A TECHNOLOGICAL APPROACH TOWARDS INTEGRATED SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Jyväskylä University School of Business and Economics

Master's thesis

2017

Ana Maria Lozano García
Corporate Environmental Management
Tiina Onkila

JYVÄSKYLÄN YLIOPISTO

ABSTRACT

Author: Ana Maria Lozano Garcia

Tittle of thesis
A Technological Approach Towards Integrated Solid Waste Management in Developing Countries

Discipline	Type of work
Corporate Environmental Management	Master's thesis
Time (month/year)	Number of pages
06/2017	112

This research is grounded in the planning concept of *Integrated Solid Waste Management (ISWM)*. ISWM was developed to promote sustainability in the waste management for developing countries. Waste managers and policy makers in developing countries have been adopting the principles of ISWM into their waste strategies for several decades. But despite their many efforts, still important problems remain, as is the case of low collection coverage, lack of proper treatment of the different waste types, high dependency on final disposal sites and even in some cities uncontrolled dumping is still accepted as the only way to handle the waste.

For that reason, waste management in developing countries needs to adopt new managerial visions and implement new technical solutions to provide a more sustainable and effective service. To do so, governments, waste managers, policy makers need to focus all their efforts in doing very well informed decisions when planning or improving their waste strategies.

The main aim of this thesis, was to study the concept of ISWM from the technology point of view, and proceed with the adjustment of *"Compendium of Sanitation Systems and Technologies (CSST) 2nd revised edition"* (Tilley et al., 2014) within the framework of ISWM. CSST is a well-known planning tool in the field of sanitation for developing countries to manage waterwaste and excreta. So that in this thesis, the structure of CSST was adjusted for the management of solid waste.

The research was carried out using as a research method 'qualitative content analysis', whereby public reports issued by relevant international organizations in the field of waste management were analyzed to construct the structure of the new compendium of ISWM. As result, the new compendium of ISWM contains a robust structure composed by: five (5) functional groups (or waste services), thirty-tree (33) sanitation technologies and thirty-five (35) products (inputs/outputs). This tool can be used either as a planning tool, communication tool or as a simple source of inspiration to contemplate the most suitable technological options and what they have to offer. The structure here presented is meant as well, to invite other researchers interested in waste management to continue the process of adjustment of CSST for solid waste management, to provide the field with a new source for planning or improving waste systems in developing countries.

Keywords
Integrated Solid Waste Management (ISWM), Waste management technology, Solid Waste and Sanitation.

Location Jyväskylä University Library

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

In our society, *waste* seems to be an inevitable output of the virtually all our human activities. *Municipal Solid Waste (MSW)* is undoubtedly one of the largest products derivative from an urban lifestyle. The rapid increase of population, industrialization and urbanization have led to even greater rise in waste generation. Today, the cities of the world produce approximately 1.3 billion tonnes of municipal waste per year, amount that has increased in 90% during the past 10 years, and it is expected to double by the year 2025 (Hoornweg & Bhada-Tata, 2012). *Municipal Solid Waste Management (MSWM)* is consider to be the most relevant service that a municipality must provide to its inhabitants, but it is often taken for granted by residents and even regulators and in many cases nobody pays special attention until piles of waste are accumulates on the doorsteps and streets and only then problems become apparent. Certainly, there is no question that, lack of proper waste management systems generate great negative impacts in the environment, human health, and the economy; indeed the remediation of improperly managed waste usually results much more expensive than manage effectively the waste in the first place.

For centuries, waste has been seen as simple refuse material lacking of value, and WM as a chain of isolated activities of collection, transportation and disposal. Yet, that way of thinking has only restrict the professionalization of the service. Experts on the field agree that in order to improve the image of this important activity, waste should be seen as a *resource* or material that can be recovered in a responsible and cost-effective way, and WM should be understood as a *complete system* with many moving parts depending of each other. Only doing so, it will be possible to move the waste from the landfill into an 'integrated system' for more effective 'resource use'.

This research is grounded in the planning concept of *Integrated Solid Waste Management (ISWM)*, which refers to "the strategic approach to sustainable management of solid wastes, covering all sources and all aspects, covering generation, segregation, transfer, sorting, treatment, recovery and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency"(Mushtaq & Surya, 2016, p. 7). During the past three decades, the concept of ISWM has gain popularity among developing countries and many countries have adjusted their waste strategies following the principles of this integrated approach. Yet, even though great efforts have been made for improving their waste systems, little improvement have been achieved.

Even though, governments and other responsible entities are continuously working towards the solution of the waste related issues, still there are very important gaps to fill in the waste strategies around the world, especially in developing countries. According to reports published by United Nations (United Nations Human Settlements Programme, 2010) and the World Bank (Hoornweg et al., 2012), both agree that the systems used for SWM in developing countries are not fully suitable to handle the current and future volume of waste generation, due to the main following reasons:

a) *Rapid increase of waste generation*: the doubling rate is estimated to be happening in only 10 years.
b) *Ineffective use of the waste management budget*: the current SWM costs in developing countries are estimated to be approximately between 20-50% of the municipal annual budget, and yet the service coverage is nearly to 50% of the population and about 30-60% of the wastes remain uncollected.
c) *Inadequate cost allocation of waste management budget*: In developing countries the most relevant and costly service is collection. In low-income countries 80-90% of the total budget is used only for collection, in middle–income countries it varies between 50-80% of the whole budget, whereas high-income countries only use about 10% of the total budget in collection, the remaining 90% gives them the opportunity to allocate more effectively the resources for other SWM activities such as sorting, recycling, recovery, treatment (waste treatment facilities), and safe disposal (engineered final disposal sites), etc.
d) *Inappropriate waste management practices*: still in many cities in developing countries, open burning and open dumping are accepted practices to handle the waste.

Ín this paper, ISWM will be revised from the technology point of view, with the final objective of producing a planning tool that will compile all the activities of the WM system and the most suitable technologies for developing countries. All this is meant to provide concise and practical information for planning or improving waste systems in developing countries. This will be done using as a reference the *Compendium of Sanitation Systems and Technologies (CSST) 2nd revised edition*, written by Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., and Zurbrügg, C. (2014). CSST is a document that presents and structures a huge range of sanitation systems and technologies suitable for developing countries for the management of wastewater and excreta. CSST has bring many benefits to the sanitation field since is meant to help all stakeholders involved in the decision making process to perform a well-informed decision when planning or improving their sanitation services.

The main aim of the present research is to begin the adjustment of CSST within the ISWM framework. This research task was carried out using the method of *qualitative content analysis of written text*, in which 19 public reports issued by relevant international organizations in the field of WM for developing countries were carefully selected and subsequently reviewed in order to build the structure of the new compendium of ISWM. The content was extracted following the same criteria and structure included in the original CSST. The criteria will be further explained in the chapter 3, numeral 3.2.

1.1. Motivation for the research

The motivation to carry out this research, springs from my professional interest in the topic of waste management, and my personal experience living in two very different countries, Colombia and Finland. During the summer and the autumn 2014, I had the opportunity to work in a Finnish company who manufacture equipment for processing biomass-into-energy, there, among other tasks I conducted a market research where I found fascinating, the amount of wastes that could be recovered and recycled in a cost-efficient way. Yet unfortunately, due perhaps to the lack of awareness, knowledge and/or funding, in many developing countries at the moment those resources are being mainly dumped, generating floods, pollution to air, land and water and endangering the public health of the citizens.

So that, while doing a preliminary research in waste management I came across with the relevant concept of ISWM, and brainstorming with one of staff members of the university, who happen to have an extended expertise in the topic of water and sanitation, she introduced me the Compendium of Sanitation Systems and Technology. Instantly, I became inspired by its functionality, simplicity and most importantly with the amount of knowledge that it comprises for improving sanitation systems, then I knew that the adjustment of this document into ISWM could provide an interesting thesis topic.

1.1.1. Reason why CSST was selected

The CSST as its name imply is a planning tool, devoted to the sanitation systems for management of human excreta and wastewater. On the other hand, solid waste management is indeed a sanitation system that works similarly to the systems included in the CSST. Therefore the key answer to why CSST was selected resides in the definition of 'sanitation' and 'sanitation systems'.

Sanitation refers to "the provision of facilities and services for the safe disposal of human urine and faeces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities. The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal."(The World Health Organization, 2016).

Sanitation has as a main objective to promote health by managing hygienically the wastes, as well as providing an efficient treatment and proper disposal methods to them. Usually, sanitation commonly relates to the management of sewage and wastewater, however, this term includes engineering infrastructure/management systems for: excreta, wastewater, *solid waste* and stormwater. A 'sanitation system' is a tool-box that includes a series of technologies and services for the proper management of different waste flows, covering all the stages since the user phase, going through collection, treatment, reuse and safe disposal (Spuhler & Gensch, 2016; Tilley, Ulrich, Lüthi, Reymond, & Zurbrügg, 2014).

Another relevant reason to select CSST (besides its close relationship with solid waste management), relies on its great recognition in the field. Since the CSST's first version was released, during the International Year of Sanitation in 2008, this document has been translated in several languages and has been distributed digitally for free through several international organizations worldwide. In 2014, the second version of the document was released and again widely accepted by the public. This is an improved, updated version, including: stakeholders, resource recovery and reuse options in the sanitation chain. Tilley et al. (2014) affirm that, its popularity is due its 'brevity', because it introduces and structures a huge range of tested technologies, in a clearly design document, that can be easily customized by the users. In recent years, the compendium has been recognized as "the most popular technical compilation in the sanitation sector and is widely acclaimed by large audience as an international reference tool" according to its authors.

CSST was selected to be the focal axis of the present research, because it has been highly beneficial for the management of other waste flows (excreta and wastewater) in low and middle income countries. So, the adjustment of the compendium could be beneficial as well for solid waste management, since it could provide a needed technical planning tool to improve Integrated Solid Waste Management in developing countries.

1.1.2. Why is this research relevant?

The present research intends to give a step forward in the development of a tool that helps to facilitate the adoption of more suitable technologies and waste practices in developing countries. So, the idea of this thesis is to bring all the benefits that CSST has given to the field of sanitation and apply it to solid waste.

Based on literature, huge loads of information regarding ISWM and waste management technologies can be found. However, the majority of the research, publications and reports found regarding 'integration' of waste management result very extensive and rather complex. Others are often dedicated to isolated activities of waste management (collection, treatment, disposal, etc), especially the literature written before the 90s when the 'integration' approach wasn't yet adopted in worldwide.

For instance, famous environmental organizations had developed very technical and complete managerial tools for implementing ISWM, yet not easily comprehensive or adaptable for the complex situation in developing countries. Just to mention couple of examples, The United States Environmental Protection Agency (US EPA), in 1995 published a complete guide called "Decision-Makers' Guide To Solid Waste Management, Volume II", and ten years later United Nations Environmental Program (UNEP) compiled into a series of 4 documents in a training manual called "Developing Integrated Solid Waste Management Plan". Those documents comprise very valuable methods to implement a more sustainable waste management at municipal or even national level, however they are very detailed and they do not facilitate the planning and decision making of ISWM from the technology point of view to all the stakeholders, these manuals are meant mostly for engineers to engineers.

On the other hand, when talking about waste management technology, the literature available is even bigger in volume and even more technical. It often deepens in the operational features of the different technologies, including very little regarding the managerial aspects (e.g. costs, suitability in different environments, non-technical requirements to operate, etc.) to adopt such a technology in an integrated system.

Now then, CSST has successfully comprise a complete range of technologies, structuring them within comprehensible sanitation systems, that are meant to facilitate the planning process, and to provide briefly, the needed information to support the decision-making process to all the stakeholders involved not only for engineers.

Therefore, in summary, the author considers that the adjustment of CSST into waste management could bring benefits to field, by simplifying and compiling waste technologies within an understandable structured system.

1.2. Research task

During the stage prior to the research, the author realized that the current status of waste management in developing countries is not sustainable, even though many countries have adopted within their waste strategies the principles of ISWM for many decades already, yet the results has not been as successful as it might be expected. At first look, it seems that developing countries have been dedicating all their efforts in improving collection and disposition sites, paying very little attention if any, to the most important aspects of ISWM which are: waste treatment, and safe recycling, reuse and recovery of valuable materials.

Therefore, the present research is specifically devoted to the study of ISWM from the technology point of view. To do so, this research has as a primary objective the adjustment of the *Compendium of Sanitation Systems and Technologies (CSST) 2nd revised edition* (Tilley et al., 2014) into the framework of ISWM.

CSST have become an important reference tool for planning sanitation systems of excreta and wastewater worldwide, especially for developing countries. Therefore, this research expects to give a step forward to the adoption of CSST in the field of solid waste management, in order to provide a tool where the principles of 'integration' within management services and 'efficient resource use' are promoted.

With that very objective in mind, in the first place it seems necessary to understand the current status of waste management in the cities of the world and become familiar with the main concepts discussed in this research.

So that, the first stage of the research has two components, background information and introduction of ISWM framework. The background information collected in order to understand and describe the main concepts of municipal solid waste and its current status worldwide, to place the ground of the research in context and time. Consequently, the ISWM was reviewed to provide a clear overview of its principles, its relevance, and its evolution. All this with the main objective of identifying the roll that technology plays within the framework.

The second phase was dedicated to introduce the original CSST and to proceed to its adjustment. The modifications made to the compendium were performed using the technique of qualitative content analysis, in which, public reports were carefully selected to provide the primary data sources of this research. Consequently, the data was reviewed and analyzed according to the same structure and the guidelines of the original CSST. The following table summarizes the specific tasks carried out during the research phase.

Table 1. Structure of the research: Phase II - Actions and methods

Steps to be made	Theory or method to be used
(a) To describe the scheme of CSST and to build the conceptual structure that will serve as a reference to compile and extract the needed information to adjust the compendium.	Compendium of Sanitation Systems and Technologies 2nd revised Edition (E Tilley, Ulrich, Lüthi, Reymond, & Zurbrügg, 2014)
(b) To select the public reports according to the structure built in the previous step. Those documents will be the primary source to extract the needed data regarding waste management services and waste treatment technologies.	Selection criteria of primary data (19 public reports) that will be used in step C and D.
(c) To analyze the contents from the reports by using the structure built in the step A (active parts of the CSST) and the principles of ISWM. In this step, the objective is to create the new structure of the compendium for ISWM.	Qualitative content analysis of written texts.

(d) To define all the new concepts gathered in the step C. Then to reveal the final structure of the new compendium of ISWM.	

1.3.Research boundaries

CSST can be seen either as planning tool or as an informative tool.

As a planning tool, CSST is a graphical structure in which users can configure their on sanitation systems. The basic idea is to select the way in which wastes entering to the sanitation system are: received, then collected, treated and finally used or disposed. To do so, a sanitation system has three active parts (or moving parts) that user can freely configure according to their needs. The active parts are: functional groups, sanitation technologies and products input/output (see numeral 3.2.1).

The CSST as an informative tool, it is a compilation of *sanitation systems* and *sanitation technologies*. The *sanitation systems* refer to the most common system configurations used developing countries for the collection, transport, treatment and disposal of wastewater and excreta. These nine systems are pre-made/ready-to-use sanitation systems that planners and decision makers can use as guidance to adjust or built their own systems. On the other hand, the compilation of *sanitation technologies* is a set of fifty-five technologies used along the whole sanitation system. Each of these technologies have its own "*technology information sheet*" which is two-page concise description of the technology, including its advantages, drawbacks and considerations for use and maintenance (see numerals: 3.2.2 and 3.2.3).

Taking into consideration that the final aim of this research is to adjust the conceptual structure of the CSST within the framework of ISWM, the author decided to focus only in the components of the CSST as planning tool because there is where structure is explained.

Sanitation systems and technology information sheets are not within the boundaries of the present research. Because they might require a separate research by their own considering the large informative load that they contain.

1.4.Thesis Outline

The present research was structured as follows:

Background	The chapter two presents the current situation of the municipal solid waste in the cities of the world, and defines important concepts of this waste type and describes how the management services are being provided today.
Theoretical framework	This chapter will introduce to the readers, the two key concepts in which, this research has its ground. Firstly, ISWM will be introduced, and secondly the structure and features of CSST will be explained.
Methodology	Chapter four describes the methodological choices of the research, including its boundaries and limitations.
Results	Chapter five includes the analysis of the public reports, which were used to gather the necessary information to adjust the structure of CSST for solid waste. As a key finding, the structure of the new compendium of ISWM was completed and its components were defined.
Discussion and conclusion	This chapter discusses the results gathered from the fifth chapter, and reflects on how the results are connected with the theoretical concepts of this research and how the research contributes to the field of waste management. To conclude, the reader can find the limitations and suggestions for further research to continue the adjustment of CSST for solid wastes.

2. INTRODUCTION TO MUNICIPAL SOLID WASTE IN THE WORLD

Among the nations of the world and their waste management authorities, 'Municipal solid waste' (MSW) is understood and legally defined in very different ways, the most notorious variations are often regarding the definition of the waste sources and the waste composition to be handle within the municipality's jurisdiction. Generally, MSW comprises all the wastes generated, collected, treated and disposed within a municipality; wastes originated in households, non-hazardous wastes from commercial premises, institutions and street cleaning, are the major sources. In some countries mainly in developing ones, MSW composition often include some wastes that are not legally consider as MSW, but still are found along the waste management services (especially in final disposition sites), as is the case of: industrial waste, fecal material and construction and demolition waste(Letcher & Vallero, 2011, pp. 109,110).

