of electronics, glass, paper, plastics, metals are recycled; residuals are treated in an aeMBT. Rejects of aeMBT and recycling procedure are disposed of on a landfill. RDF is sold as “recovered energy” to a cement kiln.
Scenario 7 “anMBT and recycling”	20% of electronics, glass, paper, plastics, metals are recycled; residuals are treated in an anMBT. Rejects of anMBT and recycling procedure are disposed of on a landfill. Recovered energy can be sold. RDF is sold as “recovered energy” to a cement kiln.
Scenario 8 “incineration and recycling”	20% of electronics, glass, paper, plastics, metals are recycled; residuals are burnt in an incineration plant. Rejects of the incineration plant and recycling procedure are disposed of on a landfill. Recovered energy will be sold.

3.7. Environmental evaluation of waste treatment scenarios by Life Cycle Assessment

The selected software tool for the LCA was developed in the 5th EU framework project “The Use of Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies (LCA-IWM)” (Project Coordinator TU Darmstadt, 2005). A manual for using the LCA Tool (den Boer et al. (Ed.), 2005), a deliverable report (den Boer et al., 2005) and a dissertation (den Boer, 2007) exist to describe this tool in detail. In particular, detailed information about the environmental assessment can be found in the “Deliverable Report on D 3.1. and D 3.2. Environmental Sustainable Criteria and Indicators for waste management (Work package 3)” by den Boer et al. (2005).

In addition, Prof. Montse Meneses from the University Rovira i Virgili in Tarragona, Spain, was consulted for the implementation of this LCA software tool in Siberian regions. She also supported the development of this tool.

The scenarios aforementioned were assessed with this LCA-IWM software tool. As described in Chapter 2.1.5., an LCA is subdivided in four parts which are explained for the software tool LCA-IWM in the following paragraphs:

1. <u>Goal and scope definition</u>
   The goal of LCA-IWM is the ecological, social and economic assessment of municipal waste management in rapidly growing European cities; i.e. cities with underdeveloped municipal waste management systems. The assessment begins with the waste disposal in the waste containers, continues with the collection, transport and treatment, and ends with disposal. The environmental assessment is based on data of the emissions of pollutants and use of resources throughout the entire system. The functional unit is the total amount of waste generated in the research area (town of Surgut and Khanty-Mansiysk) entering the waste management concept in one year (den Boer, et al., 2005).

2. Life cycle inventory (LCI)
   Regarding the goal of the LCA-IWM, the assessment waste management from towns with underdeveloped waste management systems, the assumption was there are not any data available for use within a LCI. Therefore, common data sets for emissions of pollutants and consumption of resources are used for the ecological assessment in the project. The origin of these data sets is from countries with an advanced developed waste management system (den Boer, et al., 2005).

3. Life cycle impact assessment (LCIA)

"CML 2001" is the impact assessment tool used within the LCA-IWM. This tool includes values for characterisation factors, and combined with the results of the inventory, come to characterised impacts of a definite category. In order to enable the comparison of the results of each category, the results were normalised and therefore the LCA-IWM software tool calculates the environmental impacts of each category as "Inhabitant Equivalent". "One inhabitant equivalent represents the total impact in a certain environmental assessment category of a certain geographical region within one year divided by the number of inhabitants within that region in the considered year", (den Boer et al., 2005, p.23) and means the normalisation factor. The CML tool also offers, besides the "Western European Inhabitant Equivalent", the "World Inhabitant Equivalents". Originally, the LCA-IWM tool uses "Western European Inhabitant Equivalent". As that does not work for Siberia, the "World Inhabitant Equivalents" was used as the normalisation factor, and therefore the factor was changed within the software tool.

The used impact categories in this LCA-IMW tool are:

- **Abiotic depletion:** Abiotic resources are natural resources. The depletion is a result of availability of reserves and rates of extraction of a resource.
- **Global warming:** Climate change includes the impact of "human emissions on the radioactive forcing of the atmosphere" (den Boer et al. (Ed.), 2005, p. 36)
- **Human toxicity:** Toxic substances which are emitted to the environment and have negative impacts on human health are included in this category.
- **Photochemical oxidation:** Air pollutants which can have negative impacts on Photochemical Ozone Creation Potential.
- **Acidification:** Many man-made emissions are acid or turn to acid caused by processes in the air and have multitude impacts on the environment.
- **Eutrophication:** Environmental impacts caused by processes through macronutrients (den Boer et al. (Ed.), 2005).

4. Interpretation

Last but not least, the results were evaluated. Furthermore, sensitivity analyses were implemented in order to identify significant factors on the results.
Lastly, a final approach to an optimal domestic waste treatment was identified (see Chapter 4.4.3 Discussion of LCA results). Appendix - Chapter 3, Table 3.7.-1 to Table 3.7.-2, lists all figures entered.

As already stated in *Chapter 3.5*, if many data are required within a complex model and these data could include uncertainties, it is recommended to carry out sensitivity analyses. Sensitivity analyses were developed to test the robustness of results by a systematic change of input data. LCA requires a lot of input data which, especially when derived from literature and/or estimated, can contain uncertainties. Therefore, testing the robustness of results of LCA is recommended (Baumann and Tillmann, 2004).

I identified two uncertainty data for the results of the assessments:

1. Waste amount and
2. Waste composition.

1. For the sensitivity of the factor *waste amount*, a range between -10% and +10% of annual entire waste amount was selected.

2. For the sensitivity regarding the factor *waste composition*, two ways were implemented in order to identify the different influences of the waste composition:

I. *Individual fractions* such as organics, plastics etc. with the entire amount of waste from Surgut were also entered. Assuming that each scenario for Khanty-Mansiysk and Surgut reacts in the same way by entering single fractions, this type of sensitivity analysis was only implemented with the figures of Surgut: Organics (kitchen), organics (garden), plastic, glass, paper/cardboard, metals, and electronics waste were entered as only one fraction with the total amount of 65,000 Mg a^{-1} as current amount and 72,600 Mg a^{-1} as forecasted amount. These seven fractions were chosen as they are the fractions which have to be entered in the LCA-IWM besides residual waste. Furthermore, only Scenarios 1-4 are used for this sensitivity analysis. Scenario 5-8 reflect scenario 1-4 with an additional recycling part; i.e. the difference between Scenarios 1-4 and Scenarios 5-8 is the amount of the single waste fraction treated in the waste treatment plant or disposed of on a landfill.

II. The *seasonal compositions* from the single waste analyses carried out in Khanty-Mansiysk and Surgut were entered in the software tool. All seasonal waste compositions were entered with the same amount of waste (current amount: 65,000 Mg a^{-1}, future amount: 72,600 Mg a^{-1}) in order to guarantee comparability.

Khanty-Mansiysk is remote in contrast to Surgut. Therefore, with an additional sensitivity analysis the impact of short and long distances was assessed for the results of Khanty-Mansiysk:

If the waste has to be transported to a central treatment plant, for example to Surgut, the distances of waste transport also could have an influence on environmental impacts. More waste collection trucks are necessary, which would result in a higher consumption of petrol and diesel and higher emissions. In contrast to distances between European towns, the distances between towns in Siberia are enormous. In so doing, different distances between Khanty-Mansiysk and possible locations of treatment plant were used in a sensitivity analysis. The distances to Neftyuganz (160km), Surgut (250km) and Py'tach (300km) were taken because they are the nearest towns to Khanty-Mansiysk. In addition, a shorter distance (50km) was also chosen in order to compare the results of LCA in regard to long and short distances.

4. Results and discussion

4.1. Waste analysis

4.1.1. Background information and identification of influencing factors for waste disposal systems in Khanty-Mansiysk and Surgut

Khanty-Mansiysk is the capital of the Ugra Region and was incorporated as a town in 1952 (Administration of KMAO, 2008). At present, the area of the town is 33.7km^2. The population has increased rapidly from 59,600 in January 2006, to 70,000 in January 2007 (Tomsha, 2007, pers. comm.). On average 500 to 600 people currently move into the town every month in 2008 (Ivanovich, 2008a, pers. comm.). The average salary has increased from 22,870 roubles (618€[4]) per month in 2005 to 27,268 roubles (734€) per month in 2006. According to local authorities, only 99 people were unemployed in Khanty-Mansiysk in 2007 (Administration of KMAO, 2008). Khanty-Mansiysk is only an administrative town, and there are no industries present at all (Tomsha, 2007, pers. comm.).

Apartment blocks between 2 to 5 and more floors as well as small one-storey houses exist at present; (apartment) houses with more than 3 floors have only been built since the end of the 1990s. There are 3,675 small houses with gardens (Tomsha, 2007, pers. comm.); approximately 15,000 people live in this residential structure (see Chapter 3, Results of questionnaires). Official updated data do not exist on how many flats in apartment blocks exist or are being planned (Kaz`mina, 2008, pers. comm.). Khanty-Mansiysk is the most progressive and fastest growing town of the Okrug.

The nearest towns are Py'tach (300km), Neftyuganz (160km), Surgut (250km) and Njangang (250 km). There are no roads or towns to the North and South. Compared to Surgut, Khanty-Mansiysk is relatively isolated (see Appendix - Chapter 3, Maps III). This condition has a crucial influence on waste management concepts regarding transport and distances for waste management facilities.
Climate conditions are very severe. In summer, the temperature is between 25°C and 30°C; during the winter the average temperature is between -30°C and -40°C. Compared to the annual average of Ugra, the temperature in summer is warmer, and the temperature in winter colder (Administration of KMAO, 2008).

In Khanty-Mansiysk, only one governmental landfill exists for the disposal of waste for the town and surrounding villages. The landfill is approximately 17km from the town, due north-east (Ivanovich, 2008, pers. comm.). The waste disposal site was opened in 1999; the disposal period is planned for 18 years - until 2017. The waste capacity was planned for 518,970m^3. The total territory of the waste disposal site is 20ha (Tomsha, 2007, pers. comm.); between 5 and 10ha are already occupied by waste (Ivanovich, 2008, pers. comm.). 435,800m^3 had already been disposed until 2005. Since 2004, there have been annual figures for waste disposal. These figures were estimated by counting the waste collection trucks running to the landfill: 195,300m^3 in 2004[5]; 196,300m^3 in 2005; 210,600m^3 in 2006, and 246,700m^3 in 2007 (Kisileva, 2008, pers. comm.). In November 2007, a pair of scales was constructed at the entrance of the waste disposal site. Since then the weight of every

[4] exchange rate: 1€ = 35roubels, Date: December 2008
[5] m^3 – represents no compaction

waste collecting vehicle has been measured. As a result, 15,500Mg or 83,500m^3 were calculated for six months (November 2007 - May 2008), but the type of waste has not been analysed or documented (see Appendix - Chapter 3, Photographic documentation).
Furthermore, a rain collecting system was built on the waste disposal site and an average of 8m^3 rain water per day is collected and transported to the sewage plant. Neither methane nor landfill leachate has been collected yet, but there are plans to measure and capture the methane. The existing soil is protected from the waste and any contamination by a layer of rubber (see Appendix - Chapter 3, Photographic documentation).
The disposal site structure consists of two layers which alternate between each other: 2m of disposed waste and 0.2m of soil. The soil is spread on the waste in order to keep the mound of waste passable for garbage trucks. The planned absolute height is 15m (see Appendix - Chapter 3, Photographic documentation) (Ivanovich, 2008, pers. comm.).

There are 1,500 waste containers for solid municipal waste in Khanty-Mansiysk and they are emptied every day. The size of these containers is between 0.5m^3 and 0.75m^3 (Tomsha, 2007, pers. comm.). It must be noted that the containers were approximately 100% filled in spring, autumn and winter. In summer, the containers were only filled to approximately 50-80%.Three companies are responsible for disposing of the waste. The “Municipal Department for Road Exploitation” (M DEP) is a governmental department as well as a waste disposal company, the town’s biggest. It disposes the waste of almost 1,000 containers. “Schistie Dom” (“Clean House”) and “Ugra Dom” (“Ugra House”) are private companies and are responsible for the emptying of the other 500 containers. The containers are the property of the firms. Approximately 75 people work for these three companies. The town council pays for the majority of waste disposal. Mechanisms or acts for signing contracts for payment of waste fees between inhabitants/owners of apartment blocks and the waste disposal company or local administration do not exist and therefore not all inhabitants, owners of apartment blocks or companies/shops pay for their waste disposal. Consequently, the waste disposal companies need the financial support by the local authorities because of the deficit in the legislation (Tomsha, 2007, pers. comm.).

In 1965, ***Surgut*** received the status of a town. Today, it covers an area of 213km^2 with approximately 291,000 inhabitants. At the moment, Surgut is the biggest town in KMAO in terms of number of inhabitants. Additionally, it is the cultural and industrial centre in Ugra (Administration of KMAO, 2008).
A gas and oil boom in the 1960s started a new development in Surgut (Administration of KMAO, 2008). In the 1970s and 1980s under the Soviet regime, Surgut was developed as a gas and oil industry town. Because of migration to Surgut the population grew from 34,000 to 107,000 between 1970 and 1979. In 1989, almost 248,000 inhabitants were counted in Surgut (MSN, 2008). Today more than 90 nationalities live in Surgut, although there are mainly Russians (63%), Ukrainians (11%), and only 0.3% of the indigenous population, the Khanty and Mansi (Administration of KMAO, 2008).

The nearest towns are Neftjuganz (90km) and Py’tach (160km) to the east, and Megion (150km) and Nischnivartovsk (250km) to the west. Kogalym (100km) is located to the north. As opposed to Khanty-Mansiysk, Surgut is surrounded by different towns and villages and is less isolated (see Appendix - Chapter 3, Map III). Two different types of residential structures exist in Surgut: apartment blocks and small houses with gardens (see Appendix - Chapter 3, Photographic documentation) (Kiseleva, 2008, pers. comm.).

Surgut is the main town for natural oil and gas production in KMAO (Administration of KMAO, 2008) and the key producer of energy for this region (MSN, 2008).
In ***Surgut*** there is only one landfill according to the local authorities. The governmental waste disposal site was opened in 1994 and planned for 20 years - until 2014. The total size is 8,650,000m^3. At present, 5,797,200m^3 are already filled with waste, 524,200m^3 alone were added in 2005. These numbers were determined by the local administration by counting the number of trucks to the landfill. The entire size of the area is 30.5ha. The planned storage height is calculated at 8.6m (Kiseleva, 2008, pers. comm.). A special drainage shaft exists for collecting methane and leachate (see Appendix - Chapter 3, Photographic documentation). Nevertheless, neither data of methane nor leachate volumes have been collected yet. The leachate is kept and used to extinguish the fires on the waste disposal site. 30 waste disposal companies work in Surgut. 3,740 waste containers exist with a size ranging from 0.5m^3 to 0.75m^3. During the waste analysis, the level to which the containers were filled was very different; namely, the containers were 10% to 100% filled, compared to Khanty-Mansiysk where the level of containers was almost the same, 100%. The companies work almost daily, except Sundays and bank holidays (Kiseleva, 2008, pers. comm.).

Besides the investigation of the research area, special circumstances which could influence the quality and quantity of waste exist and also had to be identified and are explained below:

- It must be considered that Khanty-Mansiysk is a rapidly growing town and therefore, the development of the infrastructure and the town itself, for example, the planned production of newspaper, is supposed to increase from 8.8 million Mg in 2005 to 11 million Mg in 2006 (Administration of KMAO, 2008) is supposed to have an influence on the waste generation.
- Khanty-Mansiysk is an administrative town, including local and national public offices as well as a university and further colleges for higher education and training centres. A higher amount of paper and cardboards can be expected in their waste than in the domestic waste.
- Khanty-Mansiysk is not divided into districts. That is important as districts could have an influence on waste generation and composition because of different social, cultural and economic situations. Therefore, it can be assumed that the waste generation is homogenous in the entire town Khanty-Mansiysk.
- Ugra State University opened in 2000 with 3,000 students and increased to 5,000 in 2007. Additionally, a technical college with higher education and a medicine institute as well as an art centre exist with approximately 1,300 students altogether. Most of the students and teachers do not live in Khanty-Mansiysk year-round and go home for holidays (July - August, January) (Lapshina, 2008, pers. comm.). It can be assumed that there is less waste during the summer and winter holidays.
- No industry exists in Khanty-Mansiysk. All products are delivered from other towns such as Surgut (Tomsha, 2007, pers. comm.).
- Khanty-Mansiysk is a city of international biathlon competition venues, which means that a lot of sportsmen, tourists and visitors can be expected in the town in February/March and consequently, to produce a higher amount of waste.
- Regarding the seasons of the year, it must be mentioned that spring and autumn can be very short (ranging between one day and one week). Usually, winter and summer are the main seasons.

- The working days also play an important role as, for example, local administration and university do not work at the weekend. Therefore, less amount of paper/cardboard is in the waste at the weekend.

For domestic waste, the following assumptions were made:

- The social changes and subsequent changes in life style as well as increasing salaries have an influence on waste composition and amount.
- The different daily behaviour of residents in connection to their residential structure such as houses with or without a garden could change the amount of organic waste.
- Differences in the cleaning and cooking behaviours on weekdays and weekends could have an effect on the waste composition as well as amount.

In addition to Khanty-Mansiysk, the following influences on the waste quality and quantity were expected in Surgut:

- Surgut is characterised by a lot of industry; it delivers many products into the Ugra Region. Consequently, different waste fractions regarding commercial or industrial waste can be assumed in Surgut as compared to Khanty-Mansiysk.
- The working day is also important because local administration and university do not work weekends; less amount of paper/cardboard in the waste.
- Winter and summer are the main seasons; spring and autumn can be only one day long.
- Surgut is not subdivided into districts either.

Factors that can change the composition of the domestic waste are the same as in Khanty-Mansiysk (see above).

4.1.2. Quantification of waste amount in Khanty-Mansiysk and Surgut

Annual and seasonal amount of solid household waste

In ***Khanty-Mansiysk***, 24,300Mg a^{-1} for 70,000 inhabitants as the entire annual waste amount or 347kg c^{-1} a^{-1} as the annual amount per capita is generated every year in the research years from 2006 until 2008.

In ***Surgut***, 65,000Mg a^{-1} for 290,200 inhabitants or 224kg c^{-1} $a^{-1}$of solid household waste was calculated per year in the research years 2006/07. For a detailed calculation of waste amount in Khanty-Mansiysk and in Surgut see *Appendix Chapter 4, 4.1., Table A4.1.-1 to Table A4.1.-89*.

The waste analysis in ***Khanty-Mansiysk*** was subdivided into two strata: apartment blocks and small houses with gardens:

- The *residents of small houses* with gardens produce a slightly higher amount of waste per capita and day than the residents of apartment blocks in spring, summer and autumn. The seasonal results show that most of the waste was produced in spring.
- The *inhabitants of apartment blocks* generate more waste in winter than the residents of small houses with gardens. Simultaneously, it the highest amount generated of residents from apartment blocks.
- The *weighted results* demonstrate that the highest amount of waste can be expected to be generated in spring and winter. Summer and autumn show a decrease (see Table 4-1).

Surgut shows the following distribution: The lowest amount was analysed in spring. In contrast to that, summer shows the highest amount. Autumn and winter have medium results (see Table 4-1).

Table 4-1: Waste amount in Khanty-Mansiysk and Surgut. Errors indicate C.I. on a 90% confidence level [kg c^{-1} d^{-1}].

Research area	Residential structure	Spring	Summer	Autumn	Winter
Surgut	**Apartment blocks**	**0.5 ± 0.1**	**0.7 ± 0.2**	**0.6 ± 0.2**	**0.6 ± 0.2**
Khanty-Mansiysk	**Weighted results**	**1.1 ± 0.2**	**0.8 ± 0.1**	**0.7 ± 0.1**	**1.2 ± 0.2**
	Apartment blocks	1.0 ± 0.3	0.7 ± 0.2	0.7 ± 0.2	1.3 ± 0.3
	Small houses with a garden	1.5 ± 0.5	0.9 ± 0.4	1.0 ± 0.4	0.7 ± 0.2

Daily amount of solid household and organic (kitchen) waste

In ***Khanty-Mansiysk***, the daily total amount of waste per capita and day demonstrates a peak on Monday and a dip on Tuesday as well as a smaller peak on Wednesday and dips on Thursday and Friday again. In contrast to the daily amount in Khanty-Mansiysk, the daily amount of waste in ***Surgut*** has an almost continuous generation from Monday to Friday (see Figure 4-1).

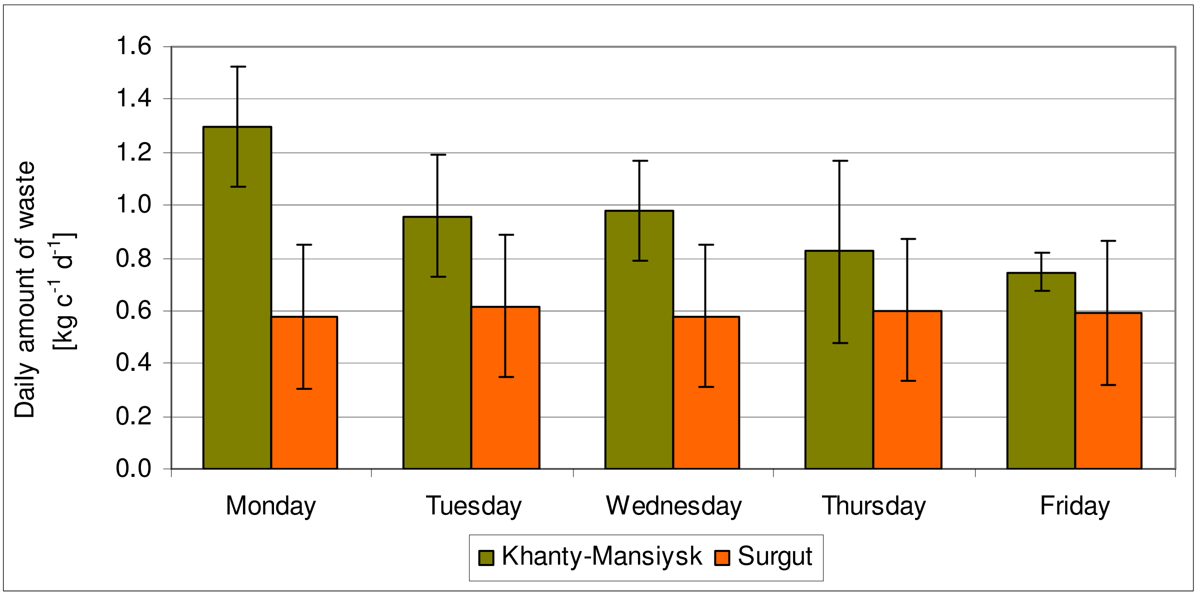

Figure 4-1: Daily total amount of waste per capita and day in Khanty-Mansiysk and in Surgut. Error bars indicate standard deviation (n=4).

Organic (kitchen) waste is the waste fraction with the highest proportion in the solid household waste in Khanty-Mansiysk and Surgut. Therefore, the daily amount was analysed as well. As concerns the daily amount of organics (kitchen), both Khanty-Mansiysk and Surgut showed their peak on Monday. The daily amount of organic (kitchen) waste recorded a decrease on Tuesday and Wednesday and second decline on Thursday and Friday in ***Khanty-Mansiysk***. In contrast to the amount in Khanty-Mansiysk, the daily amount of organics (kitchen) is almost consistent in Surgut from Tuesday till Friday (see Figure 4-2).

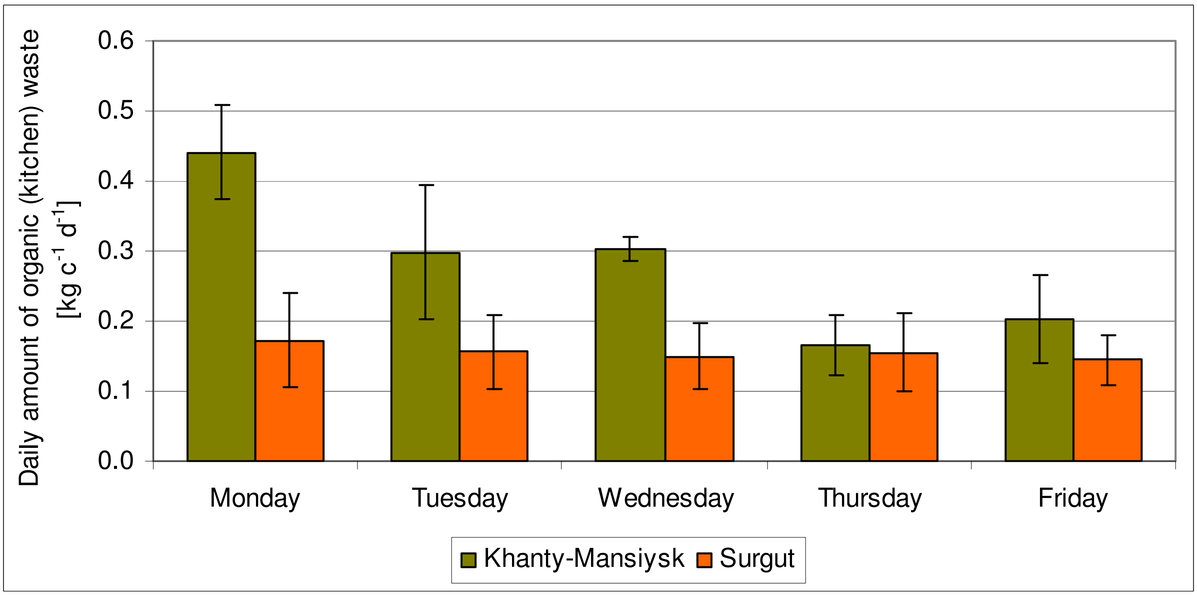

Figure 4-2: Daily amount of organic (kitchen) waste per capita and day in Khanty-Mansiysk and in Surgut. Error bar indicates standard deviation (n=4).

4.1.3. Composition of waste in Khanty-Mansiysk and Surgut

The domestic waste in Khanty-Mansiysk and in Surgut shows ***annually*** comparable waste compositions. Five main fractions exist:

1. organics (kitchen),
2. organics (garden),
3. plastics,
4. glass and
5. paper/cardboard.

They comprise 74.9% of the total waste composition in Khanty-Mansiysk, or rather 78.2% of the annual average of waste in Surgut. Almost all other fractions are under 5.0% and do not play a key role for this first analysis and are classified as “residual waste”, with the exception of electronic, metal and hazardous waste. A complete subdivision of “residual waste” is given in Appendix – Chapter 4, 4.1., Table A 4.1.-75.

Differences in the waste compositions of Khanty-Mansiysk and Surgut are:

- higher proportions in organics (kitchen), organics (garden) and paper/cardboard as well as a much higher proportion of hazardous waste in Khanty-Mansiysk compared to Surgut;
- higher proportions of plastics and glass in Surgut than in Khanty-Mansiysk.

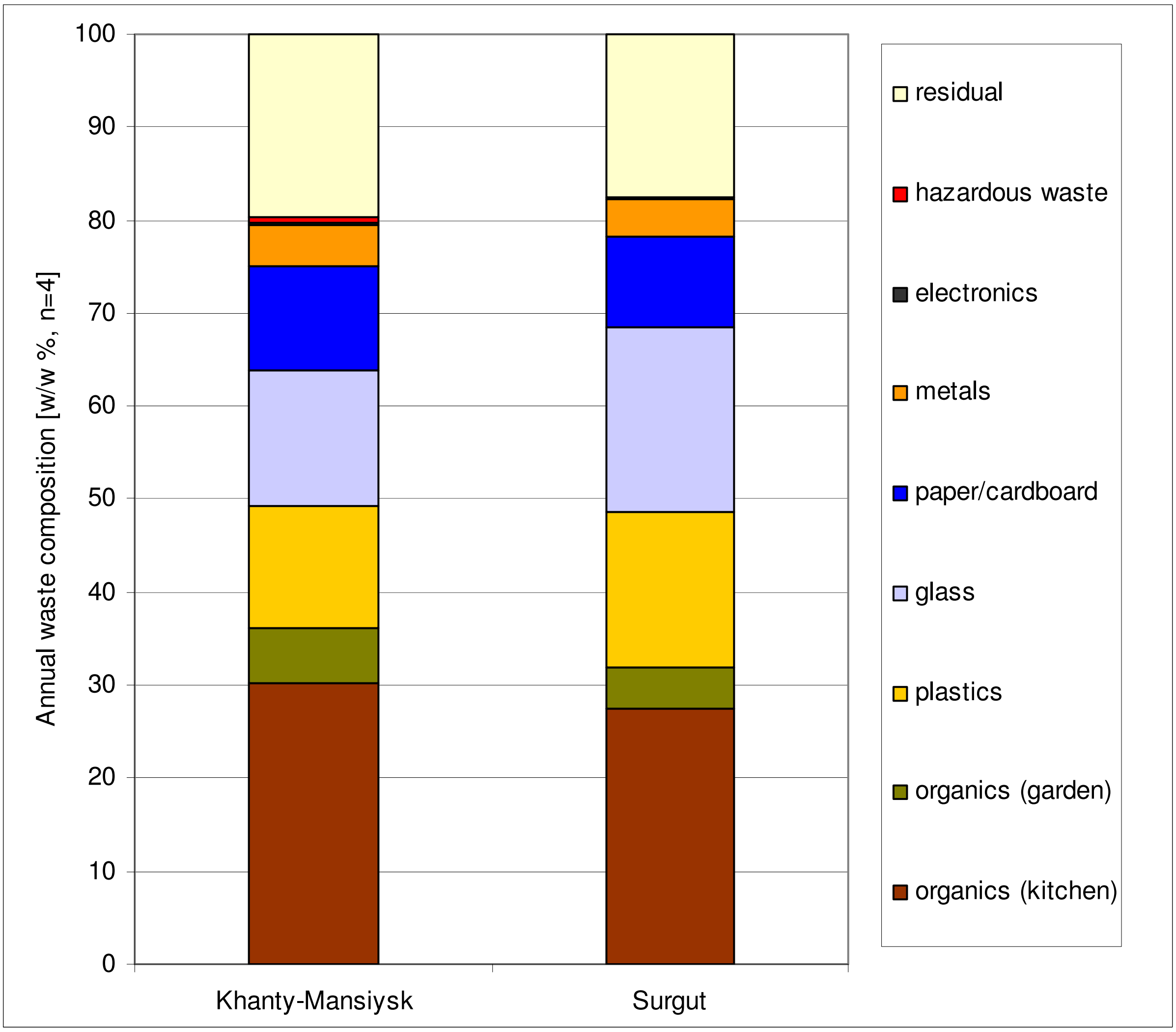

Figure 4-3: Annual waste composition in Khanty-Mansiysk and Surgut

Although the waste as a whole showed comparable composition, a subdivision into ***seasons*** reveals differences in the five main proportions (see Figure 4-4):

- The proportion of *organics (kitchen)* shows a high fluctuation among the seasons in Khanty-Mansiysk and Surgut. A significantly lower percentage was analysed in spring than in summer, autumn and winter in Khanty-Mansiysk. In contrast, in Surgut the highest percentage was analysed in spring and lowest percentage in winter.
- The proportion of *organics (garden)* shows a typical seasonal fluctuation, an extremely high amount in spring and autumn, lower amounts in summer, and very little in winter in Khanty-Mansiysk. In Surgut, it shows a peak in autumn, but all other seasons are similar to each other.
- The proportion of *plastics* has a decrease in autumn but all other three seasonal analyses show a similar result in Khanty-Mansiysk. In contrast to Khanty-Mansiysk, plastic waste has a higher proportion in spring, but it is very similar in the other seasons in Surgut.
- The proportion of *glass* is very high in spring and less in summer, but very similar in autumn and winter in Khanty-Mansiysk. In Surgut, the proportion of glass demonstrates big variation, the proportion in summer and winter are almost the same, but in spring and autumn they collapse.

- The proportion of *paper/cardboard* is similar in spring and autumn but less compared to the proportions in summer and winter in Khanty-Mansiysk. This fraction shows a decrease in autumn but comparable proportions in all other seasons in Surgut.