The working definition of MSW chosen for this paper is the one currently used by the European Environmental Agency (2013) and all its member states, in which, MSW refers to: "waste generated in households and waste comparable to household waste generated in production, especially in the service industries. The general common feature of municipal waste is that it is generated in the consumption of final products in communities and is covered by municipal waste management systems." (European Environmental Agency, 2013, pp. 7-8; Statistics Finland, 2015).

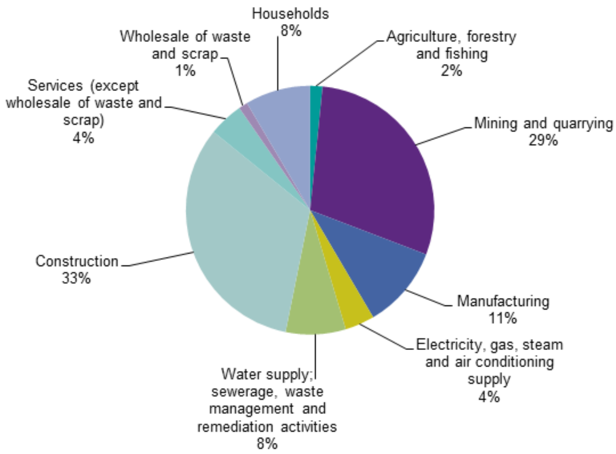


Figure 1. EU-28 Waste Generation by Economic Sectors and Households.
Note. Retrieved from EUROSTAT (2015)

MSW compared with other waste categories is not so great in volume but, it is considered the most challenging one to be handled due to its complexity. For instance, Eurostat (2015) estimates that, the total waste generation from economic activities and households in EU-28 exceeded 2.5 million tons in the year 2012, household waste and similar wastes participate only with 8%, which is equivalent to 213 thousand tons/year (see Figure 1). However, MSW becomes relevant and complex for its special features. Firstly, MSW contains million different materials that may require a different type of processes in order to be properly treated, yet since the majority of the materials entering to the system are all mixed, it becomes very difficult to handle. Secondly, it involves large number of stakeholders such as local authorities, private sector (formal/informally constituted), NGO's, service providers and the service users which are the whole community. Lastly, MSW generation and handling process is highly influenced by the local social, political and economic situation (Letcher & Vallero , 2011).

A municipal waste stream is characterized by the *waste generators* and/or the *types of solid wastes* that are handled. A waste generator is understood in MSW as the agent or pathway where a purchased, acquired or grown item is discarded (United Nations Human Settlements Programme, 2010, p. 216). Waste generators contribute to MSW stream with non-municipal and hazardous wastes as well. Clearly, the differentiation between *municipal wastes* from a *non-municipal waste* lies in the legal framework of each country, so the stricter the waste legislation is, the most rigorous are the waste categorization and its separation, in order to provide a proper treatment for each waste type. The following table lists and names the most common MSW generators and describes in detail the type of wastes they usually produce, distinguishing non-municipal and hazardous wastes as well.

Table 2. Waste Generator and Waste Types.
Note: Adapted by the author using as reference: Hoornweg & Bhada-Tata, 2012, p. 7, table 2; United Nations Human Settlements Program (UN-HABITAT), 2010, pp. 6,7.

Source	Typical waste generator	Types of MSW	Hazardous or Non-Municipal Wastes
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes and special wastes (e.g. bulky items, consumer electronics, white goods, batteries. oils and tires).	Waste oils (e.g. from vehicles and other appliances), household hazardous wastes (e.g. paints, aerosols, gas tanks, waste containing mercury, motor oil and cleaning agents), e-wastes (e.g. computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process wastes if the municipality does not oversee their collection)	Housekeeping wastes, office wastes, wastes from manufacturing processes, packing, food wastes, ashes and special wastes.	Construction and demolition materials. Hazardous wastes similar and/or stronger to the ones produced by households.
Commercial	Small workshops in urban areas, stores, hotels restaurants, markets, office buildings.	Paper, cardboard, plastics, wood, food waste, glass, metals, special wastes.	E-waste and hazardous waste.

Institutional	Schools, hospitals (excluding medical waste), prisons, government buildings, airports.	Same as commercial	Hazardous wastes often mixed with body fluids, chemicals and sharp objects
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and waste treatment plants.	Street sweepings, landscape and tree trimmings, general wastes from public areas, and sludge waste.	
Construction and demolition (C&D)	New construction sites, road repair, renovation sites, demolition of buildings.	Same as commercial	Bulky materials, wood, steel, concrete, dirt, bricks, ties, windows and roofing materials. Household repairs and refurbishment, particularly "do-it-yourself" wastes are most likely to enter to the MSW stream.
(!) The items below are considered as MSW just if the municipality attends its collection and disposal.			
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.		Industrial process wastes, scrap materials, off-specification products, slag, tailings. Mines and quarry waste (e.g. mineral waste, soil).
Medical waste	Hospitals, nursing homes, clinics and health centers.		Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive wastes (e.g. from cancer therapies) and pharmaceutical waste.
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms.		Spoiling food wastes, agricultural wastes (organic material including crop residues, manure, slurry and silage), and hazardous waste (e.g. pesticides)

As it can be seen in the table above, the list of non-municipal wastes is large and the waste management system of each country decides how to handle them. In developed countries, there are separated systems designed to collect and handle those wastes, to minimize its generation, reduce toxicity and dispose safely, yet in some cities hazardous wastes can reach disposal. Meanwhile in developing countries, even though efforts has been made to segregate waste streams and dispose them safely, still the MSW stream includes an important percentage of non-MSW wastes and hazardous wastes. Very often in developing countries, mixed wastes (including hazardous wastes) are disposed together in their final disposition sites without segregation or pretreatment. And what makes the problem more severe is that still in many low-income countries, "uncontrolled dumping" is still an acceptable way to handle virtually all kind of waste (Daniel Hoornweg & Bhada-Tata, 2012; United Nations Human Settlements Programme, 2010).

Therefore, Municipal Solid Waste Management (MSWM) has been forced to redefine more precisely what MSW is, in order to provide a more professional service with more sustainable practices to handle responsibly and safely the increasing and more diverse waste flow (Letcher & Vallero, 2011).

2.1.MSW generation

The generation of MSW is highly influenced by the economic status of the waste generators so, the higher the income of the waste generators the more waste is generated. Local factors such as the standard of living, consumption patterns, industrialization and commercial practices play a major roll and reveals important data for waste generation (Eawag, 2008).

The waste increment tends to vary greatly among regions, countries and even from city to city within the same country, despite their size. It might be thought that the bigger the population is, the larger the amount of waste. However, MSW has in some cases little in common to the population in number. Experts agree that economic indicators like *Gross National Product (GDP)* and *Gross National Income (GNI)* could have a more powerful correlation with the volume of waste generated within the countries (Daniel Hoornweg & Bhada-Tata, 2012; Letcher & Vallero, 2011; Williams, 2005). For that reason in this thesis the classification of the World's Economies according GNI Per Capita will be used for differentiating developing countries from developed countries (see table 3).

Table 3. Operational Classification of the World's Economies according GNI Per Capita (2015).
Note: Adapted from http://data.worldbank.org/news/new-country-classifications-2015.Copyright © 2015 The World Bank Group, All Rights Reserved.

	General categorization	**Income group**	**Limit values GNI per capita (USD$)**
Developing countries	Low income countries	*Lower-income*	(-/=) $ 1,045
	Middle income countries	*Lower-Middle-income*	(+)$ 1,045 until $4,125
		Upper-middle-income	+$4,125 to $12,736
Developed countries	High income countries: OECD	*High-income*	(=/+) $12,736

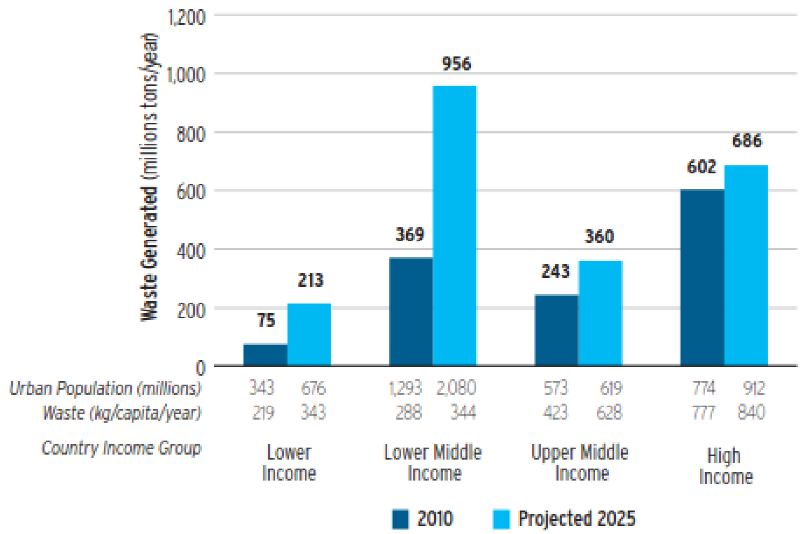
Besides, economic indicators and population growth, MSW generation is influenced by other relevant factors such as: the waste collection system and its frequency, family income level, residence type, education, seasons, culture and social practices (Letcher & Vallero, 2011, p. 110; UNEP - United Nations Environmental Programme, 2011, p. 297)

The latest global report published by The World Bank in 2012, titled "What a waste: A global review of solid waste management", uses economic indicators and population rates to compare the waste volumes accross the world, and makes a prognostic to the waste generation by the year 2025. The report points out that, during 2010 the MSW generated worldwide reached 1.3 billion tons, and only in 15 years the waste volume is expected to double, so by the year 2025, approximately 2.2 billion tons of municipal waste will be produced (Hoornweg & Bhada-Tata, 2012, p. 8). Those alarming figures reveals how important is to be prepared and find reasonable ways to handle the increasing waste affluent around the globe.

Looking at the problem closely, MSW generation worldwide in correlation with the population is nowadays virtually unbalanced. High-income-countries having one third of the world's population, they alone produce almost half of the total waste worldwide, exactly 46% of it. Low-middle-income countries (including India and China) represent, 43% of the world's population, they produce almost 30% of the world's MSW. Upper-middle-income countries with a population equivalent 20% worldwide produce nearly to 20% of the waste. And low-income countries with 11% of the world's population, have the lowest waste generation, contributing with 6% to the waste worldwide(Hoornweg & Bhada-Tata, 2012, pp. 10,11).

Now then, when projecting all together the current data of urban waste generation, country's GDP and population growth to the year 2025, the results are surprising. It might be expected that the rule of "the higher the income, the higher the waste increment" will show in the projections, however it seems that in the long run the population might impact dramatically the waste generation in the cities of the world.

Figure 2. Urban Waste Generation by Income Level and Year 2010-2025
Note: Retrieved from: (Daniel Hoornweg & Bhada-Tata, 2012, pp. 12, fig. 13).

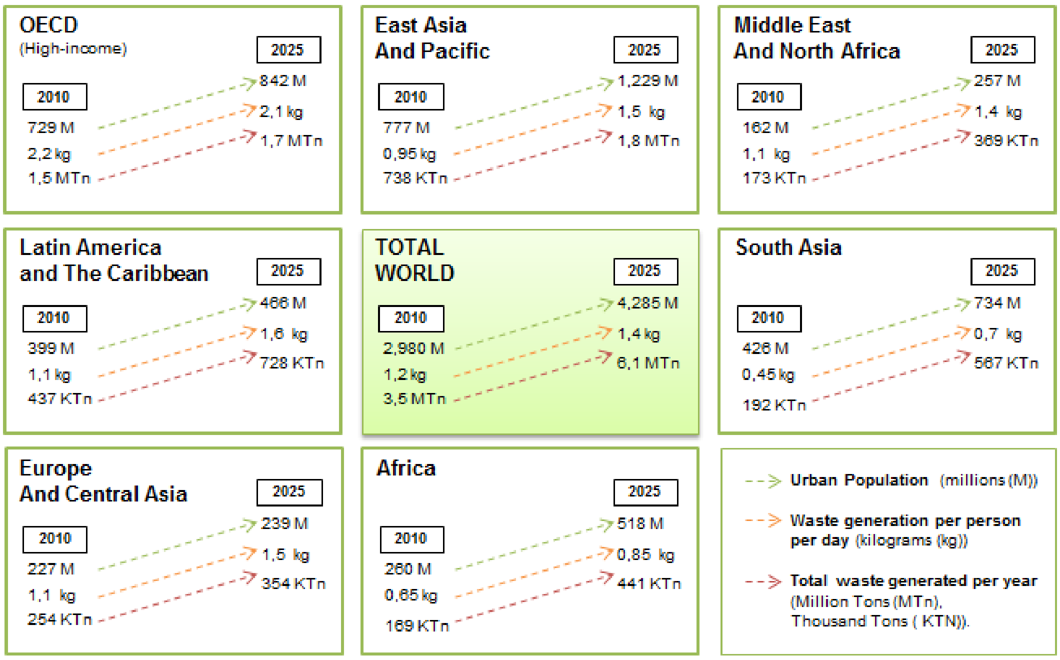


The figure 2 urban waste generation by income level and year 2010-2025 reveals that, by the year 2025, the highest waste increment shall come from developing countries where population is expected to increase dramatically, and from emerging economies where income will continue to rise.

According to calculations made by the author based on the numbers presented in the figure 2, by 2025, lower-income-countries will clearly reach and even exceed the doubling rate of their current waste volume, and their population is expected to increase between 60% and 97%. In Upper-middle-income and high-income countries, the situation seems a bit different, since the population will increase in much smaller rate, in 8% and 18% respectively, yet the waste generation in upper-middle-countries is expected to increase in 48% and for high-income-countries the increment will be only 14%.

Nevertheless, to locate the focal areas where waste raisings represent the biggest problem to the world is important to see the waste statics according to the regions of the world. The figure 3, presents the population of different regions of the world and their waste in volume, during 2010 and the projected values to the year 2025. When analyzing that figure is evident that the waste generation is far away in balance with the amount of population living in the regions.

Figure 3. World's Waste Generation and Population, Values from 2010 Projected to 2025
Note: Adapted from What a Waste: A Global Review of Solid Waste Management, 2012, p. 10, table 4.



If we look at the actual values of 2010 it could be said for instance that:

a) High-income countries (OECD) are responsible of nearly half of the total waste generated around the world.

b) MENA (Middle East and North Africa) and LAC (Latin America and Caribbean) generates the same amount of waste daily, even though MENA double the population of LAC.
c) ECA having a population of 227 million people it generates the same amount of waste per day than AFR and SA together, so that 686 million can generate the same amount of waste daily than 227 million people.

In contrast when we look at the projected values to 2025, the increase in population has a higher correlation with amount of waste projected (for obvious reasons), but the waste increment doesn't follow the same rate for all the regions. Regions as, EAP, MENA, SA and AFR will almost double their population and the waste generation rate will follow. Meanwhile OECD, ECA and LAC will slightly increase their population size, yet waste generation doesn't follow the same line.
Interestingly, OECD countries will be the only ones reducing their waste generation. Probably due to the fact that many of them have been straightening their waste management policies during the last decades, and have set strategies and clear targets to tackle the waste problem since its generation all the way to its treatment and safe disposal, but their daily waste generation clearly still keeps exceeding the media around the globe. As it is the case of Canada, US, European/Nordic Countries, Australia, New Zeeland and Japan (Hoornweg & Bhada-Tata, 2012; Letcher & Vallero, 2011).
The population of LAC will not increase in a considerable rate, yet the wastes generated will nearly double their volume. At the present moment, LAC as virtually all developing and transitional countries have being facing major troubles handling and managing their waste; even though efforts has being made, their waste management systems seems to be ineffective and weak specially regarding collection and safe disposal.

2.2. MSW composition

The composition of urban waste stream as its generation is constantly changing due to the same factors mentioned above, however, factors such as income, lifestyle and residence type (urban vs. rural) and seasons affect greatly to variation in composition. MSW affluent is often divided into six main categories: organic, paper, plastic, glass, metals and others (see Table 4). Waste managers agree that generally that categorization of MSW is sufficient for planning purposes (Hoornweg & Bhada-Tata, 2012, p. 16; Letcher & Vallero, 2011, pp. 111,112; Williams, 2005, p. 80).
Even though the author recognizes that MSW should be classified as specifically as needed according to the waste treatment technologies in place, in this study the classification mentioned above was chosen because is sufficient for the development of the planning tool.

Table 4. Types of MSW and Their Sources.
Note: Retrieved from: What a Waste: A Global Review of Solid Waste Management, 2012, p. 16, table 9.