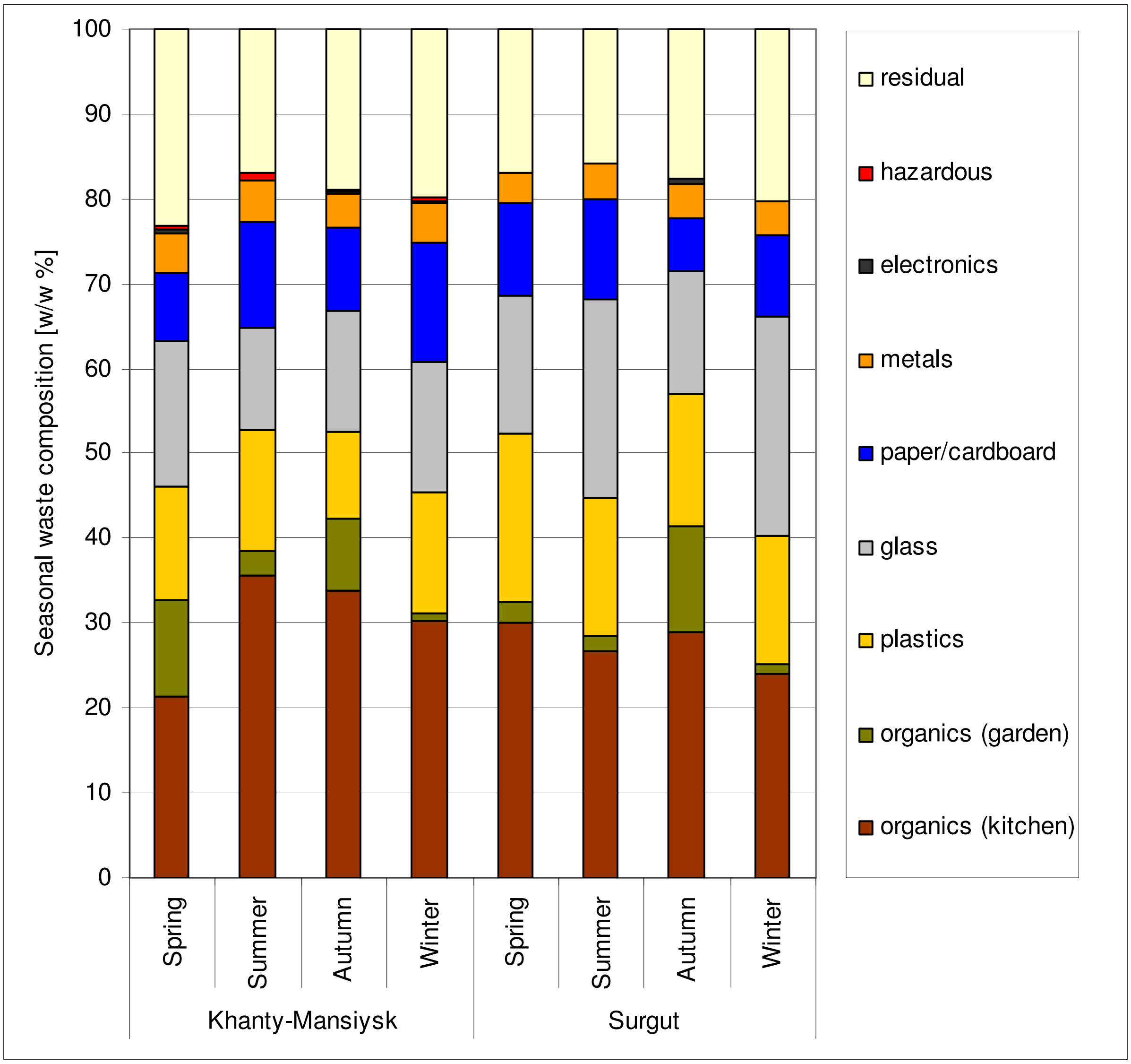

Figure 4-4: Seasonal distribution of waste composition in Khanty-Mansiysk and Surgut

Because of the subdivision of the residential structure in ***Khanty-Mansiysk*** into two *strata*, the annual averages of both strata will also be analysed in order to compare their commonalities and differences. The five main fractions, organics (kitchen), organics (garden), plastics, glass and paper/cardboard, comprised 76.6% of the entire waste composition in the stratum "apartment blocks" and 68.8% in the stratum "small houses with gardens".

Significant differences are between the compositions of waste from both residential structures:

- More *organic (kitchen)* waste is in the residential structure "apartment blocks" than in the residential structure "small houses with gardens".
- More *organic (garden)* waste is in the residential structure "small houses with gardens" than in the residential structure "apartment blocks".

- Together, *organics (kitchen) and organics (garden)* show very similar results: for apartment blocks 36.3% and for small houses 35.9%. It also means that the inhabitants of both strata produce a similar percentage of organic waste but in opposite distribution.
- The proportions of *glass and paper/cardboard* are higher within the residential structure "apartment blocks" than within "small houses with gardens".
- No electronic waste was generated by residents of apartment blocks.
- Higher proportion of hazardous waste was generated in the residential structure "small houses with gardens" than in the residential structure "apartment blocks" (see Figure 4-5).

The seasonal subdivision is demonstrated in Appendix – Chapter 4, 4.1., Table A 4.1.-37.

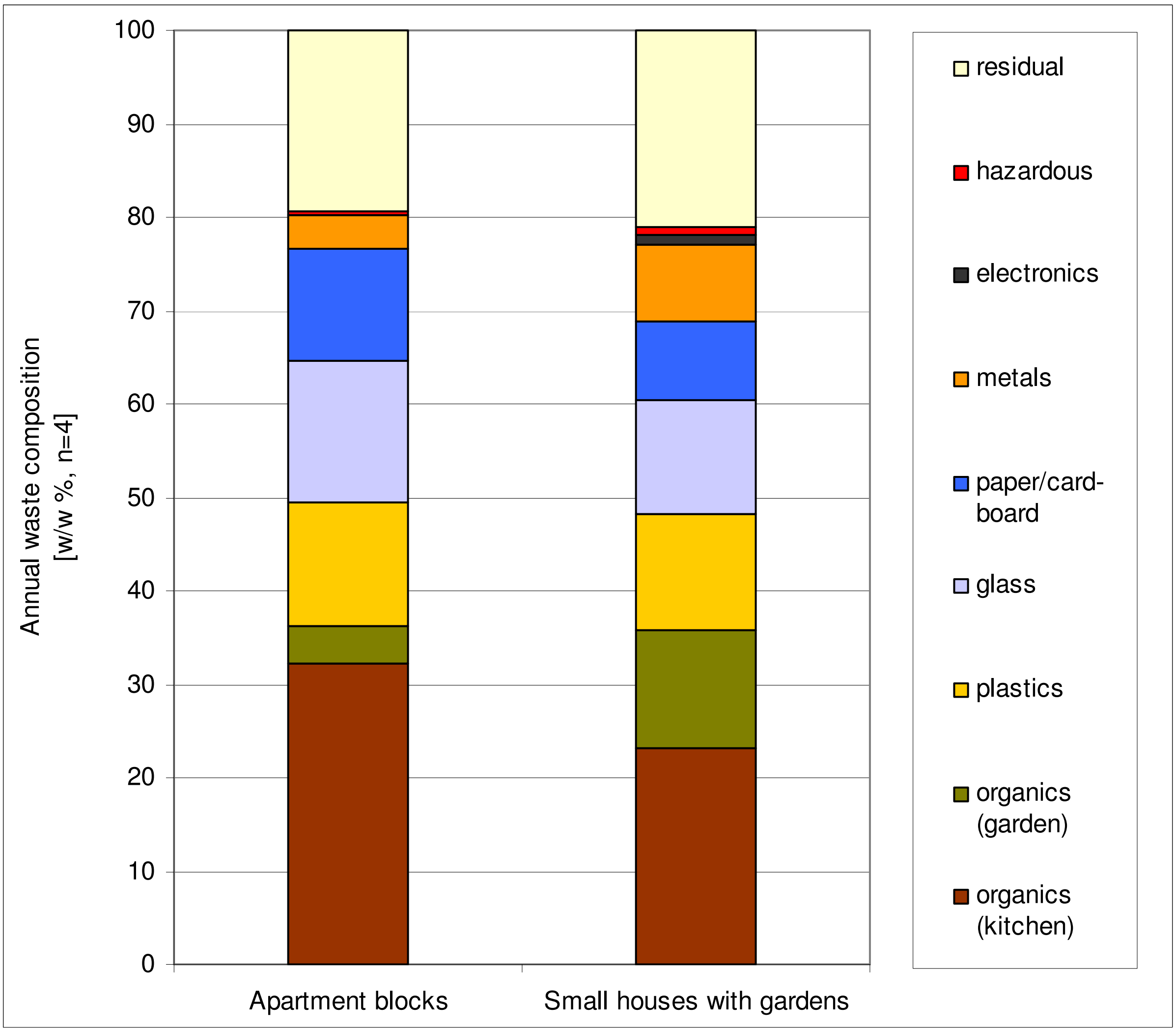

Figure 4-5: Comparison of annual waste composition between "apartment blocks" and "small houses with gardens" in Khanty-Mansiysk

4.1.4. Discussion of waste analyses data

Annual waste amount in Khanty-Mansiysk and Surgut

Significant dissimilarities were found in the amount per capita and year between Khanty-Mansiysk and Surgut (see Table 4-1). Approximately 50 inhabitants per container were given by the local administrations of both towns. This was the basis for the calculation of annual and daily amounts of waste per capita (see Appendix – Chapter 4, 4.1., Table A4.1.-1 to Table A4.1.-89). As the figure of inhabitants per container is the same, it could be assumed that the containers would also be filled similarly. However, the level to which the containers were filled showed clear differences. In Khanty-Mansiysk the containers were almost 100%

filled; the containers in Surgut on average to 50%. So, it can be surmised that this number - number of inhabitants per container- is not exact and will cause incorrect results for waste generation of each town. In addition, an accurately determined total number of inhabitants for Khanty-Mansiysk is not available because of its extreme migration boom. Therefore, other ways for calculating the annual waste amount had to be found.

The SWA-Tool recommends calculating the annual amount in three ways:

1. with the number of inhabitants;
2. with the number of households or
3. with the number of survey units in the entire research area such as a town.

1. For ***Khanty-Mansiysk***, I calculated 24,300 Mg a^{-1} domestic waste which would be equivalent to 50 capita per container and 70,000 inhabitants living in Khanty-Mansiysk. I already estimated the *number of inhabitants* of 70,000 as an exact number of inhabitants in Khanty-Mansiysk is unknown (see Chapter 3.2. Preparation of an integrated waste management concept). The population of Khanty-Mansiysk might already have reached 80,000 in 2007, which would mean an annual amount of domestic waste of 27,700Mg a^{-1}.
2. The *number of households* was extrapolated from the number of inhabitants. As the number of inhabitants is already only an estimate, a calculation of the entire amount of waste with the number of households does not seem appropriate.
3. 1,500 waste containers (*survey units*) exist in Khanty-Mansiysk. These containers contain not only domestic waste but also a mixture of domestic and commercial waste (municipal waste). An average of 51kg domestic waste per container per day was weighed during the waste analyses. Under the assumption that all containers with only household waste and municipal waste are filled comparably and the weight of the containers with municipal waste is comparable to containers with only household waste, 27,600Mg a^{-1} of waste were extrapolated for the annual waste amount.

In addition to the calculations based on the SWA-Tool, the scales in front of the landfill in Khanty-Mansiysk and the calculations by the local authorities also offer further annual numbers of waste amounts:
The scales in the front of the waste disposal site in Khanty-Mansiysk measure daily and therefore, the annual waste amount can be calculated. As mentioned in *Chapter 4.1.1 – Background information and identification of influencing factors for waste disposal systems in Khanty-Mansiysk and Surgut*, 15,550 Mg a^{-1} for six months were registered by weighing the municipal waste delivered to the landfill. Thus, a figure of 31,100Mg a^{-1} of waste per year can be estimated (Ivanowich, 2008, pers. comm.). (***Note:*** The scale was built in Khanty-Mansiysk in November 2007 and does not operate every day. I could observe that. Therefore, I have to assume that the number given is also only an estimation.)
The local administration also counted the municipal waste disposal trucks and calculated 247,000m^3 a^{-1} of municipal waste for 2007 (see Chapter 4.1.1 – Background information and identification of influencing factors for waste disposal systems in Khanty-Mansiysk and Surgut). According to Dahlén and Lagerkvist (2008), 1m^3 of solid household waste is equivalent to 100 kg[6], which means that this figure is equal to 24,700 Mg a^{-1}.
The various annual waste amounts are shown in Table 4-2.

[6] As a rule of thumb, 1m^3 of waste equals 100kg of solid waste in Sweden and also in other countries with similar cultural background (Dahlén, 2009, pers. comm.). I assumed that solid household waste generation in towns is similar in Sweden and in Russia.

Table 4-2: Extrapolation of annual waste amounts in Khanty-Mansiysk

Results of waste analysis (2006 - 2008)			Figures given by local authorities	
Household waste[A]		**Municipal waste**		
24,300 Mg a^{-1} Calculation based on a number of 70,000 inhabitants and 351 kg c^{-1} a^{-1}	**27,700 Mg a^{-1}** Calculation based on a number of 80,000 inhabitants and 351 kg c^{-1} a^{-1}	**27,600 Mg a^{-1}** Calculation based on number of survey units of 1,500 waste containers and 51kg per waste container	**31,100 Mg a^{-1}** First result of scale at the front of waste disposal site 2007-2008 (Ivanowich, 2008, pers. comm.)	**24,700 Mg a^{-1}** Result of counting the waste disposal trucks in 2007: 247,000 m^3 a^{-1} (m^3 - without pressure) (Kiseleva, 2008, pers. comm.)

Note: (A): Local authorities do not provide data on only household waste.

An exact figure for *domestic waste* only can not be calculated by using the SWA-Tool in Khanty-Mansiysk because:

- An exact number of inhabitants per container and the total number of inhabitants for the town Khanty-Mansiysk is not available.
- The number of containers for only private households is unknown.
- The figures based on weighing the trucks on a scale can not be subdivided into waste disposed of, solid household waste, or commercial waste, or mixed (commercial and household) waste.

Therefore, an exact calculation of amount of domestic waste via SWA-Tool is impossible.

It can be stated regarding *municipal waste* that the local administration only collects data on municipal waste and even provided varying figures for 2007: 24,700Mg a^{-1} and 31,100Mg a^{-1}.

However, the different figures calculated for annual amounts of domestic waste and municipal waste do not vary greatly. A figure for the former is necessary for further calculations. Based on the assumption that the number of inhabitants in the research area is correct and that 70,000 inhabitants lived in Khanty-Mansiysk in 2007, I presumed that 24,300Mg a^{-1} is the annual amount of *domestic* waste.

For ***Surgut***, the three ways aforementioned were also used to calculate the annual waste amount:

1. 65,000 Mg a^{-1} of waste were produced by the *inhabitants* in the research years 2006 and 2007, a figure that results from the waste analysis.
2. In contrast to Khanty-Mansiysk, a *number of households* exists, namely 108,580. But the number of waste containers only for households is not given. Therefore, a calculation based on the number of households can not be done.
3. 3,740 containers *(survey units)* exist for household and mixed waste of domestic and commercial waste (municipal waste) in Surgut. Approximately 32.3kg of waste per container per day was researched. Based on this measurement, 44,000Mg a^{-1} of waste is produced in one year. The same assumption was made as in Khanty-Mansiysk: The amount of waste

and weight of all containers is comparable although they contain commercial and/or domestic waste.

In addition to the calculations through the SWA-Tool recommendations, 490,000m^3 a^{-1} as the annual municipal waste amount is given by the local authorities (Kiseleva, 2008, pers. comm.). Waste disposal trucks were counted again. 49,000Mg a^{-1} of municipal waste is the annual result by calculating 100kg per 1 m^3.
A scale does not exist at the entrance of the landfill in Surgut and hence, there is no data regarding waste amounts (see Table 4-3).

Table 4-3: Extrapolation of annual waste amounts in Surgut

Results of waste analysis (2006 - 2008)		**Figure given by local authorities**
Household waste	**Municipal waste**	
65,000Mg a^{-1} Calculation based on a number of 290,200 inhabitants and 224 kg c^{-1} a^{-1}	**44,000Mg a^{-1}** Calculation based on a number of survey units of 3,740 containers and 32 kg per waste container	**49,000Mg a^{-1}** Result of counting the waste disposal trucks [m^3] in 2007: 490,000 m^3* a^{-1} (* - m^3, without pressure) (Kiseleva, 2008, pers. comm.)

Note: (A): Local authorities do not provide data on only household waste.

Both figures for municipal waste, 44,000Mg a^{-1} and 49,000Mg a^{-1}, are less than the figure for domestic waste; i.e. 65,000Mg a^{-1}. Furthermore, the former figures differ enormously from the latter. As domestic waste is a part of municipal waste, it was assumed that annual amount of municipal waste has to be higher than the annual amount of domestic waste. In contrast to Khanty-Mansiysk, there are more uncertainties in the extrapolatoin of the annual waste amount. There are two assumptions:

1. The number of waste containers indicated in the town Surgut by the local authorities is incorrect. The local authorities in Khanty-Mansiysk and Surgut provided a similar number of inhabitants per waste container (50). Under this precondition that 290,200 inhabitants live in Surgut and 50 inhabitants per container are the basis of calculation, almost 5,800 containers instead of 3,740 containers should exist in Surgut. If calculating with the number of 5,800 containers and an average of 32.3kg of waste per container, and assuming there is a daily disposal, the result would be 68,000Mg a^{-1} of domestic waste per year. This figure is comparable with the figure of 65,000Mg a^{-1} that is a result of the waste analysis carried out in the course of this dissertation.
2. Another landfill exists since a second landfill was mentioned on a landfill field visit to Surgut in Spring 2006 (Kiseleva, 2006, pers. comm.). Therefore, it can be assumed that not the entire amount of waste is disposed on the landfill from which the figure 49,000Mg a^{-1} originates.

Furthermore, a comparison between the amount of calculated annual domestic waste, 65,000Mg a^{-1}, and the amount of municipal waste, 44,000Mg a^{-1} or 49,000Mg a^{-1}, shows that

the latter is much lower than the former. As domestic waste is a part of municipal waste, the figure of the municipal waste should be higher than the figure for domestic waste.
65,000Mg a^{-1} of domestic waste means 224kg c^{-1} a^{-1} based on 290,200 inhabitants in Surgut. In contrast to that, 350kg c^{-1} a^{-1} of domestic waste is the estimated figure in Khanty-Mansiysk. As Surgut is a town with a better infrastructure such as shopping facilities etc. it was assumed that the locals of Surgut produce more, or at least an equal amount, of waste per capita as the residents in Khanty-Mansiysk, which is not the case. In order to arrive at an explanation, further research is necessary.
Finally, this discussion obviously demonstrates there is a huge deficit of reliable data for the calculation of an annual amount of domestic and/or municipal waste in Surgut. In contrast to Khanty-Mansiysk, there are no similarities and/ or overlapping between the individual figures of waste amount per year. Nevertheless, a figure for further calculation is necessary. As I am convinced that the figures of amount per capita and year in Surgut and in Khanty-Mansiysk can not differ so extremely, I concluded that a figure of 224kg c^{-1} a^{-1} or 65,000Mg a^{-1} of domestic waste which was calculated through the SWA-Tool can be assumed as the annual domestic waste amount, also based on the assumption that the number of inhabitants in the research areas is almost correct. As in Khanty-Mansiysk, further research for a figure of the annual waste amount is also essential in Surgut.

Statistical accuracy of annual results

At the beginning of research, the assumption was made that the natural variation coefficient of solid household waste in Khanty-Mansiysk and in Surgut is comparable to the natural variation coefficient of solid household waste in Europe, which means 30%. This assumption was made based on the experiences of ARGUS e.V. (Zwisele, 2006, pers. comm.). Therefore, a natural variation coefficient of 30% was supposed and 7.8% of sampling error (statistical accuracy/ confidence interval (mean)) with a 90% confidence level were defined for 40 sampling units in ***Surgut*** (see Chapter 3.2. Preparation of an integrated waste management concept).
Surgut demonstrates a natural variation coefficient of 42.1% and as a result, 17.8% sampling error at a 90% confidence level (see Table 4-4). One reason why the sampling error deviates from the assumption is that the figure for variance within the campaigns is evidently higher than that for variance among the seasons. That means that the deviation of waste amount is mainly in each campaign; i.e. deviation between the containers in each season is bigger than the deviation between the seasonal analyses. Especially the amount of waste on Monday was higher than the amount of waste on the other days of the week. Therefore, the supposed natural variation coefficient of solid household waste can not be verified with such a deviation. As the waste analyses were not implemented completely in Surgut, i.e a daily analysis from Monday till Friday was not implemented, further waste analyses are necessary for determination of the natural variation coefficient and sampling error of solid household waste in Surgut.
However, the waste amount of the non-analysed days was estimated. A calculation of the natural variation coefficient was also done with these estimations of waste amount of non-analysed days and the waste amount of analysed days. The result is a natural variation coefficient of 39.5% with 16.8% sampling error at a 90% confidence level (see Table 4-4). This demonstrates that a complete waste analysis, i.e. daily waste analysis from Monday till Friday, could almost lead to the pre-assumption of 30% natural variation coefficient.
Nevertheless, the expected sampling error could not be kept and further research as to why there is such a deviation among the waste amount per day is necessary.

Table 4-4: Overview of statistical accuracy of annual results in Surgut

Basis for calculation	Sampling size [m³]	Natural variation coefficient [%]	Sampling error at a 90% confidence level [%]
Starting point (planned)	40	30.0	7.8
Calculation based on analysed days	18	42.1	17.8
Calculation based on analysed days and on estimation of non-analysed days	40	39.5	16.8

In ***Khanty-Mansiysk*** the waste analysis was subdivided into two strata and the results of both strata were weighted for a final annual result. Therefore, a natural variation coefficient of 30% was supposed again and 11.0% of sampling error (statistical accuracy) with a 90% confidence level were defined for 20 sampling units (see Table 4-5).
The annual results of the waste analysis in ***Khanty-Mansiysk*** differ from the assumption with a natural variation coefficient of 43.5% and a sampling error of 36.3% on 90% confidence level. High deviations not only among the containers but also among the seasons cause the discrepancy between the defined sampling error of 11.0% and the calculated sampling error of 36.3%. For example, the mean of the overall result in winter is 119.6kg and 69.5kg in summer and demonstrates a huge difference between them. Additionally, taking samples of the planned 20 sampling units was not accomplished.
However, a calculation of natural variation coefficient and sampling error was also done based on analysed days and estimation of the non-analysed days. As a result, 37.9% as the natural variation coefficient could be calculated with 24.5% sampling error on 90% confidence level. In this case, the natural coefficient and the sampling error get closer to the initial situation; 30% for the natural variation coefficient and 11.0% for the sampling error. It bears remarking that further research is necessary as to why there are such deviations among the waste amounts per container within one waste analysis, and especially, why there are such deviations among the seasons in order to find the reason for this difference between the planned sampling error and calculated sampling error at a 90% confidence level.

Table 4-5: Overview of statistical accuracy of annual results in Khanty-Mansiysk

Basis for calculation	Sampling size [m³]	Natural variation coefficient [%]	Sampling error at a 90% confidence level [%]
Starting point (planned)	20	30.0	11.0
Calculation based on analysed days	12	43.5	36.3
Calculation based on analysed days and on estimation of non-analysed days	20	37.9	24.5

Annual composition of waste in Khanty-Mansiysk and Surgut

The annual compositions of waste in Khanty-Mansiysk and in Surgut demonstrated only few differences. The noticeable differences are in the proportions of plastic, glass and hazardous waste:

- More glass and plastic are produced in Surgut than in Khanty-Mansiysk.

- In contrast, more hazardous waste is produced in Khanty-Mansiysk than in Surgut.

It was expected that in Surgut more hazardous waste such as batteries is produced than in Khanty-Mansiysk because the town Surgut is bigger and has better infrastructure (shopping facilities, cinemas, restaurants, opera etc.). One reason for less hazardous waste amount in Surgut than in Khanty-Mansiysk could be the sample size. The sample size was smaller in Surgut than in Khanty-Mansiysk. As that is only an assumption, more waste analyses are necessary in order to identify reasons for significantly less hazardous waste amount in Surgut.

Testing of assumptions regarding domestic waste

At the beginning of the research for the waste analysis (see Chapter 4.1.1 – Background information and identification of influencing factors for waste disposal systems in Khanty-Mansiysk and Surgut), it was assumed that several factors would change the composition of the domestic waste:

- The social changes and changes in lifestyle as well as increasing income have an influence on waste amount and composition.

Regarding the daily waste generation per capita, approximately 0.7 to 1.3kg c^{-1} d^{-1} were produced (Appendix – Chapter 4, 4.1. Table A4.1.-1 to Table A4.1.-89). The assumption that the amount per day and capita would increase within the two years of the research could not be conclusively verified. One reason is the uncertain number of residents per container which does not allow an exact calculation. Another reason might be the short time period. In Surgut the waste analyses were carried out in one year only; in Khanty-Mansiysk in two years only. In addition to that, no historical data exist for a comparison to be made. It can be assumed that the time period was insufficient for analysing an increase in the amount of waste.

Although the mean waste amount in the containers has increased during the years of the waste analyses, this does not allow a conclusion regarding the waste increase per capita since the number of inhabitants per container is uncertain. Finally, though the waste analysis could not demonstrate an increase in the amount of waste in both Khanty-Mansiysk and Surgut, it can be expected because of the results of waste prognosis. Those results show a rise in the amount of waste for the next five years (see Chapter 4.3.1 Forecasting waste amount in Khanty-Mansiysk and Surgut).

A variation in the waste composition is perceivable from an increasing amount of electronic waste. In 2006, no electronic waste was found, but the waste analysis in Khanty-Mansiysk in 2008 for small houses with gardens already demonstrated 2.3% electronic waste. The social transformation has already had an influence on the waste composition, and it is very important to consider these results in future waste management concepts, especially in building up waste disposal mechanisms for new waste streams.

- The varying daily behaviour of residents in correlation to their residential structure such as houses without or with a garden could change the amount of organic waste.

As mentioned above, the overall amount of organics (kitchen) and organics (garden) is similar in both residential structures in ***Khanty-Mansiysk*** but with different amounts of organic (kitchen) and organic (garden) waste within each residential structure (see Table 4-6).

Finally, the hypothesis that residents of "small houses with gardens" produce less organic waste in total could not be verified in Khanty-Mansiysk. They generate lower amounts of organics (kitchen) but they produce more organic (garden) waste than residents of apartment blocks, especially in spring and autumn. The statements provided in the questionnaires support this result. Residents from small houses with gardens do not compost their organic waste but instead use organic waste to feed their pets (see Chapter 4.2.1 Results of questionnaires in Khanty-Mansiysk).

As opposed to Khanty-Mansiysk, the analyses in ***Surgut*** demonstrate that apartment blocks produce more organic (kitchen) and organic (garden) waste than small houses with gardens (see Table 4-6). The results in Surgut show an unusual outcome because the residents of small houses produce hardly any organics (garden). A reason for this result can be that the analysed waste amount for small houses with gardens was too small and not enough samples were taken. The aim of this part of the analysis in Surgut was only to get additional information from small houses and, consequently, it is more a tendency than a reliable result. A second reason could be that the gardens are no longer used for gardening. Again, only 1% of the total residential structure is occupied by small houses, and therefore this stratum does not play a key role in waste generation.

Table 4-6: Annual proportions of organics (kitchen) and organics (garden) in Khanty-Mansiysk and Surgut [w/w %]

	Residential structure	Organics (kitchen)	Organics (garden)	Total
Khanty-Mansiysk	Apartment blocks	32.2	4.1	36.3
	Small houses with gardens	23.2	12.7	35.9
Surgut	Apartment blocks	27.4	4.5	31.9
	Small houses with gardens	21.2	0.3	21.5

In addition, the seasonal results of organics (garden) in Surgut showed that the most organics (garden) is produced in autumn (see also Figure 4-4). The high proportion of organics (garden) in Surgut in autumn resulted from street cleaning. It was mostly leaves from trees which are located around the waste containers. Although the aim of the waste analyses was to analyse solid household waste only it could not be implemented in this case.

- Differences in the cleaning and cooking behaviours on weekdays and weekends could have an effect on both waste composition and amount.

The analysis of the daily distribution demonstrates that there is a higher amount of organics (kitchen) on Mondays in Khanty-Mansiysk and Surgut. The amount of organics (kitchen) waste generated is consistent on the other days in Surgut but decreases in Khanty-Mansiysk from Monday till Friday (see Figure 4-2). This shows that daily behaviour does influence the waste composition and needs to be taken into account.

4.2. Public participation

4.2.1. Results of questionnaires in Khanty-Mansiysk

An overview of the results of the χ^2-tests and correlation factors are given in Table 4-7 at the end of this chapter. A total overview of all calculations, critical numbers and interpretations are given in Appendix – Chapter 4, 4.2.

Questions regarding the social situation

How many people live in your household?

The average number of people per household is unknown in Khanty-Mansiysk because of the enormous migration and as registration is not mandatory. For a calculation of the waste amount per capita this number plays an important role. Therefore, a useable number of people per household had to be discovered through questionnaires. The results of the first question show that an average of 4 persons live in small houses with gardens and 3 persons live in flats in apartment blocks.

The χ^2*-test* does not reach a significant result (χ^2 (1, N = 198) = 0.33, p = 0.05). Therefore, a statement about whether or not a link exists between the residential structure and the number of people living in the household can not be made.

Since when have you lived in Khanty-Mansiysk?

Were you born in Khanty-Mansiysk?

Because of the migration boom, both of these questions seemed important because changes of waste amount can be expected in certain times such as holidays as it was assumed that newcomers would travel to their families that live in other regions. Almost half of the people interviewed from small houses with gardens were born in Khanty-Mansiysk (SH: 44). Compared to this result, 62 residents of apartment blocks moved to Khanty-Mansiysk during the last years.

The χ^2*-test* produced a significant result (χ^2 (1, N = 183) = 4.18, p= 0.05) (see Table 4-7) and formed a link with a small correlation (Φ = 0.15) between the first characteristic “residential structure” and the second characteristic “migration”. That means more people that live in apartment blocks moved to Khanty-Mansiysk and more people that live in small houses with gardens were born in Khanty-Mansiysk.

How much money is available to your household per month?

To get a picture of the social conditions, questions about income were asked as well. Residents of small houses earn an average 17,300 roubles per month (approximately 467€), compared to inhabitants living in apartment blocks earning an average 21,900 roubles per month (approximately 592€).

The χ^2*-test* does not get a significant result (χ^2 (1, N = 114) = 0.28, p = 0.05). Therefore, a conclusion about a link or no link between the residential structure and the salary can not be made.

Questions regarding recent waste disposal

How much money do you pay for waste disposal?

Results for the payment of waste charges showed huge differences. 63 interviewees of apartment blocks and 70 interviewees of small houses with gardens said either that they do not pay any fees or have no idea whether they do, or they made no statement. 37 of the inhabitants from apartment blocks and 30 of inhabitants from small houses stated that they pay waste disposal fees. Only one resident of small houses with gardens pays more than 550 roubles (14.90€) per month. On average, people from small houses with gardens pay 155 roubles (4.20€), inhabitants from apartment blocks 160 roubles (4.30€).

The χ^2*-test* regarding the answers of "who pays waste disposal fees" reaches a significant result (χ^2 (1, N = 135) =10.35, p= 0.05) with a medium correlation (Φ = 0.28). Therefore, it can be stated that the residential structure and the payment have a link: More inhabitants from apartment blocks pay waste disposal fees compared to inhabitants from small house with gardens.

Although the question regarding payment only offers to fill in how much money they pay for waste disposal per month, additional answers were given by the involved people and so, the detailed reasons for non-payment can be listed. The results show that most of the inhabitants of small houses do not pay for waste disposal (SH: 49) and most of the inhabitants of apartment blocks do not know whether they pay for waste disposal (AB: 22). A very high figure of *'no statement'* (AB: 22; SH: 12) was also an answer to this question.

The χ^2*-test* for the answers in regard to "statement for non-payment" has a significant result (χ^2 (1, N = 99) = 16.25, p = 0.05) with a strong correlation (Φ = 0.41). Therefore, the "residential structure" has a close link to "statements for non-payment" and proved that people from small houses do not pay for the waste disposal and people from apartment blocks do not know whether they pay fees for waste disposal.

Do you have any problems with the waste disposal or the waste containers?

When asked about their satisfaction with the waste disposal system in Khanty-Mansiysk, most of the inhabitants stated that they are satisfied with the disposal (AB: 81 and SH: 68) and do not have any problems with the current system. More people from small houses with gardens (SH: 27) than people from apartment blocks (AB: 14) have trouble with the waste disposal.

The main reason for dissatisfaction mentioned by the inhabitants of both residential structures is irregular waste disposal which results in littered streets and container places. Unlocked waste containers are also an issue for residents in apartment blocks. Inhabitants of small houses complained about the long way to the waste containers.

The χ^2*-test* regarding the satisfaction of waste disposal got a significant result (χ^2 (1, N = 190) = 5.26, p = 0.05) with a small correlation (Φ = 0.17). However, there is a connection between the "residential structure" and the "satisfaction with the waste disposal". The inhabitants of small houses with gardens are not as satisfied with the waste disposal as the inhabitants of apartment blocks.

Did you buy any electronics such as a television or computer in the last year?
Did you dispose of any electronics in the last year?

The next two questions examined consumer behaviour with regard to electronic equipment. The aim of the questions was to find out whether new waste disposal systems need to take into account a new fraction. While more than half of the people questioned bought electronics in the last year (AB: 56, SH: 46), almost half of the other people have not bought electronics yet (AB: 43, SH: 54). The next question refers to whether they already discard electronics. Only a few of the inhabitants interviewed threw away electronics in the last year (AB: 10, SH: 21) and most of inhabitants asked say that they haven't disposed of electronics yet. They discarded the electronic waste either in the waste container next to their houses or they gave it to their relatives.

The χ^2-*test* regarding purchasing electronics does not have a significant result (χ^2 (1, N = 200) = 2.0, p = 0.05). The distribution of answers within the χ^2-*test* is almost equal. Therefore, a statement can not be made whether a lot of people bought electronics in the last year. In contrast to that, the χ^2-*test* for the question concerning disposal of electronics produces a significant result (χ^2 (1, N = 200) = 4.62, p = 0.05), with a small correlation (Φ = 0.15). That is why it can be stated that more electronics were disposed of in the residential structure "small houses with gardens" than in the residential structure "apartment blocks".

How do you treat your organic waste?
The type of treatment of organic waste was the next question. The assumption was that inhabitants of small houses with gardens would compost their organics in contrast to inhabitants of apartment blocks. Only 27 of the inhabitants of small houses with gardens questioned compost their organics. It should be pointed out that 31 people from small houses gave the additional information that they feed their pets with their food leftovers.
The significance between "residential structure" and "treatment of organics" was determined. *The* χ^2-*test* for the question reaches a significant result (χ^2 (1, N = 200) = 25.21, p = 0.05) with a medium correlation (Φ = 0.36). Therefore, there is a link between the residential structure and disposal of organics.

The significance of composting within the residential structure "small houses with gardens" and "feeding pet" was not tested. Some of the people asked answered this question with a double-answer (composting and feeding pets). Therefore, the characteristics were no longer independent of one another. Furthermore, statements regarding pet-feeding were mentioned additionally without further questions. It can be assumed that is not a complete survey.

Questions regarding a new waste management concept
If the new system includes a recycling progress, would you collect waste such as plastic waste separately in your flat?
The penultimate question refers to whether in the future the interviewed person is willing to separate his waste in his own house/apartment and then dispose of it instead of not separating at all. The question was asked to find out if people would change their behaviour and support a new waste disposal system that includes recycling. 80 of inhabitants of apartment blocks and 80 of residents of small houses with gardens would be willing to separate the waste already in their kitchen. In contrast, 18 of inhabitants of apartment blocks and 20 of residents of small houses with gardens would not separate the waste already in their kitchen.
The χ^2-*test* for this question does not demonstrate a significant result (χ^2 (1, N = 198) = 0.09, p = 0.05) with a very small correclation (Φ = 0.02) as the distribution of answers within the χ^2-*test* shows that this distribution is almost equal between the answers for "willing for separation" and "not-willing for separation" within both residential structures. Therefore, a conclusion about a link between residential structure and willingness to recycle can not be drawn.

If you have any advice or wishes regarding waste disposal or information about waste, please mention it here.
The last question was related to requirements of a new waste management concept in Khanty-Mansiysk. Most interviewees stated that a recycling system should be introduced. The wish for a higher number of waste containers is in second place and results from the complaints regarding littered streets. Only then is regular disposal noted. Other comments refer to capacity building and retaliation for polluting the environment. New or other containers are also requested by the inhabitants.
This question was an open question for wishes, and therefore a significance test is not appropriate.
An overview of all results is given in Table 4-7.

Table 4-7: Results of χ^2-tests and correlation factor

Research object	**N**	χ^2	**Φ**	**Significant result on 95% C.L., $\chi^2 > 3.84$ (Bortz, 2005)**
Questions regarding the social situation				
Significant interdependence between number of person per household and residential structure	198	0.33	0.04	no
Significant interdependence between migration and residential structure	183	4.18	0.15	yes
Significant interdependence between income and residential structure	114	0.28	0.05	no
Questions regarding recent waste disposal				
Significant interdependence between payment for waste disposal and residential structure	135	10.35	0.28	yes
Significant interdependence between knowledge about payment and residential structure	99	16.25	0.41	yes
Significant interdependence between problems with waste disposal and residential structure	190	5.26	0.17	yes
Significant interdependence between purchasing electronics and residential structure	200	2.00	0.10	no
Significant interdependence between disposal of electronics and residential structure	200	4.62	0.15	yes
Significant interdependence between treatment of organic waste and residential structure	200	25.21	0.36	yes
Questions regarding a new waste management concept				
Willingness of separate collection of waste	198	0.09	0.02	no

4.2.2. Discussion of questionnaire results

Questions to the social situation

The hypothesis that more people living in the apartment blocks had moved to Khanty-Mansiysk and more people of the small houses (also the original houses of Khanty-Mansiysk before the migration and construction boom started) already lived in Khanty-Mansiysk could be proven. It was assumed that people from apartment blocks have not lived in Khanty-Mansiysk for long and they would leave the town for public and other holidays, as opposed to people from small houses who will stay in the town for public holidays. Because of the significant result, it can be assumed that more people from apartment blocks will leave the town during holidays. With the intention to establish whether less waste is generated on and during public and other holidays, these questions were asked and this fact has to be considered in the waste management concept.

According to the questions regarding the number of persons per household – the χ^2-test for this question does not reach a significant result as the distribution of answers within the χ^2-*test* demonstrate an equal distribution; therefore, it can be assumed that there is not a significant difference between the number of persons per household within both residential structures.

Regarding the question of income, it can only be assumed that inhabitants living in small houses with garden receive a smaller salary in contrast to apartment blocks where inhabitants with a higher income live. This question does not show significant results and therefore a statement about links or no a link between the residential structure and income can not be made.

Questions regarding recent waste disposal

The significant results regarding the payment for waste disposal strengthen the thesis that inhabitants of apartment blocks have hardly any knowledge about what and if they are paying. More transparency in the refuse charge system is necessary because a new concept will include a higher price for waste disposal. The success of the implementation of waste management also depends on the acceptance of the refuse charge system by the inhabitants. Therefore, inhabitants have to know which charge, for which treatment and why they have to pay. The development of the new concept should also include further public discussion, also about the waste disposal fees.

The significance of the question regarding “satisfaction” shows two results. On the one hand, the people are quite satisfied with the waste disposal system, while on the other satisfaction depends on the residential structures. That means an integrated waste management concept has to deal with the problems of waste disposal in the different residential structures (“apartment blocks” and “small houses with gardens”). Several problems were mentioned, mainly by inhabitants from “small houses with gardens”. A new concept should deal with these complaints and try to find solutions.

The question regarding purchase of electronics does not show a significant result. In contrast to that, the question regarding disposal of electronics does demonstrate a significant result. It can be assumed that the amount of electronic waste will increase because the results of the waste analysis also show that the amount of electronics increased between Spring 2006 and Summer 2008, mainly in the residential structure small houses with gardens. Additionally, a global increase of electronic waste is already proven (UNEP, 2008). Therefore, future waste management needs to consider this additional type of waste.

Although the question regarding the treatment of organic waste showed a significant result (disposal of organic waste depends on the residential structure), it could not be evidently proven that the inhabitants of small houses compost their organic waste. Less organic waste is produced by residents with a garden because they feed their pets, but they also produce a high amount of organic (garden) waste. For future research it might be interesting to find out why so few inhabitants compost their waste. Supporting private composting could reduce the proportion of organic waste in the future.

Questions regarding a new waste management concept

The question regarding willingness to recycle does not demonstrate a significance as the distribution of answers within the χ^2 – *test* as the distribution of answers is very equal. That could mean that there are no differences between the residential structures apartment blocks and small house with gardens as well as the willingness to recycle. As almost 80 of 100 interviewees per residential structure answered that they would collect their waste separately. Nevertheless, other questionnaires which are already used for the determination of willingness for changes in waste management systems all over the world very often show a disadvantage: Although interviewed persons demonstrate a high willingness to separate waste, they do not do so in practice. “Expressed willingness” and “actual recycling rate” always differ (Dahlèn et al., 2009). Hence, a future waste disposal system cannot act on 80% willingness (corresponds to 160 interviewees/agreement of 200 questionnaires) to separate waste, which was the result of the questionnaires. However, it also demonstrates that people in Khanty-Mansiysk are aware of the importance of recycling and that the current waste disposal system needs to change. Therefore, the implementation of a new waste disposal system has a chance and can reduce risks to human health and the environment.

The last question aimed to involve the residents in the development of future waste disposal strategies. It can be stated that the answers given are a mix of solutions for technical problems as well as environmental protection and support the thesis that the inhabitants of Khanty-Mansiysk are interested in improving the waste disposal system. As these answers can not be tested through a significance test, a common opinion for solutions of an integrated waste management concept can only be supported by implementing further contacts to the inhabitants with additional questionnaires or steering committees as recommended in the manuals for preparing integrated waste management concepts by the EC (2003) and The World Bank (2001).

Finally, the results of the survey shows that the inhabitants interviewed are more or less satisfied with the current waste disposal and willing to support the recycling and separation of re-usable materials in their households, which is a good basis for the implementation of a new system. The results also demonstrate several problems with which a new waste disposal management will have to deal. An example is the current non-transparency of charges for waste collection.

4.3. Waste prognosis

4.3.1. Forecasting waste amount in Khanty-Mansiysk and Surgut

The figures of waste amount used for the prognosis in 2012 are based on the waste analysis (compare Chapter 4.1.2 Quantification of waste amount in Khanty-Mansiysk and Surgut). The future number of inhabitants in Khanty-Mansiysk is estimated by the local authorities at 100,000 residents in 2012 (Tomsha, 2007, pers. comm.). The future figure of residents in Surgut is unknown according to the urban administration (Kaz'mina, 2008, pers. comm.). Taking into account the recent growth, I estimated a continuing growth by almost 1,000 persons per year and therefore, 295,000 inhabitants could be expected in 2012 (see Table 4-8). For a detailed listing of all calculations/waste prognoses see Appendix – Chapter 4, 4.3., Table A-4.3.1 to Table A-4.3.5.

Table 4-8: Basis data for the prognosis of waste amount

	Current waste amount per capita in 2007 [kg c^{-1} a^{-1}]	**Annual waste amount in 2007** [Mg a^{-1}]	**Current number of residents in 2007**	**Estimated number of residents in 2012**
Khanty-Mansiysk	347	24,300	70,000	100,000
Surgut	244	65,000	290,200	295,000

According to the calculation by the prognosis software tool (PST), waste generation will increase from 347kg c^{-1} a^{-1} to 365kg c^{-1} a^{-1} (data set 1) or to 372kg c^{-1} a^{-1} (data set 2) in Khanty-Mansiysk. Waste generation in Surgut will increase from 224kg c^{-1} a^{-1} to 242kg c^{-1} a^{-1} (data set 1) or to 246kg c^{-1} a^{-1} (data set 2).

The EC guidelines (2003) recommend a low and a high hypothesis for waste prognosis which are both based on population growth and waste arising (see Chapter 2.1.4 Tools for waste prognosis and Chapter 3.5 Prognosis of solid household waste). In regard to the recommendations, the low hypothesis is 231kg c^{-1} a^{-1} for Surgut and 358kg c^{-1} a^{-1} for Khanty-Mansiysk. The result for the high hypothesis shows 235kg c^{-1} a^{-1} for Surgut and 365kg c^{-1} a^{-1} for Khanty-Mansiysk for 2012.

As mentioned above, Russian experts who are also working on waste management concepts in Russia were asked for waste prognosis: Slyusar (2008, pers. com.) always bases calculations on an annual increase of 0.3% in the waste amount. That means an increase to 227kg c^{-1} a^{-1} in Surgut and to 352kg c^{-1} a^{-1} in Khanty-Mansiysk. Ulanova (2008, pers. com.) expects an increase between 20 and 30 kg per capita within 5 years. As concerns annual waste generation, the residents of Khanty-Mansiysk will produce between 367kg c^{-1} a^{-1} and 377kg c^{-1} a^{-1} and the inhabitants of Surgut between 244kg c^{-1} a^{-1} and 254kg c^{-1} a^{-1}.

To summarise, the prognosis of domestic waste using different tools varies between 227kg c^{-1} a^{-1} and 254kg c^{-1} a^{-1} in ***Surgut*** for the year 2012. This means a difference between the minimum and maximum of 27kg c^{-1} a^{-1}. For ***Khanty-Mansiysk***, the forecasts of domestic waste vary between 352kg c^{-1} a^{-1} and 377kg c^{-1} a^{-1} for the year 2012. 25kg c^{-1} a^{-1} is the difference between the maximum and minimum prognosis of domestic waste for 2012 for Khanty-Mansiysk.

The overall results of all waste estimations for Surgut and Khanty-Mansiysk are shown in Figure 4-6.

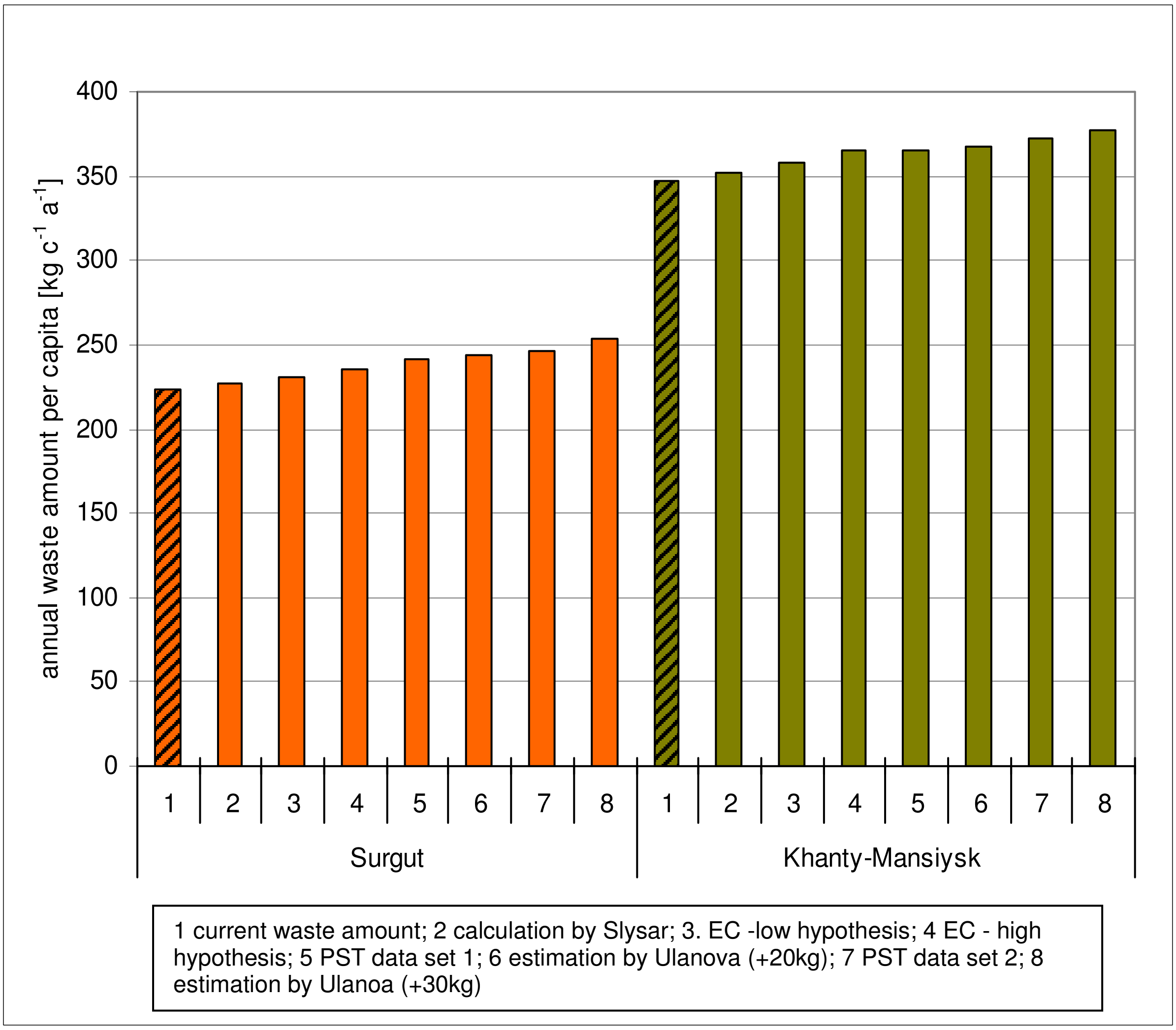

Figure 4-6: Comparison of current and forecasted amounts of domestic waste. Amount is forecasted for 2012 based on different calculations

4.3.2. Forecasting waste composition in Khanty-Mansiysk and Surgut

In regard to the estimation of quality, the prognosis tool calculates the percentages of the different waste proportions such as organics and plastics. The forecasted waste compositions for 2012 are comparable as analysed in 2007. Solid household waste mainly consists of organics, plastics, glass and paper/cardboard in equal ratios in Khanty-Mansiysk and Surgut in 2007 and 2012 (see Figure 4-7). Data set 1 and data set 2 result in the same percentages of waste composition. Therefore, the differences within data set 1 and data set 2 do not play a role regarding waste composition (see Appendix – Chapter 4, 4.3., Table A4.3.6 to A-4.3.8).

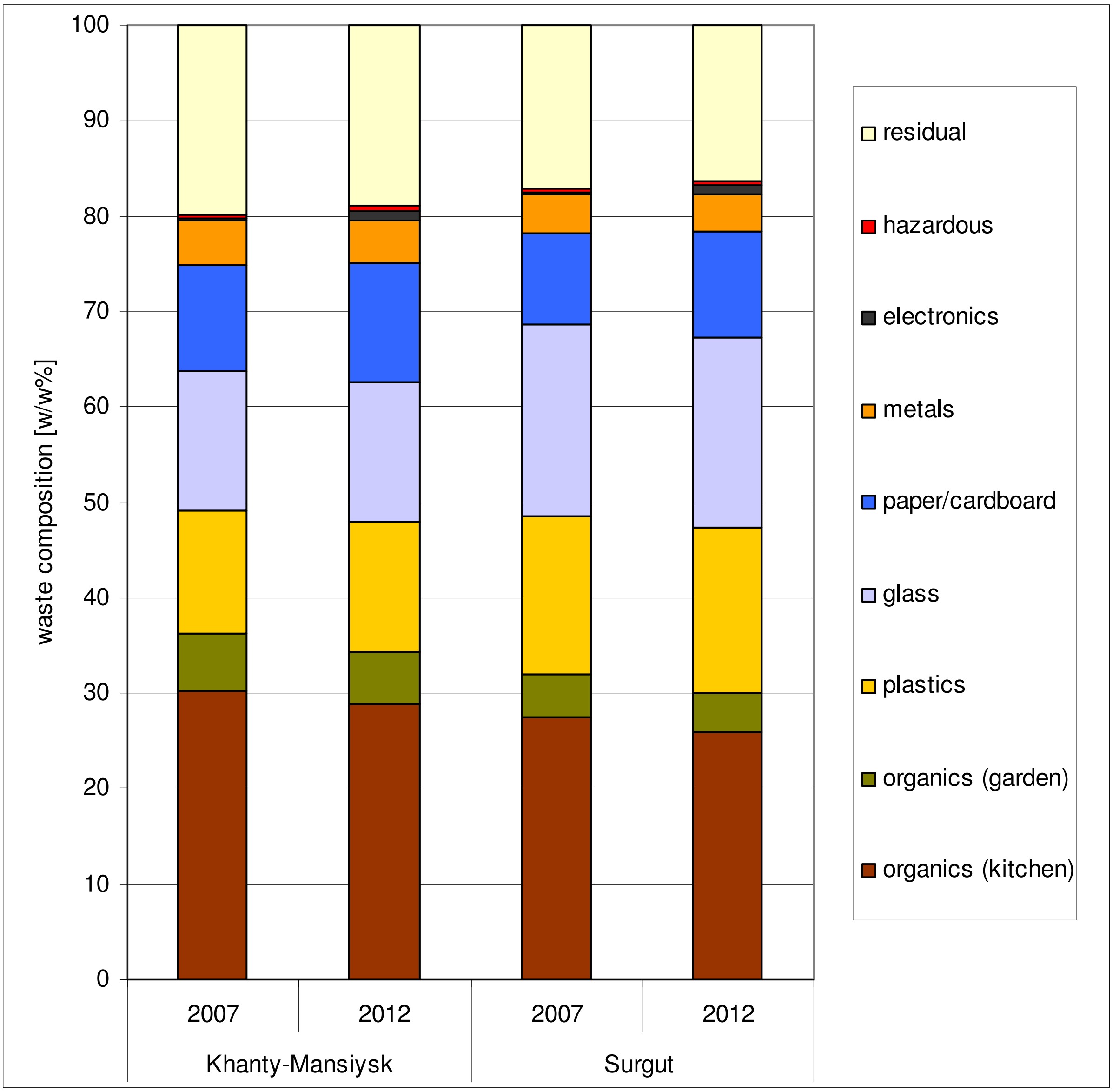

Figure 4-7: Comparison of current and forecasted waste compositions in Khanty-Mansiysk and Surgut

The guideline by the EC (2003) only calculates the waste amount, and estimations of waste composition are not included.
Both Russian experts said that a future waste composition prognosis is complicated. Slyusar (2008, pers. com.) explained that an estimation of changes in the composition is very difficult because no historical data exist, but she always takes into account that the percentage of paper and plastic waste will increase. Ulanova (2008, pers. com.) said that it is not calculable at the moment because data are missing and social life is changing significantly - also affecting the type of waste generated.

In order to estimate a possible future waste composition, I assume that a similar development caused by the preconditions of globalisation, such as the spread of a western lifestyle and increased consumption (Nuscheler, 2006) could infiltrate waste composition worldwide. In order to enable comparison on an international level in the fields of waste, the towns of Khanty-Mansiysk and Surgut are compared with Helsinki, Finland, and Berlin, Germany, both highly developed cities with a well-organised waste disposal and recycling system. In addition, Helsinki also has similar climate conditions to Surgut and Khanty-Mansiysk. This plays an important role regarding the organic proportion of the waste.

Usually, more organics are produced in the southern hemisphere than in the northern because of lifestyle and environment (Zwisele, 2008, pers. comm.). In Helsinki and Berlin solid household waste is separately collected as residual waste and recyclable waste. The figures of both types of waste were combined into one in order to compare the entire solid household waste composition with Khanty-Mansiysk and Surgut. Neither Khanty-Mansiysk nor Surgut has a system of separate waste collection.

The detailed differences between the four cities regarding the percentages of organic waste, lightweight packaging, glass, paper/cardboard, electronics, hazardous and residual are shown in Figure 4-8. (***Note:*** Lightweight packaging is the combination of metals and plastic. Individual data of metals and plastic of the separated collected waste are not available for Berlin because of the collection system in Berlin (Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz, 2008a, pers. comm.):

- The proportion of organic waste is quite similar in all cities.
- The proportions of lightweight packaging and glass are higher in Surgut and Khanty-Mansiysk than in Helsinki and Berlin.
- In contrast to that, the proportion of paper/cardboard is higher in Helsinki and Berlin than in Khanty-Mansiysk and Surgut.
- Regarding the electronic waste, Khanty-Mansiysk, Surgut and Helsinki demonstrate a similar proportion. In contrast to that, Berlin showed the highest proportion of electronics.
- The proportions of hazardous waste and residual waste are quite similar in all four cities.

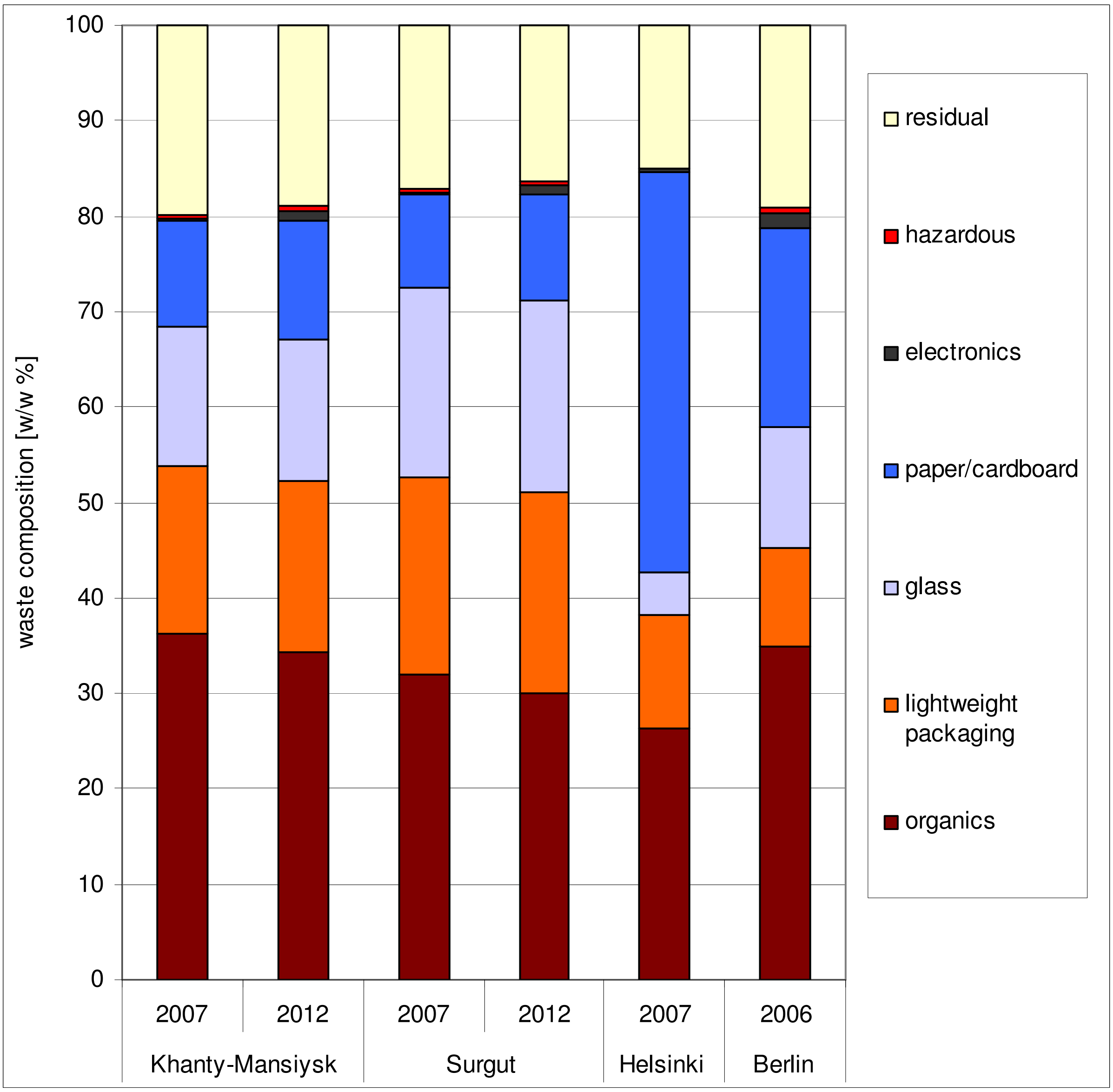

Figure 4-8: Comparison of waste composition of Khanty-Mansiysk, Surgut, Helsinki and Berlin

4.3.3. Sensitivity analysis

Waste amount

Regarding the prognosis of the waste amount, three key factors exist and which of these three factors has the main impact on the results of future waste amount was tested by means of sensitivity analyses within the prognosis software tool. Those key factors are:

1. the current annual municipal/household waste amount in Surgut and in Khanty-Mansiysk;
2. a well-determined number of current inhabitants in Khanty-Mansiysk and prognosis of future number of inhabitants, especially in Surgut and
3. both data sets for the prognosis tool.

Testing current waste amount

In *Chapter 4.1.4. - Discussion of waste analyses data,* it was demonstrated that there are great uncertainties regarding the annual amount of solid household and/or municipal waste. Therefore, all different annual waste amounts which are given in *Chapter 4.1.4., Table* **4-2** *and Table 4-3* were tested with the waste prognosis tool, with data set 1 and 2.

As the calculation within the software tool depends on the number of inhabitants, all figures of annual waste amount were tested with the number of inhabitants of 70,000 in Khanty-Mansiysk.

The difference between the current waste amounts and their forecasted amounts is the same: between 17 and 18kg c^{-1} a^{-1} in data set 1, and between 24 and 25kg c^{-1} a^{-1} will increase in data set 2 in ***Khanty-Mansiysk*** from the current waste amount in 2007 to the forecasted waste amount in 2012 (see Table 4-9).

In ***Surgut***, data set 1 also demonstrates a rise between 17 and 18kg c^{-1} a^{-1} as in Khanty-Mansiysk; and in data set 2, to between 21 and 22kg c^{-1} a^{-1} (see Table 4-10).

Table 4-9: Sensitivity of annual amounts and prognosis based on social data in Khanty-Mansiysk in 2012

			Data set 1		**Data set 2**	
	Annual amount in 2007 based 70,000 inhabitants (compare Table **4-2**) [Mg a^{-1}]	Current amount per capita in 2007 [kg c^{-1} a^{-1}]	Forecasted amount in 2012 [kg c^{-1} a^{-1}]	Difference between current and forecasted amount [kg c^{-1} a^{-1}]	Forecasted amount in 2012 [kg c^{-1} a^{-1}]	Difference between current and forecasted amount [kg c^{-1} a^{-1}]
Calculation based on inhabitants	24,300	347	365	**18**	372	**25**
Calculation based on number of containers	27,600	394	412	**18**	419	**25**
Calculation based on measurement of scales	31,100	445	462	**17**	469	**24**
Calculation based on number of disposal trucks	24,700	353	370	**17**	377	**24**

Table 4-10: Sensitivity analysis regarding different annual amounts based on 290,200 inhabitants in Surgut

			Data set 1		**Data set 2**	
	Annual amount in 2007 based on 290,200 inhabitants (compare Table 4-3) [Mg a^{-1}]	Current amount per capita in 2007 [kg c^{-1} a^{-1}]	Forecasted amount per capita in 2012 [kg c^{-1} a^{-1}]	Increase between current and forecasted amount [kg c^{-1} a^{-1}]	Forecasted amount per capita in 2012 [kg c^{-1} a^{-1}]	Increase between current and forecasted amount [kg c^{-1} a^{-1}]
Calculation based on inhabitants	65,000	224	**242**	**18**	**246**	**22**
Calculation based on number of containers	44,000	159	**176**	**17**	**181**	**22**
Calculation based on number of disposal trucks	49,000	338	**356**	**18**	**360**	**22**

Finally, it can be stated that there is a linear correlation between the current waste amount and forecasted waste amount. Nonetheless, as it is the basis of the calculation for waste prognosis, reliable data regarding current waste amount are necessary.

Testing number of population

In ***Khanty-Mansiysk*** the current number of inhabitants is unknown. With an increase of 5,000 people, a number between 70,000 and 80,000 inhabitants was entered in the programme. The future number of inhabitants also includes a 5,000 step from 90,000 to 100,000. 100,000 residents as the maximum were assumed by the local authorities for 2012 (Tomsha, 2007, pers. comm.).

In ***Surgut***, the figure of 290,200 inhabitants is given by the local authorities. A forecasted number of inhabitants does not exist in Surgut by the local administration (Kaz'mina, 2008, pers. comm.). I assumed 295,000 for 2012 based on the current increase of number of inhabitants in Surgut. Under the assumption that the number could vary between +1% and -1% (292,000 and 298,000 inhabitants), a sensitivity analysis was implemented. These figures were used for the current and future number of inhabitants. A migration boom as in Khanty-Mansiysk is not listed. Therefore, a smaller increase of inhabitants should be reflected in the assumptions and sensitivity analyses (see Appendix – Chapter 4, 4.3., Table A4.3.-10 to Table A4.3.-11).

The result of testing the sensitivity of number of population shows that the number of inhabitants does not play an important role. Between 17 and 18kg c^{-1} a^{-1} (data set 1) or between 22 and 23kg c^{-1} a^{-1} (data set 2) is always the difference between the current and future waste amount in both Khanty-Mansiysk and Surgut.

The ratio between the current number of inhabitants and the future number of inhabitants is significant for the result: If the difference between the current and future number of inhabitants is bigger, for example 70,000 inhabitants in 2007 and 100,000 inhabitants in

2012, then the increase of waste amount is higher with 18kg c^{-1} a^{-1}. In contrast to that, if the difference between the current number of inhabitants (80,000 inhabitants) and the future number of inhabitants (100,000 inhabitants) is less, only a decrease of 17kg c^{-1} a^{-1} is the result (see Appendix – Chapter 4, 4.3., Table A4.3.-12 to Table A4.3.-13).

Testing data set 1 and data set 2

As was proven in paragraphs *"Testing current waste amount"* and "*Testing number of population"* that the current amount of waste as well as number of inhabitants do not have a significant impact on forecasted waste amount, both data sets were only calculated with one current waste amount of 24,300Mg a^{-1} and 70,000 inhabitants in 2007, and 100,000 inhabitants in 2012 for Khanty-Mansiysk. All data entered was changed with a rate of ±10%. A table with all calculated figures via prognosis software tool is given in *Appendix – Chapter 4, 4.3., Table A4.3.-14 to Table A4.3.-15*.