Type	Sources
Bio waste	Food waste, yard waste (leaves, grass, brush), wood, process residues
Paper and cardboard	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, and paper beverage cups. Strictly speaking, paper is organic but unless it is contaminated by food residue, paper is not classified as organic.
Plastic	Bottles, packing, containers, bags, lids and cups.
Glass	Bottles, broken glassware, light bulbs, colored glass.
Metals	Cans, foil, tins, non-hazardous aerosol cans, railings, bicycles.
Special waste	bulky items, consumer electronics, white goods, batteries, oils and tires

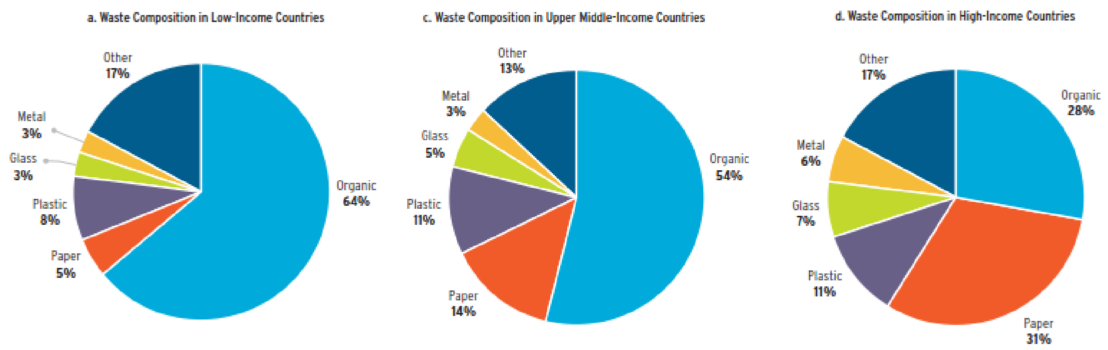
Non-municipal waste

Even though, non-municipal wastes are out of the boundaries of the present research is important to clearly identify them because they can be often found mixed with MSW in developing countries.
The largest and most representative waste stream with those characteristics is *Construction and Demolition (C&D).* Due to its high volume, municipalities around the world often does not contemplate its collection and disposal. Instead, municipalities have in place separate management systems for this waste stream. However, C&D is a rich material in soil, gravel and clay content and other useful materials that can be recycled and reuse for landfill engineering (e.g. to build landfill cells, for capping to cover the final site) for road ways, car parks and landscaping (Williams, 2005, pp. 113-114). In developing countries C&D waste is approximately 10-15% of the total waste matrix, meanwhile in high income economies C&D has a much larger portion and can reach levels up to 50% of the total waste generation (United Nations Environment Programme, 2011, p. 292).
Likewise, other non-MSW types are: *healthcare waste*, *agricultural waste*, and *other processes waste* from ICI sector (Industrial, Commercial and Institutional sector), because they are different in composition than household waste. In some cities of the world, those wastes are collected mixed with the MSW stream, and end up being disposed all together, generating negative impacts to the environment and human health. Municipalities in developed economies do not attend those kinds of wastes, but in developing and emerging economies where the waste legislation is less severe, those wastes are not well separated from the MSW waste stream (Hoornweg & Bhada-Tata, 2012, pp. 16-17; United Nations Environment Programme, 2011, pp. 294-296).

Therefore, due to the difference in waste legislation among countries regarding non-municipal waste types, they won't be taken into consideration in the present research. Only the wastes that follow the working definition of MSW will be considered, the ones are listed in the table 1 under the column municipal waste types and the broad classification can be found in the Table 4.

Variation in waste composition in the cities of the world

Figure 4. MSW composition by income 2010.
Note: Retrieved from: What a Waste: A Global Review of Solid Waste Management, 2012, p. 19, fig. 8.



When analyzing the municipal waste composition worldwide according the countries' wealth (see Figure 4), two important trends can be seen. On one hand, it seems that, the lower the country's income, the higher the content for organic material present in MSW. So that low income countries has the highest average of organic content being this 64% of the MSW matrix, middle-income has 54-59%, and high–income has only 28% respectively. On the other hand, as the wealth of the economies increases, more diverse the MSW composition becomes. So that, whereas the organic portion decreases, the paper and inorganic portion increases, becoming paper, plastic, metal and glass (recyclables) more than half of the MSW.

Similarly, when analyzing the MSW composition by regions same trends are present and similarities among regions are apparent. Municipal waste in AFR MENA and EAP tend to have nearly 60% of organic portion, 30-35% of paper, plastic and others wastes, and only 5-8% of glass and metal (Hoornweg & Bhada-Tata, 2012).

LAC and SAR have nearly the same amount of organic portion, 54% and 50% respectively, however, in SAR region the composition is clearly different than all the other regions. In SAR the second biggest portion after organics are other wastes with a participation of 37%, this figure is clearly in disproportion with other regions, when this waste type does not exceed in any case 17%. Paper, plastic, metal and glass, all together do not exceed 13%. In LAC, paper, plastic and other wastes are about 40% and only 2% and 4% metal and glass, which seems to be align with the other regions trends (Hoornweg & Bhada-Tata, 2012).

EAC municipal waste is the most diversified matrix after OEDC has less than half of organic portion and the portion of paper and inorganics is similar to the OEDC distribution. In OEDC countries, organics are just 27% and paper is the highest portion with 32% and inorganics are the remaining 40% (Hoornweg & Bhada-Tata, 2012).

United Nations (2010, pp. 11) as well as many other waste manager experts point out that, accurate data of volume and quantities of waste types, are essential to plan an effective waste strategy. However, all of them recognizes the lack of reliable and compatible data and constant monitoring in the sector are an important drawback. Waste statistics are often incompatible or simply non-existent en many cities of the world, including many cities from developed nations.

2.3.Collection

An important indicator of the efficiency of a waste management strategy is the collection rate (or collection coverage). Collection of MSW is important for human health and for the environment, wastes that remains uncollected will most likely have a negative fate and could endanger both, the nature and the city's environment. The organic fraction of MSW that remains uncollected may attract the proliferation of mosquito, rats and other animal populations. Uncollected solid waste may end up dumped without control in water bodies, open dumps or burned, and local communities may be exposed to diarrhea, respiratory infections and other diseases. In the cities, usually the non-collected waste causes blockages in the sewage system causing flooding and consequently may provide the perfect conditions for waterborne diseases to spread (United Nations Human Settlements Programme, 2010, pp.22).
As mentioned in past chapters, MSW is only a small portion of the total waste generated by economic activities yet, its collection requires the most complex collection system. A well-functioning collection system should aim to ensure the maximum coverage within the municipality while optimizing operative costs, which indeed represent a big challenge to the local authorities. For instance, waste manager experts and authorities agree that collection is the most costly service within the whole MSW management system but that doesn't necessary determine the collection´s efficiency (Williams, 2005, pp. 119; Letcher & Vallero, pp. 62).
The World Bank (Hoornweg & Bhada-Tata, 2012, pp.16) estimates that, in low-income countries, collection costs can often be up to 80%-90% of the total budget yet the collection rate just cover 41% of the total MSW generated. In high-income countries, collection can represent even less than 10% of the total budget and the collection rate is usually higher than 90%, and often the collection methods selected by them are less labor intensive and more mechanized, efficient and organized. As result, that reduction in collection costs allows them to allocate

more effectively the resources in other activities of the waste management system, e.g. in waste minimization, in a more adequate treatment and in safe disposal methods (see Figure 5).

Collection rate, is the most important indicator of efficiency which measure the portion of MSW that is actually collected and becomes active part of the waste management system. When looking at the global estimations of collection efficiency by regions (see Figure 5), it can be seen that OECD countries have the highest efficiency, while MENA, LAC, EAC and EAP have an efficiency ranking between 85-70%, and lastly the regions of SAR and AFR rate 65% and 47% respectively (Hoornweg & Bhada-Tata, 2012, pp.16).

Figure 5. Waste Collection Rates by Income and by Region.
Retrieved from: What a Waste: A Global Review of Solid Waste Management, 2012, s. 15, fig. 4 and 5. Copyright © 2012 The World Bank Group, All Rights Reserved.

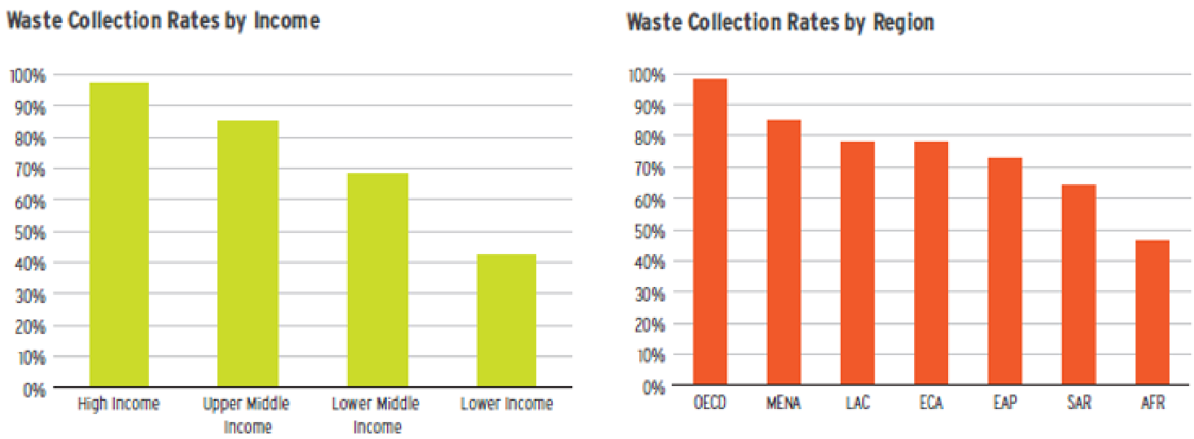
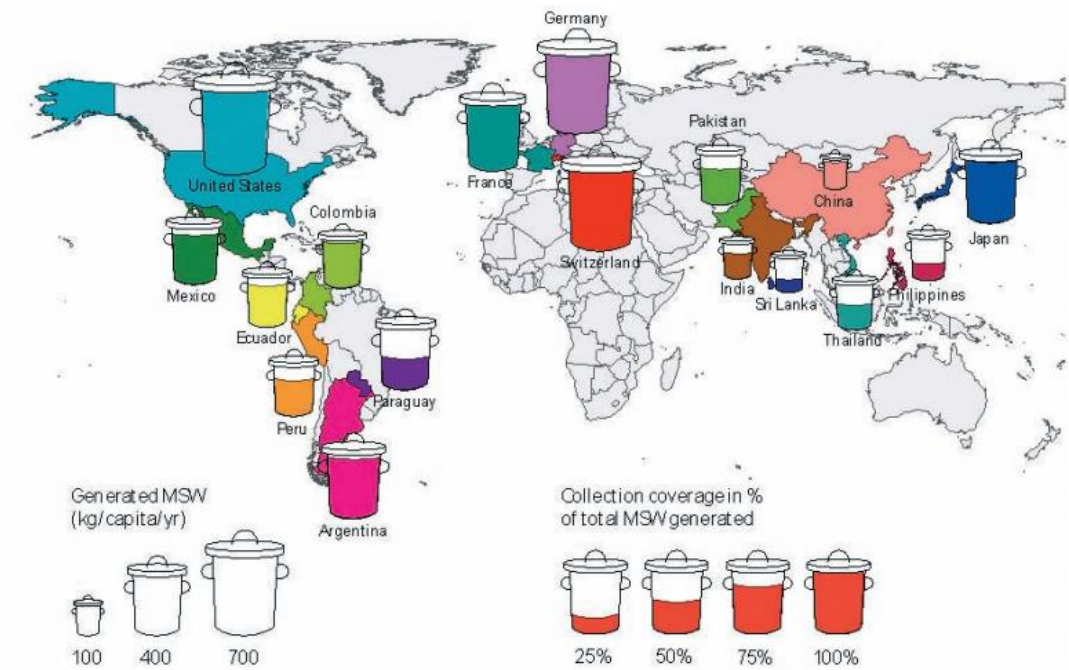


Figure 6. Total MSW generated (kg/capita/yr) and collection coverage in % in 17 countries.(Eawag, 2008)



When looking closer at the collection coverage within the region (Figure 5) in contrast with the collection coverage of different countries of the same region (see Figure 6), the figures can tell that many countries of the same region are considerably out of the media. For instance, the average in LAC is approximately 78%, yet Paraguay has a coverage of 50% and Colombia that rates nearly to 100%; same can be seen in EAP, where the average is 72%, yet China rates 100% while Thailand and Philippines are clearly below 50%; in SAR the media is 65%, yet Sri Lanka rates approximately 25%(Eawag, 2008).

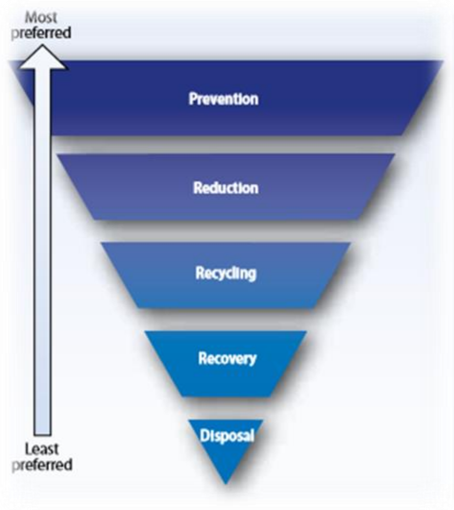
Besides the collection coverage, other important stage that takes place prior the collection phase is the "*waste separation*", and it affects greatly the design of the collection system. The local waste management and its legislation dictates, how the waste should be separated prior collection and how it should be sorted at the sorting facility (if existent), being the first one the most preferred option. S*eparation at the source* is an important asset for quality and quantity of the recyclable materials; mixed, dirty or contaminated recyclables loses or diminish its value in the market. So that, separation usually aims to obtain tree clean and unmixed waste streams: "wet" which is the organic fraction, "dry" is the recyclable fraction (glass, paper, metal and plastic) and "waste" the residues remains. In the cities of the world, waste separation varies greatly. Often, in cities where waste legislation is forceful, the waste practices, education and culture at the community level is higher and as result, separation tends to be more effective. In developing countries, MSW separation tends to be low, often waste generators dispose the litter all together and "waste pickers" (often from the informal sector), remove the recyclable portion in different stages of the waste handling process, some remove the valuable materials at the source or during collection, and others at the disposal sites (Hoornweg & Bhada-Tata, 2012, pp.13,14) .

3. THEORETICAL FRAMEWORK

3.1.Integrated Solid Waste Management (ISMW)

During nearly five decades, *Integrated Solid (Sustainable) Waste Management,* better known as *ISWM,* has been internationally recognized as the most complete strategic approach for improving waste management sector in developing countries. Due to its extended history, global institutions, associations, regulators and the academy have developed variety of definitions of this concept. However, in all the definitions, ISWM stands for the principle of "*integration*" of all the three dimensions involved in the management of solid waste, which are: *services and procedures* (collection, transportation, treatment and disposal), *stakeholders* (service users, service providers, subcontractors, regulators and governments), and *aspects affecting managerial activities* (financial, operational, legal, political, social and environmental aspects). The aim of this multilevel integration is to maximize the efficiency of resource use while, assuring public health and environmental protection (United Nations Environment Programme, 2011; United Nations Human Settlements Programme, 2010; Hoornweg & Bhada-Tata, 2012; EPA U.S., 2012).

Figure 7. Waste management hierarchy
Note: Retrieved from: Waste Investing in energy and resource efficiency, 2011, pp. 9, figure 1.
Copyright © 2011 UNEP - United Nations Environmental Program.



ISWM has its basis in the well-known "waste management hierarchy" (Figure 7). The waste hierarchy presents a scale of the most and less preferred options to handle municipal solid waste. The hierarchy can be classified into three groups: (1) Mechanisms to avoid and reduce waste generation. (2) Measures to encourage segregation and to promote resource utilization by establishing effective systems towards the "4Rs": Reduce, Reuse, Recycle and Recovery. (3) Lastly, the less preferred option, final disposal, which mainly implies the use of sanitary landfills and controlled dumps as acceptable options. However, other not acceptable options such as uncontrolled dumping, open burning and ocean dumping, should be taken into consideration but as a problematic area. Those are not included into the hierarchy because do not bring any environmental benefit to waste service. In a nutshell, an ISWM system is based on the principles of the waste hierarchy and should aim to move the waste upstream, in order to increase the professionalism of the waste management service, offering suitable options to safely handle waste as a resource, in a more strategic way (Hoornweg & Bhada-Tata, 2012).

ISWM as a planning tool for a management system covers a wide range of factors, which are unique according to the local conditions, one single plan cannot be identically implemented in one country to another, not even among the cities within the same country. An ISWM plan consists in a package of laws and regulations, technologies and infrastructures, institutions, financial mechanisms and big variety of stakeholders, which are interdependent one to another, and the consistency in the interaction of those factors will dictate the efficiency of the whole management system (UNEP. International Environmental Technology Center, 2009, p. 10). An ISWM plan covers as well all the activities of waste management, from the user interface, collection, conveyance, segregation, treatment and all the way to the final disposal. Therefore, when developing an ISWM plan, waste statistics and information regarding all the factors mentioned above are the key to build a successful management system.

World's institutions and international associations have been supporting the implementation of ISWM in the countries of the world as a tool to create sustainability in the sector, as well as to offer a response to the waste related issues and the resource scarcity that our society is facing.