Both data sets demonstrated noticeably that the factors "life expectancy", "population aged 15 – 59 years" and "averaged household size" have the most impact when they change:

- The highest amount of waste forecasted at 412kg c^{-1} a^{-1} (data set 1) and 431kg c^{-1} a^{-1} (data set 2), was produced by a 10% decrease of current life expectancy. In this scenario the increase from this changed current life expectancy to the future life expectancy is the highest one, from 61.3 years to 69.1 years, instead of 68.1 years to 69.1 years as in the original input.
- With 309kg c^{-1} $a^{-}1$ (data set 1) and 313kg c^{-1} a^{-1} (data set 2), a decrease of forecasted amount was also produced by changing the "life expectancy", only the other way round. The future life expectancy was decreased to 62.2 years, and in this scenario the current life expectancy is 68.1 years. That means the software programme calculates with a negative ongoing life expectancy.

That means the software programme calculates higher amounts of waste if the social situation improves and *vice versa*; that is, if the social situation declines, the waste amount will also decrease. Both data sets show these results and there is always a difference of 4-5kg c^{-1} a^{-1} between the amounts of waste in data set 1 and the amounts of waste in data set 2. As a result, this is not a huge difference and it can be ignored.

Finally, the original input of data set 1 and data set 2 do not show a conspicuous difference in the final result. Noticeable differences are created by changing the figures of each input such as "Life expectancy" or "population aged 15 - 59 years". Therefore, the figure of each data set plays a significant role.

Composition of waste

Regarding the waste composition, two factors play a role and were tested through sensitivity analysis:

1. data set 1 and 2 and
2. the current waste composition entered in the prognosis software tool.

Testing data set 1 and data set 2

Data set 1 and 2 have an influence on the waste amount, and therefore it could be assumed that data set 1 and data set 2 also have an impact on the waste composition. As stated in *Chapter 4.3.2. Forecasting waste composition in Khanty-Mansiysk and Surgut,* there is no difference of the waste compositions between data set 1 and data set 2. Also the sensitivity analysis done in *paragraph "Testing data set 1 and data set 2"* (a range of ±10% of each figure entered) demonstrated there is only a slight influence. For example, the changed figures of “Labour force in agriculture” and the “National/urban infant mortality rate” have a low impact of 0.1% on the proportion of organics (kitchen), organics (garden), and plastics (see Appendix – Chapter 4, 4.3., Table A4.3.-14 to Table A4.3.-15). Therefore, data set 1 and data set 2 do not have a key influence on the result of waste composition.

Testing current waste composition

Only the waste compositions of “small houses with gardens” of each seasonal waste analysis were entered in the software programme instead of the weighted waste compositions of “apartment blocks” and “small houses with gardens” in Khanty-Mansiysk. The aim was to test whether there is an impact on the results.

The result is that in almost every category the difference between the current percentage and the future percentage is the same. For example, 1.5% is the difference between the current percentage of glass and future percentage of glass. Exceptions are organics (kitchen) and organics (garden). One has to enter in the PST the subdivision of both these figures, and this subdivision changed from season to season. For example, the subdivision organics (kitchen) to organics (garden) is 41% to 59% in autumn and 97% to 3% in winter. Because of this different ratio, they can not show an equal difference in the results (see Appendix – Chapter 4, 4.3., Table A4.3.-16).

Finally, it can be stated that the future waste composition depends on the factors “GDP”, “national/ urban infant mortality rate”, “Labour force in agriculture”, all of which was proven by the sensitivity analysis with data set 1 and data set 2. Therefore, they have to be researched thoroughly. In addition, the ratio between organics (kitchen) and organics (garden) also plays an important role.

4.3.4. Discussion of waste prognosis results

Waste quantity

Regarding the prognosis of waste amount there are two factors to discuss:

1. the current amount of waste as the basis of the prognosis and
2. the different calculations by the Russian experts.

1. The forecasted waste amounts depend on the *current waste* amount per capita in Khanty-Mansiysk and in Surgut, and the results already demonstrate uncertainties. Without an exact current number for current waste amount, a prognosis is hardly implementable. As described in *Chapter 4.1.4. Discussion of waste analyses data*, there is further research demand.

2. It is significant that the prognoses of the two *Russian experts* interviewed were totally different from one another. Slyusar (2008, pers. com.) forecasted the minimum (352kg c^{-1} a^{-1} in Khanty-Mansiysk and 227kg c^{-1} a^{-1} in Surgut) on the one hand, and on the other Ulanova (2008, pers. com.) predicted the maximum (377kg c^{-1} a^{-1} in Khanty-Mansiysk and 254kg $c^{-1}a^{-1}$ in Surgut) for 2012. The difference between the minimum and maximum prognosis is 25kg c^{-1} a^{-1} in Khanty-Mansiysk and 27kg c^{-1} a^{-1} in Surgut. One reason for these different outcomes might be the different tools applied. Slyusar’s (2008, pers. com.) prognosis is based on a tool comparable to the calculation by ADEME (EC, 2003) and resulted in an annual waste increase of 0.3%. Ulanova (2008, pers. com.) implemented a waste analysis on Olchon Island. She forecasted the annual waste amount based on the results of this analysis. Nevertheless, both agree that waste amount will rise.

Composition of waste

Regarding the results of the waste prognosis software tool, the composition in Khanty-Mansiysk and in Surgut will change only insignificantly.

When comparing the current and forecasted waste composition in Khanty-Mansiysk and Surgut with the current waste amount in Helsinki and Berlin, changes in the future waste composition of Khanty-Mansiysk and Surgut can be expected:

- According to the software tool, the *organic* proportion of the domestic waste will decrease in Khanty-Mansiysk and Surgut. The waste composition in Helsinki already shows a very low percentage of this proportion. In the household waste in Berlin the percentage of organic waste is comparable to that of the waste of Khanty-Mansiysk in 2007. It can be assumed that the fraction of organics will decrease in the future for the household waste in Khanty-Mansiysk and in Surgut.
- The composition of domestic waste in Khanty-Mansiysk and in Surgut shows very high proportions of *lightweight packaging* in compared to the domestic waste of Berlin and Helsinki. Whereas the prognosis software tool shows a decrease for this fraction, Slyusar (2008) expects an increase of plastic waste which includes a higher proportion of lightweight pack. Because of these different results, further analyses are necessary to get a final result.
- Waste composition in Helsinki and Berlin has a lower proportion of *glass* than Khanty-Mansiysk and Surgut. It can be assumed that the lower proportion is due to the fact that a well-organised glass return system in shops exists and glass therefore does not appear as waste, especially in Helsinki (Taskanen, 2008, pers. comm.). The prognosis software tool does not show any changes of proportion of glass in the waste for Khanty-Mansiysk and Surgut in the future. So, only by implementation of a glass return system in Khanty-Mansiysk and Surgut can a reduction of the glass proportion be assumed.
- In contrast to glass, the household waste of Berlin and especially Helsinki showed a high proportion of *paper/ cardboard*. This corresponds with the results of the prognosis software tool that also showed an increase of this proportion. So, it can be assumed that the percentage of paper/ cardboard will increase in the waste of Khanty-Mansiysk and Surgut.
- The software tool shows an increase for *electronic* waste for the waste of Khanty-Mansiysk and Surgut. The waste compositions of Berlin and Helsinki also demonstrate higher electronic proportions than the proportion of waste in Khanty-Mansiysk and Surgut at present. It can be assumed that the proportion of electronics will increase.
- In contrast to the waste compositions of Berlin, Khanty-Mansiysk and Surgut, the composition of waste in Helsinki shows a very low percentage of *hazardous* waste. The percentage of hazardous waste in the domestic waste of Berlin as well as Khanty-Mansiysk and Surgut (at present and future) demonstrates comparable results. It can be assumed there will be only few changes in the fraction of waste for Khanty-Mansiysk and Surgut.

However, a change of waste composition in Khanty-Mansiysk and Surgut in the next 5 years is foreseeable.

4.4. Environmental assessment of scenarios

4.4.1. Results of LCA-IWM

The overall results given in Figure 4-9 and Figure 4-10 demonstrate that the impact categories global warming and abiotic depletion have a key influence on the environmental assessment for each scenario proposed for Khanty-Mansiysk and Surgut. The impact category abiotic depletion in particular largely indicates an environmental relief, with the exception of Scenario 1 “landfill”. In this scenario, abiotic depletion, namely material and/or energy recovery, is not implementable. Acidification, human toxicity, photo-oxidation and eutrophication have only secondary influence on the results of the environmental assessment for each scenario. A total overview of all calculations is given in Appendix – Chapter 4, 4.3.

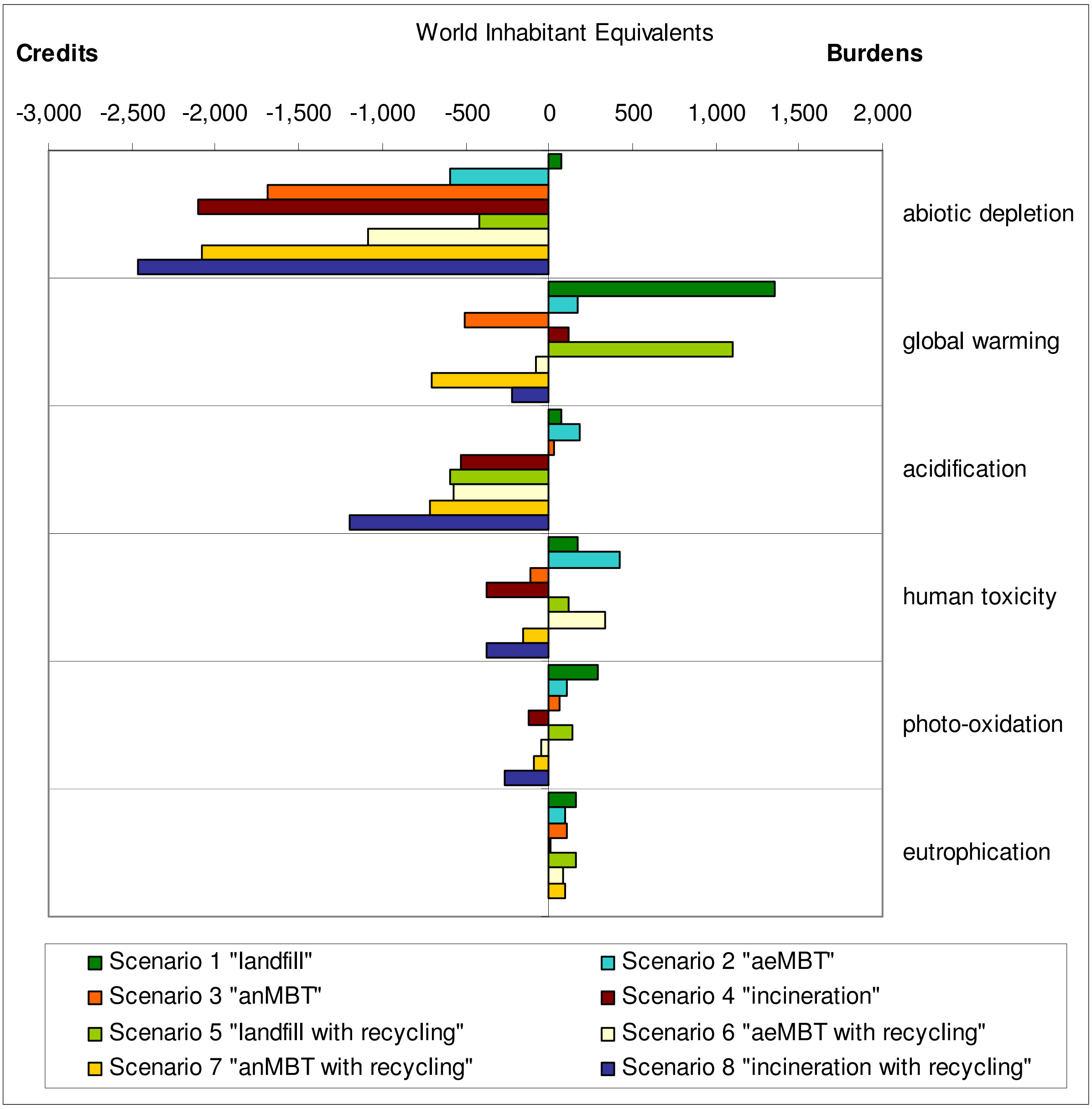

Figure 4-9: Results of LCA-IWM for Khanty-Mansiysk

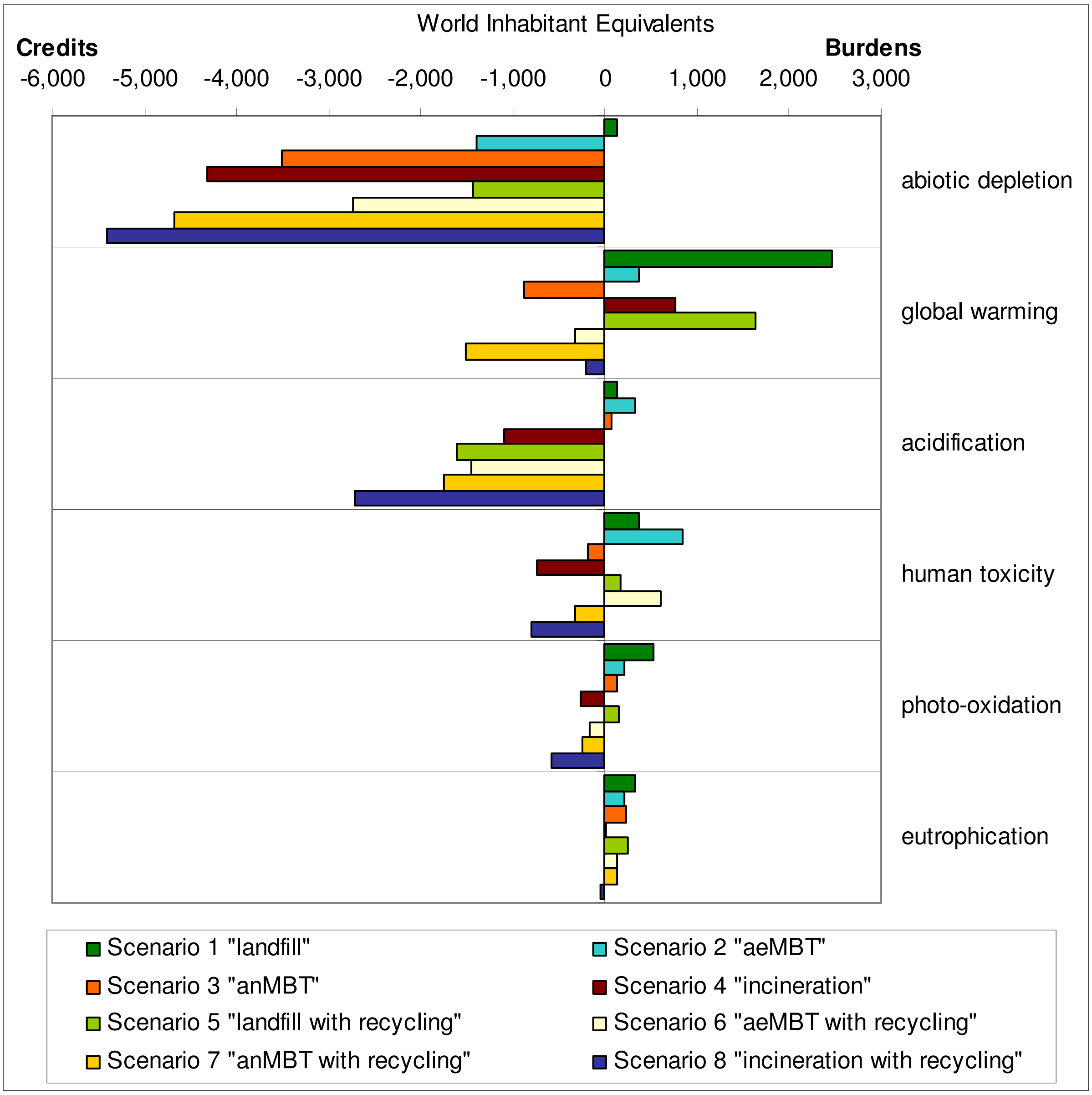

Figure 4-10: Results of LCA-IWM for Surgut

The overall results of each impact category are composed of the results for the environmental impact of "treatment plants", "collection and transport" and "temporary storage" (see Table 4-11). The assessment showed that the indicator "treatment plant" has the greatest influence on the overall result within each impact category.

The results for "collection and transport" are different between Scenarios 1-4 and Scenarios 5-8 because two types of "collection and transport" were created for the environmental assessment. The first type consists of only one way, from waste collection point to the treatment plant/ landfill. It is used in Scenario 1 to 4. The second type (Scenario 5 to 8) includes a transfer station and therefore several transport routes: waste transport from waste collection point to the transfer station and from there to the different treatment plants, as the recycled materials have to be transferred to different treatment plants. The result of the environmental impact of "temporary storage" is almost the same in each impact category and, with 0/1 World Inhabitant Equivalents, has only a very small influence on the overall results of each impact category. In the table below, Scenario 1 "landfill" and Scenario 5 "landfill with recycling" for Khanty-Mansiysk are given as examples for the subdivision of the overall results of each impact category into single results of the impact of “treatment plants”, “collection and transport” as well as “temporary storage” (see Table 4-11).

Table 4-11: Subdivision of the overall results of each impact category into single results of impacts of “temporary storage”, “collection and transport” and “treatment plants” [World Inhabitant Equivalents]

	Scenario 1 "landfill" for Khanty-Mansiysk				**Scenario 5 "landfill with recycling" for Khanty-Mansiysk**			
Impact category	Temporary Storage	Collection & Transport	Treatment plants	Total	Temporary Storage	Collection & Transport	Treatment plants	Total
Abiotic depletion	1	7	63	**71**	2	118	-538	**-418**
Global warming	1	5	1,353	**1,359**	1	77	1,029	**1,107**
Human toxicity	0	1	171	**172**	0	10	108	**118**
Photo-oxidation	0	1	296	**297**	0	12	123	**136**
Acidifi-cation	0	5	70	**75**	1	78	-668	**-589**
Eutro-phication	0	1	163	**164**	0	17	147	**163**

The examples show that “temporary storage” and “collection and transport” always indicate burdens on the overall result of each impact category. Scenario 5 “landfill with recycling” demonstrates a higher impact/ burden on the environment within “collection and transport” for each category compared to Scenario 1 “landfill”, which owes to longer transport ways for the recycled materials.

4.4.2. Sensitivity analysis

Sensitivity of waste amount

A range of ±10% of the annual waste amount was the basis of the sensitivity analyses for each scenario in Khanty-Mansiysk and Surgut. As a consequence, all results of each impact category also changed with a difference of ±10% compared to the original amount entered into the software tool in both in Khanty-Mansiysk and in Surgut. That means there is a linear correlation between the waste amount and results of each impact category for every scenario (compare Appendix – Chapter 4, 4.4., Table A4.4.-3 to Table A4.4.-6 and Table A4.4.-22 to Table A4.4.-25).

Sensitivity of waste composition

Two sensitivity analyses of the composition of waste were carried out by:

1. entering as waste input the five main fractions organics (kitchen), organics (garden), plastics, glass and paper/cardboard, plus electronics and metals, as only one material
2. entering the seasonal waste composition analysed through the waste analyses carried out in Surgut and in Khanty-Mansiysk

into the software programme LCA-IWM.

The discussion of the sensitivity of waste composition is limited to the two main impact categories abiotic depletion and global warming. These two impact categories are the main categories as they have the primary influence within the environmental assessment (see

Appendix – Chapter 4, 4.3, Table A4.4.-7 to Table A4.4.-57 for all results of these sensitivity analyses).

The sensitivity analysis regarding the single waste fractions were difficult to carry out for the two scenarios Scenario 2 "aeMBT" and Scenario 3 "anMBT". An environmental assessment of the fractions "glass" and "metals" could not be done. "High caloric fraction for energy" and "Inerts for landfilling" could not be calculated through the software programme and were shown as "error". As the "High caloric fraction for energy" has a significant impact for credits within the assessment, a distortion of the results was assumed. Therefore, the sensitivity analysis of glass and metals was not finished for these two scenarios.

1. Single waste fraction

The impact category abiotic depletion plays a main role and generally produces positive results; i.e. in almost all scenarios material and/or energy can be recovered from the waste. A recovery of energy or material is not possible in Scenario 1 "landfill". The waste fractions plastics, paper and electronics have a very positive effect on abiotic depletion in Scenario 2 "aeMBT, Scenario 3 "anMBT" and Scenario 4 "incineration" as abiotic/natural resources can be saved through recycling or (energy) recovery of such as plastics or paper (see Figure 4-11).

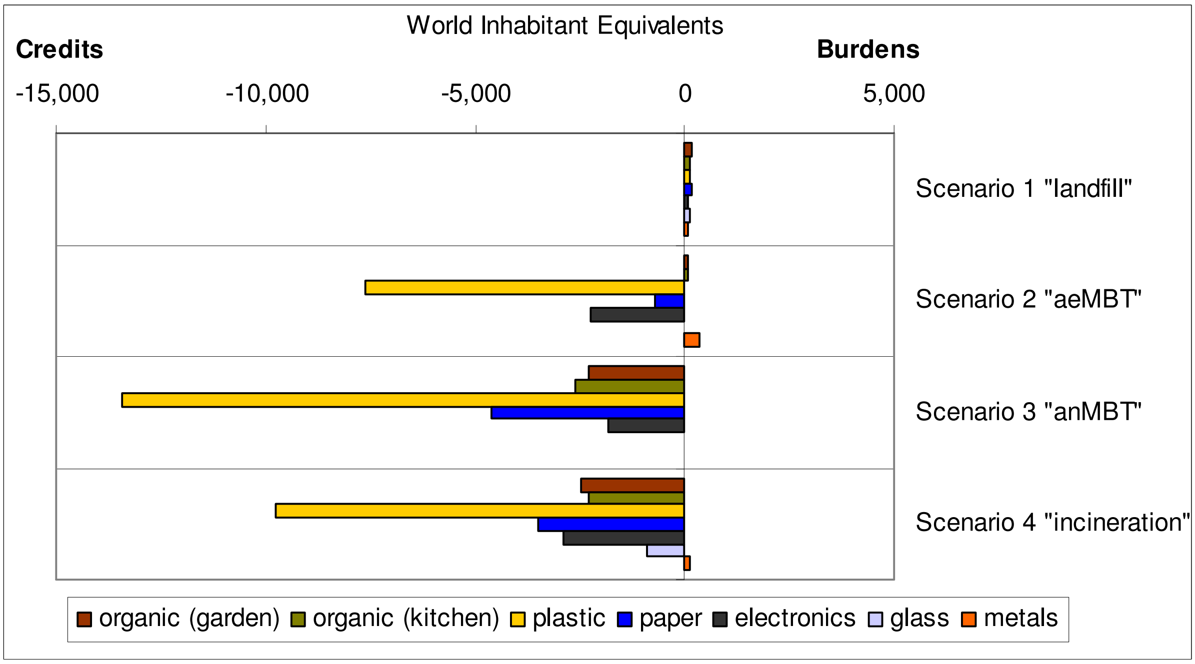

Figure 4-11: Influence of each waste fraction on abiotic depletion per scenario

The results of the impact category global warming can be positive or negative within the environmental assessment of each scenario proposed for Khanty-Mansiysk and Surgut (see Figure 4-9 and Figure 4-10). Plastic, paper, organics (kitchen) and electronics have a main effect on the impact category global warming. The effect of plastics, for example, can be positive as in Scenario 3 "anMBT", or negative as in Scenario 4 "incineration" (see Figure 4-12). The reason is that burning of plastic waste produces CO_2 emissions which are counted as negative, i.e. burdens, within the impact category global warming (den Boer, et al. (ED.), 2005).

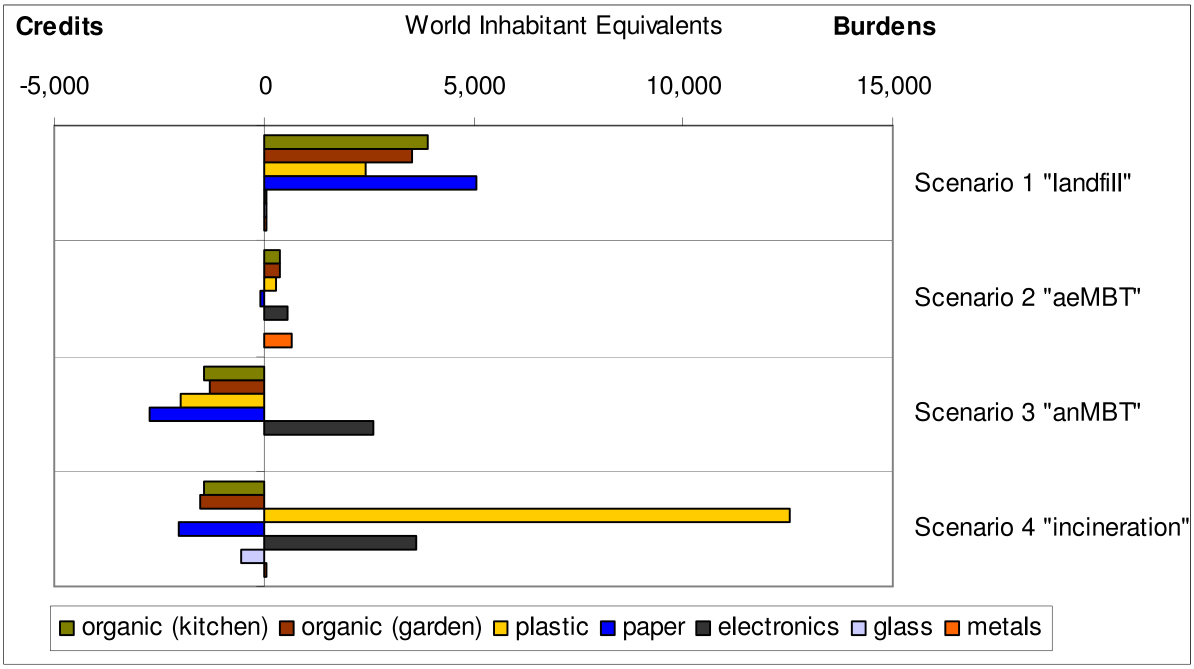

Figure 4-12: Influence of each waste fraction on global warming per scenario

In summary, it can be stated that there is one waste fraction with a key influence within each impact category. Especially plastic, but also paper, electronics and organics play an important role for the environmental assessment of each scenario.

2. Comparison of seasonal composition

In **Khanty-Mansiysk** the results of the seasonal compositions of the residential structure "small houses with gardens" were used for the sensitivity analysis as these results show noticeable deviations among the seasons. The seasonal waste compositions have an influence on the overall result of the impact categories global warming and abiotic depletion per scenario. For example, the composition of waste in autumn analysed in ***Khanty-Mansiysk*** has a significant negative effect on the impact category *global warming* for the Scenarios 1, 5 and 6 (see Figure 4-13). The main differences between the waste compositions during the different seasons are that the organic fraction is significantly higher in autumn. Organic is, besides the fraction plastics, the key waste fraction for the impact category global warming (see Figure 4-12).

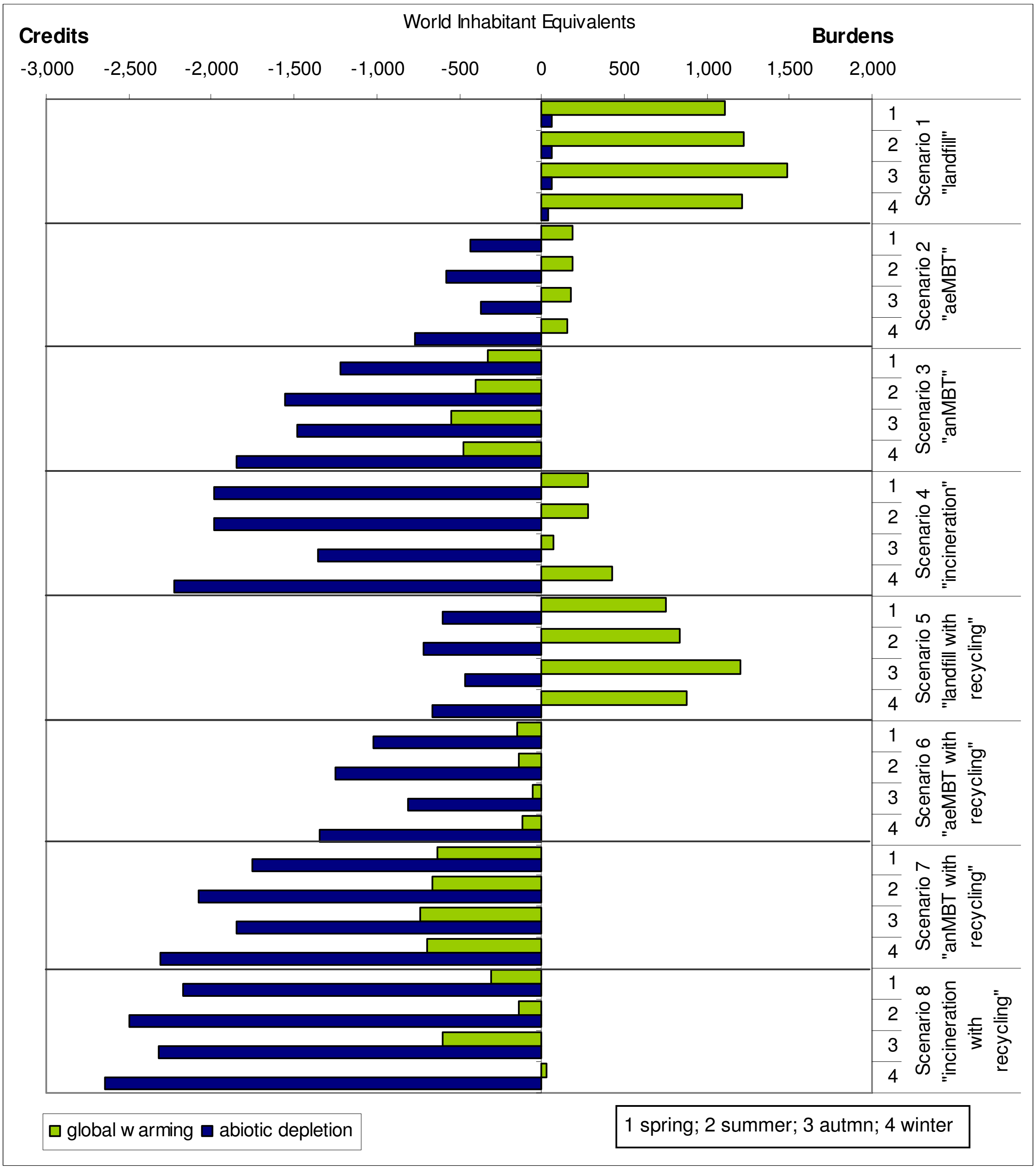

Figure 4-13: Sensitivity of seasonal waste composition on the results of the impact categories global warming and abiotic depletion in Khanty-Mansiysk

The results of the sensitivity analyses for Surgut demonstrate the following: the indicators abiotic depletion and global warming show differences between the results of the sensitivity analysis with the waste composition of spring and autumn as well as the results of the sensitivity analysis with the waste composition of summer and winter (see Figure 4-14). The main difference of waste compositions between spring/autumn and summer/winter is that there is less paper and organic (kitchen) waste in spring/autumn than in summer/winter. These fractions exert the major influence on the two categories abiotic depletion and global warming (see Figure 4-11 and Figure 4-12).

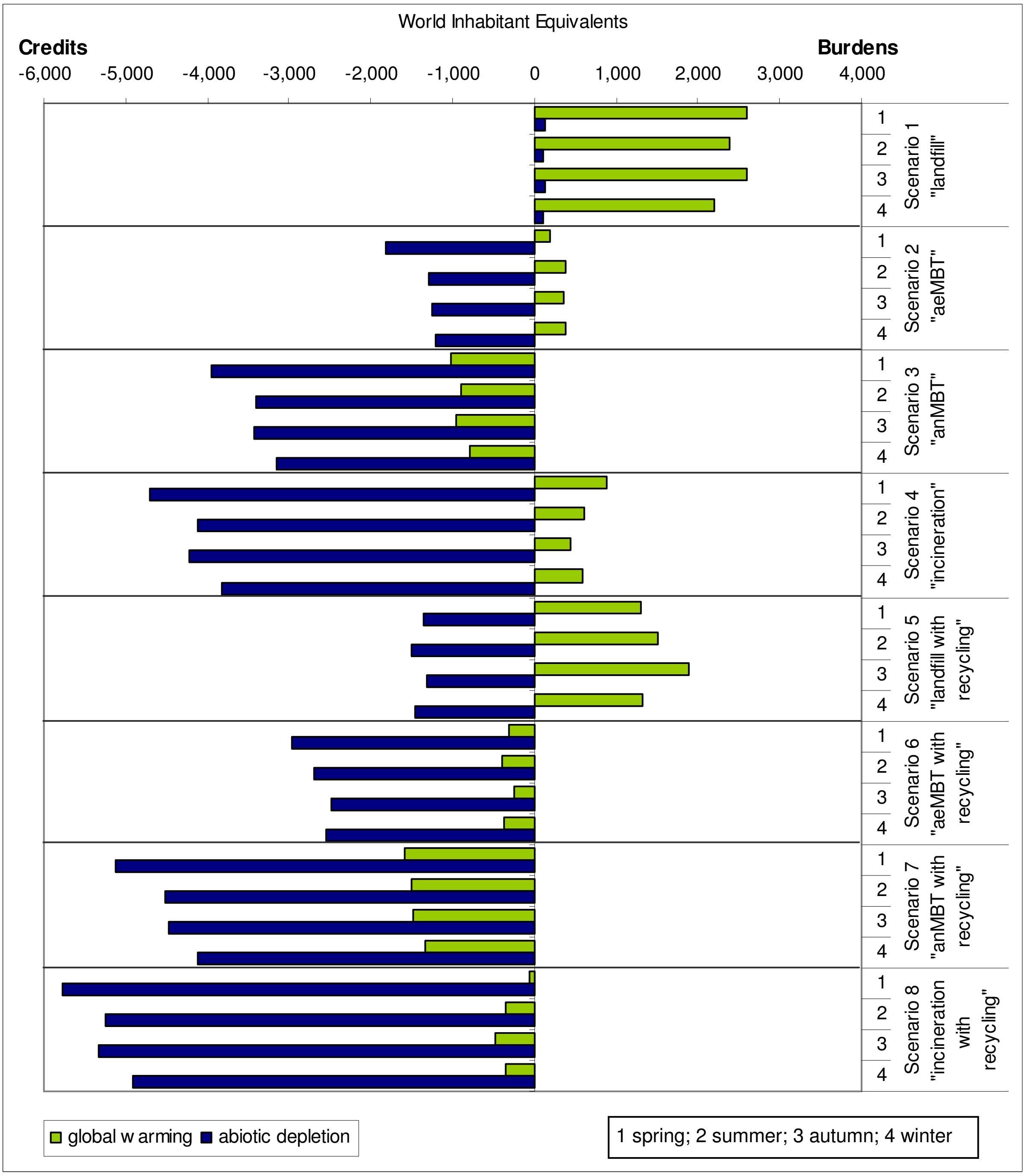

Figure 4-14: Sensitivity of seasonal waste composition on the results of the impact categories global warming and abiotic depletion in Surgut

It can be stated that the seasonal waste compositions have an influence on the results of each impact category.

Sensitivity of distances of waste transport

The uncertain factor “distances” was only chosen for the sensitivity analysis for Khanty-Mansiysk. In contrast to Surgut, Khanty-Mansiysk’s location is isolated, and therefore the distances of waste transports play a role for the environmental assessment of each scenario. Scenario 5 “landfill with recycling” was selected for testing the impact of “distances” in the environmental assessment. Distances of 50km, 160km and 300km were taken for the

sensitivity analyses. A distance of 250km was chosen as original input data for the environmental assessment of each scenario with a recycling part.
An influence is recognisable on each impact category: The greater the distance, the greater the burden for the environment and *vice versa*: the shorter the distance, the lower the environmental burden (see Figure 4-15).

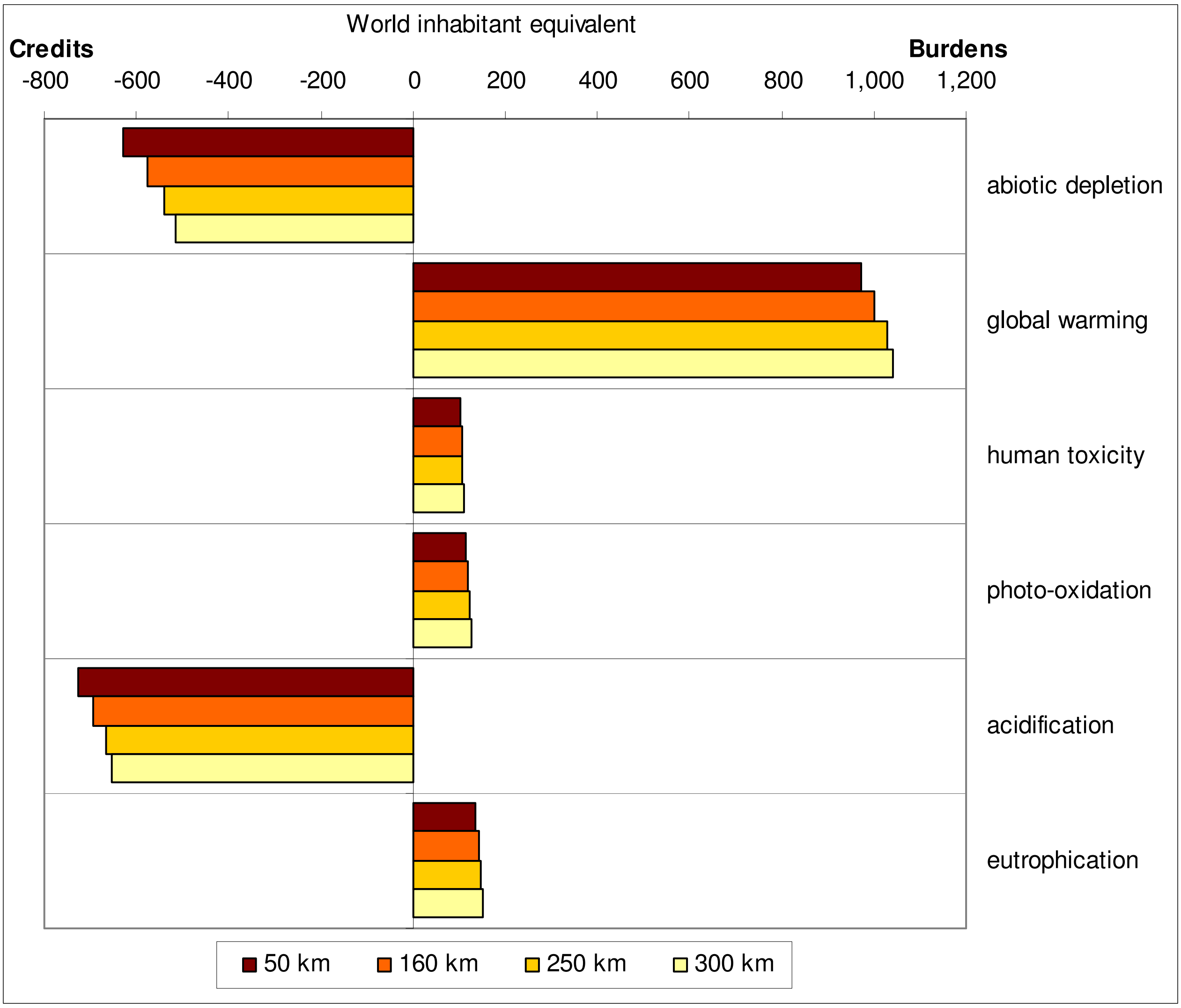

Figure 4-15: Influence of the uncertain factor “distances” on the results of Scenario 5 “landfill with recycling” for Khanty-Mansiysk

4.4.3. Discussion of LCA results

There are two aspects to discuss regarding the results of the LCA:
1. Which is the most environmentally sound scenario and why?
2. Which criterion such as waste amount or composition has the greatest impact on the single score results of the LCA-IWM?

<u>1. Ranking of scenarios</u>

In ***Khanty-Mansiysk***, the results of scenario 8 “incineration with recycling” show no negative impacts on the environment. Scenario 7 “anMBT with recycling” has only few negative impacts on the environment. Only the indicator eutrophication measures a burden. Therefore, these scenarios appeared as the most environmentally sound scenarios. Scenario 4 “incineration” also demonstrates few negative impacts with respect to global warming and eutrophication, and for Scenario 6 “aeMBT” only few negative impacts arise in the categories human toxicity and eutrophication. Scenario 3 “anMBT” has few negative impacts in the categories acidification, photo-oxidation and eutrophication. Comparing Scenario 1 “landfill” with Scenario 5 “landfill with recycling” the results also demonstrate clearly that recycling can reduce the burden on the environment. The impact categories abiotic depletion and acidification indicate a burden instead of a relief. The negative influence of global warming is also less in Scenario 5 “landfill with recycling” than in Scenario 1 “landfill”. Scenario 2 “aeMBT” can only achieve a relief for the indicator abiotic depletion. All other impact categories measure a burden for the environment. Scenario 1 “landfill”, the current situation in ***Khanty-Mansiysk***, demonstrates that this is the scenario with the highest negative impact for the environment as all impact categories indicate burdens for the environment (see Figure 4-16).

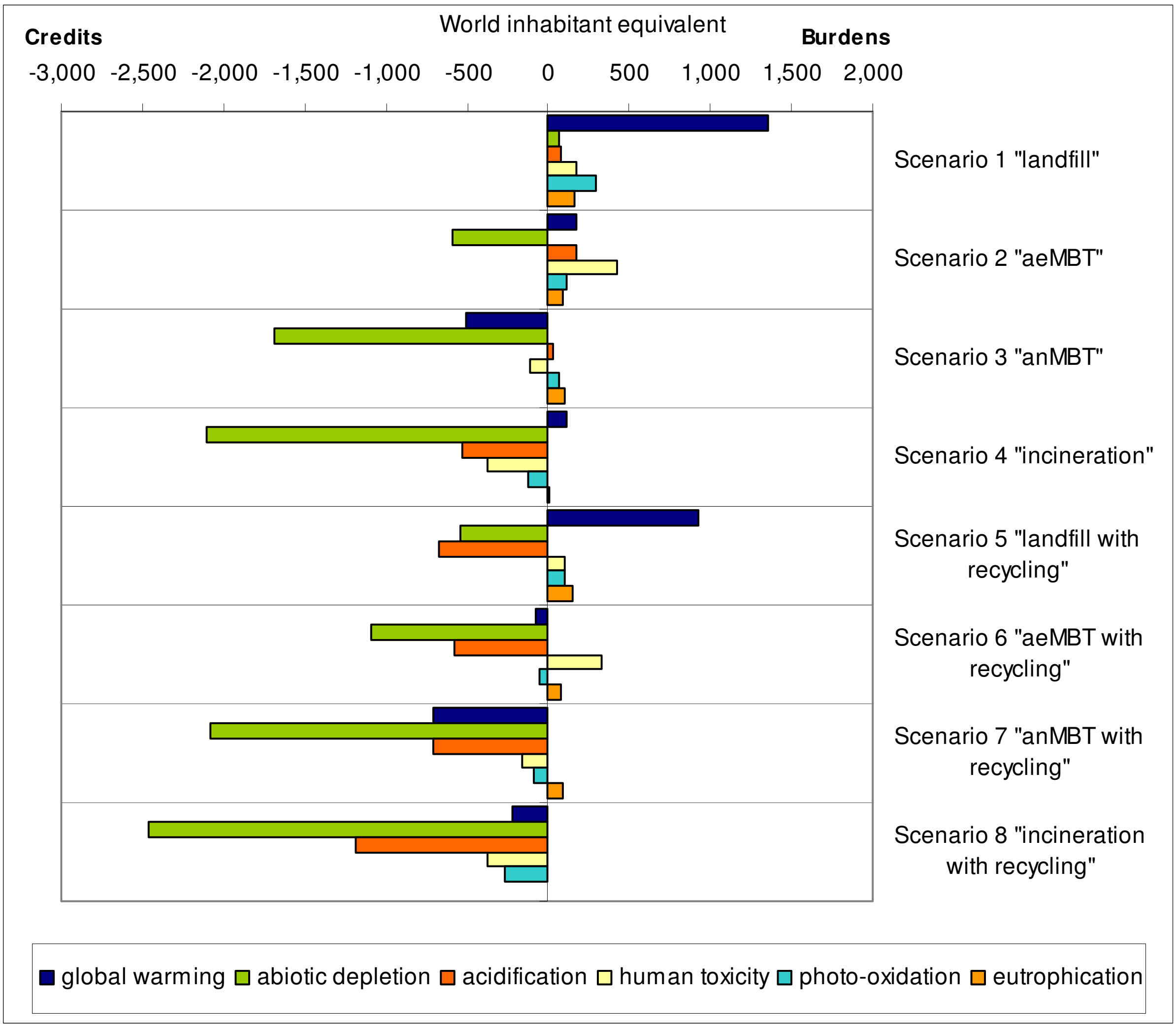

Figure 4-16: Comparison of each impact category per scenario in Khanty-Mansiysk

In Surgut, the environmental assessment of the scenarios has similar results (see Figure 4-17).

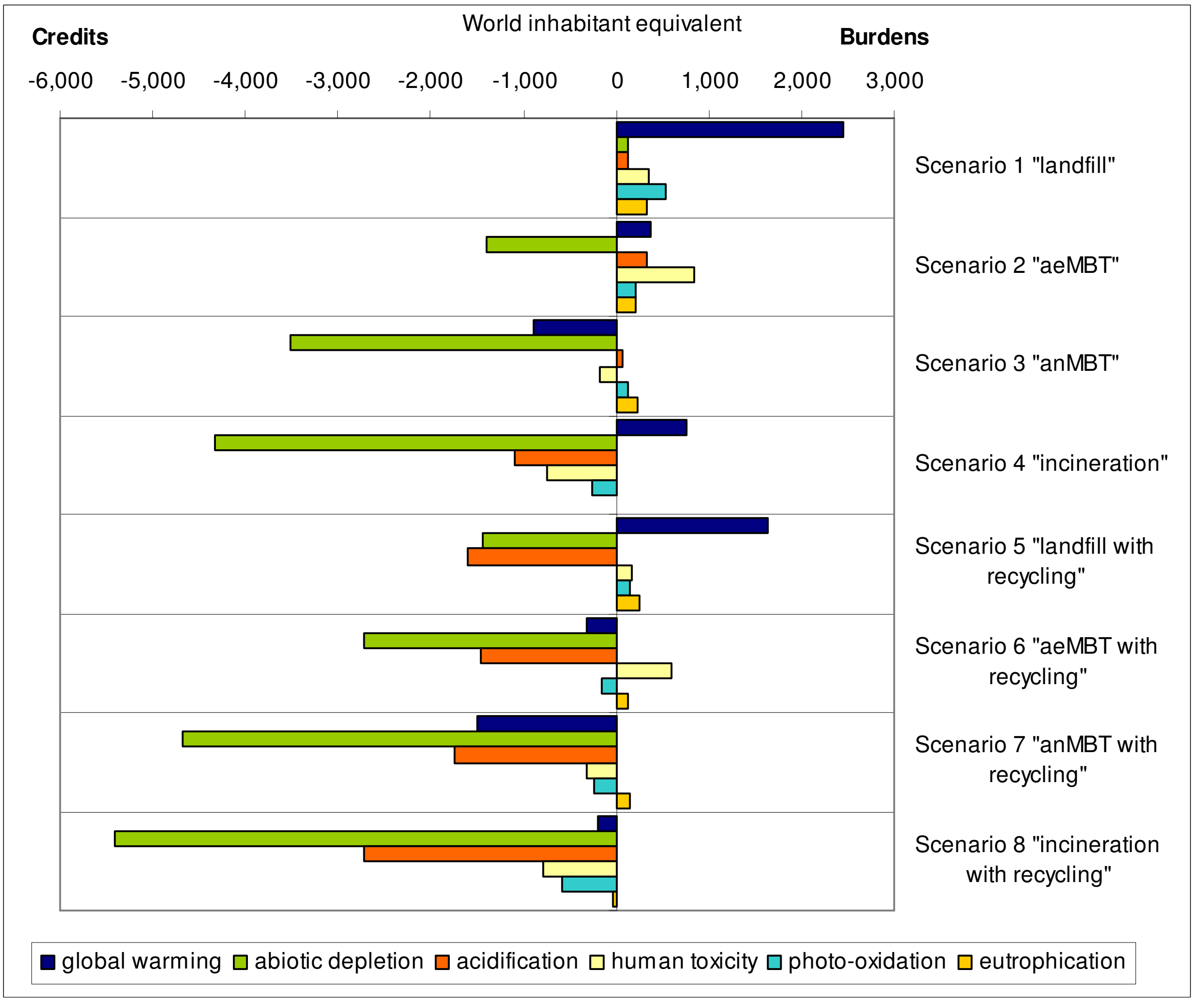

Figure 4-17: Comparison of each impact category per scenario in Surgut

Finally, it can be stated that Scenario 7 "anMBT with recycling" and Scenario 8 "anMBT with recycling" demonstrate the fewest impacts on the environment. However, there is a risk in the assessment of the part "collection and transport". The final environmental burden of "collection and transport" could not be determined through the LCA-IWM. The reason is that the individual routes from the transfer station to the treatment plants for recycling are unknown as these treatment plants do not exist currently. Estimates of the distances for transport of the waste had to be made. As the sensitivity analysis of distances of transport clearly demonstrates that it will always have a negative impact on each impact category, further research into which scenario is the most environmentally sound is necessary. Due to the remoteness of Khanty-Mansiysk, the transport of waste will play a significant role within the environmental assessment of an integrated waste management concept.
Nevertheless, the comparison of all scenarios also clearly demonstrates there are hardly any differences between the results of each scenario for Surgut and Khanty-Mansiysk. Therefore, the same waste management strategy could be used for both towns.

2. Influences on the results of LCA-IWM

The results of the sensitivity analyses demonstrated that there is a correlation between the results of the LCA-IWM and the waste amount, composition as well as transport distances.
An increase of *waste amount* corresponds with a worsening of the results of the environmental assessment and vice versa, based on the linear correlation between the

waste amount and results of the LCA-IWM. Therefore, a reduction of the waste amount, for example through recycling, reduces environmental burdens. The *composition of waste* or a single fraction -both currently and in future- also has an impact on the environmental assessment. That means that an increase or decrease (for example through recycling) of one of the waste fractions tested in the sensitivity analyses can also affect the environmental assessment of the proposed scenarios, either negatively or positively. Furthermore, the present as well as future waste composition and waste amount will play a role in the development of waste management concepts. As treatment plants usually have a lifespan of 20 years (Beigl et al., 2005), a forecasted waste composition and amount have to be considered. The *transport distances* always have positive results/ burdens on the total results of each impact category; that is, the longer the distance, the worse the results of each category will be.

Finally, it can be stated that annual waste amount, waste composition and distances for waste transport have a major impact on the environmental assessment within the LCA-IWM.

5. Applicability of decision support tools

5.1. Analysis of solid household waste

The implementation of the waste analysis in Khanty-Mansiysk and in Surgut followed the "Methodology for the Analysis of Solid Waste (SWA-Tool)" by the European Commission (EC, 2004)[7]. Only few problems appeared while taking samples. In contrast to that, the evaluation of the results was hardly possible by considering the recommendations by the SWA-Tool. Therefore, a revision of the SWA-Tool, especially for Siberian regions, is essential and was developed in the following chapter.

"Standard test method for determination of composition of unprocessed municipal waste" by the American Society for Testing and Materials International (ASTMI, 2003)[8] and the results by Dahlén and Lagerkvist (2008) were also consulted. ASTMI was chosen because the study by Martinho et al. (2008) demonstrates that besides the SWA-Tool, ASTMI is most developed in detail out of all tools recommended by intergovernmental and international organisations for solid waste analysis. Therefore, it can support to identify and to demonstrate alternatives for work steps of a waste analysis (see Chapter 2.1.2). I also referred to the results by Dahlén and Lagerkvist (2008) as they also developed recommendations for work steps of waste analysis based on international discussions.

As the aim of standardised tools is the national and/ or international comparability of results (Dahlén and Lagerkvist, 2008; Scott, 1995), key criteria for the implementation of a standardised tool for the analysis of solid waste has to be determined. Dahlén and Lagerkvist (2008) and Martinho et al., (2008) recommend:

- definition of waste
- sampling type
- sampling level and sampling unit
- sample size
- duration of analysis
- sample preparation and sorting
- sorting catalogue
- evaluation and
- data presentation

as these criteria are essential within waste analysis.

I widened these criteria by "time period for recurrence of waste analyses" because this additional criterion also plays a significant role when implementing a waste analysis. Personnel, equipment, health and safety requirements and costs are also important and need to be discussed (Martinho et al., 2008) but they do not play a main role for the comparability of results. A summary of all criteria is given at the end of this chapter in Table 5-3.

[7] Abbreviated in the following text as: "SWA-Tool". Literature is based on the description of the SWA-Tool (EC, 2004) and will not be mentioned again in the text.
[8] Abbreviated in the following text as: "ASTMI". Literature is based on this standard (ASTMI, 2003) and will not be mentioned again in the text.

5.1.1. Definition of waste

The SWA-Tool gives a detailed definition of solid municipal waste which consists of residual/ household waste and co-collected commercial waste. An internationally defined and scientifically recognised definition of municipal waste does not exist which can result in different types of waste being analysed; for example, only residual/ household waste or only commercial waste or municipal waste as a whole. A comparison of the results of waste analysis with different types of waste is not possible afterwards. ASTMI does not offer a terminology of its research object "municipal waste". As a detailed description of the type of waste to be analysed is essential in waste analysis tools, especially for the comparison of results, the suggested definition of the European Union for municipal, solid household and commercial waste should be used (see Table 5-3).

5.1.2. Sampling type

Regarding the sampling type, SWA-Tool suggests a stratified random sampling. An advantage of a stratified random sampling is the reduction of sampling units and therefore, of the costs of waste analyses. Dahlén and Lagerkvist (2008) also describes that the sampling type recommended by SWA-Tool causes a minimum of sampling errors. A subdivision of the entire research area in sub-research areas based on defined influencing factors/ criteria is the precondition for stratification. ASTMI suggests a random sampling which is a simple form of stratified random sampling.

Influencing factors/ criteria are factors which can have an impact on waste generation: i.e. the quantity and type of waste. Examples are residential structure and collection day. Thus, the entire research area such as a town can be subdivided into so-called strata (see Chapter 3.3, Stratification). A stratum means a homogenous subgroup of the entire research group. ASTMI does not describe any influencing factor on waste generation. In contrast to ASTMI, SWA-Tool offers more than eight criteria for possible impacts on waste generation. An analysis of the research area on the basis of these criteria supports the development of a waste management concept. Dahlén and Lagerkvist (2008) support this aspect as well.

In Khanty-Mansiysk a stratified random sampling was implemented. The chosen influencing factors were the residential structure and season. It was assumed that waste produced by inhabitants who live in "apartment blocks" and inhabitants who live in "small houses with gardens" as well as waste produced during the different seasons varies in quality and quantity. This assumption proved to be correct: the overall percentage of organic waste was similar in both strata. However, within the single stratum "apartment blocks" and "small house with gardens", the organic proportion varied and also changed during the different seasons. Therefore, the case study proves the fact that influencing factors exist and should be taken into account when implementing waste analyses. A stratified random sampling as sampling type is suggested for the revised description of the SWA-Tool.

5.1.3. Sampling level and sampling unit

The SWA-Tool offers the use of the collection truck or the waste containers outside on the street or the waste bin in the kitchen as *sampling levels* but recommends using the containers in the street. A *sampling unit* should have a comparable size and containers with different sizes can be added up to one comparable size.

In contrast to that, ASTMI recommends using the collection truck as sampling level and to mix, quarter and cone the waste. One quarter is suggested as the sampling unit. A disposal truck with a minimum of 0.765 m^3 (1-yd^3) results in one unit between 91kg and 136kg – is described as an example in ASTMI.

There are three key advantages for sampling level “containers in the street”:

1. The waste is less mixed and broken, which reduces the risk of personal injury.
2. A fixed or defined unit improves the accuracy of the statistical evaluation of the waste analysis. In contrast to that, quartering the load of a collection truck can lead to a difference in sampling units of between 91kg and 136kg (as the example of ASTMI demonstrates) and uncertainties in the statistical evaluation.
3. It is possible to follow the link from the waste and to its producers, i.e. the local population. The use of containers as well as possible problems with the waste containers and their locations can be identified and be taken into account when considering the social aspects of the integrated waste management concept.

A disadvantage is that it is necessary to know the exact number of inhabitants per waste container for calculating the daily or annual waste amount as SWA-Tool recommends calculating the daily or annual amount of waste per capita from the waste amount from the waste containers. If the correct number of inhabitants per container is unknown or not available, the formula by the SWA-Tool is hardly usable (see Chapter 4.1.4 Discussion of waste analyses data).

The recommended tool by ASTMI allows a better calculation of the entire amount of waste in one research area per day or year. ASTMI suggests to extrapolate the daily and annual waste amount from the weight of each waste disposal truck running to the landfill/ treatment plant per day, which allows an exact calculation of amount of waste per day and year. Nonetheless, a pair of scale is an essential precondition for weighing the waste disposal trucks and does not exist for all landfills and or treatment plants (compare equipment of landfill in Surgut).

Both tools hold uncertainties for calculating the annual or daily waste amount *per capita*:

- If the number of inhabitants per one container is unknown, the calculation by the SWA-Tool is inexact.
- If the number of inhabitants of a town is unknown, then the calculation by the ASTMI tools is also hardly implementable.

Usually, the number of inhabitants of a town is known by the local administration as opposed to the number of inhabitants per waste container. Nevertheless, owing to the migration boom in Khanty-Mansiysk and the lack of mandatory registration, an accurate figure on inhabitants of this town is not available at the moment. Furthermore, if the SWA-Tool should become an internationally recognised tool, it has to be considered that in many countries waste containers do not exist. If the ASTMI should become internationally recognised, it has to be taken into account that not all landfills globally are equipped with a scale for weighing the waste disposal trucks. As SWA-Tool also offers the waste disposal truck as sampling level, the advantages and disadvantages of both sampling levels, waste disposal truck and waste containers, should be described in the revised SWA-Tool. With this knowledge the users can decide which sampling level is the most suitable to apply in their research area for analysing the waste (see Table 5-1). A combination of both sampling levels (waste disposal trucks and containers in the street) seems to have the fewest disadvantages for calculating waste amount and is to be described within the review of the SWA-Tool. For sorting the waste, the sampling level “waste containers in the street” (if containers exist) should be used mainly as it demonstrates fewer disadvantages.

Table 5-1: Advantages and disadvantages of SWA-Tool and ASTMI regarding sampling level

Waste analysis tool	Recommended sampling level	Advantage	Disadvantage
ASTMI	Waste disposal truck	- More accurate calculation of annual amount possible by weighing the waste disposal trucks every day.	- By counting the disposal trucks uncertainties can arise, for example when converting from m^3 to kg: According to Russian law, $1m^3$ of waste equals between 200kg and 220kg (Ulanova, 2007). According to Dahlén and Lagerkvist (2008); however, $1m^3$ of waste amounts to 100kg (2007). - Sufficient space for unloading the truck(s) is a precondition and not given everywhere. - Equipment for disposal of the waste after sorting is necessary and needs to be available. - The implementation of the sample preparation, i.e. “mixing, coning and quartering” can be difficult. - The preparation of the sample and the analysis include higher risks of personal injury. - If a town’s population is unknown, a calculation of the waste amount per capita is hardly possible. - A scale to weigh the disposal trucks is necessary.
SWA-Tool	Waste containers	- More options for analysis: • *in situ,* which requires less organisation and equipment • or external: additional waste containers, a car for transportation and a place where the analysis can be carried out are necessary - Contact to the locals can be established. - Existence of defined sampling units.	- If number of inhabitants per waste container is unknown, a calculation of the annual/ daily waste amount and annual/ daily waste amount per capita is not possible. - Precondition is presence of waste containers with comparable volumes.

5.1.4. Sampling size

The SWA-Tool recommends a *sample size* of 35 units for the analysis of household waste if the variation coefficient is known (usually, approximately 30%). A formula is also given for calculating the sample size based on the known variation coefficient. It is recommended to take a 95% confidence level based on a 10% statistical accuracy. 45 units in general for household waste and 80 units in general for a mixture of household and commercial waste should be analysed if the variation coefficient is unknown.
ASTMI also recommends this formula which is recommended in the SWA-Tool. In contrast to SWA-Tool, the formula by ASTMI is based on the mean and standard deviation of single fractions. If these figures are unknown, calculating the sampling units does not seem to be implementable. ASTMI gives some examples of the mean and standard deviation analysed in the USA. The question is whether these numbers can be used in other countries as well, or rather how to determine mean and standard deviation of waste fractions before a (first) waste analysis. Although both tools use the same formula, it is easier to follow the description and calculation of the SWA-Tool, especially if the first waste analysis without pre-investigated data is to be implemented.
Dahlén and Lagerkvist (2008) also point out that there is a disagreement among international experts about the size of sampling units and states "[…] there is no absolute recommendation […]. As a rule of thumb, a minimum number of samples is 10 if the sample size is 100kg or larger.". They recommend analysing at least 5 x 100kg of waste for each <u>single stratum</u>.

A container with a volume of 1m^3, namely one *sampling unit*, is the basis for the calculation of the entire sampling size in the SWA-Tool. The volume or amount of waste that is actually in the container does not play a role. Container(s) with a volume of 1m^3 is the minimum for one unit for the statistical evaluation of waste analysis according to the SWA-Tool. This figure, 1m^3 for one unit, is not explicitly mentioned in the SWA-Tool and was only established for the implementation of the waste analysis in Khanty-Mansiysk and Surgut after consultations with Mr Zwisele (2008, pers. comm.), one of the authors of this tool. ASTMI recommends to take a quarter of waste which should be mixed, cone and quartered from the loading truck.
For a statistical evaluation, the basis is 1m^3 and simultaneously the minimum of one sampling unit, i.e. waste container(s), as per the SWA-Tool. I follow this suggestion, one sampling unit should be 1m^3 in order to allow a statistical evaluation as it proves a well-implementable sample size in Khanty-Mansiysk and Surgut.

Another recommendation by the SWA-Tool is to analyse a minimum of 6m^3 of waste for each stratum with 1m^3 per sampling unit per analysis. Because of the subdivision into two strata in Khanty-Mansiysk and therefore the subdivision of sampling units on both strata (compare Chapter 3.3.), 10m^3 of waste containers for "apartment blocks" and 5m^3 of waste containers for "small houses with gardens" were sorted in Khanty-Mansiysk (compare Chapter 3.3, Stratification). The duration of one waste analysis covered the 5 working days, Monday to Friday, with 1m^3 waste containers as the sampling unit per day for the stratum "small houses with gardens". Therefore, the 6m^3 of recommended sampling units could not be subdivided into sample units of equal sizes as the waste containers existing in Khanty-Mansiysk have a volume of 0.5m^3. Consequently, the decision was made to reduce the recommended amount to 5m^3 of waste containers/ sampling units. Dahlén and Lagerkvist (2008) recommend at least 5x100kg per stratum. Considering both recommendations and that 1m^3 of solid household waste (globally) corresponds to almost 100kg as a rule of thumb, 5x1m^3 or 5x100kg of solid household waste seems to be appropriate as a minimum for a statistical evaluation of the results from a waste analysis. For a 5-day-analysis, 5 sampling units can also be spread equally per day.

5.1.5. Duration and time period for recurrence of waste analyses

In regard to the *duration* of a waste analysis both tools agree. The minimum that needs to be analysed is the waste generated within one week: ASTMI defines one week as between 5 and 7 days. SWA-Tool recommends a duration of 5 working days for one waste analysis. In order to get an overall overview of the daily waste amount and composition, a 7-day analysis is recommended.

Furthermore, it is described that the analysis should be done on a daily basis but there is no detailed explanation of the time scope. For example, a daily waste disposal system with different collection times such as in the morning on one day and in the evening on another day can result in a distortion of the daily waste amount. A further calculation of the annual waste amount will not be accurate. The daily waste analysis should be dependent on the time of waste disposal, i.e. the time lapse between waste disposal and waste analysis should be the same on every day of the waste analysis, for example 24 hours. This interdependence between time of waste disposal and time of waste analysis is not mentioned in the SWA-Tool. ASTMI recommends to count and weigh the waste disposal trucks daily and therefore, the time of waste disposal does not play a role for calculating the waste amount. The waste analyses in Khanty-Mansiysk and Surgut were carried out from Monday till Friday, just before the waste was disposed of on these days. The aim was to guarantee a defined time lapse between the waste disposal and waste analysis, and therefore, to guarantee comparable waste amounts. Nevertheless, a defined time period between waste analysis and waste disposal have to be mentioned in the revised version of the SWA-Tool.

Usually, transformation countries such as Russia are confronted with new problems such as an extreme increase of waste and change of waste composition. In addition, they can not resort to historical data. Therefore, a five-year *recurrence* should be implemented twice in order to build up a data bank and to show possible changes. After that, a 10-year period seems to be appropriate as a 10-year period is usually used as the time period for planning and implementing of waste management concepts (Beigl et al., 2005). A regular analysis of waste is essential for the continuation of a waste management concept.

5.1.6. Sample preparation and sorting

ASTMI explains how the samples should be prepared in the work step *sample preparation*, i.e. mixing, coning and quartering the waste from waste collection trucks.
For the waste analysis in Khanty-Mansiysk and in Surgut solid household waste was sorted from waste containers as the sampling unit and a sample preparation was not necessary.