3.1.1. Waste in terms of ISWM

Colloquially, 'waste' usually refers to a material considered as "unimportant, valueless or no longer useful" after the completion of a process (Oxford University). According to that definition, in nature, waste does not exist, since anything is refused, everything is recycled or reused into other cycles within the ecosystem. Yet in our society, waste seems to be an inevitable output of our human systems, which at the end has strong implications in terms of environmental, social, financial and legal issues for businesses, local authorities, communities and governments.

Now then, with the introduction of the concept of "sustainability", many dimensions of our human systems have begun to change and waste management is not the exception. In ISWM, waste is seem as both positive and negative, depending mainly on its potential as a source income or economic value. ISWM recognizes that both formal and informal sectors depend on waste as an income source. The formal sector includes large industries using waste materials as industrial feedstock, as is the case of the paper, cardboard and metals. The informal sector operates mainly in low and middle-income countries where, waste represent the only free resource that poor people might use for income, mainly by hand-picking and resealing the useful materials found in the waste stream. However, not all wastes can be recognized as good or resource, non-useful materials should count with proper pretreatment and safe disposal options (van de Klundert & Anschutz, 2001).

3.1.2. Principles of ISWM

The Dutch NGO, WASTE with an extended experience implementing ISWM in the countries of the world, points out that every waste management system shall be guided for four principles: *equity, effectiveness, efficiency and sustainability* (van de Klundert & Anschutz, 2001, pp. 11,12).

Equity stands for the community, since waste services should be offered to all the residents without distinction. Beyond the moral responsibility, it is a fact that areas of the city where waste remains uncollected generate negative impacts to the air and water supply for the whole city, and it is a symptom to recognize a clear failure of the public service (van de Klundert & Anschutz, 2001, pp. 11,12).

Effectiveness refers to the service coverage and resource recovery, in which the waste management model should aim to safely remove all the waste and provide suitable ways where the valuable materials are recovered. A WM model is not effective when only central, business and touristic areas are clean, the isolated and poor areas should be taken care equally(van de Klundert & Anschutz, 2001, pp. 11,12).

Efficiency refers to maximize the benefits of the service, by optimizing the costs and the resource usage. A WM is efficient when the city is equally clean, and the whole community pays fare fees to maintain the service, and when the management system have adequate financial, technical, operational and labor resources to operate (van de Klundert & Anschutz, 2001, pp. 11,12).

Sustainability refers to the self-sufficiency of the management system, regarding to the use of resources and how that suits to the local conditions. A WM system should make adequate use of labor, equipment and resources (air, water and soil) according to the present and future availability (van de Klundert & Anschutz, 2001, pp. 11,12).

3.1.3. ISWM versus Conventional Waste Management

The following table present a comparative summary between the drawbacks of conventional waste management and the benefits of adopting ISWM principles into a waste strategy.

Table 5. Conventional Waste Management versus ISWM.
Adapted by the author from: UNDESA (2012), Chapter 5 - MUNICIPAL SOLID WASTE MANAGEMENT: TURNING WASTE INTO RESOURCES. p. 8. Box 5.1 Convencional Waste Managenet versus Integrated Solid Waste Management.

factor	Conventional WM	ISWM
Public health and environmental protection	Due to environmental pollution in water, land and air caused by poor WM, the community could be exposed to: - Water-borne diseases caused by flooding for uncollected wastes. - Respiratory diseases due to the inhaling of downwind from open dumping and waste burning. - Diarrhea and malaria among others, due to proliferation of vermin in the dumpsites and the presence of leachate in city' the water supply.	Promotes the combination of centralized and decentralized treatment options, which should have effective systems for the capture of pollutants and hazardous substances (e.g. landfills with leachate treatment and gas extraction systems), in order to improve efficiency and minimize pollution.
Public awareness	- Focuses on removing waste from sight, yet little has been done to reduce waste volumes and to encourage separation at the source. - WM often relies entirely on governmental institutions, so private sector and local communities have a limited role in the waste system.	- ISWM encourages stakeholder involvement in the waste strategy, so that the community and the private sector can play an active role in the waste system. - It proposes as well the concept of 'extended producer responsibility' in which, manufacturers must be responsible for the costs associated with the end of life of their own products.
Value of waste	- Earlier thinking was that waste is an 'unwanted' material lacking of value. - Separation of waste streams are almost inexistent. Hazardous materials from hospitals, commercial premises, and small industries are often mixed with MSW, making almost impossible to provide proper treatment to each waste type and affecting greatly material recovery. - Valuable materials easily reach disposal.	- Waste is a resource with economic value. ISWM promotes the principles of resource efficiency to value waste and to diminish the increasing pressure in waste management sites. - Incorporates the usage of the waste hierarchy. In which, waste prevention and the 4R's are priority. - Proposes clear long-term strategies to facilitate recycling of valuable materials (such as

	- Minimal recycling rates. Waste pickers and informal sector often carry out recycling at the generation point or in disposal sites.	plastic, glass, paper and cardboard, metals) and promote energy recovery (e.g. biogas or compost from organic waste, and Solid Recovered Fuel SRF from waste fraction with high-calorific content, etc.). - Encourage the implementation of a separate management system for hazardous waste. - Seeks to address the diversification of wastes, in which emerging waste streams such
Stakeholder involvement	There is minimal participation of communities and private sector in the decision making process.	Enforce multi-stakeholder participation in decision-making and recognize their role in the waste system. Decision makers, regulators and local institutions are encourage to assure the participation of NGO's, CBO's, waste pickers from informal sector, private sector, residential and commercial communities in WM.
Employment conditions	Often workers and informal waste pickers were exposed to serious health hazards such as HIV, tetanus, PCB's, neural damage, cuts with sharp objects, premature drinking, stress, and problems in the skin, gastrointestinal infections and respiratory difficulties. Other social hazards such as child labor are a common issue.	- Promotes the implementation and development of waste technologies to handle the waste safely and to increase recycling and energy production from waste. - Assure the implementation of measures to assure health and safety working conditions in the waste sites. - Seeks the recognition of the informal sector (scavengers/waste pickers) in legally established associations, in order to define their role in the waste strategy, and recognize their rights for a fair work.
Service coverage	The service was often non-equal. Slums and poor areas of the city did not receive same municipal services.	Promotes the adoption of economic and labor strategies to assure the waste service to all citizens.

Treatment and disposal	Illegal dumping in land, on water bodies, open dumping and burning were 'acceptable' means to handle the waste. Trans-boundary movement of wastes for disposal lacked of an efficient regulatory framework.	Facilities for treatment and recycling of valuable material are highly encouraged. Final disposition is recognized as the less preferred option to handle the waste.

3.1.4. History of the concept of ISWM

The term of *ISWM* has been shaped during nearly five decades. According to Wilson, Rodic & Velis (2013), during the 1970s for the very first time, the approach of "integration" in waste management became known in the research field. Since then, the concept has been associated in variety of ways to the management of general waste and solid waste, and has exponentially increase its appearance in the research field. The table 6, summarizes the main research approaches related to "integration" in SWM in the history.

As can be seen in the Table 5 , along the history the majority of "integrations" were referring to the technical elements, for instance, the integration of waste streams, integration of treatment technologies, integration of facilities, and more importantly the integration of the WM system in a regional level. Then during the mid-1990's, the "integration" took an important overturn, suggesting the inclusion of the targets of the waste hierarchy into the management system, addressing all the waste problems in a single strategic plan where waste prevention, recycling and safe final disposal are priority (Wilson et al., 2013).

Another influential fact was the introduction of sustainable development in the global agenda. During the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, Agenda 21 included in the discussions the issues of waste management across the cities of the world, especially in developing countries. As response, several international associations and non-governmental organizations with presence in developing countries, begun to realize that the approach of "technical fix" (as called by Wilson (2007)) wasn't enough to solve evident failure of the current waste management systems. The World Bank, UN-HABITAT, UNDP and the Swiss Agency for Development and Cooperation conformed a collaborative programme, where waste management in developing countries was the priority. In 1995, during a workshop helded in Ittingen, Switzerland, that collaborative programme gave as a result the first conceptual framework of integrated municipal SWM in low-income countries in which the tripple bottom line of sustainability is included (Wilson et al., 2013, p. 53).

During the same year (1995), the Dutch government established a new programme called, Urban Waste Expertise Program (UWEP), in which the NGO

WASTE was in charge to build further the integrated framework. After six years of research, Van de Klundert & Anschutz (2001) presented for the very first time the concet of Integrated Sustainable Waste Management (ISWM as know today) with its analytic tool and specific framework. This approach was instantly widely accepted and adopted in developing countries (Wilson et al., 2013). Over time, the concept has been in continue improvent and was complemented with more accurate assesment tools. The latest approches of ISWM, has been done including important tools such as Life Cycle Assesment (LCA) and the prespective of circular economy, stressing the importance of recovery and reuse of resources within the whole supply chain.

The frameworks mentionated here will be futher explained in the following chapter.

Table 6.Peer-reviewed literature of the evolution of ISWM
Adapted from: Wilson, Rodic, & Velis, Integrated sustainable waste management in developing countries, 2013, pp. 53,54

Thematic use	Description – system components	Timeline and Relevant references
Waste and wastewater processing integration	Integrating solid waste management with wastewater treatment, and sometimes also with energy generation and food production	Murray et al. (1971); Ingelfinger and Murray (1975); Diaz et al. (1996)
Solid waste processing integration	Integrating various technical elements into a single waste treatment process (e.g. as in modern mechanical biological treatment plants)	Crocker (1983); Diaz and Golueke (1989); Smith (1990)
Facility integration	Integrating different types of solid waste treatment and disposal facilities in close proximity, often with various treatment processes and a landfill site co-located	Crocker (1983); Diaz and Golueke (1989); Smith (1990)
Integrated planning for a region/metropolitan area	Integrating a number of neighboring political units into a region for the purposes of analysis/planning/siting and permitting common facilities to serve the whole region. Often the term implies the use of a systems approach or mathematical modelling	Tobin and Myers (1974); Barlaz et al. (1995); Huang et al. (1997); Zotos et al. (2009); Xi et al. (2010)
Integration of decision makers	Consolidating contradictory suggestions from multiple institutional statutory bodies involved in solid waste management decision making	Clarke et al. (1999)
Integrated (solid) waste management (using the waste hierarchy)	Integrating SWM according to principles of the waste hierarchy, combining waste prevention or reduction, reuse, recycling/composting, energy recovery and disposal, or discussing the role of particular technological solutions.	Smith (1990); Johnke (1992); USEPA (2002); Heimlich et al. (2005); Memon (2010); Consonni et al. (2011)
Integration (consolidation) of	Consolidating disparate, disconnected or partly	Rudden (2007)

disparate legislation and policies	overlapping/contradicting legislation and policies into strategies or overarching initiatives, for example as emerging from EU regulations and directives (e.g. Race against Waste programme (see www.raceagainstwaste.ie) in Ireland)	
Integrated solid waste management in industrial parks	Exploring industrial symbiosis and economies of scale in managing solid wastes of industries located in the same park, as a part of the industrial ecology approach to resource management	Geng et al. (2007)
Integrated analysis of SWM options with other (environmental, economic) aspects.	For example, integrating analysis of SWM options with air pollution in a city, energy consumption, cost–benefit analysis, etc.	Karagiannidis and Moussiopoulos (1995); Daskalopoulos et al. (1998); Thorpe (2001)
LCA	'Integrated waste management' and 'integrated solid waste management' are terms that have been used to describe life-cycle assessment (LCA) approaches to waste management	Constant and Thibodeaux (1993); Huang et al. (1997); McDougal et al. (2001); Thomas and McDougall (2005); Bjorklund et al. (2011); Giugliano et al. (2011)
Integrated resource management	Integration of waste with resources management, often in the context of a 'closed-loop' recycling, eco-design/recyclability of new products or general 'circular economy	Pontin (1980); Nilsson (1991); Lisney et al. (2004); Amos (2005); Deutz et al. (2010); Carter (2012)
Integrated sustainable waste management (ISWM)	Integrating across three dimensions – all the elements of the waste hierarchy, all the stakeholders involved and all the 'aspects' of the 'enabling environment' (political, institutional, social, financial, economic and technical). Used particularly in developing countries.	Schu¨ beler et al. (1996); Van de Klundert and Anschu¨ tz (2001); Anschu¨ tz et al. (2004); Scheinberg et al. (2010b)

3.1.5. Analytical frameworks of ISWM

In literature, there have been three main frameworks explaining the key system elements or dimensions of ISWM: 'the cube' by Schübeler et al. (1996), 'ISWM' by Van de Klundert & Anschutz (2001) and the 'two triangles' by Wilson et al. (2012). In the present chapter all three frameworks will be introduced and at the end of the chapter the author present the working framework to be used in the research and justify this methodological choice.

The first integrated framework for waste management, was primarily attributed to Schübeler in 1996, and was officially tittled '*Municipal Solid Waste Management*

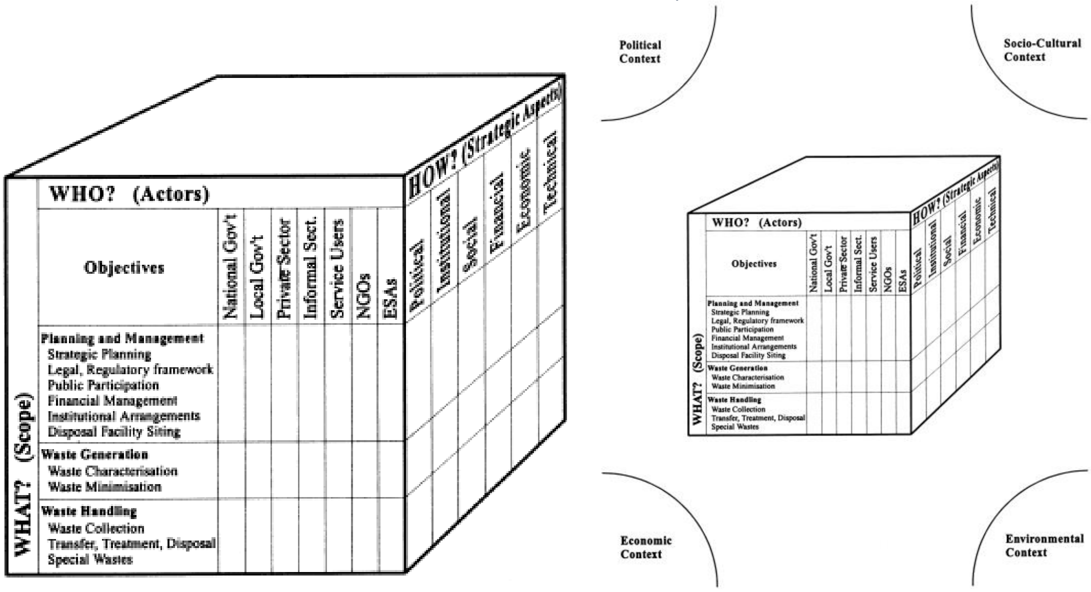
(MSWM) in Low-Income Countries' but is better known as 'the cube' (see Figure 8). This framework was prepared by the 'Collaborative Programme of MSWM in low-income countries' carried out by the Urban Management Program (UMP), which was a partnership between UN-Habitat, The World Bank and United Nations Development Programme (UNDP) with the special contribution of the Swiss Agency for Devepment and Cooperation (SDC).

This approach was built upon in the early blosoming concept of sustanability and integration. According to Schübeler et al. (1996), a sustainable SWM can not exist with out having a holistic perspective to the entire cycle of material use, so WM should take into consideration not only collection, handling and waste disposal, but production, distribution and consumption of the goods as well. This statement implies as well the inclusion of the needs of the urban and natural environment.

Schübeler's conceptual framework was built upon three dimensions, that he called: *what?, who?* and *how?*. '*What*', stands for the scope of the waste management activities, which is sudivided in planning and management, waste generation and handling of wastes (collection, transportation, treatment, disposal including special hazardous wastes). This first dimension not only includes the WM activities, but a vast list of managerial tasks such as strategy, legislation, finantial management and institutional involvement among others. *'Who'*, implies the actors and partners involved in the system. And lastly, *'how'* refers to the strategic aspects that should be adressed by MSWM in the scope of politics, institutions, finances, economy, social and technical aspects (Schübeler et al., 1996, pp. 16-21). The frame is recognized by its graphical reprentation as 'the cube of MSWM', which can be seen in the Figure 8.

The second set of elements of this conceptual framework, are what Schübeler called the 'contexts'. To assure affiency of the waste service and sustanability, the management system should be in armony with the local conditions in which it operates, in terms of (1) political, (2) socio-cultural, (3) economic and (4) environmental levels. Those conditions are what he denominated 'contexts'. Every of those contexts are greatly affecting the governance and waste operations. So, the three dimensions(what, who and how) and the contexts should be working together towards the same long term goals in order to become sustainable(Schübeler et al., 1996, p. 24).