Regarding the *sample sorting* there is another difference between ASTMI and SWA-Tool. SWA-Tool recommends to screen the waste twice and a subsequent manual sorting. ASTMI suggests only a manual sorting. For this reason, the use of the SWA-Tool requires more equipment than the tool by ASTMI, and in some countries this can lead to implementation problems. The first screening (> 40mm) is suggested by the SWA-Tool to reduce the work of waste sorting.

Martinho et al. (2008) and Dahlén and Lagerkvist (2008) discuss the impacts of screening on results and possible errors in the results of waste analysis. Martinho et al. (2008) suggests to determine screening in regard to the impact of screening on outcomes such as the component in fines such as organic, size of screenings (< 10 or < 20 mm), mass of fines as well as of additional separation and their cost. Dahlén and Lagerkvist (2008) describe the disadvantages of additional screening such as more equipment and work.
A screening of the waste in Khanty-Mansiysk and Surgut was not possible because the essential equipment was not available. Nevertheless, it was possible to separate the fraction “fines” through manual sorting during the waste analyses in Khanty-Mansiysk and Surgut. For example, sand from pet toilets and dust from vacuum cleaners were usually packed in extra waste bags.
With an optional screening there is always a residual risk; the composition can be changed such that, for example, the fraction “fines” could show a higher percentage than without a screening. Therefore, further research on what kind of impact a screening has on the results is necessary, as Martinho et al., (2008) asked for.

5.1.7. Waste catalogue

ASTMI offers a primary waste catalogue with 13 categories. In contrast to that, SWA-Tool offers a 12 primary and 35 secondary categories catalogue. The first categories of ASTMI and SWA-Tool are listed in Table 5-2. Textiles, hazardous waste, complex products, inert and fines are not described as categories in the ASTMI. A comparison between the first categories of the ASTMI and SWA-Tool is not practicable. However, the aim of standardised tools is to enable the comparability of results nationally or internationally. Also Dahlén and Lagerkvist (2008) described the lack of a uniform global sorting catalogue as a prerequisite for comparable results and as a precondition of an internationally scientific recognised standardised tool. As the catalogue by the SWA-Tool includes a first and a secondary category and additional categories such as hazardous waste to ASTMI, the catalogue by SWA-Tool should be used.

Table 5-2: Primary waste categories by ASTMI and SWA-Tool

ASTMI **1. Categories**	**SWA-Tool** **1. Categories**
Food waste	Organic
Yard waste	---
Other organics	---
Wood	Wood
Mixed paper	Paper/cardboard
High-grade paper	---
Newsprint	---
Corrugated	---
Plastic	Plastic
Glass	Glass
---	Textiles
Ferrous	Metals
Aluminium	---
---	Hazardous waste
---	Complex products

---	Inert
Other inorganics	Other categories
---	Fine

5.1.8. Evaluation of waste analyses and presentation of results

ASTMI only recommends evaluation of the waste composition and amount. In contrast to that, SWA-Tool suggests a statistical evaluation of the mean, the standard deviation, the variation coefficient, the relative confidence interval, and the composition. The aim of such a statistical evaluation is a detailed overview of possible uncertainties in the waste generation.
The evaluation of results was not very comprehensibly described in SWA-Tool. Although an annual and a seasonal statistical evaluation are requested, only the method of calculation for seasonal evaluation is given. Furthermore, the calculation of the sample size is based on the natural variation coefficient. Nevertheless, the calculation method for this coefficient is not given either. Finally, it can be stated that a complete review of the description of the evaluation of results is essential.

Additionally, to demonstrate the evaluation, different figure-examples instead of one figure-example were used in the description of the tool. Different explanations to demonstrate the results in the case studies which are given in addition to the description of the tool also complicated the understanding of evaluation of the results of the waste analysis. Furthermore, it is recommended to determine an overall result for the relative confidence interval in the tool but there is no description of how to calculate this.

Presentation of results also plays a role for comparing the results. Only the SWA-Tool offers suggestions for the presentation of results. Examples of figures/ diagrams and tables are given in both the tool itself and the case studies for the tool. The booklets of the case studies given besides the manual for the SWA-Tool differ extremely in the calculation, presentation and evaluation of their results. As one objective of a standardised tool is to create comparable results, only one method of calculation, presentation and evaluation of the results should be given.

In conclusion, different methods of annual statistical calculation have to be given by ARGUS GmbH (Zwisele, 2008) in order to implement the evaluation of results as recommended by the SWA-Tool. Regarding the presentation of results, bar diagrams were used for comparing the different strata in Khanty-Mansiysk. Circle diagrams and/ or bar diagrams are useful for the demonstration of annual waste composition. Tables should be used to illustrate all statistical assessments. A total revision of the evaluation part in the SWA-Tool is recommended.

5.1.9. Equipment and costs for waste analyses

Equipment as well as health and safety requirements are described in both tools. More details are given in the SWA-Tool. In addition, the SWA-Tool also describes the number of working hours and possible personnel numbers required for the implementation of one waste analysis based on the amount of solid waste.
It was difficult to organise the equipment for the waste analyses in Khanty-Mansiysk and in Surgut. Small containers could not be bought in either town, so the decision was made to use buckets. Puncture- and acid-proof gloves and overalls were not available either. Both were bought in Germany and taken to Khanty-Mansiysk and Surgut. Further equipment such

as for screening the waste could also not be produced; therefore, the waste analyses were done without screening the waste. A further condition was that equipment needed to be portable. It had to be used in Khanty-Mansiysk and in Surgut and no cars/ trucks were available to transport the equipment. Public transport had to be used for haulage between Khanty-Mansiysk and Surgut. In addition, the equipment had to be carried by hand from the waste disposal companies to the site of waste analyses and back. Therefore, another requirement was that the equipment had to be lightweight. However, local conditions such as the possibility to organise/ buy and/ to make equipment for the waste analysis have to be considered during the preparation of waste analysis and should be mentioned in the revised tool.

Costs of waste analyses mainly depend on the staff salary and equipment and can only be calculated for each single analysis. As opposed to ASTMI, the SWA-Tool tool offers an overview of equipment and working hours required for an analysis. So, an individual calculation could be done before of the start of waste analysis. The implementation of the project in Khanty-Mansiysk and in Surgut was dependent on the help of the local administration. Ugra State University made contact and asked for support from waste disposal companies. In addition, students of Ugra State University supported the project by sorting the waste. Because of less and light equipment, it was possible to bring the equipment via public transport from Khanty-Mansiysk to Surgut and back to Khanty-Mansiysk. Waste analyses were done *in situ* and therefore, a special location/ building and funding for a building was not necessary to some degree. However, the waste analysis was dependent on the weather as, especially in the wintertime with average temperatures of -30℃, a waste analysis was hardly feasible. So, costs need to be calculated based on the local conditions for the implementation of a waste analysis.

An overview of all proposals for a new guideline that is applicable in Siberian regions is given in Table 5-3.

Last but not least, inexact expressions were used in the ***manual of the SWA-Tool*** such as the terms of *survey units,* and *sampling units* were permuted. Errors in the text such as incomplete sentences made it difficult to understand the details. Therefore, a revision is necessary.

A summary of all suggestions is given in Table 5-3.

Table 5-3: Summary of commonalities and differences between ASTMI and SWA-Tool (based on Martinho et al., 2008; Dahlén and Lagerkvist, 2008)

Tools / Contents	ASTMI (2003)	SWA-Tool (2004)	Proposals for implementation for a revised guideline in Siberia	Proposal based on
Waste definition	No definition of the "unprocessed municipal solid waste" which is to be analysed.	Definition of residual household waste and co-collected commercial waste is given.	Municipal waste: "Waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households." (Directive 99/31/EC on landfill of waste, p. 0003). *Solid household/ domestic waste* composed of garbage and rubbish, which normally originates from houses (EEA, 2008). *Commercial waste* is defined as waste from small shops, enterprises or administration (EEA, 2008).	Directive 99/31/EC on landfill of waste; EEA multilingual environmental glossary
Sampling type	Random sampling	Stratified random sampling	Stratified random sampling	SWA-Tool
Sampling level	Waste collection vehicle	External waste containers outside of the household/ business properties	Analysis of waste composition: ➢ External waste containers outside the household/ business properties Analysis of waste amount: ➢ Measurement/Weighing all waste disposal trucks which run to the waste disposal site and/or waste treatment plant per day.	SWA-Tool ASTMI
Sampling unit	A quarter of a waste disposal truck	Volume of the waste bin	➢ Volume of the waste bin minimum $1m^3$ per day per strata, and weighing the waste of disposal trucks for daily waste amount ➢ No scale available: only the volume of the waste bin, minimum $1m^3$ per day per strata or ➢ No waste containers available: Volume of truck, minimum 100kg per day per strata The overall aim is to guarantee the accuracy of statistical evaluation.	SWA-Tool ASTMI Dahlén and Lagerkvist (2008)

Tools / Contents	ASTMI (2003)	SWA-Tool (2004)	Proposals for implementation for a revised guideline in Siberia	Proposal based on
Sample size	Formula for calculation is given, based on mean and standard deviation and on 90% or 95% confidence level with 10% accuracy.	Natural variation coefficient is known: ➢ Table with figure is given based on 95% confidence level, 10% accuracy Natural variation coefficient is unknown: ➢ 45m^3 - household waste	Waste containers: ➢ 35m^3 – household waste, minimum 5m^3 for a single stratum if a 5-day week is chosen for a waste analysis Disposal truck: ➢ 35 loadings with minimum 100 kg per day per strata based on 90% or 95% confidence level, maximum allowance for random sampling between 10% and 30%	SWA-Tool ASTMI Dahlén and Lagerkvist (2008)
Influencing factor	No statement	Stratification Criteria: seasonality, residential structure, bin size, collection system, source of waste, socio-economic influences, collection day	Stratification Criteria: seasonality, residential structure, bin size, collection system, source of waste, socio-economic influences, collection day	SWA-Tool
Duration of analysis	Analysing waste of at least one week's collected waste	Daily or weekly waste collection: ➢ one week (Monday-Friday) corresponds with the full collection cycle. Bi-weekly: ➢ duration of waste sampling of 2 weeks	➢ 5-7 day-week ➢ similar time lapse between waste analysis and waste disposal in order to guarantee a comparable waste generation	SWA-Tool ASTMI Kaazke (2009)
Sample preparation	Mix, cone and quarter of the material from the waste disposal truck	No statement	No preparation	Kaazke (2009)
Sorting of sample	Manual sorting of the entire material	➢ 1st screening < 40mm, manual sorting of > 40mm ➢ 2nd screening of < 40mm, < 10 mm = fines; manual sorting of > 10mm	Manual sorting of the entire material (Screening can be optional. Firstly, further research on influences of screening should be done.)	ASTMI

Tools / Contents	ASTMI (2003)	SWA-Tool (2004)	Proposals for implementation for a revised guideline in Siberia	Proposal based on
Sorting catalogue	13 primary categories	13 primary categories, 35 secondary categories	13 primary categories, 35 secondary categories	SWA-Tool
Evaluation	Recommendations are available	Recommendations are available. Record sheet as Excel spreadsheet is given but not available from the EU.	Recommendation followed by the SWA-Tool but after an complete revise of the "Chapter 3.4. Evaluation of waste analysis" in the SWA-Tool.	SWA-Tool
Data presentation	No statement	Examples for tables and diagrams are available	bar/ circle diagrams, tables	SWA-Tool Kaazke (2009)
Personnel	No statement	Recommendations are available	Recommendations as per SWA-Tool.	SWA-Tool
Equipment	Recommendations are available	Recommendations are available	Recommendations as per SWA-Tool.	SWA-Tool
Health and safety	Recommendations are available	Recommendations are available	Recommendations as per SWA-Tool.	SWA-Tool
Costs	No statement	Recommendations are available	Recommendations as per SWA-Tool.	SWA-Tool
Time period for repetition	No statement	No statement	Twice after 5 years; after that, once every 10 years	Kaazke (2009)

5.1.10. Applicability and recommendation for using SWA-Tool in Siberian regions

Although several differences exist between ASTMI and the SWA-Tool, both tools do not differ widely from one another.

Despite all the issues mentioned above regarding the SWA-Tool, I am convinced the tool is a good basis for local authorities without any experience in waste analyses, but a revision is essential. Additionally, I am also confident that the tool can be accepted and used globally because it was developed within the 5th EU framework and thus already tested in several countries such as Poland and Bulgaria, and many countries also supported the development, including the USA and Sweden. The key advantage is its flexibility as the SWA-Tool offers different ways of implementing work steps, for example for choosing the level of sampling (external waste bin or waste disposal truck). The sometimes inexactly formulated work steps as well as the description of the evaluation of the results in the SWA-Tool can make the user feel uncertain and therefore, this tool needs to be further improved. A “user version” and a “long version” of the SWA-Tool exist with only few differences. The long version should be revised and become the scientifically recognised document.

Overview of recommendations for revision of the SWA-Tool (EC, 2004) for an optimal application, especially in Siberian regions:

Regarding sample-taking:

- The definition of one unit (1m^3 and/or 100kg) should be stated.
- The advantage and disadvantage of the different types of sampling levels (disposal truck and/ or waste containers) should be explained, as aforementioned in Table 5.-1, so that users can decide for themselves which is the optimal technique.
- The time interval between the daily waste disposal and daily waste analyses should be defined. 24 hours as a basis should be used.
- A time period for repeating the annual waste analysis ought to be described.
- Screening of the waste is not always feasible. Its effect on the results should first be researched.

Regarding evaluation of results:

- A complete review of the description of statistical evaluation in the SWA-Tool is essential so that users can follow the explanation effortlessly. It would also include a list of all necessary formulas for the evaluation of the results.
- Only one final version of the evaluation and presentation of the results should be given in the revision of the tool.

Regarding the manual:

- A revision of the text is necessary to eliminate errors and avoid the permuting of terms. This would enable better comprehension of the manual.

5.2. Questionnaires

While preparing the questionnaires recommended by The World Bank (2004) virtually no problems occurred. Not all questions suggested were used as it was a pilot project; i.e. it was the first carrying out of a questionnaire regarding waste management concept in Khanty-Mansiysk. Nevertheless, The World Bank (2004) does not offer any recommendations on how to implement the questionnaires and evaluate the results. Therefore, modifications are necessary for an optimal use of the questionnaires recommended by The World Bank (2004) in general, and specifically in the Ugra Region.

For the preparation and implementation of questionnaires the following factors play a key role:

- the type of question including the importance of taking intercultural communication into consideration (Kromrey (2002);
- the type of questionnaire;
- the type of implementation;
- the sampling and sampling size and
- evaluation (compare Atteslander (2008); Kromrey (2002); Bortz and Döring (2006), Lamnek (2005); Diekmann, 2008).

5.2.1. Types of questions

There are three types of questions:

1. *Open questions* do not offer any answer and the persons asked have to solve the task set by themselves.
2. The *semi-open questions* also give the opportunity to formulate the answer, but in contrast to open questions, only one answer should be right.
3. *Closed-ended questions* offer answers and the person interviewed has to decide on an answer.

The suggested questionnaire by The World Bank (2004) consists of closed-ended and open questions. A mix of these two types of questions was used in Khanty-Mansiysk as well.

A disadvantage of closed-ended question is that answers outside of the given answers are not possible, which can lead to information losses. Therefore, in some cases, the type of question was changed from closed to open in the questionnaires used in Khanty-Mansiysk in order to prevent information loss. An example is the question regarding problems with the current waste disposal: The question for the "reason for the problems" is a closed-ended question in the questionnaire proposed by the World Bank (2004). It was changed to an 'open' question in the questionnaires in Khanty-Mansiysk. I decided to take an open question instead of closed-ended because the aim was to get all possible information about problems with the current waste disposal.

A test run of the questionnaire was carried out with teachers at Ugra State University, and although this test run did not demonstrate any problems, some issues had arisen during the implementation of the survey in Khanty-Mansiysk.

There were some problems regarding the payment (an open-ended question) for waste disposal because the difference between "not knowing whether they pay" or "not paying at all" had to be asked and noted additionally by the students carrying out the surveys.

The closed-ended question regarding the disposal of organics also showed some problems when asking the residents of small houses with garden. Feeding the pets was not included as an answer but a possible answer/ a fact for the residents of small houses with gardens.

Because of personal questioning it was possible to acquire a lot of additional information. It also demonstrates clearly that for some questions not all possible answers were offered, especially for residents of small houses with garden, and hence, a revision of the questions is necessary.
Nevertheless, advantages of closed-ended questions are comparability of results, objectivity of evaluation, less expenditure of time for implementation of questionnaires and easy answerability for interviewees. Therefore, closed-ended questions are recommended within a questionnaire regarding waste management.

Komrey (2002) described the issue of *intercultural communication* in surveys. He explained that "different languages" exist in "several subcultures" (Komrey, 2002). This means that there could be a number of different interpretations of just one question. I agreed with this opinion and tried to adapt the language of The World Bank questionnaire (2004) to the language in Khanty-Mansiysk. First of all, the questions needed to be translated from English into Russian. I translated the questionnaire into Russian together with a teacher from the Ugra State University. Ms Natalia Popova is a teacher for English and German who lived in Germany for several years but grew up and lives in Siberia. So, a very good translation of my comprehension of the question by The World Bank (2004) with little comprehension difficulties should be guaranteed. After this work, I asked several teachers at the Ugra State University how they would understand the questions and did a test run with other teachers in order to test the understanding of the questionnaire. Although there was a revised version of the questions, some problems appeared during the implementation as described above. A further survey would require a revision of the questions.

5.2.2. Types of questionnaire

In addition, questionnaires can be distinguished by the degree of standardisation: from complete standardised model to a model without standardisation. The first one means that all interviewees obtain the same questionnaires with the same question sequence and if there are closed questions, then they will have same answers. To be able to compare the results is the aim of this type of questionnaire. The World Bank (2004), Kobus (2003) and Raje et al. (2000) suggested to use a standardised questionnaire because the research aim of standardised questionnaires is to compare the results and to identify the significance of the results within the entire population. For this reason a standardised questionnaire in accordance with the questionnaire suggested by The World Bank (2004) was implemented in Khanty-Mansiysk and should be used for further research.

5.2.3. Types of implementation of questioning

Two main types of implementation exist, oral and written questioning. Telephone interviews and personal interviews via field visits are examples for oral questioning. Mailed questionnaire is an instance of a written survey (Kromrey, 2002). Telephone interviews and mailed questionnaires have several disadvantages. A telephone interview requires a large number of people with a telephone and knowing the telephone numbers, and in many countries (such as Russia), this is not common. The return of mailed questionnaires depends on the willingness of the people to answer and that is dependent in turn on the topic and importance of the questionnaires. Finally, the disadvantage of the door-to-door survey is its high cost, for example for the interviewers, but it has the highest return quota.
The World Bank (2004) does not explain thoroughly how to implement their questionnaires. The remarks at the beginning of the questionnaires such as "Time of Interview" lead to the

assumption that it is an interview via field visit. Kobus (2003) recommended a dispatch by post. Plümer and Multhaup (1995) implemented the questionnaire through door-to-door survey. Raje et al. (2000) recommended the personal interview to identify the satisfaction level with current waste disposal management.

As recommended by Raje et al. (2000), a door-to-door survey was carried out in Khanty-Mansiysk. A mailed questionnaire was not feasible as there was no budget for stamps or postage of the letters/ questionnaires. It also seems that the inhabitants of Khanty-Mansiysk mainly have mobile phones and therefore, telephone numbers were not available. Thus, telephone interviews were not possible. A door-to-door survey with students of Ugra State University appeared to be the only way to carry out the questionnaires and to ensure a high number of questionnaires answered. It has to be mentioned that the students worked on a volunteer basis. Usually, a door-to-door survey requires a well-funded budget.

Between 5 and 10 questionnaires could be completed in 1 hour per interviewer in Khanty-Mansiysk. For the case that questions regarding willingness to pay and environmental concern are added to the questionnaire, it can be assumed that only 5 questionnaires per hour maximum can be carried out per interviewer.

Usually, a door-to-door survey achieves the highest figure of questionnaires answered. The disadvantage of this type of survey is the (high) number of interviewers needed. If no addresses or telephone numbers to contact the interviewers are available, a door-to-door survey only is implementable.

5.2.4. Types of sampling

In social research different tools of sampling exist such as random sampling and systematic sampling. Both of them can be subdivided into several tools such as stratified random sampling and quota procedure. The main issue is to obtain representative samples. A representative sample is defined as one where there is no big difference between the sample and the original quantity. So, the original quantity can be derived from the sample with regard to its statistical data (Atteslander, 2008). To arrive at representative samples within a random sampling requires knowledge about all research objectives of the population. As this precondition is hardly implementable in most of the demographic description survey an *ad hoc* sampling can be used. Nevertheless, knowledge about the population researched is essential (Bortz and Döring, 2006).

Plümer and Multhaup (1995) implemented an *ad hoc* sampling without stratification. Kobus (2003) recommended a stratified sampling regarding residential structure, educational background and income level; he does not explain anything about random or *ad hoc* sampling. The World Bank (2004) does not specify a sampling procedure, but in the section ´public participation´ it is recommended to identify all groups according to their social background. Therefore, an implementation of questionnaires within these identified groups seems to be useful.

I used a stratified sampling. Instead of a random sampling, an *ad hoc/ arbitrary sampling* was implemented. The difference is that no sampling plan exists and there is a risk of non-representative samples. The data for a sampling plan, for example profession and financial situation which could have an influence on the daily behaviour with waste, were not available. The main influence was expected from the residential strata. These strata were already identified for the waste analysis. Based on this stratification, the same strata were taken for implementation of questionnaires in Khanty-Mansiysk - *inhabitants of apartment*

blocks and *inhabitants of small houses with garden*. Within these strata, arbitrary apartments and arbitrary houses were chosen.
Although a (stratified) random sampling only guarantees an inference statistic instead of an *ad hoc* sampling, an *ad hoc* sampling can be used as well on the condition that the total population and its characteristics are well known. Therefore, carefully implemented *ad hoc* sampling is suggested.

5.2.5. Sampling sizes

Bortz and Döring (2006) recommend to carry out 87 questionnaires for χ^2 - *tests* and a medium correlation. Representative sampling is the precondition. They also provide an overview of all possible significance tests and their optimal sample sizes. Kobus (2003) suggested to send out 300 questionnaires with an expected return rate of 30%. Therefore, approximately 90 questionnaires can be calculated as the analysis basis. Plümer and Multhaup (1995) referred to their case studies. Between 81 and 421 questionnaires were carried out. The World Bank (2004) provides a table with optimal sample sizes based on a 90% confidence level. Kobus (2003), Plümer and Multhaup (1995) and The World Bank (2004) do not describe a correlation between sample size and statistical evaluation. In contrast to them, Bortz and Döring (2006) describe such correlations. A significant result with a medium correlation can be already reached with a sample size of 130 questionnaires. Therefore, the rule is to collect as many questionnaires as possible under the condition that the sampling is representative (compare “sampling” as aforementioned).
For a demographic description survey, the number of the total population is irrelevant for the sample size (Bortz and Döring, 2006).
200 questionnaires were carried out in Khanty-Mansiysk. This figure is based on the experiences of the case studies by Raje et al. (2000) and Plümer and Multhaup (1995). Under the circumstances in Khanty-Mansiysk, 200 questionnaires also seemed to be implementable: If calculating 10 minutes per questionnaire and students working two hours per day, the survey would take 16 days. Therefore, 100 questionnaires per stratum seemed a good sample size.

5.2.6. Description and evaluation of results

Description and evaluation of determined results play a very important role in the social sciences. Significance tests were developed in order to prove the hypothesis statistically and to determine the correlation between the total population and inhabitants interviewed within demographic description survey. The χ^2 - *tests are* significance tests. These tests are not dependent on the number or criteria and/ or type of criteria (nominal or ordinal data). A minimum of 5 answered questions per criteria and a representative sampling are the precondition (Bortz and Döring, 2006). Therefore, the χ^2 *–tests* are simple to implement and are recommended for further survey.

5.2.7. Applicability and recommendation for application of questionnaires in Siberian regions

It must be stated that when preparing the questionnaires, I assumed that this would be the first time the residents in Khanty-Mansiysk would participate in the development of a waste management concept. Consequently, the decision was made that the questionnaires should only take 10 minutes in order not to scare off interviewees. Practice showed that an inquiry could take from anywhere between 5 minutes up to 30 minutes because the inhabitants were actually interested and outlined several problems.

Finally, it can be stated that user participation via questionnaires based on the proposal of The World Bank (2004) works and can be used as a tool. The questionnaire developed for Khanty-Mansiysk can be applied in revised version for the Ugra/ Siberian regions. In addition, the questionnaire should be expanded to include questions regarding environmental concerns and knowledge as well as willingness to pay. These aspects are also included in the questionnaires by The World Bank (2004). A detailed description of how to implement questionnaires is crucial and needs to be worked out.

It seems there is hardly any research on significance tests of questionnaire results regarding waste management. Raje et al. (2000) already developed criteria and an index to prove his hypotheses but did not use a significance test either. It seems that a statistical evaluation has not been included in waste management concepts even though integrated waste management concepts require a co-operation between engineering and social sciences. Thorough research for applicability of significance tests for questionnaires regarding waste management appeared as necessary, especially for Siberian regions.

Overview of recommendations for optimal implementation of questionnaires as recommended by The World Bank (2004), especially in Siberian regions:

- All questions suggested by The World Bank (2004) should be used for further surveys in the Siberian region. Questions need to be adapted to the local language. The main type of questions should be closed-ended.
- A standardised questionnaire through a door-to-door survey should be implemented.
- Stratified sampling according to the stratification of waste analysis and a carefully implemented *ad hoc* sampling are suggested.
- 100 questionnaires per stratum according to the stratum of the waste analysis should be implemented. 100 questionnaires meet the requirements of an inference statistic.
- A statistical evaluation through χ^2 *–tests* for nominal and cardinal data is recommended in order to determine the statistical probability of the interviewees' answers. The results of the inference statistic should support the status report for the development of an integrated waste management concept.

5.3. Waste prognosis implementation

Four different tools were used for forecasting the waste amount:

1. Formular within a software programme (Project Coordinator TU Darmstadt, 2005);
2. Formula by EC guideline recommended in “Preparing a waste management plan” (EC, 2003);
3. Formula by Slyusar (2008, pers. comm.)
4. Estimation by Ulanova (2008, pers. comm.).

Using the prognosis software tool (Project Coordinator TU Darmstadt, 2005) and the formulas given by EC (2003) and Slyusar (2008, pers. comm.) was quite simple after the waste amount and waste composition for Khanty-Mansiysk and Surgut were verified. Finding experts for waste management in Russia was quite complicated as there is only little research done on waste management in Russia.

There are two key factors for evaluation of the results of waste prognoses (Karavezyris, 2000):

1. Reliability describes the stability as well as the accuracy of results.
2. Validity refers to the degree of exactness of results.

5.3.1. Reliability and validity of tools for prognosis of waste amount

The main emphasis for forecasting the waste is on the software tool for waste prognosis which was developed within an EU project.

In contrast to the formulas described above, the approach of the aforementioned waste prognosis software program is more complex (Karavezyris, 2000):

4. $M^t = c_0 + c_1 * \log S_l^t + c_2 * E_{15\ 59}^t + c_3 * H^t + c_4 * L^t$

M: waste amount
c: regression coefficient
S_l: infant mortality rate on suburban level (alternative: S_u = Infant mortality rate on urban level)
E: number of inhabitants
H: size of households
L: life expectancy
t: forecast year (Karavezyris, 2000).

The reliability of the prognosis of waste amount depends on different socio-economic factors for the future, for example population growth. Correspondingly, the precondition for waste prognosis is that these forecasted factors prove to be true (Beigl, 2006) (see Chapter 1.1.4.). The advantage is that the software tool is based on detailed international research. It is the first international approach which also includes Eastern European countries (Beigl, et al., 2005). A disadvantage is that as the software tool is aimed to forecast the waste amount and composition of European towns, no default data for Russia exists in the software programme. However, there are data of Eastern European countries such as Lithuania which have comparable waste generation and also share a common history with Russia. Therefore, similarities between the solid household waste in Russia and in Lithuania can be assumed. Consequently, the default data of the waste prognosis software tool for Lithuania was used for the calculation. Some accessible data such as waste composition or life expectancy can be changed by the user. The data required can be researched and entered in the programme easily. A forecast for Khanty-Mansiysk and Surgut was only possible in this way.

Nevertheless, using the default data of Lithuania increases the risk of inaccuracy of waste prognosis, especially concerning the waste composition (compare example - proportion of electronic waste as aforementioned). A problem occurred during the implementation of the software program because of lacking data:
As the urban input data for Khanty-Mansiysk and Surgut were the same, the tool could only estimate almost the same increase for future waste amount of 20kg c^{-1} a^{-1} for Surgut and 21.5kg c^{-1} a^{-1} for Khanty-Mansiysk in 2012. Within the LCA-IWM prognosis software tool it is possible to subdivide into data input for *urban* and *national* level. The lack of urban data for both towns, for example for “average of household size” or “population aged between 15 and 59 years”, made it necessary to derive this information from data from the national level. Town characteristics such as migration boom and rapidly growing economy have an influence on the waste generation, and these characteristics can differ extremely from the national average and vary from town to town (Beigl, 2006). For example, Khanty-Mansiysk can report an economic boom whilst in Surgut the economy shows a more or less linear development. Therefore, it can be assumed that the increase of waste amount is higher in Khanty-Mansiysk than in Surgut, and not almost the same as the waste prognosis software tool calculated (see Chapter 2.2.). Finally, results of waste prognosis depend on urban/ regional characteristics such as migration boom and population aged 16-59. Therefore, to achieve exact results for each town it is essential to determine current data such as waste amount as well as these aforementioned characteristics at the local level.

The prognosis software tool was developed within a project where several other methodologies were used for testing the reliability and validity of results. Default data of different countries which are entered in the program are tested and consequently, reliability and validity for the results of these default data can be assumed (compare manual and deliverable report for the prognostic tool by Beigl et al. (2005)). Nevertheless, the user has to interpret the results correctly, which can be difficult without any experience. Hence, the user should have knowledge about the historical and current waste generation.

In the case of this dissertation, the annual domestic waste amount and composition in Russia, a country which is not included in the software program, was predicted. All data required were determined for Russia and entered into the system. In order to support the reliability and validity as well reduce uncertainties, further tools such as expert interviews and using the most common calculation, were also applied:

The formulas by EC (2003), Slyusar (2008, pers. comm.) and the estimation by Ulanova (2008, pers. comm.) have in common that they only need two parameters for calculating the future waste amount, which also means that they have a linear correlation. All formulas are given for a 5-year waste prognosis (see Table 5-4). It can be stated that the reliability of the figures for the waste amount forecasted through these three formulas depends on the knowledge about current waste amount as well as the prognosis/ trends of waste volume growth and/ or population development.

Table 5-4: Waste prognosis formulas

	Source	Formula	Precondition
1.	EC (2003) (low hypothesis)	$G_{n+5} = A_{inhab} * (1.004)^5 * P_{t/a*inhab} * (1.006)^5$	• Waste amount per capita and year "n" • an annual population development of +0.4% • an annual increase of waste amount of +0.6%
	EC (2003) (high hypothesis)	$G_{n+5} = A_{inhab} * (1.009)^5 * P_{t/a*inhab} * (1.01)^5$	• Waste amount per capita and year "n" • an annual population development of +0.9% • an annual increase of waste amount of +1.0%
2.	Formula by Slyusar	$G_{n+5} = G_n * (1.003)^5$	• Total waste amount in the research area • an annual increase of waste amount of +0.03 %
3.	Estimation by Ulanova (minimum)	$P_{t/a*inhab+5} = P_{t/a*inhab} + 20kg_{(2012}$	• Waste amount per capita and year "n"
	Estimation by Ulanova (maximum)	$P_{t/a*inhab+5} = P_{t/a*inhab} + 30kg_{(2012)}$	• Waste amount per capita and year "n"

n:	current year
G_n:	total amount of waste in defined area and in researched area for year n
G_{n+5}:	total amount of waste in defined area and in researched area for year n+5 years
A_{inhab}:	number of inhabitants in year n
$P_{t/a*inhab}$:	waste amount per capita in year n

The formula by EC (2003) is based on an annual maximum population growth of +0.9%. Approximately, 300 people per month moved to Khanty-Mansiysk in 2007, and the number of inhabitants could have increased from approximately 70,000 to 73,600 within one year. Therefore, the annual population growth can be estimated at +5.0% in Khanty-Mansiysk in 2007, which means that the original type of formula by EC (2003) is in fact not applicable for Khanty-Mansiysk. As the formula can be subdivided into calculation of population growth and development of waste generation, only the latter part of the formula was used. The precondition is still that there is an increase of waste amount between +0.6% and +1.0% per year. The formula described in the guideline by the EC (2003) was mainly developed for European countries including Eastern European countries.

Both Slyusar (2008, pers. comm.) and Ulanova (2008, pers. comm.) explained that a prognosis of waste amount is very difficult in the Siberian region because of the extreme cultural and social changes at the moment. This is also apparent in the varying results of their forecasts:

- Slyusar (2008, pers. comm.) used a formula specified by Russian law and forecasted the smallest increase of waste amount. The increase of waste amount by 0.3% per year is based on a prognosis from 1996. It can be assumed that this figure is not correct anymore, especially for rapidly growing towns and cities in Russia. OECD (2008) already analysed that Russia is also experiencing an extreme increase of waste amount and had already surpassed the amount forecasted for 2030.
- Ulanova (2008, pers. comm.) estimated an increase of waste based on the results of waste analyses she carried out on the Olchon Island and forecasts the maximum of increase with the waste prognosis results of the dissertation.

Finally, it can be mentioned there is a risk of validity and reliability of these three tools for forecasting the waste amount in Siberian regions.

5.3.2. Reliability and validity of tools for prognosis of waste composition

The waste prognosis software tool offers a calculation of the change in the waste composition, but the waste prognosis software tool was inconclusive with regard to waste composition for Russia/ Siberian regions. For example, electronic waste can not be entered separately within the waste prognosis software tool but the software system calculates a future proportion based on default data developed for European countries. The data of Lithuania were chosen as the default data for the calculation of the waste prognosis for Khanty-Mansiysk and Surgut (see Chapter 3.5.) However, in this case, the software system can not be used as the current proportion of electronic waste in the waste composition of Lithuania is already higher than the current proportion of electronics in Khanty-Mansiysk and in Surgut. The software tool does not seem to be flexible enough to consider the special condition of the Siberian region.

In order to achieve a result, I took the data on electronic waste from the waste analysis in Khanty-Mansiysk and Surgut and estimated a possible future proportion of this waste stream for Surgut and Khanty-Mansiysk in 2012 based on the proportion of electronic refuse in Berlin and Helsinki in 2007. The assumption was that a comparable proportion of electronic waste could feature in Surgut and Khanty-Mansiysk in 2012 as it does in Berlin and Helsinki in 2007. The comparison with other towns as described in the previous chapter does not include the local development in Siberian regions. Both tools can only show a tendency of future waste composition in Siberian regions.

The difficulty of forecasting the waste composition is the diversity and complexity of indicators which have an effect on the waste composition. Dahlén and Lagerkvist (2009) demonstrate this fact by identifying 43 influences that include legislation, technical design of collection equipment and residential structure. As the composition of waste has an impact on the decision for a waste management concept, further research for tools of forecasting the waste composition is more essential than ever.

Neither the formula for waste prognosis by the EC (2003) nor Slyusar (2008, pers. comm.) nor Ulanova (2008, pers. comm.) can calculate waste composition.

5.3.3. Time horizon of waste prognosis

All waste prognoses are calculated for the year 2012*, a time horizon of 5 years*. Only a 5-year prognosis was demanded because the migration boom, the rapidly economic development, social changes, and absence of historical waste data increase the risk of forecast errors. Nevertheless, a long-term prognosis for 10 years should be the aim for the future as a 10-year period appears to be useable and suitable in regard to the time period for planning and implementing of waste management concepts (Beigl et al., 2005). Additionally, long-term targets need to be considered for planning the size of treatment plants, and their cost are also stated in the guideline by the EC (2003). Therefore, a 5-year prognosis is not very useable for the development of a sustainable waste management concept on the one hand. On the other, there is a high risk of an incorrect prognosis with a long-term horizon as aforementioned. I recommend repeating the waste analysis in 5 years, as a verification of the waste prognosis results is thus possible. If the prognosis proves true, a long-term prognosis of waste amount and composition with the prognosis software tool seems to be appropriate.

5.3.4. Importance of waste prognosis as a sustainable indicator in the international context

Rida (2008) analysed international sustainability indicator systems for waste management. Such sustainability indicator systems are created for assessing and reviewing concepts of any type. Sustainability indicator systems with main emphasis of waste management concept were developed by the OECD, UN/ United Nations Commission for Sustainable Development (UNCSD) and EU/EEA. Indicators within international sustainability indicator systems for waste management include current waste amount per year and/or per capita, current waste composition, recycling quota etc. Rida (2008) found that as concerns waste composition and waste amount, only the current waste amount plays a role as an indicator in environmental and sustainability indicator systems of the international organisations aforementioned. The prognosis of waste amount and composition are not indicators within their indicator systems. This analysis also reflects the disregard of impact of current waste composition as well as the influences of prognosis of waste composition and waste amount for the development of waste management concepts.

Furthermore, Beigl et al. (2005) states that although waste prognosis is an essential part of a waste management concept, there is not much (international) research to improve waste prognosis tools. In addition, their analysis shows that waste prognosis is mainly based on waste amount in correlation with population development. Socio-economic factors which have a main influence on waste amount and composition do not play a main role in forecasting waste amount (Beigl et al., 2005). It also seems that tools for forecasting waste composition are currently not developed.

Therefore, further research and more intensive implementation of waste prognosis; i.e. waste composition and waste amount, in integrated waste management concepts internationally are more essential than ever, especially against the background of a global increase of waste (OECD, 2008) and change of waste composition.

5.3.5. Applicability and recommendation for using waste prognosis tools for Siberian regions

Finally, it can be stated, as the formula by Slyusar (2008, pers. comm.) seemed to be outdated, its further use is not recommendable. As the formula by EC (2003) is the most (internationally) recognised formula (Karavezyris, 2006) and because a low and a high hypothesis are given, the risk of uncertainties seemed to be containable. Nevertheless, a determination of population growth and increase of waste amount is necessary. I am convinced a circumspect application of the software tool in combination with additional interviews with (local) experts regarding waste management would lead to more accurate forecasted waste amount and waste composition (with restrictions) and can be used by local authorities in Siberian regions. The prognosis tool and the manual are free of charge and can be downloaded from the Internet. One aim of the software tool was user-friendliness which has been achieved. Users are in the position to enter and calculate all data required without any experience using such a software programme. Nevertheless, reliable data of current waste amount and waste composition are the significant basis for waste prognosis.
Despite the different approaches of the four tools used in the dissertation, the results for predicting the *waste amount* were similar. Only the waste prognosis tool offers to forecast the *waste composition,* but is not fully suitable for that purpose. However, to obtain reliable results of forecasted waste amount and composition for Russia, further development of the

prognosis software tool is necessary. As data of current waste amounts have not been finally verified, further waste analyses are required in order to calculate correctly forecasted waste amount and waste composition.

Overview of recommendations for an optimal application of waste prognosis tool, in particular the software prognosis tool (Project Coordinator TU Darmstadt, 2005), especially for Siberian regions:

Regarding the use of the prognosis software tool:

- In order to improve the accuracy of waste prognosis, the continuous monitoring of waste amount and composition in Siberia as well as the development of a data bank regarding waste amount and composition should be implemented. These data should be entered in the prognosis software tool.
- The tool should be reviewed and expanded by default data for the country Russia, in addition to the 32 countries which are already included.
- Some data requested such as "GDP per capita in USD PPP at 1995 prices" should be updated in the software prognosis tool.

Regarding the evaluation of the results:

- Experts of waste management for waste prognosis should be consulted in order to support the results of the prognosis software tool.
- Results of the prognosis software tool should be checked via a further waste analysis in 5 years, i.e. in 2012. If the results of the waste analysis support the results of the prognosis software tool, a further use of the prognosis software updated tool is recommendable.

5.4. Life Cycle Assessment

While applying the LCA-IWM software tool several problems appeared, in particular data to be entered in the software tool were not available. Furthermore, the description of the work steps in the software tool's manual was frequently incomprehensible. Therefore, a personal introduction was necessary. As concerns the application of LCA-IWM in Siberian regions, four main issues appeared:

1. Data background for LCI and LCIA within the LCA-IWM
2. Default data and data required by the user
3. Target group
4. Applicability of the manual and deliverable reports.

5.4.1. Data background for LCI and LCIA within the LCA-IWM

The data for the Life Cycle Inventory (LCI) of the LCA-IWM are common data sets for emissions of pollutants and resources and are used for the ecological assessment in the project. The origin of these data sets is from countries with an advanced developed waste management system (den Boer, et al., 2005).

"CML 2001" was chosen as the databank for Life Cycle Impact Assessment (LCIA). The data were normalised to "Western European Inhabitants Equivalents" (see Chapter 2.5.). As that was not useable for Siberian regions, another normalisation for the data was necessary for the Siberian regions. A request to the developer of "CML 2001" as to whether they also offer a "Siberian or Asian Inhabitant Equivalents" or "World Inhabitant Equivalents" was sent. They offered a "World Inhabitant Equivalents (WIE)", and therefore the entire LCA-IWM software tool had to be rewritten with this new normalisation factor.

Usually, databases for LCA are based on scientifically analysed data, for example air emissions from a landfill, which is determined under Central European conditions such as climate (Winkler, 2008, pers. comm.). As the climate in Siberian regions is different to that of Central Europe it can be assumed that emissions of landfills develop differently; i.e. more slowly than in Central Europe. Maurice and Lagerkvist (2003) determined the production of landfill gas emissions in northern Sweden and discovered that seasons/ climate have a significant impact on the production of landfill gas emissions. Lower gas emissions can be expected in the winter time. As LCA-IWM does not offer special data for landfill gas emissions in northern regions, another request for data on landfill emissions in northern region for LCA was sent to Mrs Björklund, a developer of OREWARE, and Mr Damgaard, a developer of EASEWASTE. ORWARE and EASEWASTE are also LCA software tools developed in Sweden and Denmark, respectively. The assumption was that one of these tools could have other data than Central European determined data for landfill gas emissions. Replies from both indicated that they do not have such data (Björklund, 2009, pers. comm.; Damgaard, 2009, pers.comm.). Further research of production/ development of landfill gas in northern regions is necessary in order to complete the databases. As aforementioned, the databases are usually based on Western European or North American conditions (Winkler, 2008, pers. comm.), which means that there is also a lack of data for Asia and Africa.

Cherbuni et al. (2008) also used an LCA software tool (SPIonexcel) to analyse the emissions from different waste management strategies/ scenarios. They determined that emissions on global and local scale differ, especially for their Scenario 2 "Municipal solid waste sorting plant". The positive results on global level (a credit) turned to a negative result on local level (a burden). I developed scenarios similar to Cherbuni´s et al. (2008), and these scenarios were assessed on the global level "World Inhabitant Equivalents" in the LCA-IWM. Under the condition that each software tool would produce similar results, it can be assumed there is a risk of the environmental assessment of the scenarios with an “aeMBT” or “anMBT” on the local level being wrong. Data on the local level in Siberia does not exist; again research is necessary. Additionally, the origin of the data bank used is not comprehensible for users of LCA-IWM.

The software tool offers only one type of transport for waste, which is transport via waste disposal trucks. As it is common in Khanty-Mansiysk to transport cargo via ships, there is the question whether ships could also perhaps transport recyclable waste to treatment plants in Surgut. “CML 2001” neither offers this option nor an option for transport via train which is also common in Siberia. An environmental assessment of waste disposal scenarios with LCA software tools with different types of transport could lead to other results. There is also a lack of data here; for example the environmental impacts of transport via ship or train as well as further development of LCA-IWM have to be researched.

Besides the problems with the LCI data, there was a calculation error in the software tool within the data file for “anMBT” and within the data file for “landfill”.

As the concerns the error for the data file “anMBT”, the total amount of waste calculated through LCA-IWM for the different waste treatment plants such as “anMBT” and “incineration” varied. That could not be true as the total amount entered in the LCA software tool was the same for all treatment plants. Each data file for each treatment plant calculates the total amount by adding up all individual amounts of organics, plastics etc. which the user has to enter. The data file for “anMBT” added up the individual amount of “organics” twice, instead of “organics” and “wood” individually. Therefore, a different total amount was calculated and can lead to erroneous assessment results.

Regarding the error for the data file “landfill”, the percentage of organic dry matters of organic garden was set as zero percent instead of 84%. This had an effect on the calculation of the global warming within the scenarios “landfill” and “landfill with recycling”.

A user with no introduction to the system of the software tool would not be able to rectify such errors. A detailed description of the location of the calculation error within LCA-IWM is given in Appendix – Chapter 5.

5.4.2. Default data and data required by the user

The software tool offers default data which the user can use if he cannot determine such data for his research area. Examples are “lifetime of a waste container” or “designed capacity of waste disposal trucks”. In some cases the user has to choose information such as “size of containers” or “material of containers”. If the proposed information does not match the real situation, the developer of the LCA-IWM software tool recommends choosing the next higher figure (Meneses, 2009, pers. comm.). For example, the containers in Khanty-Mansiysk are 500l containers made of steel. This figure (500l) combined with the material (steel) could not be entered, which is why the decision was made to select 770l steel containers.

The default data do not offer all possible alternatives; however, the availability of default data supports the easy application of the LCA-IWM. Nevertheless, the default data are only based on common data sets similar to the data of the LCI and LCIA aforementioned. Further research of the default data is necessary to build up regional specific LCA tools such as for Siberia. The aim is to strengthen the validity of the results within a LCA.

Although the default data do not offer all possible alternatives, the availability of default data supports the easy application of the LCA-IWM. Nevertheless, the default data are only based on common data sets as well as the data of the LCI and LCIA aforementioned. Further research of default data as the data of LCI and LCIA to build up a regional specific LCA tool such as for Siberia is necessary. The aim is to strengthen the validity of the results within a LCA.

Of course some data are required which is not offered by the default data of the LCA-IWM, such as the waste amount and waste composition, and data on the research area such as population etc. Figures for waste amount and composition for the years 1995, current year of assessment, a year of a waste prognosis (which the user has to choose, max. 10 years in future), and waste generation in 2003 were needed. The minimum of data to be entered regarding waste is the current and forecasted amount of waste and composition of waste. The input for 1995 plays a role for assessing the implementation of the EU Landfill Directive (see Chapter 2.2). The figures for 2003 can be the same as the data for the current situation/year.

The software tool calculates environmental impacts of each scenario based on prognostic data. As a prognosis software tool was also designed in the same project in which this assessment software tool was developed, gathering this data are not very difficult.

Finally, it can be stated that only a minimum of data are required. Most of the data are offered as default data. For the case that the user does not have any more determined data than for waste composition and amount, it is possible to use the LCA-IWM with the default data. If the developed scenarios such as the scenarios used in the dissertation are all assessed with the same default data, a comparison of scenarios is possible. It must also be said that in this case the results do not correspond with results which are based on a complete research, but the scenarios can be compared to each other as all scenarios include the same risks.

5.4.3. Target group

The software tool was mainly developed for local authorities assuming that local authorities have prior knowledge of and experience with LCA software tools (Meneses, 2009, pers. comm.). I assume that local authorities in many Eastern European countries and in Russia, also in the Siberian region, do not have such experience. Therefore, the use of this tool could be difficult for local authorities. A personal introduction to this software tool for local authorities, especially in Siberian regions, is necessary.

5.4.4. Applicability of the manual and deliverable reports as well as validity of the results of LCA-IWM

There are a *manual* (den Boer et al. (Ed.), 2005) and a *deliverable report* (den Boer et al., 2005) that instruct the user how to use the LCA-IWM software tool. The manual explains the tools of data entry step-by-step, and the deliverable reports give detailed background information about the development content of the software tool.

However, there are some inexact descriptions in the manual:

- If the size and material of the existing containers in the research area can not be found in the software tool, no alternatives for entering the information about the existing situation are provided.

- The input of recycling scenarios is not comprehensibly described and it can lead to incomplete scenarios and therefore, to wrong results of the assessment of these scenarios. In addition, the recycling quota is fixed. If the user wants to create recycling scenarios with different recycling quotas, she/he can not change these figures as this is not described in either the manual or the deliverable reports.
- The user can only decide whether “Light fraction (RDF)” is to be burned in a cement kiln or not. If the user chooses that “Light fraction (RDF)” should not be burned in cement kilns, the software automatically chooses that it will be burned in an incinerator. The precondition is that the scenario includes an incinerator, yet this is not mentioned explicitly and one could create a scenario without an incinerator, but the option incinerator will be activated by LCA-IWM. If both or one of these plants are not available in reality, the developed waste management scenarios do not reflect the real situation. This can lead to misguided decisions for waste management strategies as the burning of rejects in an incineration or cement kiln can produce credits for the environment and therefore, a better result for scenarios with aeMBT or anMBT could be possible. This means that the tool is not applicable if an incineration and/or cement kiln is not available in the research area.
- Although the case studies in the manual describe a certain type of landfill for contaminants, LCA-IWM does not offer an assessment of such a landfill. According to the process description of the treatment plants in the manual, the contaminants can be disposed of on a landfill or burned in an incinerator. Again, such a choice is not available in the software programme. In addition, the amount of contaminants calculated by the software tool is not visible to the user. This missing data can also lead to incorrect assessment as the user does not know that contaminants are not considered in the ecological assessment.
- The removal of calculation errors and changing of normalisation as aforementioned is not possible if the user only has the information from the manual and deliverable report. All data files for the modules are hidden and the user does not have access to them without a personal introduction to the LCA-IWM software tool.
- Although the manual describes that hazardous waste can be disposed of on a landfill for hazardous waste, the LCA-IWM software tool does not include such a type of disposal. A change in the handbook and/or software tool is necessary as it can lead to wrong results, especially of the results from scenarios with incineration plants.

Only after personal training in the software tool, calculation tools and how to access the hidden data files is a change of all data easily possible, and a better understanding of the results and a competent handling with the software tool are guaranteed. The case studies presented in the manual support the use of LCA-IWM. However, this would be even more helpful and less confusing if the input of data of at least one case study as an example were described.
The manual needs a revision regarding the inexact descriptions.

5.4.5. Applicability and recommendation for an application of LCA-IWM

It can be stated that as concerns data background, a large volume of data does not exist yet, particularly on the local level for Siberian regions, and further research is necessary. The advantage of the LCA-IWM software tool is its easy operation. Users with little or no knowledge of LCA tools can work with this program if the scenarios are simple and the conditions of the research area/ town are very close to the default data in the software

programme. Advanced use requires a briefing in this software tool. After that, the user can easily change and work with the data. Manipulating the data of course involves risks which can turn into a disadvantage.
A summary of all advantages and disadvantages is given in Table 5-5.

Table 5-5: Summary of advantages and disadvantages of LCA-IWM regarding its application in Siberia

Criterion	Advantages	Disadvantages
Data basis	➢ Existence of scientifically supported data bank for LCI	➢ Data bank is based on analyses under Western European conditions, not under Siberian conditions such as climate. ➢ Origin of data bank is not comprehensible for users.
	➢ Default data such as size and life time of waste containers (for 32 European countries such as Lithuania) exist.	➢ No default data for Russia are entered in the software tool.
Impact Assess-ment	➢ Assessment of ecological, economic and social impacts for waste management scenarios is possible.	➢ Original normalisation factor: Western European Inhabitant Equivalent (CML 2001) which is not useable for Siberian regions.
		➢ Caused by the World Inhabitant Equivalents, only a global assessment instead of local assessment is possible.
Use	➢ Simple use, but the precondition is that basic knowledge on the part of local authorities about using a LCA software tool should be available.	➢ There are calculation errors in the software tool.
	➢ Prognosis of waste composition and amount are considered.	➢ The tool is inflexible in several situations such as rejects of aeMBT and/ or anMBT are transferred to cement kiln or incineration, only a disposal on a landfill is not possible.
		➢ Inexact descriptions in the manual lead to uncertainties in implementation of LCA-IWM.
		➢ The development of the LCA-IWM is finished and no further development and/ or research is going on.
Results	➢ Overall results are given in tables and figures.	
	➢ There is possibility of subdivision of overall results into temporary storage, collection and transport as well as treatment plant.	

Although the approach of this tool -to assess waste management regarding their impact on society, ecology and economy- is the first within LCA software tools, LCA-IWM needs to be improved. It holds too many disadvantages in general and in particular, for application in Siberian regions such as the absence of modelling absolutely own scenarios. Therefore, a use of this tool for Siberian regions is currently not suitable.

Overview of recommendations for an optimal environmental evaluation of integrated waste management concepts, especially in Siberian regions:

- Further research regarding decision support tools for the ecological assessment of integrated waste management concepts in Siberian regions is essential. An alternative can be: *Environmental Impact Assessment.*
- Research on local environmental data such as the time period and volume of emissions from landfills is essential. Such data are the basis for the support decision tools of ecological assessment; i.e. an assessment of integrated waste management concepts is not possible without these data.
- The EU has introduced a waste hierarchy within its laws regarding waste management which among others classifies waste treatments based on their environmental impacts. The implementation of a waste hierarchy in the Russian laws according to the EU laws can support environmental evaluation of integrated waste management strategies.

5.5. Guideline for preparing an integrated waste management concept

"Preparing a waste management plan. A methodological guidance note" by the EC (2003) was used for testing an integrated waste management concept development manual in this dissertation. While the guidance note by the EC (2003) was applied, one main problem appeared: Although there is a step-by-step description of the preparation of a waste management concept, hardly any decision support tools are suggested for the implementation of each work step. Therefore, different decision support tools such as a tool for waste analysis first had to be determined and then applied. As the complete development of an integrated waste management concept would go beyond the scope of this dissertation, only the first work steps for the development of a concept such as waste analysis were tested. However, the applicability of the guideline by the EC (2003) should be discussed.

Although the guidance note by the EC (2003) was mainly developed for the national level with links to the local level, it is only evaluated on the local level. As the literature study in *Chapter 1* demonstrates, the key contents for developing manuals for waste management concepts are:

- the aim,
- the level of implementation,
- the target group,
- the type and definition of waste and
- the general outline:
  - Mobilising the planning part
  - Description of current situation
  - Planning part and public participation
  - Implementation and further review (compare Appendix – Chapter 2, Table A2.1.-1).

Furthermore, legal regulations play an essential role for the implementation of a waste management concept (UNEP, 2004).

In addition to the guidance note by the EC (2003), the manuals by The World Bank (Wilson et al., 2001) and UNEP (2009a-d) were consulted to identify alternatives for preparing guidelines for waste management concepts. These manuals were chosen as they mainly aimed at the local level.

5.5.1. Aim

According to the EC (2003), the aim of an integrated waste management concept is to support a toolkit for waste management planning and development of proper planning processes throughout the EU. The manuals by the UNEP (2009d) and The World Bank (Wilson et al., 2001) describe similar aims; that is, to support urban authorities and to strengthen the waste management process.

5.5.2. Level of implementation

The guidance note by the EC (2003) describes how a national waste management plan should demonstrate a strategy for an entire country and a local waste management plan should include detailed descriptions of the current waste management system (EC, 2003). These two different approaches demonstrate the different ideas on structure and content of the manuals for developing national and local waste management concepts. The following question has arisen: Can only one manual describe the development of a waste management concept on different levels such as local or national level? The results of the decision support tools used in this dissertation demonstrated that they are dependent on local conditions such as climate or distances between towns and/or villages under research and therefore, local conditions need to be considered in the development of waste management concepts.

Therefore, the preparation of two manuals is recommended:

- one for the development of a strategy with general principles for the waste management on the national level. An example is the manual by the OECD (2007).
- another one for the development of a waste management concept on local level. Examples are the manuals by The World Bank (Wilson et al., 2001) and by the UNEP (2009d).

The main difference is the degree of detail of aim and description of work steps. Furthermore, these two manuals have to refer to each other as the local waste management concept is based on the national waste management concept and *vice versa*.

5.5.3. Type and definition of waste

The guidance note by the EC (2003) does not differentiate between types of waste. In contrast to that, the manual by The World Bank (2001) refers to municipal waste and the manual by UNEP (2009) includes municipal waste, construction and demolition waste, industrial waste as well as hazardous waste.

The manual by the EC (2003) as well as all tools used in the dissertation for such waste analyses were evaluated only in respect of solid household waste. Nevertheless, a complete waste management concept should include all waste streams produced in one area/ research area. The EU provides a list of 20 waste types in the *Commission Decision 2000/532/EC*. Examples are No.1, Wastes resulting from exploration, mining, dressing and further treatment of minerals and quarry, or No.17, Construction and demolition waste (including road construction) with a definition of each waste type (Commission Decision 2000/532/EC). Nevertheless, this list does not include “waste caused by regional conditions” or “waste cause by environmental disaster” as it is recommended in the UNEP manual (2004).

An example of waste caused by regional conditions is snow. Snow is a huge problem in the Ugra region. Snow only arises from October until April. Street sweeping, which is listed as No. 20 03 03 (Commission Decision 2000/532/EC), does not occur in the wintertime. The snow is currently disposed of on a place very close to the river Irtysh in Khanty-Mansiysk. When it starts melting a high amount of snow/water runs in the river without flooding the town. However, the snow itself is waste as it is polluted by chemicals such as exhaust fumes and, when melted, can pollute the ground- and surface water. Additionally, the snow is also extremely polluted with glass bottles, bins, dust etc. Some nets are built round the snow hill every year and is supposed to retain the waste in the snow, but it does not work very well (Rybik, 2005, pers. comm.).

It is recommended to use the more extensive list by the EU when writing a manual for preparing an integrated waste management concept on local level.

5.5.4. General outline

A comparison of the manuals by the EC (2003), The World Bank (Wilson et al., 2001) and the UNEP (2009d) shows that the sequence of the general outline in the manuals is very similar:

- Mobilising the planning part
- Description of current situation
- Planning part and public participation
- Implementation and evaluation of waste management concept (see Chapter 2.1.1 Strategies for preparing integrated solid waste management concepts).

A change in the sequence of the outline does not seem necessary for a revised version of a manual on the preparation of an integrated waste management concept.

The main difference between the manuals is that the UNEP manual, for example (2009a-d), describes decision support tools for each work step in contrast to the manual by the EC (2003). There are several examples:

- Regarding the tool of waste analysis, UNEP (2009a) offers a tool developed by CASCADIA Consulting Group (2003, 2004 and 2005) and Sky Valley Associates (2003). The manual of the EC (2003) only suggests collection of relevant information from the local authorities (see Appendix – Chapter 2, Table A2.1.-1).
- The guidance note by the EC (2003) also does not describe a decision-making process for an optimal waste treatment. In the training manual by UNEP (2009d), however, a matrix with the social, ecological and economic advantages and disadvantages of each waste treatment concept is given.
- The manuals by the EC (2003), The World Bank (Wilson et al., 2001) and the UNEP (2009d) explain that the preparation of a waste management concept has to include environmental evaluation and monitoring. Only the manual by EC (2003) has no description of any steps for the monitoring and review of waste management concepts. However, this step is indispensable for a sustainable implementation of a waste management concept (UNEP, 2009d).

A detailed description of each work step in the reviewed guidance note of the EC (2003) is necessary as it is a precondition for the correct use of a tool. Although various tools for implementing the work steps within the guidance note, such as the SWA-Tool, were already developed in framework projects of the EU, there is no reference within the “guidance note for a waste management concept” of the EC (2003) to these tools. Therefore, it is recommended to create a manual including detailed descriptions of the tools of each work step for the development of integrated waste management concepts on local level.

5.5.5. Target group and basis of legislation

The same *target groups* are named in all three manuals: mainly local authorities and NGOs (see Appendix – Chapter 2, Table A2.1.-1). As the reviewed guideline for preparing a waste management should work on the local level, local authorities should be the key target group.

It can be stated that only the guidance note by the EC (2003) refers to *international/ national legislation*, in contrast to the manuals by The World Bank (Wilson et al., 2001) and UNEP (2009). This is because EU framework legislation exists where the guidance note by the EC (2003) is in effect. In contrast to that, the manuals by The World Bank (Wilson et al., 2001) and UNEP (2009a-d) can not refer to national and/ or framework legislation as these two manuals are created for use in every country of the world. However, implementing a waste management concept on both national and local levels can not work without a legislative basis (UNEP, 2004). International agreements such as the “Basel Agreement” play a significant role, also on local level. Therefore, to consider current international and national legislation should be a precondition for developing a waste management concept and should be stated in manuals for developing a waste management concept.

5.5.6. Consideration of local conditions

Local conditions have a significant influence on the development of a regional waste management concept. There are special circumstances in the Ugra region which have to be considered while preparing a local waste management concept:

- severe climatic conditions, vast distances between the cities, and some villages with roads that are useable only during the winter time,
- rapidly growing industry, extreme differences in urban and rural lifestyles, and sparsely populated rural areas as well as
- types of waste and its seasonal occurrence (e.g. snow and street sweeping).

As an example, the seasonal arising of street sweepings will be explained: After the thaw in April/ May the streets are extremely polluted and need an additional clean-up. Besides the dust the waste mainly consists of plastic and glass bottles, cans etc. So, a very high amount of street sweepings can be expected in spring. In the winter time there is no street sweeping because the streets are covered in snow.

This example clearly demonstrates that local circumstances such as climate conditions have an impact on waste generation because the snow reduces the waste amount of street sweepings to zero. The urban waste management concepts have to take into account that in the winter time no street sweepings exist and in spring a very high amount of street sweepings occurs.
It is recommended to research the local conditions in detail which then need to be included in the development of an integrated waste management concept.

5.5.7. Applicability and recommendation for using the guidance note by the EC for the Siberian region

A detailed evaluation of the guidance note by the EC (2003) can not be made as an entire waste management concept was not developed within the dissertation. Developing a complete waste management concept would go beyond the scope of the dissertation. Only the key work steps for preparing a concept such as waste analysis were tested in the course of the dissertation. The management of solid household waste is presently the biggest problem in Khanty-Mansiysk and Surgut. However, it is also only one part of all the waste types generated. But for a complete waste management concept for both the regional and urban level municipal waste and all other types of waste have to be considered.

Only if all waste categories and streams are identified according to the list by the EU can a decision about the type and size of waste disposal be made and a final waste management concept be developed. Surveys of every waste type have to be implemented in all towns in the Ugra Region and reviewed in continuous time periods in order to have constant reliable and current data, and to check the effectiveness of the waste management concept.

Recommendation for an optimal application of the guidance note by the EC (2003), especially in Siberian regions:

- The guidance note by the EC (2003) needs to be reviewed and updated regarding current national legislation in the EU. Several laws in the EU regarding waste management were revised in the last months such as the “EU Framework Directive” in January 2009.
- The guidance note should be set up as a detailed guideline for the local level and should be supported by a step-by-step explanation of the tools proposed for implementing the different work steps of developing integrated waste management concepts.
- Additionally, a “set of decision support tools” should be developed which supports the “main guidance note” by suggesting different tools for implementing each work step. This “set of decision support tools” should include the tools for waste analysis, questionnaires and waste prognosis reviewed within this dissertation. Decision support tools for ecological monitoring should be researched and included in this set of guidelines as well. It also should be subdivided into guidelines for municipal waste (including household waste), industrial waste etc. as the requirements of analysis and treatment for each type of waste are very different. The user can then decide which tool is most suitable in her/ his situation.

6. Conclusions

The key objective of the dissertation was to evaluate whether tools which were developed in European Union framework projects for preparing an integrated solid waste management concept are applicable in Siberian regions, i.e. transferable outside the EU. Based on my research, waste analysis, waste prognosis, public participation and environmental assement of waste management strategies are the main steps for the development of integrated waste management concepts. Tools for waste analysis, waste prognosis, environmental assessment of waste management concepts, and preparation of waste management concepts that were developed in European Union framework projects could be tested during my dissertation. As no tools for public participation as part ofdevelopming integrated waste management concepts have been developed in European Union framework projects yet, the tool for public participation developed by The World Bank was applied.

Solid household waste analyses were implemented in Khanty-Mansiysk and in Surgut with the SWA-Tool (EC, 2004). This tool was developed in the 5th EU framework programme. It proved to be useable for analysing solid household waste. However, the statistical evaluation of the waste analysis results was not comprehensibly described in the SWA-Tool. Therefore, recommendations regarding sample-taking, evaluation of results and the manual of the SWA-Tool were developed in order to guarantee a competent application of the tool.

Public participation was achieved by using oral questionnaires. As the EU does not offer a decision support tool for public participation, a tool recommended by The World Bank was tested in Khanty-Mansiysk. Although The World Bank (2004) suggests a completely formulated questionnaire, neither proposals for the type of implementation of the questionnaires nor for the statistical evaluation of the results are given. Consequently, ways of implementation and statistical evaluation were recommended in order to guarantee an appropriate use of the questionnaire.

Prognosis of waste amount and composition were done with the software tool developed in the 5th EU framework programme (Project Coordinator TU Darmstadt, 2005). The software tool was easy to use. The main problem when testing the SWA-Tool for Khanty-Mansiysk and Surgut was the unverified annual waste amount. Therefore, an accurate waste prognosis was virtually impossible. Nevertheless, waste prognosis plays a significant role in waste management concepts. Recommendations were developed regarding the use and evaluation of the results. However, it needs to be updated and expanded by default data for Russia for a proper application. Furthermore, it should be supported by (Russian) expert opinions in order to assure an optimal application.