Figure 8. Conceptual framework of Municipal Solid Waste Management (MSWM).
Source: (Schübeler et al., 1996, p. 17)



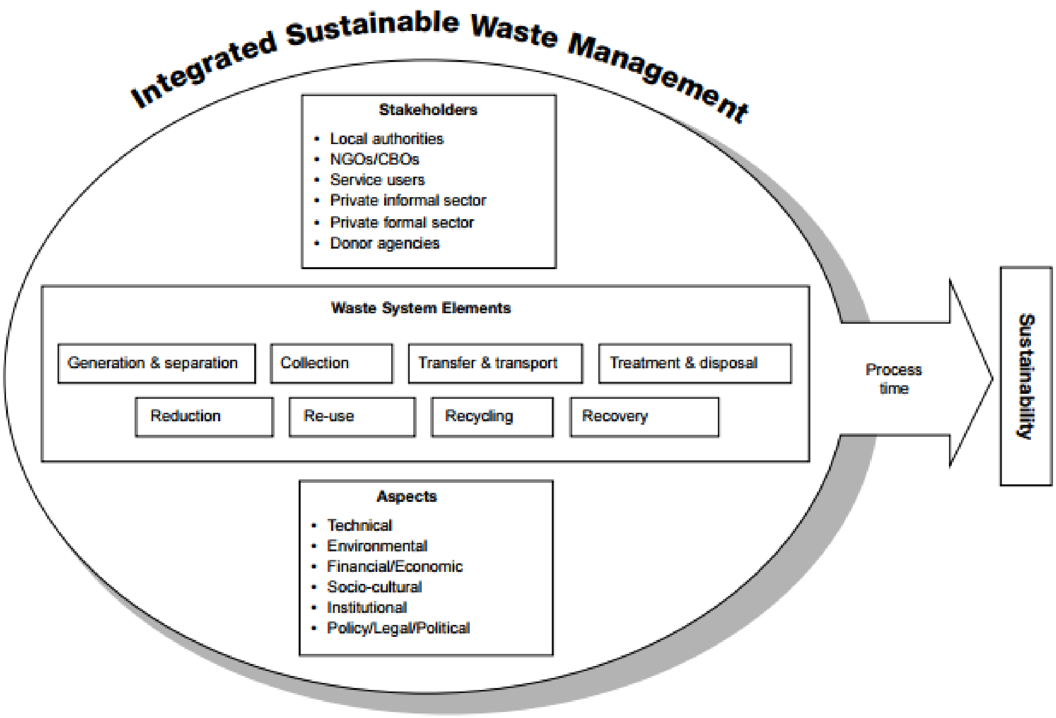
The second framework gave the name to '*Integrated Sustainable Waste Management'* as it's known in our time, *'ISWM'*. This framework was structured by Van de Klundert, member of the Dutch NGO WASTE. The concept was developed in the frame of the Urban Waste Expertise Programme (UWEP), which was a 6 years research programme (1996-2001) carried out with the collaboration of a large group of local researchers in developing countries, whom contributed with the local experiences of their countries. Some of the countries whom took part of the research group were: Philippines, Mali, Peru, Costa Rica, India, Colombia and Vietnam. UWEP was funded by the Dutch Ministry of Foreing Affairs, under the responsibility of Netherlands Agency for International Cooperation (DGIS) (van de Klundert & Anschutz, 2001).

Similarly to the early thinking, ISWM framework outlined three key interconnected dimensions: (1) stakeholders, (2) elements and (3) aspects, (see Figure 9). This dimensions works similarly to Schübeler's conceptual framework, however in a simplyfied way. *Stakeholder's* dimension may correspond to the 'who', which lists all the actors involved in the waste service including the informal sector, private sector, users and provider, authorities, NGO's, Community-Based Organizations (CBO's), and donor agencies, among others(van de Klundert & Anschutz, 2001, pp. 11-14).
E*lements'* dimension is the physical part of waste management (generation, separation, collection, transfer and trasport, treatment and diposal) in the light of the waste hierarchy (Reduction, Reuse, Recycle and Recovery), this dimension might correspond to the 'what' in a more structured way (van de Klundert & Anschutz, 2001).

And lastly, the *aspects* correspond to strategic approches of WM taking into consideration the local conditions of technical expertice, enviroment and health, financial and economic condition, socio-cultural costums, and institucional structures. This dimesion is equivalent to the fussion of the 'how' and the 'contexts' of Schübeler's conceptual framework (van de Klundert & Anschutz, 2001).

This improved version of ISWM, became an important topic of disscussion in developing countries worldwide, and during the whole 2000's it was center of research in the field mostly regarding asessment tools and implementation. One of the most representative research was followed by the second phase of the UWEP which gave as a result a guideline manual for planing and implementing ISWM (Anschütz, Ijgosse, & Scheinberg, 2004). Later on the second UWEP evolved into a new 'Collaborative Working Group (CWG) on SWM in low and middle-income countries', in which the large international team carried out a research aming to compare the waste managent system in 20 cities across the six continents. The final document was tittled "Solid Waste management in the world's cities" in 2010 for UN-habitat (Wilson et al., 2013, p. 55). This important research was forced to adapt the ISWM framework in order to be able to compare the very different waste systems in the chooosen cities, so this research resulted in an alternatively framework for ISWM.

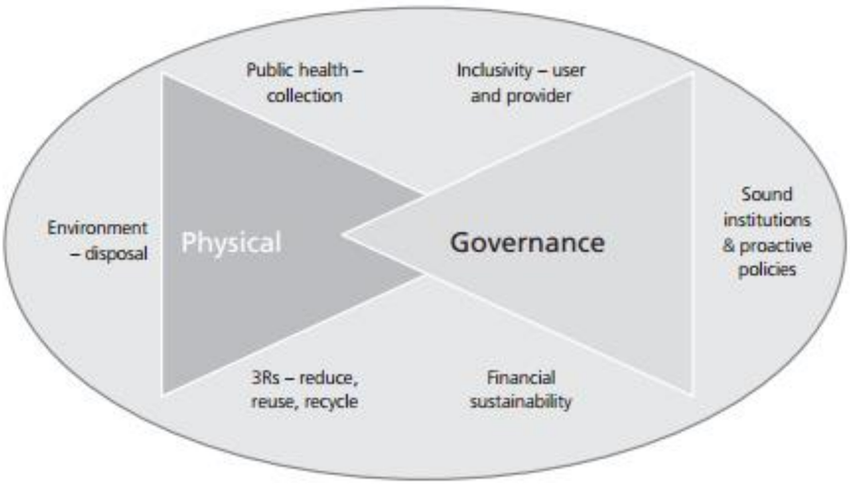
Figure 9. Original version of ISWM framework
Source:(van de Klundert & Anschutz, 2001, p. 14)



The third and latest framework is an alternative approach presented originally by Scheinberg et al. in 2004 and later on adapted by Wilson, Rodic and Velisin in 2012. *The Figure 10* presents the graphical representation of the framework, known as the two ovelaping triangles of ISWM. The first triangle brings together, what the authors called '*the key development drivers*' and '*the physical elements*'of SWM. The first side of the triangle is *public health*, which seeks to assure clean and healthy urban conditions for all the community by performing an effective collection of solid waste. The second side is *enviromental protection,* WM services should be planned in a such a way that the surrounding natural areas are pollution free, specially regarding the waste treatment and final disposal methods. The last side of the triangle is denominated '*resource management*' or as was recently tittled '*the 3R's*' (Reduce, reuse, recycle), WM should value the waste as resource by using the approach of 'closing the loop', in which useful materials and nutrients shall be returned to use either in the value chain (e.g. metals, paper and cardboard) or to nature (e.g. compost) (Wilson, Rodic, Scheinberg, Velis, & Alabaster, 2012, pp. 2-3; Wilson et al., 2013, p. 55).

The second triangle relates to the '*governance strategies*', which are the aspects to take into consideration to enable a well functioning and effective waste service. The first component of govenance in WM is '*inclusivity*', in which service users and providers are taking into consideration to contribute in the improvement of the system. The second component belongs to the *institutions* whom are resposible of the regulation and management of the waste service, so robust and proactive institutions shall be in charge to support the ISWM goals through a clear and transparent *waste legislation*. Lastly, WM shall be financially viable and sustainable, meaning that the system in cost-effective and affordable for the community (Wilson et al., 2012, p. 3; Wilson et al., 2013, p. 55).

Figure 10. ISWM framework 'Two triangles'.
Source: (Wilson et al., 2013, p. 57)



In this research paper, the framework selected to work with is the 'ISWM' published by the NGO WASTE and structured by Van de Klundert & Anschutz (2001). This tridimensional framework in comparison with the others has two important elements that might provide clarity to the present research. Firstly, the technical mechanisms are clearly defined as a single aspect affecting ISWM, and secondly, the system elements are grouped as it occurrs in the waste cycle including the 4R's. If comparing this two factors with the other frameworks, it can be seen that Schübeler's conceptual framework is very similar to Van de Klundert's, however this last one has a simplified structure without overlaping aspects. On the other hand, the 'two triangles' approach seems to include the technical aspects and waste cycle within the physical dimension of ISWM, but this dimension includes as well the development goals of WM, so for the practical considerations of the present research, this framework results rather complex to be used.

3.1.6. Technical aspects of ISWM

Technology plays a significant role in waste management because, it is perhaps the most visible aspect in all the system, and might be the most relevant physical component of management. The technical aspects concern to all equipment and facilities, which are currently in use or intended to be used for making the system elements to work. Therefore, this aspect covers the wide range of technologies that enables separation, collection, transfer and transportation, treatment and disposal of wastes, including as well the physical components to achieve reduction, re-use, recycling and recovery (van de Klundert & Anschutz, 2001, p. 14). In ISWM, any technology is better than another is, however the preference of one over others is determined by its suitability to achieve the goals set in the waste strategy; a technology is preferable when it fulfill the best environmental and economic performance within the system, while adjusting perfectly with the local conditions (Williams, 2005, p. 369).

The management of the technical components within the framework of ISWM should aim to assure the sustainability of the system. Schübeler et al. (1996, p. 49) states that, the management of technical aspects should be: (1) economically viable during its whole life-cycle; (2) innovative and coherent when designing the technical systems, so that the responsabilities of the stakeholders are in line with the system' operations; (3) environmentally responsible, aiming and to improve the conditions of the urban environment while minimizing pollution in air, water and land. Therefore, every technical component used in SWM should be intentionally planned, taking into consideration every aspect of its operation, maintenance, performance and lifecycle costs, because everything matters and may dictate the effectiveness of the whole system. A poorly planned technology may lead to a low efficiency in costs and overall performance.

Often the technical components of ISWM are classified according to the system element where they operate(Schübeler et al., 1996; Williams, 2005). For instance, Van de Klundert & Anschutz (2001) recognize eight *system elements* which are:

generation & separation, collection, tranfer & transport, treatment & disposal, and the 4R's. Similarly, Tchobanoglous et al (1993) as cited by Williams (2005, pp. 369-370) identified six '*functional elements*': (1) waste generation, (2) handling, separation and storage prior collection, which equals to the user interface, (3) collection, (4) Processing and transformation of solid waste, in other words material recovery and treatment, (5) transfer stations and transport, and lastly (6) disposal.

Eventhough both are almost same, both are grouped in slighly different way. So, for the porpouse of the present research, the author decided to combine them both. The table 6, presents the system elements with a description of the technologies often used in every stage. The technologies and their cathegories where extracted from several sources(Williams, 2005), (Schübeler et al., 1996, pp. 45-49) & (UNEP & CalRecovery, 2005).

Table 7. System Elements of ISWM and Technologies.
Adapted by the author.

Functional Group or System Element	**Technologies**
1. Generation and composition	Total input material entering to the waste management system and its classification
2. User inteface	Waste containers and collection points
3. Waste collection and transport	Vehicles used in primary and secondary collection
4. Resource recovery and recycling	Mechanisms for recycling: paper, metals, textiles and tyres
5. Treatment options	- Biological treatment: Anaerobic digestion, composting and animal digestion. - Thermal treatment with energy recovery: pyrolysis, gasification, Refused Derived Fuel (RDF) and combustion - Mechanical and Biological Treatment (MBT)
6. Final Disposal	- Sanitary landfill - Incineration - Uncontrolled dumping (dumpsites/open dumps, dumping on water bodies and uncontrolled burning)

Undoubtedly, facilities and technology to treat waste result considerably costly in most of the cases. However, within the framework of ISWM, waste managers and decision makers are encouraged to address the waste-related issues not only relying on acquiring costly facilities or equipment, but most importantly, implementing mechanisms that enable waste prevention, reduction and recycling, with the ultimate goal to deal with less waste amounts in a more efficient way. Nowadays, the capacity and operative life of the facilities have been seriously affected by increasing amount of waste, and the lack of suitable land to establish new facilities, without mention the increasing prevalence of the attitude known as "Not In My Backyard" (NIMBY) among the urban communities.

Indeed, to minimize the economic burden that waste management has become, municipalities are forced to generate new avenues of income to the waste management system. For instance by setting clear policy directions to promote waste reduction in the supply chain, a more efficient resource recovery, and a recycle-based society, not only to generate additional income but to reduce the pressure on landfill sites, and to provide a cleaner, healthier and more pleasant urban environment.

3.1.7. The latest approaches in ISWM

To conclude this chapter, it seems relevant to look into the future visions for the WM field. Along the history, waste systems have evolved from "*waste disposal thinking*" (the throw-away & hide-from-sight-thinking) to a "*waste management thinking*", where the waste entering to the system was collected, sorted, treated, recycled or reused in more efficient way before 'safe' final disposal. Now experts in the field invite waste managers to move from that thinking to '*resource management thinking*', in which is imperative to recognize the waste as a resource in order to recover its full economic value along the supply chain, and help as well, to minimize the use of the now scarce raw/virgin materials (Wilson et al., 2015).

The earlier thinking in the field had always recognize the waste since the very moment an item is discarded. However, the current thinking focuses in what happens before that, and how to address the waste-problems from its source. With this in mind, experts begun to pay special attention to the origin of the materials before becoming waste, so it became compulsory to figure out for instance, under what kind of conditions the item was refused?, or how can it be avoided?; and if cannot be avoided so, is it recoverable or can be recycled? and how should it be done?; or if it is hazardous, can it be produced with less hazardous substances?, answers to questions like these are currently just scratching the surface, but are expected to give a new important turn to the waste field. That way of thinking is known in modern literature as 'waste and resource management' in the framework of a 'circular economy'(Wilson et al., 2015).

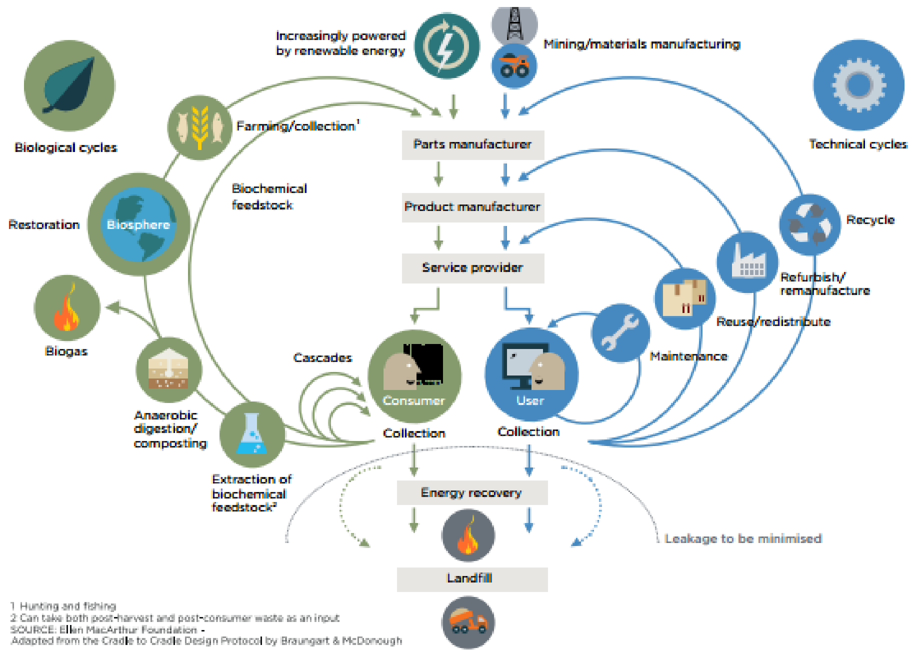
Originally, economy has been a linear path of *taking* (natural resources), *making* (products and services) and *discarding* (waste), which has lead us to resource scarcity and environmental degradation. The concept of 'circular economy' aims to close the loop by optimizing the resource use along the whole 'value circle', the main principles to close the loop are: (1) Preserving and controlling the finite stocks and renewable resources. (2) Recirculating materials within the supply chain. (3) Assuring longer useful-life-time to the products by repairing, sharing, refurbishing and recycling. Lastly, (4) providing an environmentally sound waste management system with emphasis in the 4R's(D. Wilson et al., 2015, pp.

23-24). The figure 9, presents the complete diagram of a circular economy system (Ellen Macarthur Foundation, 2016).

The term of 'circular economy' in waste management, refers strongly to waste prevention and resource recovery in the frame of Sustainable Production and Consumption (SPC). The SPC frame seeks to improve the way goods are designed, manufactured, packed, transported, marketed and consumed, in order to assure a conscious and effective use of resources while taking into consideration the sustainability pillars(D. Wilson et al., 2015). In this matter, the role of waste management and its governance should be to promote the use of strategic systems in which, industry can contribute and commit to tackle the waste-related problems, by taking responsibility for end of the product's end-of-life. This indeed bring us to the concept of '*producer responsibility*' that has become an important topic for an extended discussion in many economic sectors in developed countries.

Another powerful phenomenon in waste management theory, besides the adoption of circular economy and resource management, is the usage of a life-cycle assessment (LCA). This approach includes a detailed overview from 'cradle' to 'grave' of the materials and products, which covers the whole process since the raw material extraction for manufacturing, all the way until the product's disposal. LCA clearly provides a complete assessment tool to move towards a circular economy and certainly, promises to be very beneficial for the waste field, because helps to analyze the materials flow (inputs and outputs) and their impact on the environment.

Figure 11. Outline of a circular economy.
Adapted from: (Ellen Macarthur Foundation, 2016. "Circular Economy System Diagram"



Even though, all this approaches are very valid and beneficial, not all the countries are prepared for working towards such ambitious goals. Countries with a highly developed waste management systems (e.g. Netherlands, Japan, Nordic Countries, etc.) are indeed leading the north towards all those important concepts. However, many countries (especially developing countries) are hold back due to the premature status of their waste management systems and policies.

By 2015, low and middle-income countries are still adopting the *waste-management-thinking,* despite all their efforts, there are still major challenges to guarantee a total coverage of the waste collection service, and to implement safe final disposal techniques to assure a complete removal of open burning and indiscriminate dumping in land and water bodies. Municipalities and regulators should act fast and efficiently to tackle those problems as soon as possible. Forecasts points out that, waste volumes will double in developing countries in less than 20 years from now due to economic development and/or population growth. In one hand, some countries are expected to have an economic evolution, which will be reflected in an increase of the income per capita and consequently in higher consumption of goods. On the other hand, some other countries (mainly low-income countries) will have a dramatic increase in population, in only 20 years from now the population is expected to double. For all those reasons, the priority of developing countries is to keep the hard work building up an integrated waste system with innovative policies and practices to assure waste prevention from now on (Wilson et al., 2015).

3.2. Compendium of Sanitation Systems and Technology

One of the key elements to reach sustainable development in the cities of the world is improving the overall sanitation and hygiene systems. Sanitation is consider as one of the most effective ways to maintain healthy and clean living conditions for the citizens, especially for the communities living in poor and densely populated areas.

According to The World Health Organization WHO (2016), the word 'sanitation' includes not only the facilities or services meant to handle, treat and dispose human urine and fecal material, but the appropriate management of solid waste as well. Poor waste disposal practices are source of contamination of soil, water and air and it is a perfect channel for proliferation of infectious diseases. Nowadays, nearly to 40% of the world's population lacks of basic sanitation systems. Often the most affected population is living the poorest areas of the low and middle-income countries. In Africa, 16% of the urban areas and 55% the rural areas do not count with sanitation services. Similarly, in Asia, 22% of the urban and 79% of the rural citizens neither count with basic sanitation.

The International Water Association (IWA), the Water Supply and Sanitation Collaborative Council (WSSCC) and the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) have joined efforts improve the knowledge and raise awareness regarding sustainable sanitation systems and technologies that are affordable and effective, especially for emerging and developing countries. As result of all those efforts, the first edition of the Compendium of Sanitation Systems and Technologies (CSST) was published in 2008, and due to its popularity, a new revised edition was recently published in 2014.
CSST is a document that compiles all the most relevant information regarding to the existing sanitation technologies, and promotes a 'system approach thinking' in which, sanitation devices and technologies should be carefully planned within a holistic system. The Compendium can be understood as a tool for material flow management of human excreta and waterwater.

In its first edition, the Compendium was a tool meant to structure a fully functioning sanitation chain; so, it comprised a wide range of technologies for collection, treatment, transportation, utilization and disposal of human excreta and wastewater. In addition, it also aimed to foster the sustainable management of excreta by presenting tools and practices for resource recovery and reuse.

According its authors from Eawag, WSSCC and IWA (Tilley et al, 2014, p.3), the Compendium was widely received by a large audience in the sanitation sector and became popular soon after its release. The authors attribute its popularity to its brevity and clarity, even though the Compendium was primarily meant to be used by engineers and planners responsible of technology delivery, other stakeholders involved in the decision-making process could easily make use of the information as well.

The second edition published in 2014, is a new revised and updated version in which, additional technologies are included and it aims to magnify its audience by providing more accessible information for all the stakeholders involved in decision-making of sanitation systems. This second edition includes an on-line free version so called 'eCompendium' that allows users to have instant access, and helps the authors to do updates in an easier way.

In the present thesis, the version to be used is the 2nd revised edition Compendium of Sanitation Systems and Technologies written by Tilley, Ulrich, Lüthi, Reymond, and Zurbrügg, 2014. This chapter explains in more detail the Compendium and its features. Due to its length, the original document cannot be included as an annex to this thesis, however in case of need additional information the eCompendium is available on-line in several languages including English, French, Spanish, Nepali and Vietnamese in the website of the Swiss Federal Institute of Aquatic Science and Technology Eawag.

3.2.1. Structure and use of the CSST

The CSST is a guidance document meant to support engineers, planners and stakeholders to make an informed decision-making process, when improvement of existing sanitation systems or installation of new configurations are required. The Compendium has been set up to support the sanitation sector operating in low and middle-income countries.

CSST is not a standalone document, it shall be used together with other literature; the information here included is a simplified version of the sanitation technologies, so that for deeper understanding of technical matters, the authors recommend to consult other relevant publications and journals.

The structure of the CSST has remain the same since its first edition. CSST has two parts: the first part presents the *'System Templates'* and the instructions to use of it and explain how to make system configurations according to the users' needs. The second part is a compilation of '*Technology Information Sheets*', the sanitation technologies included in this part were carefully selected, and only tested technologies that are safe, hygienic and are economically feasible were included. (Tilley et al., 2014, p. 7)

As introductory chapter, CSST includes two important sections to explain to the users how to use the Compendium and how to build their own sanitation systems with the tools it provides. Firstly, the user can find the compendium's terminology, where all the key words used along the document are explained;

and secondly there is brief manual to learn how to use the system templates(E. Tilley et al., 2014, p. 7).

In the coming subchapters, find a summary of the parts previously mentioned, including introductory chapter, system template and technology sheets. However, only the structure and relevant functional parts, which are going to be used for adjusting the compendium into ISWM shall be included here. For further information go to the original document.

Compendium Terminology

To begin, the Compendium defines a *Sanitation System* as follows: "A Sanitation System is a context-specific series of technologies and services for the management of these wastes (or resources), i.e., for their collection, containment, transport, transformation, utilization or disposal"(Tilley et al., 2014, p. 10).

A sanitation system has tree active parts (1) products, (2) functional groups and (3) technologies. The *products* are the materials (wastes/resources) to be handled within the system; those products are going to be traveling through the functional groups, in other words, a *functional group* is a stage needed for the sanitation process (e.g. user interface, collection, transportation, treatment, and use/disposal). Every functional group has specific *technology* to handle different kind of products and deliver them for the next stage of the process (e.g. toilets in the user interface, or biogas rector in treatment). So in order to configure a sanitation system, firstly, products must be defined, and then technologies should be selected to assure the utilization and flow of each product through all the functional groups(Tilley et al., 2014).

Table 8. Active parts for configuring a sanitation system.
Adapted by the author from(E Tilley et al., 2014, pp. 10-13)

Active parts	Definition	List of components
Products	Materials also called 'wastes' or 'resources'. The materials can be categorized, as follows: - Products generated by humans (e.g. Urine and faces) - Products required in the functional technology (e.g. Flush water to move excreta through the sewers) - Products generated after the complexion of a process (e.g. Biogas) The products can be either and input or an output. The products flowing into the system are known as "inputs", and the products moving out of each sanitation technology are known as "outputs". Every product has a custom color e.g.:	- Anal cleansing water - Biogas - Biomass - Blackwater - Brownwater - Compost - Dried feces - Dry cleansing materials - Effluent - Excreta - Feces - Flushwater - Greywater - Pit humus - Pretretment products - Sludge

	Anal Cleansing Water Biogas Biomass	- Stored urine - Stormwater - Urine
Functional Groups	A functional group is a grouping of technologies that have similar functions. There are five functional groups, each of them has a predefine color. The technologies belonging to same functional group can be easily identifiable since they share same color and capital letter (e.g. U color red =User interface technology). Additionally, technologies belonging to the same group are compared regarding how resource intensive (i.e., economic, material and human) they are. Then, every technology has a number from lowest to highest, which means that the lower the number the less resource intensive it is and vice versa.	U **User Interface** (Technologies U.1-U.6): Red S **Collection and Storage/Treatment** (Technologies S.1-S.12): Orange C **Conveyance** (Technologies C.1-C.7): Yellow T **(Semi) Centralized Treatment** (Technologies T.1-T.17): Green D **Use and/or Disposal** (Technologies D.1-D.13): Blue
Sanitation Technology	Technologies are defined as: the specific infrastructure, methods, or services designed to contain and transform products, or to transport products to another functional group. Each of the 57 technologies included in this Compendium is described on a **Technology Information Sheet** in part 2.	

3.2.2. System Templates

The compendium includes nine templates of fully working sanitation systems. A system template is a predefined combination of technologies to manage the product flow since the *User Interface* until *Use or Final Disposal*. The templates allow the users to select the most appropriated technologies and configure a complete sanitation system(Tilley et al., 2014).
The systems included in the templates, all have been tested and proven to work in practice. Some of them can be rather simple and others more complex, depending on the number of technology choices and products it has. A simple template has relatively less technologies and products to choose from, and a complex template includes multiple number of technologies and products to choose(Tilley et al., 2014).

The system templates included in the Compendium are:

- System 1: Single Pit System
- System 2: Waterless Pit System without Sludge Production
- System 3: Pour Flush Pit System without Sludge Production
- System 4: Waterless System with Urine Diversion
- System 5: Biogas System
- System 6: Blackwater Treatment System with Infiltration

- System 7: Blackwater Treatment System with Effluent Transport
- System 8: Blackwater Transport to (Semi-) Centralized Treatment System
- System 9: Sewerage System with Urine Diversion

(Tilley et al., 2014, p. 15)

To see closely how a System Template looks like, see the Annex 2. Example of a System Template.

3.2.2.1. How a Sytem Template works

The core objective of the Compendium is provide a planning tool for configuring and presenting in a comprenhensive way a sanitation system. For this purpose, the Compendium presents a sanitation system as a matrix that can be seen in the Figure 12. Explanation of a System template.

This matrix is in fact composed of **products** (rows) flowing throughout the **functional groups** (columns). So that, products are systematically collected, transported, treated, transformed, used or disposed using compatible tecnologies. Every functional group contain different technologies that handle one or several product inputs and generate a product output as result; the output product becomes input for the next functional group(E Tilley et al., 2014, p. 16).

Figure 12. Explanation of a system template.
Extracted from: Tilley;Ulrich;Lüthi;Reymond;& Zurbrügg, 2014, ss. 16, fig. 2

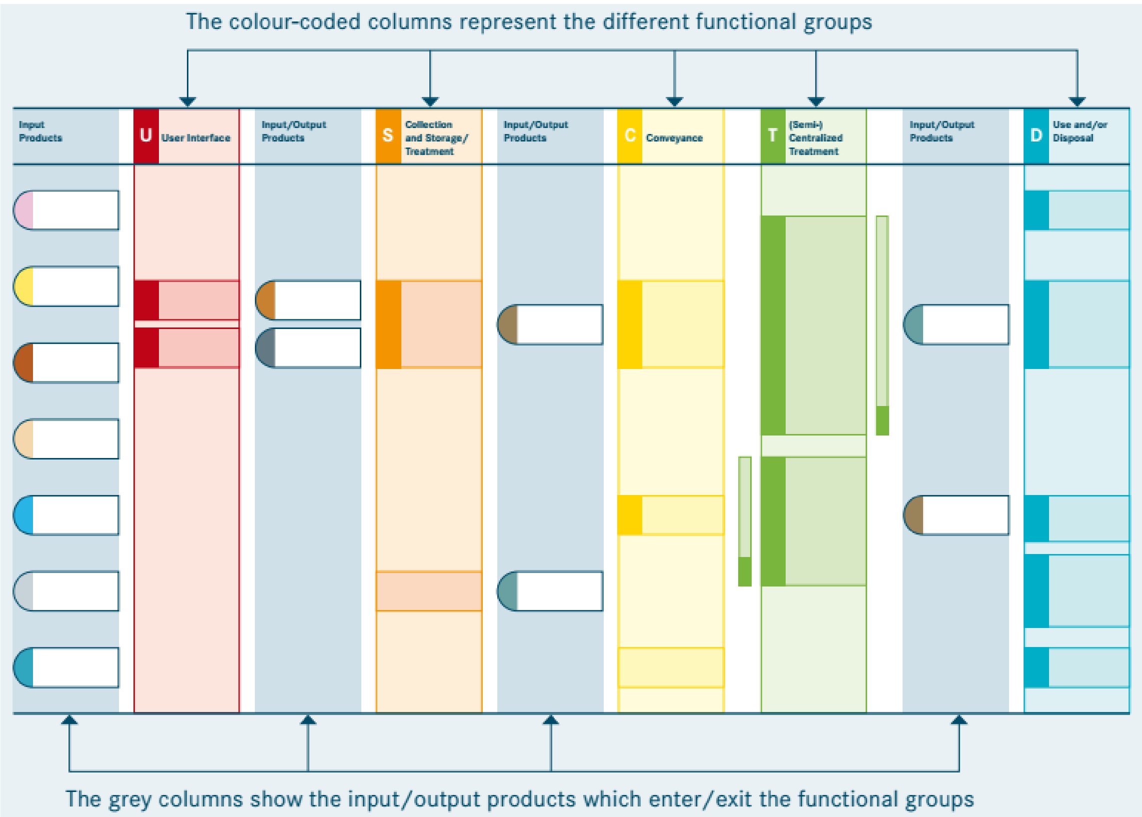
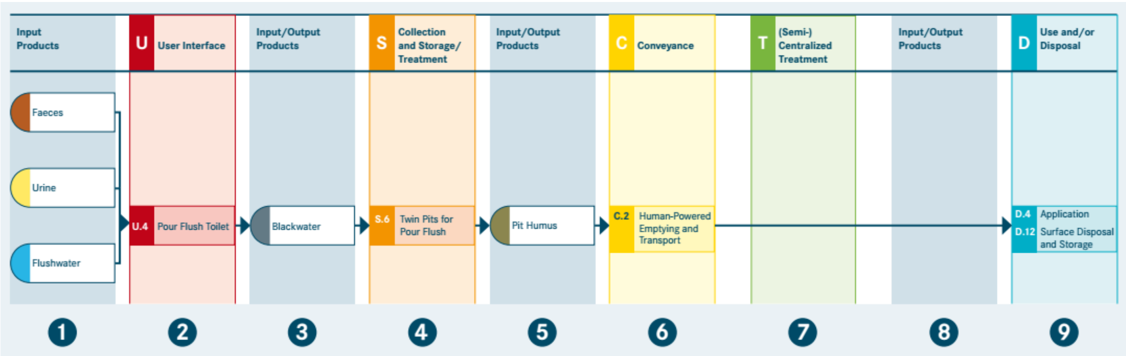


Figure 13. Practical example of how the products and functional groups work.
Extracted from: Tilley;Ulrich;Lüthi;Reymond;& Zurbrügg, 2014, ss. 18, fig. 4



The Figure 13 presents a simple system configuration to explain how the parts of the matrix work. The *rounded colored boxes* placed within the gray columns are the inputs/outputs products. The *colored rectangular boxes* placed in the color columns include the technologies that can be use within that specific functional group.
In this same figure, it can be seen how the products move from right to left, since the column 1 to the column 9. So that, the system example can be read as follows:

> **(1)** *"Originally there are tree input products or wastes entering to the system (feaces, urine and flushwater).*
> **(2)** *The three input products enter in the User Interface (U) though a "pour flush toilet" (U.4.)*
> **(3)** *The mixture of the three inputs during the User Interface generates "Blackwater"*
> **(4)** *The Blackwater is then moving to the next functional group which is Collection and Storage/Treatment (S), using "twin pits for pour flush" (S.6.).*
> **(5)** *Then the resulting product is "pit humus" and it is ready to move to the next functional group.*
> **(6)** *Conveyance (C), pit hummus is then transported using "human-powered empting and transport" (C.2.)*
> **(7)** *and* **(8)** *are not needed steps*
> **(9)** *Pitt hummus is directly transported to be Used or Disposed (D). Here there are two options, either the pitt hummus can be used to spread onto land for soil conditioning (D.4. Application), or it can be directed for temporary storage or final disposal (D.12. Surface disposal and Storage)".*

Tilley et al., 2014, p. 18

Each of the nine system templates has the following components: (a) its own matrix; (b) a graphical representation; (c) a description of features and applicability of the system; (d) some "considerations" regarding for instance appropriateness, maintenance and capital costs, and some advantages and disadvantages.