Different scenarios for waste treatment in Khanty-Mansiysk and in Surgut were developed and ***environmentally assessed*** through Life Cycle Assessment. The LCA-IWM software tool (Project Coordinator TU Darmstadt, 2005), also developed in the 5th EU framework programme, proved to have too many disadvantages in general and for use in Siberian regions. The key disadvantage is that the software tool does not seem to be flexible enough to take local conditions into account. Additionally, banks of ecological data of a LCA software tool mainly relate to a region such as Western Europe (Eriksson et al., 2002). As no data bank for Siberian regions has been developed yet, LCA software tools demonstrate similar problems for an application in Siberian regions in general. For these reasons, further research on decisions support tools for ecological assessment of integrated waste management concepts in Siberian regions is essential.

These four work steps aforementioned play a significant role within the ***preparation of waste management concepts*** on local level. The guidance note by the EC (2003) describes the work steps, but it does not recommend tools for implementing these work steps. For an appropriate application, the reshaping of the guidance note by the EC (2003) to a general manual for preparation of an integrated waste management concept is suggested. This general manual is also supported by a set of decision support tools. The set would describe the implementation of each work step thoroughly by listing decision support tools.

The quintessence of the dissertation is that almost every implemented tool can be used with modification by local authorities in Siberian regions.

Which aspects have to be considered in further research on an integrated waste management concept in Siberian regions?

When developing an integrated waste management concept, ecological, social and economic conditions have to be taken into account. It can be stated that many components of waste management planning such as policies, costs etc. were not discussed in the dissertation as this would be beyond its scope. Nevertheless, these issues play a significant role and need to be discussed and researched during the preparation of an urban/ regional waste management concept in the Ugra region. There are some examples listed in relation to developing an integrated waste management concept that need to be discussed and researched:

- Developing an overall aim of a waste management concept in the Ugra Region and the time period for this concept
- Developing a land use plan and maps as well as designating new space(s) for landfills
- Researching and determining the influences of local conditions on waste management, such as differences and common points regarding waste amount and composition for each district/ town in the Okrug Ugra, low population density in rural areas, long distances between the towns, villages with roads only in the winter time, and the severe climate conditions
- Analysing all waste streams and their consideration in the overall waste management concept
- Analysing whether recycling and transport of recycled materials to other cities (minimum distances 250 km) is sustainable
- Analysing whether waste treatment plants such as anaerobic and/ or aerobic Mechanical Waste Treatment plants work under Siberian climate conditions.

Additionally, integrated waste management planning requires overlapping planning as it influences other sectors such as land use planning and *vice versa*. The migration boom in the Ugra region creates high demands on land use planning, which also includes the allocation of (more) space for waste disposal sites/ treatment plants. Neither for KMAO nor Khanty-Mansiysk and Surgut are there (regional) plans, and unplanned land use is apparent. Therefore, the formulation of general principles for regional development in the Ugra Region, the preparation of regional plans, and land use maps are essential. Introducing an integrated waste management concept in combination with regional developing planning is one of the key tasks of a local administration.

In conclusion, the current waste management concept in Khanty-Mansiysk and in Surgut consists of collecting the waste daily and disposing of it on landfills. The infrastructure in Surgut and especially Khanty-Mansiysk is no longer sufficient to accommodate the demands of current waste disposal. Reasons are the extreme increase of waste amount and change of waste composition caused by a rapidly growing economy and migration boom in the Ugra region. Consequently, it is imperative to deal with the changed situation and to improve waste management. First steps for an integrated waste management concept on local/ urban level were implemented through waste analysis, survey of residents' opinion of the current waste disposal, waste prognosis and development of waste treatment scenarios, and their environmental assessment. Local authorities in Khanty-Mansiysk and in Surgut should build on these determined data within the dissertation.
New technical equipment has been and will be introduced to both landfills in Khanty-Mansiysk and in Surgut and a change from uncontrolled dumping to a controlled waste disposal is recognisable. Nonetheless, the challenge is to push this development further towards an integrated waste management concept. Disposal of untreated waste on a landfill is the worst waste management scenario, a fact which is accepted globally (UNEP, 2008). Minimising risks for human health and ecology should be one of the priority tasks of local authorities. Despite the complex process of developing an integrated waste management concept, a change of the current waste management situation is a matter of urgency in Khanty-Mansiysk and in Surgut.

Appendix - Chapter 2 Background Information

Regarding Chapter 2.1. Literature study of decision support tools for the preparation of integrated solid waste management concepts

Table A2.1.-1: Comparison of manuals developed by intergovernmental organisations

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
Title	Strategic planning guide for municipal solid waste management	Waste management planning. An environmentally sound approach for sustainable urban waste management	Developing Integrated Solid Waste Management Plan	Preparing a waste management plan. A methodological guidance note	Guidance manual on environmentally sound management of waste
Date of publication	2001	2004	2009	2003	2007
Aim	To improve the municipal waste management in cities	To support countries worldwide to implement the waste targets of Agenda 21	To support urban authorities and to strengthen the waste management process	To support a toolkit for waste management planning and development of proper planning processes throughout the EU	To support enhanced ecologically based waste management within the OECD area
Target group	Local/urban authorities	Local authorities but also government	City authorities, civic authorities, private sector, NGO etc.	Government, local authorities	Mainly government but also local authorities and private sector
Level of implementation	Local/urban	Local or regional, but with links to national level	Local	National, but links to regional or local level	National
Type of waste (dealt with in manual)	Solid municipal waste	• mainly: municipal waste • additional chapters:	• Municipal waste • Construction and demolition waste	Solid waste (no subdivisions)	Waste (no subdivisions) but excluding radioactive waste

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
		- hazardous waste - health care waste - waste from natural or industrial disasters	• Industrial waste • Hazardous waste		
Outline:			*(Only regarding municipal waste)*		*(Instead of work steps, OECD offers recommendations to the governments and operators of waste treatment facilities. Recommendations always start with: Member countries should […])*
Mobilising the planning part	• Mobilising support and organisation of the work (Step 1) • ***Tools for public participation:*** Creating a steering committee	• Description of importance of well worked waste management systems		• Identify the problem, scope of plan • Consulting process • Starting with EIA • Determine time-schedule • verify links to other plans and policies • ***Tools for public participation:*** Creating a steering committee	• Recommendation 1: "[…] have an adequate regulatory and enforcement infrastructure at an appropriate governmental level […]." • Recommendation 2: "[…] develop and implement practices and instruments that facilitate the efforts of competent authorities to monitor the implementation of CPEs […]."

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
					• Recommendation 10: "[…] encourage the development and implementation of an environmental liability regime for facilities that carry out risky or potentially risky activities […]."
Description of current situation	• Determine waste composition and quantity, waste management operations and waste prognosis, background data to the city (Step 2 – Baseline) • ***Tools for waste analysis:*** enquiry, questionnaires, waste sorting, • ***Tools for waste prognosis:*** formula is given	• Determine waste generation, treatment, number of households, companies etc. • ***Tools for waste analysis:*** Sorting tests or measurement of waste stream, request from producer, transport firms	• Determine general information (climate, socio-economic, etc.) and waste related (waste generation, collection, treatment), future trends • Assessment of current waste system • ***Tools for waste analysis:*** waste analysis recommended by CASCADIA (2003, 2004, 2005) and SKY VALLEY ASSOCIATES (2003) (Volume 1 and Volume 2)	• Determine waste quantities, collection and treatment • ***Tools for waste analysis:*** A: weighing the waste, B: calculation of waste amount based on the currently used equipment, C: enquiry of waste disposal companies • Verify financiering as well as previous objectives	• Recommendation 4: "[…] information exchange between producers, waste generators, waste managers and authorities […]." • ***Tools for waste analysis: ---***

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
Planning part and public participation	• Defining priorities, targets and objectives with a defined time table (Step 3)	• Describe future proposals • Setting goals (clean technologies, recycling, LCA, eco-audit schemes, education) • Waste prognosis • Check out of connections to other policies • Verify economic conditions • Identify measurable indicators for implementation of described targets • Public participation • ***Tools for waste prognosis: ---***	• Setting future strategies, goals and objectives • Public participation • Structuring of the plan - Decision for technologies - Subdivision of responsibilities • ***Tools for waste prognosis:*** scenario building approach (Volume 3)	• Determine assumptions for future waste generation • ***Tools for waste prognosis:*** recommendations followed by ADEME • Verify detailed objectives • Preparation of action plan: - Decision of waste collection system and treatment plans etc. - Assigning of responsibilities - Achieving financing • ***Tools for environmental assessment:*** EIA	• Recommendation 4: "[…] including participation in sectoral trade or industry association […]." • Recommendation 5: "[…] integrate into national policies and/or programmes the core performance elements […]". • Recommendation 6: "[…] consider incentives and/or relief measure for facilities that fulfil the core performance elements […]." • ***Tools for public participation:*** Exchange of information (Recommendation 4) • ***Tools for waste prognosis: ---***

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
	• Identifying and evaluating options (Step 4) - Development of the framework - Identify waste collection and recycling, treatment and disposal - Funding - Public awareness	• Preparation of plan: - Decision of waste collection system and treatment plans - Decision of splitting up of responsibility between local authorities and industry		• Measures for implementation of action plan: - Strengthen public awareness - Introduction of economic instruments and Integrated product policies - Support environmental agreements between industries and local authorities	• Recommendation 8: "[…] move towards internationalisation of environmental and human costs in waste management […]." • Recommendation 9: "[…] provide incentives to take part in environmentally sound recycling schemes"
	• Developing of the long-term perspective of the waste management concept (Step 5)			• Planning and long-term development of future waste generation and their treatment facilities	• Recommendation 11: "[…] ensure the implementation of the core performance elements […] does not discourage recycling in Member countries, recognising, in particular, the flexibility appropriate for each member country to increase the rates of environmentally sound recovery of low risk waste."

Organisation	The World Bank (Wilson et al., 2001)	UNEP (2004)	UNEP (2009a-d)	EC (2003)	OECD (2007)
	• Preparing the action plan (Step 6) - Clarify responsibilities and time table for implementation of action plan				
Implementation and further review	• Implementation the strategic plan (Step 7) • ***Tools for environmental assessment:*** ---	• Public participation within the implementation of the plan - Main emphasis: waste education, strengthens environmental awareness • ***Tools for public participation:*** Exchange of information • ***Tools for environmental assessment:*** LCA	• Implementation of the plan • Communication, review and continuing revision - Main emphasis: education for example in schools - Waste management concept is not "one-off" process and needs reviews - ***Tools for environmental assessment:*** --- (Volume 4)	• Implementation via legislation, regulation etc.	• Recommendation 3: "[…] ensure that waste management facilities are operating according to the best available techniques […]." • Recommendation 7: "[…] implement the technical guidance for environmentally sound management of waste that has been developed by the OECD […]." • ***Tools for environmental assessment:*** ISO 14001 (including LCA)

Table A2.1.-2: Tools for waste analysis subdivided into tools on national level for single countries as well as tools developed by international and intergovernmental organisations (modified and expanded after Dahlèn, 2008)

(Number of Tools)	Tool	Reference/Institution
National level		
US (7)	Uniform waste disposal characterisation method	CIWMB, 1999, California Integrated Waste Management Board
	Methodology for conducting composition study for discarded solid waste	Reinhart and McCauley-Bell (1996), University of Central Florida
	Solid waste/characterisation methods	Rugg (1997), Environmental Engineers' Handbook
	Characterisation of municipal solid waste in the United States	Franklin and Associates (1999), US EPA
	Cost-effective solid-waste characterisation methodology	Gay et al. (1993), Bovay Northwest Inc., US
	Guidelines for Waste Characterisation Studies in the State of Washington.	CASCADIA Consulting Group (2003), Washington State Department of Ecology (recommended by UNEP)
	Oregon Solid Waste Characterization and Composition	Sky Valley Associates, Department of Environmental Quality, Oregon (2003) (recommended by UNEP)
Sweden (5)	Hushållsavfall. Genereringstakt och sammansättning/Household waste. Generation rate and composition	Gustafson and Johansson (1981), Luleå University of Technology (LTU)
	Plockanalys av hushållsavfall. Metoder och trender/Household waste composition studies. Methods and trends	Ohlsson (1998), Luleå University of Technology (LTU)
	Waste component analysis as a planning tool	Petersen (2004), Dalarna University College
	NSR solid waste characterisation method	RVF (2005a), NSR Research, Sweden
	Municipal solid waste composition analysis manual	RVF (2005b), The Swedish Association of Waste Management (RVF)
Switzerland (2)	A goal-oriented characterisation of urban waste	Maystre and Viret (1995), Institute of Environmental Engineering, Lausanne
	A survey of the composition of household waste	SAEFL (2004), Swiss Agency for the Environment, Forests and Landscape
Great Britain (1)	Assessing the composition of municipal solid waste. Method developed from the Environment Agency of England and Wales	Burnley et al. (2007), Department of Environmental and Mechanical Engineering, The Open University, Milton Keynes

(Number of Tools)	Tool	Reference/Institution
National level		
The Netherlands (1)	Physical investigation of the composition of household waste in the Netherlands	Cornelissen and Otte (1995), RIVM (The Netherlands National Institute of Public Health and Environmental Protection)
South Africa (1)	Appropriate approach in measuring waste generation, composition and density in developing areas	Mbande (2003), South African Institution of Civil Engineering
Finland (1)	Solid waste, municipal: sampling and characterisation	Nordtest (1995)
Germany (1) (***Note:*** A lot of company- and state-level based tools exist but they all have a comparable approach (Zwisele, 2008, pers. comm.), therefore the different types are calculated as 1 tool.)	Examples are: (a) Sampling method for the determination of quantity and composition of solid waste and Sorting analyses for the determination of material composition of solid waste (b) Directive for conducting of determination of municipal waste amount and composition in the federal district Brandenburg	(a) Zwisele (2005) and Büll (2006), ARGUS-Statistik (b) Regional Environment Agency Brandenburg (1998)
International organisation		
ERRA (1)	Waste analysis procedure. Reference multi-material recovery	ERRA European Recovery and Recycling Association (1993)
ASTMI (1)	Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste	ASTM International (2003), American Society for Testing and Materials
CEN (1)		
Intergovernmental organisation		
IEA (1)	Work in harmonising sampling and analytical protocols related to municipal solid waste conversion to energy	Scott (1995), International Energy Agency (IEA)
EU/ European Commission (2)	REMECOM-European Measurement for Characterisation of Domestic Waste	ADEME/ European Commission (1998), Life-Program, Brussels
	SWA-tool, Methodology for the analysis of solid waste	European Commission (2004), 5th Framework Program, Vienna, Austria

Appendix - Chapter 3 Methodology

Regarding Chapter 3.3. Analysis of solid household waste

Regarding Type of waste sampling and stratification

Table A3.3.-1: Time period and weather conditions during waste analyses in Khanty-Mansiysk

Time / Residential structure	Spring	Summer	Autumn	Winter
Apartment blocks	**May 2006**	**August 2008**	**October 2006**	**January 2007**
Conditions of waste analysis	App.10°C Heating period stops, sunshine, beginning of thaw	App. 15 °C No heating period	App. 6 °C Heating period starts	App. -25 °C Heating period, snow
Small houses with gardens	**April 2008**	**August 2008**	**September 2007**	**December 2007**
Conditions of waste analysis	App. 9°C Heating period stops, sunshine, beginning of thaw	App. 15 °C No heating period, heavy rainfalls	App. 12 °C Heating period starts	App. -8 °C Heating period, snow

Table A3.3.-2: Time period and weather conditions of the waste analysis in Surgut

Time / Residential structure	Spring	Summer	Autumn	Winter
Apartment blocks/ small houses with gardens	**May 2007**	**August 2006**	**October 2006**	**March 2007**
Conditions	14°C Heating period stops	16°C No heating period	1°C Heating period, snow	-16°C Heating period

Regarding Calculation of sampling size

Table A3.3.-3: Number of sampling units and statistical accuracy of each seasonal waste analysis in Khanty-Mansiysk

	Mon	**Tue**	**Wed**	**Thu**	**Fr**	**Total units**	**Sampling error** (at a 90% confidence interval)
Spring							
Apartment blocks	1	1	1	1	1	5	
Small houses	1	1	1	1	1	5	
Total	2	2	2	2	2	**10**	**16%**
Summer							
Apartment blocks	1	1	1	1	1	5	
Small houses	(A)	(A)	1	1	1	3	
Total	1	1	2	2	2	**8**	**17%**
Autumn							
Apartment blocks	1	1	1	1	1	5	
Small houses	(A)	1	1	1	1	4	
Total	1	2	2	2	2	**9**	**16.5%**
Winter							
Apartment blocks	1	1	1	1	1	5	
Small houses	2	2	2	2	2	10	
Total	3	3	3	3	3	**(15)**	**(13%)***

Note: (A): Waste was disposed of before the analysis could be implemented; (*): The sampling unit is 0.5 m^3 instead of 1 m^3. It does not achieve the suggested accuracy based on 1 m^3.

Table A3.3.-4: Sampling units and statistical accuracy of each waste analysis in Surgut

	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Total units**	**Sampling error** (90% confidence interval)
Spring							
Apartment blocks	n.a.	n.a.	2	2	2	(6)	(20%)*
Summer							
Apartment blocks	2	n.a.	2	n.a.	2	6	20%
Autumn							
Apartment blocks	n.a.	2	2	2	2	8	17%
Winter							
Apartment blocks	2	2	2	n.a.	n.a.	6	20%

Note: n.a.: no analysis; (*): The sampling unit is 0.5 m^3 instead of 1 m^3. It does not achieve the suggested accuracy based on 1 m^3.

Regarding Generation of random sampling plan

	1st stage (stratum: residential structure)	**2nd stage** (sub area – house blocks)	**3rd stage** (random selection of bins)
		Doronina Street	Collection site 1
		Schkalowa Street	Collection site 2
	Apartment blocks	Schewtschenko Street	Collection site 3
Khanty-Mansiysk			
	Small houses	Ostrowskaja Street	Collection site 4
		Doronina Street	Collection site 5
		Schkalowa Street	Collection site 6

Figure A3.3.-1: Generation of stratified random sampling plan in Khanty-Mansiysk

	1st stage (stratum: residential structure)	**2nd stage** (sub area – house blocks)	**3rd stage** (random selection of bins)
		Lenina Street	Collection site 1
	Apartment blocks	Rabotschal Street	Collection site 2
Surgut			
	Small houses	Stroistestki Street	Collection site 3

Figure A3.3.-2: Generation of stratified random sampling plan in Surgut

Regarding Evaluation of the results

Table A3.3.-5: Analysed amount of waste during waste analyses [kg]

	Season	Apartment blocks	Small houses with gardens	Total
Khanty-Mansiysk	Spring	1,094	790.0	1,884
	Summer	368.5	294.5	663.0
	Autumn	725.5	405.0	1,130.5
	Winter	342.5	368.5	711.0
	Total	***2,530.5***	***1,858.0***	***4,388.5***
Surgut	Spring	167.5	11.5	179.0
	Summer	445.0	39.5	484.5
	Autumn	517.5	79.0	596.5
	Winter	381.5	23.5	405.0
	Total	***1,511.5***	***153.5***	***1,665.0***
	Overall result			**6,053.5**

Photographic documentation

Research area: Khanty-Mansiysk

Figure A3.3.-3: Khanty-Mansiysk Landfill, 1st mount of waste; February, 2006 (Wilke, 2006)

Figure A.3.3.-4: Khanty-Mansiysk Landfill, 1st mount of waste (on left) already closed and 2nd mount of waste (on right) almost filled to capacity; August, 2008 (Kaazke, 2008)

Figure A3.3.-5: Scales from the landfill of Khanty-Mansiysk; May, 2008 (Kaazke, 2008)

Figure A3.3.-6: Rain collection system at Khanty-Mansiysk landfill; May, 2008 (Kaazke, 2008)

Figure A3.3.-7: Residential structure: apartment blocks in Khanty-Mansiysk; August, 2006 (Kaazke, 2006)

Figure A3.3.-8: Residential structure: small house with gardens in Khanty-Mansiysk; August, 2008 (Kaazke, 2006)

Research area: Surgut

Figure A3.3.-9: (Municipal) waste on the landfill in Surgut; May, 2006 (Kaazke, 2006)

Figure A3.3.-10: Landfill in Surgut; view to the entrance of the landfill; May, 2006 (Kaazke, 2006)

Figure A3.3.-11: Landfill in Surgut; view to the 1st mount of waste; May, 2006 (Kaazke, 2006)

Figure A3.3.-12: Residential structure: apartment blocks in Surgut - place 1; October, 2006 (Kaazke, 2006)

Figure A3.3.-13: Residential structure: apartment blocks in Surgut - place 2; October, 2006 (Kaazke, 2006)

Figure A3.3.-14: Residential structure: small houses with gardens in Surgut; October, 2006 (Kaazke, 2006)

Implementation of waste analyses in Khanty-Mansiysk and in Surgut

Figure A3.3.-15: Waste analysis in winter time; January, 2007 (Kaazke, 2007)

Figure A3.3.-16: Waste analysis in summer time; July, 2008 (Kaazke, 2008)

Figure A3.3.-17: Glass as a waste fraction; July, 2008 (Kaazke, 2008)

Figure A3.3.-18: Organics (kitchen) as a waste fraction; October, 2006 (Kaazke, 2006)

Regarding Chapter 3.4. Public participation through questionnaires

Text A3.4.-1: Questionnaire
(The original questionnaire was in Russian and then translated into English for the doctoral thesis.)

Within the cooperation between the Yugra State University and Technical University Berlin, research on waste generation and management will be implemented in Khanty-Mansiysk. Some information can only be provided by residents.
Please answer the questions if you have lived for longer than one year in Khanty-Mansiysk. It is an anonymous questionnaire and your answers will only be used for the development of a waste management concept.
(_) – means you have to put a mark in one of the given answers.

Thank you very much for your support!

Questions to the social situation
How many people live in your household? _

Since when have you lived in Khanty-Mansiysk? _
Were you born in Khanty-Mansiysk? _

How much money is available to your household per month? _

Do you live in a house or in an apartment? _
(_) – house with garden
(_) – flat in an apartment block

What kind of apartment block is your flat located in?
(_) – apartment blocks with > 2 floors
(_) – middle apartment blocks (2 floors)
(_) – cottages (2 floors)

Do you pay rent?
(_) – no, I own a house
(_) – yes
How much is your monthly rent ? _

Questions regarding recent waste disposal
How much money do you pay for waste disposal? _
Is this charge included in your rent?
(_) – yes
(_) – no, I pay extra to:_

Which company is responsible for the waste disposal in your street? _
How often is the waste collected (once a week, twice a week…, every day)? _
What time does the waste disposal company empty the container? _
Do you have any problems with the waste disposal or the waste containers?
(_) – no
(_) – yes, I have the following problems: _

Did you buy any electronics such as a television or computer in the last year?
(_) – no
(_) – yes, I bought: _

Did you dispose of any electronics in the last year?
(_) – no

(_) – yes, I discarded: _
Where did you discard these electronics? _

How do you treat your organic waste such as bread and fish?
(_) – I throw it away in the waste containers on the street.
(_) – I compost it in my garden.

Questions regarding a new waste management concept
If the new system includes a recycling progress, would you collect waste such as plastic separately in your flat ?
(_) – yes
(_) – no, because _

Tips and wishes: If you have any advice or wishes regarding waste disposal or information about waste, please mention it here: _

Thank you very much for answering the questionnaire!

Regarding Chapter 3.5. Prognosis of waste generation

Table A3.5.-1: Amount and composition of waste entered in waste prognosis software tool for Khanty-Mansiysk and Surgut

	Surgut		Khanty-Mansiysk	
	Annual waste composition [w/w %]	Annual waste amount [Mg a^{-1}]*	Annual waste composition [w/w %]	Annual waste amount [Mg a^{-1}]*
organic (kitchen)	27.4	17,800	30.3	7,400
organic (garden)	4.5	2,900	5.9	1,400
plastic	16.7	10,900	13	3,200
glass	20	13,000	14.6	3,500
paper/cardboard	9.6	6,300	11.1	2,700
metals	4	2,600	4.6	1,100
electronics	0.2	130	0.2	50
hazardous waste	0.5	300	0.5	100
residual	17.1	11,070	19.8	4,850
total	100	**65,000**	100	**24,300**
total per capita		224 kg c^{-1} a^{-1}		347 kg c^{-1} a^{-1}

Note: (*): Numbers differ because of rounding up.

Table A3.5.-2: Numbers entered in waste prognosis by LCA-IWM for Khanty-Mansiysk

Input	Number	Year of number	Source	Date of research
Current data				
Number of city residents	70,000	2007	Tomsha (2007, pers. comm.)	30.01.2007
Waste amount	See Table A3.5.-1	2008	Kaazke (2006-2008, waste analysis)	April 2006 – August 2008
Waste fraction	See Table A3.5.-1	2008	Kaazke (2006-2008, waste analysis)	April 2006 – August 2008
Population aged 15 – 59 years	63.6%	2007	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Averaged household size	3.2	2008	Kaazke (2008, questionnaires, compare Chapter 3)	May 2008
Urban/National infant mortality*	16.6 % 16.8 %	2005-2010 2005-2010	http://esa.un.org/unpp/index.asp?panel=3 http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Life expectancy*	65.5 years 68.1 years	2005-2010 2005-2010	http://esa.un.org/unpp/index.asp?panel=3 http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
GDP per capita in USD PPP, in 1995 prices	11,794	2003	http://pwt.econ.upenn.edu/php_site/pwt_index.php	02.07.2008
Labour force in agriculture	10.8%	2007	https://www.cia.gov/library/publications/the-world-factbook/print/rs.html	02.07.2008
Prognosis for year 2012				
Number of city residents	100,000	2012	Tomsha (2007, pers. comm.)	30.01.2007
Population aged 15 – 59 years	59.7%	2015	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf (2012 was entered in the waste prognosis tool)	02.07.2008
Averaged	3.2	2012	Author's assumption (The author assumed that this figure will hardly change in the	

Input	Number	Year of number	Source	Date of research
household size			next 5 years. She also compared it with the changing of this figure in the waste prognosis tool from Estonia, Latvia and Lithuania, and they also demonstrate no changes.)	
Urban/National infant mortality	15.4 %	2010-2015	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Projected growth rate per capita GDP % per year	7.3	2003-2013	http://www.iccfglobal.org/pdf/margo-thorning100103.PDF	02.07.2008
Labour force in agriculture	10%	2012	Author's assumption. No future data for 2012 exist. It can be assumed there will be a slight decrease. Therefore, 10 % was chosen. http://w3.unece.org/pxweb/Dialog/varval.asp?ma=02_COSummary_r&ti=Country+Overview+by+Indicator%2C+Country+and+Year&path=../DATABASE/Stat/10-CountryOverviews/01-Figures/&lang=1	02.07.2008

Note: (*): The United Nations/ Department of Economic and Social Affairs offers different numbers for "current urban/national infant mortality" and "current life expectancy". Therefore, Data set 1 and Data set 2 were created; i.e. both figures were entered in the waste prognosis software tool.

Table A3.5.-3: Numbers entered in waste prognosis by LCA-IWM for <u>Surgut</u>

Input	Number	Year of number	Source	Date of research
Current data				
Number of city residents	290,000	2007	Tomsha (2007, pers. comm.)	30.01.2007
Waste amount	See Table A3.5.-1	2008	Kaazke (2006-2008, waste analysis)	April 2006 – August 2008
Waste fraction	See Table A3.5.-1	2008	Kaazke (2006-2008, waste analysis)	April 2006 – August 2008
Population aged 15 – 59 years	63.6%	2007	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Averaged household size	2.7	2008	Kiseleva, (2008, pers. comm.)	12.08.2008

Input	Number	Year of number	Source	Date of research
Urban/National infant mortality*	16.8 16.6	2005-2010 2005-2010	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf http://esa.un.org/unpp/index.asp?panel=3	02.07.2008
Life expectancy*	65.5 68.1	2005-2010 2005-2010	http://esa.un.org/unpp/index.asp?panel=3 http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
GDP per capita in USD PPP in 1995 prices	11794	2003	http://pwt.econ.upenn.edu/php_site/pwt_index.php	02.07.2008
Labour force in agriculture	10.8%	2007	https://www.cia.gov/library/publications/the-world-factbook/print/rs.html	02.07.2008
Prognostic year 2012				
Number of city residents	295,000	2012	Author's assumption (compare also Chapter 3)	
Population aged 15 – 59 years	59.7%	2015	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf (2012 was entered in the waste prognosis tool)	02.07.2008
Averaged household size	2.7	2012	Author's assumption (The author assumed that this figure will hardly change in the next 5 years. She also compared it with the changing of this figure in the waste prognosis tool from Estonia, Latvia and Lithuania, and they also demonstrate no changes.)	
Urban/National infant mortality	15.4%	2010-2015	http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Life expectancy	65.8* 69.1*	2010-2015	http://esa.un.org/unpp/index.asp?panel=3 http://www.un.org/esa/population/publications/popdecline/nikitina.pdf	02.07.2008
Projected growth rate per capita GDP % per year	7.3	2003-2013	http://www.iccfglobal.org/pdf/margo-thorning100103.PDF	02.07.2008
Labour force in agriculture	10%	2012	Author's assumption. No future data for 2012 exist. It can be assumed there will be a slight decrease. Therefore, 10% was taken. http://w3.unece.org/pxweb/Dialog/varval.asp?ma=02_COSummary_r&ti=Country+Overview+by+Indicator%2C+Country+and+Year&path=../DATABASE/Stat/10-CountryOverviews/01-Figures/&lang=1	02.07.2008

Note: (*): The United Nations/ Department of Economic and Social Affairs offers different numbers for "current urban/national infant mortality" and "current life expectancy". Therefore, Data set 1 and Data set 2 were created; i.e. both figures were entered in the waste prognosis software tool.

Regarding Chapter 3.7. Assessment of waste treatment scenarios by LCA-IWM

Table 3.7.-1: Numbers entered in the LCA-IMW software tool for Khanty-Mansiysk

General			
Country:	Lithuania		
Number of inhabitants:	3,585,000		
Name of city:	Khanty-Mansiysk		
Number of inhabitants:	70,000		
Number of households:	22,000		
Area of town	34 km^2		
Average amount of rain	450 mm		
Average temperature	3 ℃		
Prognosis model	**Waste amount in 2007**	**Waste amount in 2012**	
paper/cardboard	2,700	4,700	
glass	3,500	5,400	
metals	1,100	1,600	
plastics	3,200	5,000	
organic (kitchen)	7,400	10,800	
organic (garden)	1,400	2,000	
hazardous	100	200	
electronics	50	370	
residual	4,850	7,130	
Total	24,300	37,200	
Collection and Transport		**Treatment plant**	
Average distance from city to landfill:	17 km	***size:***	40,000 Mg a^{-1}
Average distance from city to treatment plants:	250 km	***Condition:***	energy recovery
Landfill			
size:	37,200 Mg a^{-1}	(6,345 Mg a^{-1} or 518,970 m^3 for 18 years given by the local authorities could not be entered because the calculated amount for the landfill was too unrealistic.)	
duration:	18 years (1998-2016)		

Table 3.7.-2: Numbers entered in the LCA-IMW software tool for Surgut

General			
Country:	Lithuania		
Number of inhabitants:	3,585,000		
Name of city:	Surgut		
Number of inhabitants:	290,200		
Number of households:	108,581		
Area of town	213 km^2		
Average amount of rain	450 mm		
Average temperature	3 °C		
Prognosis model	**2007**	**2012**	
paper/cardboard	6,200	8,100	
glass	13,000	14,500	
metals	2,600	2,800	
plastics	10,900	12,500	
organic (kitchen)	17,800	18,800	
organic (garden)	2,900	3,000	
hazardous	300	400	
electronics	130	750	
residual	11,170	11,750	
Total	65,000	72,600	
Collection and Transport		**Treatment plant**	
Average distance from city to landfill:	10 km	***Size:***	90,000 Mg a^{-1}
Average distance from city to treatment plants:	50 km	***Condition:***	energy recovery
Landfill			
size:	72,600 Mg a^{-1}		
duration:	20 years (1994-2014)		

Appendix - Chapter 4 Results and discussion

Zip File

Appendix - Chapter 5 Applicability of decision support tools

Regarding Chapter 5.4. Applicability of LCA-IWM

The errors can be detected in the following way:

Error 1:
Assessment Tool -> Modules -> 07. MBP_anaerobic_plant_1.xls -> MBPana_Input_2 -> C26.

Cell "C26" calculates the input of wood for the treatment plant. The last figure in the calculation in cell "C26" had to be changed from "25" to "27" because "25" set the link to "organics" and 27 set the link to "wood".

Error 2:
Assessment Tool -> Modules -> 09. Landfill_plant_1.xls -> LF_Input_2 -> C113.

Cell "C113" shows the "input waste characteristics of material based on waste composition". Cell "C113" had to be changed from "0%" to "84%". As "84%" is written in modules "09. Landfill_plant_2.xls" and "09. Landfill_plant_3.xls", it can be assumed there was a typographical error in cell "C113" in "09. Landfill_plant_1.xls".

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