3.2.3. Technology information sheets

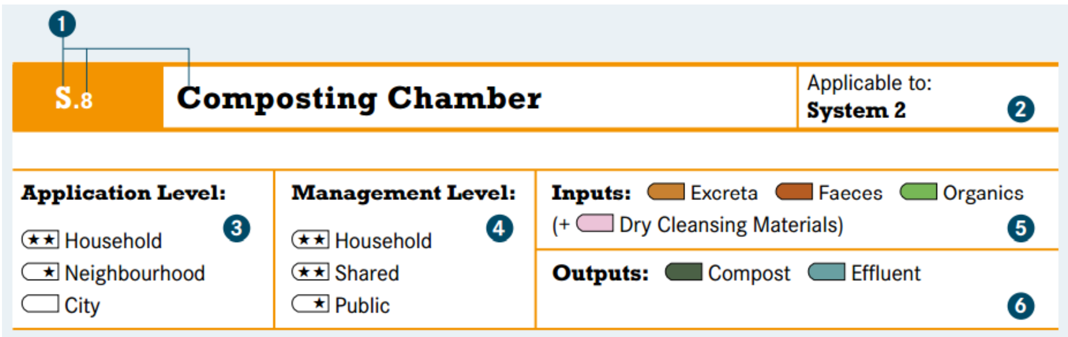
In this second section of the Compendium, users can find a description of fifty-seven selected technologies that have been tested and proven to work, are economically affordable and environmentally responsible. The ultimate function of the sheets is to feed to feed the System Templates and to present a brief fact-based-summary of every selected sanitary technology. However, the fact sheets are not intended to be a design manual or technical reference, rather are meant to be a starting point when considering the adoption of new or improved sanitation technologies. Moreover, the technology descriptions are to serve as a source of inspiration and discussion amongst engineers and planners who may not have previously considered all of the feasible options(E Tilley et al., 2014, p. 39).

The sanitary technologies are grouped and presented in a specific order according to the functional group were they belong. Each technology has its own double-page '*technology information sheet*'. See Annex 3, example of a double-page Technology Information Sheet.

Every fact sheet follows the same conceptual structure that can be divided in two parts, header and body. The header contains an illustration and a heading chart, so that here the user can visualize how the technology looks like, and the chart summarizes all the needed information to link the technology to the system template. The Table 9 explains in detail the information included in the heading and its features.

Table 9 Parts of the heading of the Technology Information Sheet.
Adapted by the author from: Tilley;Ulrich;Lüthi;Reymond;& Zurbrügg, 2014, pp.40,41.

Figure 14. Parts of the heading of a technology information sheet
Extracted from: Tilley;Ulrich;Lüthi;Reymond;& Zurbrügg, 2014, pp.40.



Part	Description and meanings
1. Technology code	- **Color and letter:** Refer to the functional group that the technology belongs. E.g., orange "S" means Collection and Storage/Treatment functional group. See in Table 8 the five functional groups. - **Number code:** Refers to the position of the technology within the group. The numbers rank from lowest to highest, the lower the number is the less resource intensive the technology is compared with the other technologies within the same functional group.
2. Applicable to System No.	Refers to the System Template(s) in which the technology can be used.
3. Application Level	Means that the technology is appropriate to be used in **Household Level** (for one or several houses), **Neighborhood level** (for several group of houses or for several hundreds of households) and/or at **City Level** (means either one unit for the whole city or a unit per every part of the city). **Stars meaning:** (✯✯) suitable, (✯) less suitable, (no star) not suitable.
4. Management Level	Refers to who should be in charge of operation and maintenance (O&M). -**Household:** residents/families are responsible -**Shared:** a group of users is responsible (e.g. schools, community-based organization, market vendors). A community of users rules a shared facility, so they should set the users' rights and duties to use the facility. -**Public:** The responsibility of O&M relies on an institution/government/agency operator. Usually only users who pay can use the facility or service.
5. Inputs	Products entering to the technology. **-Without parentheses:** products that are regular inputs meant to go into the technology. So that it means that is mandatory or main product. -**In parentheses ():** products that are additional or optional. **-Plus +:** Means that can be mixed with a product. The plus can be placed before the product or after the product, meaning that the product should be mixed with the previous or the following product. E.g., Mixed with the previous (X,+Y,Z); Mixed with the following (X,Y+,Z)
6. Outputs	Products flowing out (results) of the given technology. The use of conventions are the same used for the inputs.

The second part of the sheet' structure is the body or the factual information. Here the users can find a summary of the most important features and considerations regarding the given technology. The Table 10, presents the main parts of the body and a short assessment of their contents. The aspects requiring testing or empirical evidence are part of the boundaries of the presents research.

Table 10. Parts of the heading of the Technology Information Sheet.
Adapted by the author from: Tilleyet al., 2014, pp.40, 41.

PART	CONTENT	Does it require further testing or empirical evidence?
Working definition	Technology' definition	NO
Design considerations	Key factors to assess when implementing the technology	YES
Appropriateness	When and under what conditions the technology is suitable to be used.	YES
Health aspects/Acceptance	Social aspects affecting either positively or negatively the usage of the technology	YES
Operation and maintenance	Description of technical and operational issues to control in order to assure a well-functioning technology.	YES
Pros & Cons	Advantages of disadvantages of the technology	Yes, in some cases
References & Further Reading	Suggested information sources to know more about the topic	NO

3.3.Theoretical approach of the research

The theoretical approach of this research counts with two main parts: *Integrated Solid Waste Management* as the main topic and *The CSST* as the planning tool to be modified.

Integrated Solid Waste Management model was used to analyze waste management as complete system, and to understand the role that 'technology' plays in relation with the other aspects of the system. As result, relevant terms to this research were defined and introduced. The literature research carried out in this topic presents principles, history, future trends of the "integrated approach", and most importantly the theoretical frameworks used over time until now. In this research paper, the framework selected to work with is the one published by the NGO WASTE and structured by Van de Klundert & Anschutz in 2001. The well-known 'Integrated Sustainable Waste Management Framework-ISWMF', which is tridimensional framework (stakeholders, elements and aspects) to reach sustainability (see Figure 9. Original version of ISWM framework
Source:(van de Klundert & Anschutz, 2001, p. 14).

This framework compared with the others has two important features that might provide clarity to the present research. Firstly, the technical mechanisms are clearly defined as a single aspect affecting ISWM, and secondly, the system elements (generation, collection, transportation, treatment and disposal) are grouped as it occurrs in the waste cycle including the 4R's (reduction,re-use, recycling and recovery).

When comparing these two factors with the other frameworks found in the literature review, it can be seen that the chosen framework is the most suitable one to provide a solid and clear structure to the present research due to the following reasons.

For instance Schübeler's framework, 'The cube of MSWM' was the very first holistic approach to sustainable waste management, which laid the basis to think waste management as a system with interconnected aspects; however, its structure has been criticized for its overlapping aspects and the rather complex relation between the parts of the system. Therefore, Van de Klundert et.al. (2001) redefined Schübeler's model into the ISWMF, which uses the same content elements than Shübeler, but simplifies the structure and removes the overlapping aspects from the original outline.

On the other hand, Wilson's (2012) model 'The two triangles of ISWM' has been developed in the light of the millennium goals of Sustainable Development (SD). Even though, this model includes similar concepts than the previous ones, it connects them in a different way, which might not be beneficial for the present research. This model does not seem to define clearly the technology aspect as an independent component of WM. In this framework, technology (which it is barely mentioned), system elements (collection, treatment and disposal) and development drivers of SD (public health, environmental protection and resource management) are all together in a single part denominated as 'the physical components of WM'. That rather general grouping does not provide a clear separated outline when addressing only the engineering and technical component of ISWM.

Now then, the second part of the theoretical framework, *The Compendium* or *CSST*, was used as the guideline to develop a planning tool for ISWM. CSST was selected prior research due to its relevance and popularity in the sanitation field. Moreover, this planning tool has benefit greatly engineers and decision makers in developing countries helping them to do a more creative and informed decision when improving existing or building new sanitation systems. Therefore, the second part of the theoretical framework was dovoted to CSST, in order to understand its structure and how it works, so that in the research phase all those spotted features can be adjusted within the ground topic of this research, ISWM.

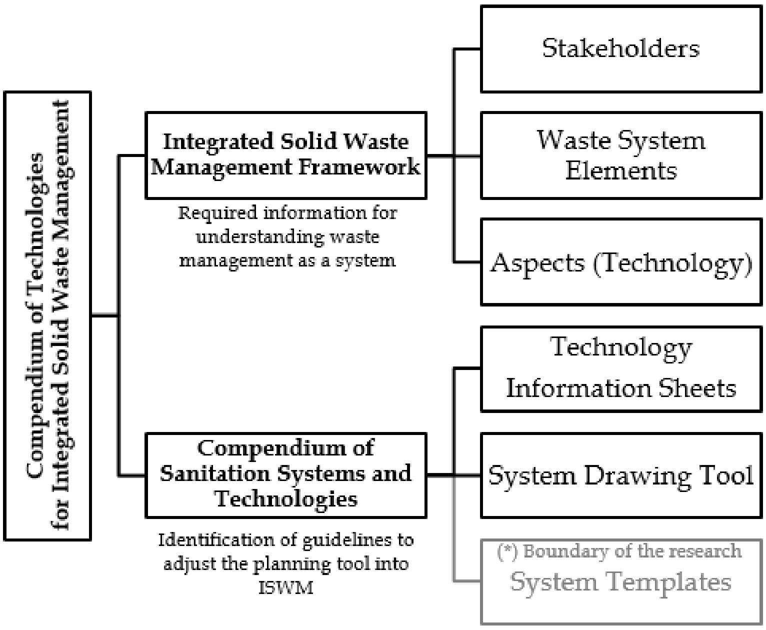
The analysis of the CSST's structure served specially to set the boundaries of the research. Even though, the Compendium has three parts, *System Templates* (customizable/preconfigured sanitation systems), *Informative Technology Sheets* (core informative part feeding the system templates), and *System Drawing Tool*, yet only the last two will be addressed in the present research. So that, this research will identify, categorize and define proven technology to handle solid waste in developing countries, in order to laid the basis for the *Informative Technology Sheets*. Then, the "*System Drawing Tool*" will be designed, in order to give a exact visual representation of the new compendium and provide a tool that can be already use for customizing own waste management systems.

Regarding to *System Templates,* they were part of the boundaries of the research and shall be recommended for further research topic. The reason behind this methodological choice, is that the configuration of the System Templates are rather extensive and deserves a specific research for its own because, according to the guidelines of the CSST, only tested and fully working sanitation systems should be included. Therefore, that would require comparing and assessing the existent sanitation systems according to their performance, in order to select the most common and effective system configurations. To do that, is recommended that the researcher should have specific engineering background and experience in waste management for testing and configuring the systems properly.

This methodological choice does not compromise the usefulness of the results or the aim of the present research. The planning tool will be ready to be used as basis to develop an informative tool for designing integrated solid waste management systems. It is important to highlight that the System Templates are the most common configurations proven to work efficiently and are mainly ready made systems to use as guidance and to simplify the configuration.. Yet, the users should be able configure and design their own systems using only the basis of the technology sheets and the drawing tool.

The theory used in the present research was not intended to be proven nor revised, but rather to be used for developing a tool to aid the waste management planning from the technology point of view. The figure 15, summarizes the theoretical approaches here discussed.

Figure 15. Model of theoretical framework



4. RESEARCH METHODS

4.1. Selection criteria of public reports

The primary data to be used in the present research are public reports issued by international associations that are widely recognized in the field of waste management. The selection criteria was not random but purposive. Taking into consideration that the data required to adjust the compendium should be homogenous with the data included in the CSST.

The selection process was initially carried out reviewing the most relevant literature found regarding ISWM in developing countries, during the complexion of the chapter 3. There, the author identified the most relevant keywords of the components of a waste management system and the type of technologies used in every stage of the waste chain. The *Table 6.* Table 7*System Elements of ISWM and Technologies*.
Adapted by the author., contains the list of keywords found to begin the search.

Then, having already the basic keywords to begin the search, the author decided the criteria for making the final selection (see Table 11). The selection criteria was based in the analysis of the contents of original CSST made in the Chapter 3.2 and specifically in the Numeral 3.2.3 Technology information sheets, in which the contents of the compendium's structure are explained.

Table 11. Selection criteria for public reports

Criteria	Yes	No
Is the document published by an international organization?		
Is the publisher an entity expert in waste management or sanitation?		
Is the document up-to-date? If not, is the information relevant today?		
Is it a technical document for planning/educational or informative purposes?		
Does it contain conceptual information/technical definitions of WM technologies?		
Are the technical definitions explained in their entire context?		
Are the contents homogeneous with the information included in the original CSST? (see Table 10) Does it include: - (*) Definition - (*) Design considerations - (*) Appropriateness - Health aspects/Acceptance - (*) Operation and maintenance - Pros & Cons - References & Further Reading (*) Obligatory contents		
Is the information applicable for developing countries?		

Consequently, the author begun the online search of the primary data using the keywords. Then, using the selection criteria, the author assessed document's contents. During the the selection, the author made sure that all the topics needed are covered in the selected reports, meaning that a minimum of three different reports should cover a desired topic.

Several reports were found but only few fulfilled all the requirements. The *Table 12. List of public reports or primary* data lists the selected public reports used in this research. Note that at the end two scholar books are included as primary data. The reason behind this selection is that both of these sources cover almost the totality of the topics required to adjust the CSST, yet they were taken into consideration only to support the information found in the public reports.

Table 12. List of public reports or primary data

Reference number	Public Report	Number of Pages
A	B.I.R. Bureau of International Recycling (2016) *World Steel Recycling In Figures 2011 – 2015. Steel Scrap – A Raw Material For Steelmaking*	44
B	Bacher et al. (2012) *Directions of future developments in waste recycling* © VTT	142
C	Coffey & Coad (2010) *Collection of Municipal Solid Waste in Developing Countries © UN-HABITAT*	200
D	Eawag/Sandec (2008) *Training Tool 1.0 – Module 6: Solid Waste Management © Eawag/Sandec*	52
E	EPA U.S. Environmental Protection Agency (2008) *AP 42, Fifth Edition, Volume I. Chapter 2: Solid Waste Disposal. Sectional 2.4 MUNICIPAL SOLID WASTE LANDFILLS*	30
F	Gendebien et al. (2003) *Refuse Derived Fuel, Current Practice And Perspectives (B4-3040/2000/306517/MAR/E3)*	229
G	Hoornweg & Bhada-Tata (2012) *What a waste: A Global Review of Solid Waste Management © World Bank*	116
H	Hoornweg, Thomas, & Otten (1999) *Composting and Its Applicability in Developing Countries © The International Bank for Reconstruction and Development/THE WORLD BANK*	52
I	Johannessen (1999) *Guidance note on recuperation of landfill gas from municipal solid waste landfills © The International Bank for Reconstruction and Development/THE WORLD BANK*	34
J	Neidel & Jakobsen (2013) *Report on assessment of relevant recycling technologies*. This report is a part of the external assistance on the EU LIFE+ project Plastic Zero, Public Private Cooperation for avoiding plastics as waste, LIFE10 ENV/DK/000098.	33
K	P.W.M.I. (2009) *An Introduction to Plastic Recycling ©Plastic Waste Management Institute*	35

Reference number	Public Report	Number of Pages
L	Rand, Haukohl, & Marxen (2000) *Municipal solid waste incineration: a decision maker's guide © The International Bank for Reconstruction and Development / THE WORLD BANK*	25
M	Rothenberger, Zurbrügg, Enayetullah, & Sinha (2006) *Decentralized Composting for Cities of Low- and Middle Income Countries - A Users' Manual © Waste Concern and Eawag*	110
N	Schluep et al. (2009) *Market potential of innovative e-waste recycling technologies in developing countries. R'09 World Congress*	8
O	Thurgood, Rushbrook, & Pugh (1998) *Decision-maker's guide to solid waste landfills – Summary © Swiss Agency for Development and Cooperation and The World Bank*	32
P	UNEP & CalRecovery (2005) *Solid Waste Management Vol. I Part I, II and III © United Nations Environment Programme*	432
Q	Villanueva & Eder (2011) *End-of-waste criteria for waste paper. European Commission - Joint Research Centre Institute for Prospective Technological Studies*	24
R	Vögeli , Riu, Gallardo, Diener, & Zurbrügg (2014) *Anaerobic Digestion of Biowaste in Developing Countries © Eawag – Swiss Federal Institute of Aquatic Science and Technology*	137
S	Wilson et al. (2015) *Global Waste Management Outlook © United Nations Environment Programme*	346

Reference number	Books	Number of Pages
T	Williams (2005) *Waste Treatment and Disposal Second Edition*	346
U	Letcher & Vallero (2011) *WASTE: A Handbook for Management* *Chapters: 4, 8, 13, 30.*	604

4.1.1. Rationale for choosing public reports and its limitations

The rationale behind the methodological choice of selecting public reports as primary data is based on the research purpose. The present research has a specific task which is the adjustment of the CSST' structure into ISWM. Therefore, the author acknowledges that the primary data should be as homogenous as possible with the original CSST in order to assure a proper adjustment of the tool.
Public reports were selected over text books or other written material for two reasons. Firstly, the information included in the CSST is meant to discuss the technologies but seem from the point of view of management, which means that it should discuss not only technical considerations but to discuss appropriateness of implementing a given technology from the economic, social, environmental

point of view. In that sense, text books often focus on the science behind the technologies but very little is found about managerial considerations. Technical public reports seems to cover that content in a better way. Secondly, the discourse in public reports is often up-to-date and discusses the currents of change and innovations that are happening at the moment of the release, and WM text books seem to be a little out-dated in that sense.
The public reports here selected are technical documents published by reputable international organizations so that the veracity and reliability of the data are assured. However, the author recognizes that text books are always useful when structuring a conceptual issue, for that reason two text books were selected for data support.

4.2. Qualitative content analysis

The adjustment of the CSST within the conceptual framework of the ISWM, is a rather new approach to try to simplify the extended information of the field of WM within a single structured tool. To do so, content analysis was selected as the research method driving the present thesis. Content analysis a difference to other methods focuses on obtaining a concise and broad description of a phenomenon, resulting in the extraction of concepts and categories for structuring or mapping a model, system or conceptual map (Elo & Kyngäs, 2007, p. 108).

The definition of content analysis has been evolving over time (Graneheim & Lundman, 2004), yet authors agree that content analysis as a research method, is a mean for analyzing data objectively and systematically, in order to interpret its meaning by describing and quantifying the phenomenon (Berelson, 1952; Downe-Wamboldt, 1992; Krippendorff, 1980). Weber (1990) states that, the key feature of any content analysis is to classify the many words included in the text and produce smaller content categories.
Currently, the research method has expand its scope to make interpretations of latent content as well (Graneheim & Lundman, 2004).

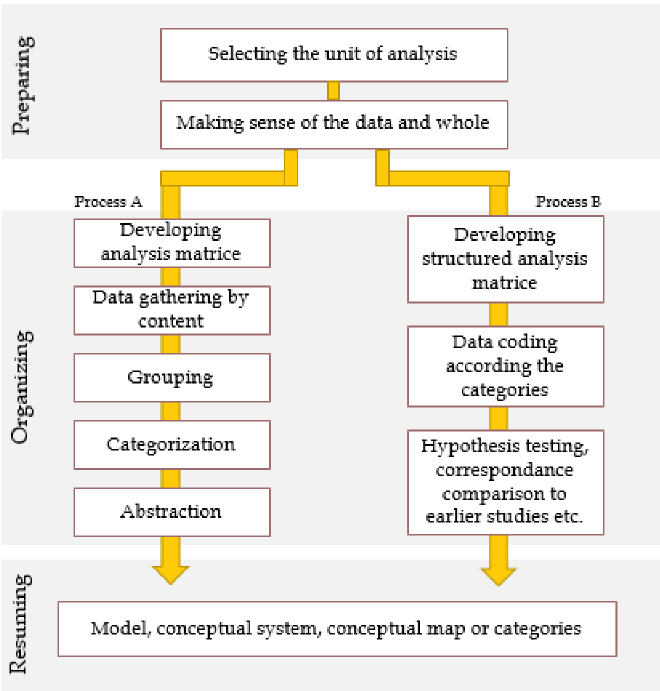
Content analysis can be classified in different ways. Initially, content analysis should be classified according to the nature of the data in either qualitative or quantitative research (Berelson, 1952; Elo & Kyngäs, 2007; Hsieh & Shannon, 2005). A quantitative research refers to the analysis of text data coding first the content in specific categories and then using statistics, the researcher builds the final description (Hsieh & Shannon, 2005). Distinctly, qualitative content analysis is used for analyzing qualitative data (in verbal, printed or electronic format) that might have been compiled from interviews, surveys, focus groups, etc., or from print media (e.g. books, articles, journals among others)(Hsieh & Shannon, 2005). In this method, the research question dictates what to analyze

and what to create, so final concepts are created through abstraction process(Elo et al., 2014).
The present research follows in this category since the nature of the primary data is qualitative and the research task in this case will dictate the outcome of the research.

Now then, a qualitative content analysis can either have *deductive* or *inductive* approach, which is often determined by the purpose of the study(Elo & Kyngäs, 2007). An *inductive* approach is recommended when the knowledge of the object of study is fragmented or incomplete. Otherwise, if the structure of the analysis is based in previous knowledge (earlier model or theory) or if the nature of the study is to test a theory, *deductive* approach is recommended(Elo & Kyngäs, 2007, p. 109). According to that classification, this thesis clearly falls into the last approach for two reasons. (1) The object of study, ISWM, is a rubust and complete framework widely accepted; and (2) the structure of the content analysis will have its basis on earlier defined structure, the CSST.

4.2.1. Phases of a deductive content analysis

Figure 16. Phases of the content analysis with deductive approach.



According to Elo et.al. (2007), the process of deductive and inductive content analysis, both have three phases: *preparation, organization and reporting*. Yet, both has different tasks to perform in the last two phases, for this reason is required to differentiate the approach of the research in early stages. The Figure 16 presents, the process of a deductive content analysis and the tasks to be performed in every phase. Alternatively, the researcher can decide between two processes for completing the deductive analysis, as can be seen in the same figure (process A and B). Having in mind that, the present research does not aim to test a theory nor a hypothesis, the process B is not suitable then, process A will be used.

Phase I: Preparation

The selected deductive process begins with the *preparation phase*, in which the researcher shall select a word or a theme as the unit of analysis (in this case is 'technology aspect of ISWM'). Then, decisions must be made regarding what shall be analyzed (see in Chapter I, aim of the study and research task), and how the sampling shall be carried out, in other words where to gather the information to analyze the selected unit (see Chapter IV, numeral 1.1 to 1.3)(Elo & Kyngäs, 2007, p. 109). After that, researcher must study the data and understand how the unit of analysis has evolve. Elo et.al. (2007, p.109) citing Dey (1993) affirms that, at this point, researchers must answer the following questions: "who is telling?, where is happening?, when did it happen?, what is happening?, and why?". Only after that, the researcher shall decide whether use deductive or inductive approach(Kyngäs & Vanhanen, 1999). In the present thesis, detailed answers to all that questions can be found in the Chapter II and III of this document, and the deductive approach was selected following the process mentioned above.

Phase II: Organization

Often deductive content analysis is used for assessing existing data in a completely new context, as it is the case of the adaptation of CSST within the conceptual framework of ISWM. The figure 17 shows the two main steps to be made during the organizing phase of a deductive research. The first is to build a "categorization matrix", and the second to proceed "to code the data according to the categories"(Elo & Kyngäs, 2007, p. 111). In a nutshell, a categorization matrix is the instrument that serve to organize the data or to abstract the data which is generally build upon earlier models (theories, mind maps or literature reviews), and it can be either "structured" or "unconstrained"(Elo & Kyngäs, 2007; Hsieh & Shannon, 2005). Once matrix is ready, coding the data begins. At this point, the researcher shall review all the content of the data and categorize it accordingly inside of the matrix(Elo & Kyngäs, 2007).

In this thesis, CSST will provide the guiding principles for the categorization matrix, minimal adjustments will be applied when developing the final matrix in order to make it suitable for ISWM, yet the core structure will remind untouched. This will benefit data coding in this research, because as Elo et.al. (2007) states when using a structured matrix, the researcher can effectively spot the data that fit into the categorization and focus specifically on it, and that is exactly what is this research is looking for.

Figure 17. Organizing phase of a deductive content analysis. Example of a matrix and data coding. Retrieved from: Elo & Kyngäs, The qualitative content analysis process, 2007, p. 112, table 3 and 4.

	Dependence	Worries	Sadness	Guilt
What kind of mental well-being threats does diabetes have for adolescents?				

Example of a categorization matrix

	Dependence	Worries
What kind of mental well-being threats does diabetes have for adolescents?	Dependence on parents Dependence on insulin Dependence on nurses Dependence on physicians Dependence of regular daily life	Worries about future Worries about health conditions Worries about future occupation Worries about getting a family Worries about having the energy to take care of oneself

Example of coding the data to a categorization matrix

Phase III: Resuming and reporting

To conclude the study, a report of the analysis process and the merging model, conceptual map or categories shall be presented. As, Elo et.al. (2007, p.112) suggests, it's important to "dissect" the analysis process and the results, in order to provide a more clear understanding for the readers, so that strengths, limitations and the validity of the results can be easier to identify and discuss. Therefore, in order to prioritize the findings in the present research, the author decides to present the results divided as follows:

a) Firstly, a summary of techniques and findings during the analysis process will be presented.
b) Subsequently as main results, the structure of the new (or resulting) "Compendium of SWM and Technologies" shall be reveled, and the "System Drawing Tool" will be adjusted accordingly to those results.
c) Lastly, a brief report of the areas that were not adjusted during this research will be enlisted and suggested for further research. This step is of special importance for the research, since this thesis aims only *to laid the basis for the primary adjusting of the planning tool within the terms of ISWM*, and the author recognizes that still more work shall be done in order to adjust the Compendium at its fullest.

4.2.2. Trustworthiness of a qualitative content analysis

Qualitative content analysis is considered an assertive method when a research study has its basis in an existing theory, because it allows the researcher to support and extend the theory(Hsieh & Shannon, 2005). As the main aim of this method is to condense a broad topic into categories or concepts describing the phenomenon as accurate as possible, providing new insights and knowledge within a determined context(Elo & Kyngäs, 2007). Despite of its advantages, content analysis has been criticized from the quantitative point of view, for being "simplistic" in terms statistical analysis of the data, and for not being qualitative enough(Elo & Kyngäs, 2007). Yet, supporters of the method agree that the performance of the results are directly proportional to the depth of the analysis, so that, "simplistic" results might be obtained when the analysis process lack of clarity or strength, otherwise, a well-supported analysis will validate the results by itself(Weber, 1990). As Elo et.al. (2007, p. 112) cites Neundorf (2002) saying "*The truth is that this method* [qualitative content analysis] *is as easy or as difficult as the researcher determines it to be*".

When using an existing theory with this research method exists other limitations that might affect the results. For instance, often this type of research might have strong bias, since researchers might tend to use more data that supports the theory than unsupportive data(Hsieh & Shannon, 2005). Additionally, other limitation can occur when the researcher is too close to the theory. The theory might cloud the researcher's vision and could lose important contextual aspects of the phenomenon(Hsieh & Shannon, 2005). To overcome these limitations, increasing neutrality and an objective process, is recommended to the researcher to provide as much details as possible of the analytical process and the data gathering(Elo et al., 2014), or audit the process using an external auditor (Hsieh & Shannon, 2005) or using agreement coefficients(Elo et al., 2014; Weber, 1990). However, it is important to have in mind that each researcher interpret the data from its own unique perspective, other co-researcher might alter the results since his perspective could differ with the author's; for that reason other experts in the content analysis field recommend to use a panel of experts to validate the results(Elo et al., 2014).

In this thesis, the author aimed to validate the analytical process through a conscientious description of the steps made. As suggested by Elo et.al. (2014), a well-reported content analysis can be a way to verify the trustworthiness of the study, which should provide clear details of the preparation of the study, the data gathering and the analytical process. Other key element used in this thesis to validate the data was to make sure that it is 'rich, appropriated, and well-saturated' as suggested by Elo et.al. (2014).

5. RESULTS OF THE RESEARCH

In this section, the structure of the new compendium for solid waste management will be revealed. The results here presented were obtained using qualitative content analysis and the primary data listed in the previous chapter. Here, the active parts giving structure to the original CSST, will be redefined within the framework of ISWM. These active parts are *functional groups*, *sanitation technologies* and *products* (see definitions: Chapter 3.2.1, Table 8. Active parts for configuring a sanitation system.
Adapted by the author from(E Tilley et al., 2014, pp. 10-13)).

Therefore, the chapter begins identifying and defining the new *functional groups.* Then using those definitions, all *sanitation technologies* found in the primary data were listed and organized according to the functional groups. Lastly, the author proceeded to define every selected technology and to compile the *product inputs and outputs* of the entire system. To conclude the chapter, the final structure of the new compendium was summarized in a table, in order to give a brief and clear view of the findings and the results achieved in the research.

5.1. Identifying the functional groups

To find the equivalent functional groups of the waste system, the theory of ISWM (see Figure 9) was used. As mentioned in the Chapter 3.1.4., the conceptual framework of ISWM defines clearly the “waste system elements”, whose share a rather close similarity with the functional groups of the CSST yet, differences were found. So, it was required to compare the definitions of both, functional groups of the CSST, and the waste system elements. Once done that, the researcher was able to set the new functional elements for solid waste. The Table 13. Definition of functional groups of Integrated Solid Waste Management., presents the results of the analytical process to identify and define the *new functional groups*.

During the process of defining the waste system elements of ISWM, the literature of ISWM framework published by the NGO WASTE was revised (Anschütz et al., 2004; van de Klundert & Anschutz, 2001) and due to the similarity of approach Schübeler et al. (1996) was reviewed as well. However in those texts, some definitions of the system elements were not found, perhaps due to the fact that the waste elements are widely known for decades and majority of authors give as understood what terms mean (e.g. collection of solid waste or disposal). So, in order to build missing definitions of waste system elements and provide better understanding of the terms, educational books and legal definitions made by international entities were used.

Once, all the functional groups of CSST and waste system element of ISWM were defined, the author begun to compare them in order to build the new functional groups. The analytical process was to think how the solid waste cycle works, having as reference the CSST. The identification of some functional groups was evident, for instance *user interfase*, *treatment* and *use/disposal* were quite straightforward, because they are quite similar processes in both sanitation systems, for solid waste management and for excreta and wastewater management.

However not all the new functional groups resulted so easy to identify. C*ollection*, *storage* and *conveyance* are clearly different processes in solid waste and waterwaste management. Whereas, for wastewater management the products moves from a defined pipeline that connect one functional group with another, it seems easier to identify the technologies used in every step of the process. Yet in solid waste, collection and conveyance are usually mixed terms. The collection of solid waste is made using different means of transportation, and along the transportation process different storage sites are used, often the 'storage' are sites called *transfer stations* which may have or not some waste separation and/or pretreatment. So, the author decided to separate in two different groups the process of 'collection' and 'storage', into a group called "*collection and transport*" and a new group called "*resource recovery*".

Other reason for building the new functional group *resource recovery*, was to include the 4'Rs from the waste hierarchy (see Figure 7. Waste management hierarchy

Note: Retrieved from: Waste Investing in energy and resource efficiency, 2011, pp. 9, figure 1.

Copyright © 2011 UNEP - United Nations Environmental Program.) which are part of the waste system elements within ISWM framework. The 4'Rs (reduction, recycling, reuse and recovery) are the ultimate measures to assure material recovery, which often take part at different stages of the waste cycle. The 'majority' of resource recovery activities that are controlled by waste managers, take part at collection, storage and treatment sites. Yet, the biggest material recovery in developing countries is made prior collection (separation at the source done by users or wastepickers) and in the transfer stations or waste management facilities. Then it made sense to isolate "*resource recovery*" as a functional group in which, waste separation and pretreatment facilities are combined.

However, one of the R's was not included, reduction. This R, take part before the waste is produce, since the ultimate aim is to *minimize or reduce* the amount waste entering to the waste system. The measures of waste reduction are often *strategies* nor technologies as such, in which costumers and producers of goods take conscience and responsibility of the waste they are producing and find ways to maximize resource use and extend the operative life of the goods (e.g. legislation for sustainable production and consumption, producer responsibility, etc.). For this reason, reduction is ‘included’ only in the actions made at the *resource recovery* stage.

Table 13. Definition of functional groups of Integrated Solid Waste Management.

Original Functional Groups CSST & Definitions ("Compendium of Sanitation Systems and Technologies 2nd Edition," 2016, p. 13)	**Waste System Elements ISWM framework (see Figure 9) & Definitions (extracted from different sources)**	**New functional groups & Definitions (waste system elements)**
User Interface U "Describes the type of toilet, pedestal, pan, or urinal with which the user comes in contact; it is the way by which the user accesses the sanitation system. In many cases, the choice of User Interface will depend on the availability of water".	**Generation and Separation** "Assessment of waste generation and evaluation of waste reduction… Involves the activities associated with the management of wastes until they are placed in storage containers for collection. This may include source separation of household waste into recyclable and non-recyclable materials. Provision for suitable storage for the wastes, which may encompass a wide variety of different types, is also part of this element. Processing includes such processes as compaction or composting of putrescible materials"(Williams, 2005, p. 369)	**User Interface** The way in which the users access to the waste management system. It involves activities associated with the management of wastes until they are placed in storage containers for collection. This may include source separation of household waste into recyclable and non-recyclable materials. Provision for suitable storage for the wastes, which may encompass a wide variety of different types, is also part of this element. It may include as well processing at the source, which includes such processes as compaction or composting of putrescible materials.
Collection and Storage/Treatment S "Describes the ways of collecting, storing, and sometimes treating the products generated at the User Interface. The treatment provided by these technologies is often a function of storage and is usually passive (e.g., requiring no energy input). Thus, products that are 'treated' by these technologies often require subsequent treatment before Use and/or Disposal".	**Collection** "Collection systems comprise household and neighbourhood (primary) waste containers, primary and secondary collections vehicles and equipment, and the organisation and equipping of collection workers, including the provision of protective clothing"(Schübeler et al., 1996). "Waste collection is the collection and transport of waste to the place of treatment or discharge by municipal services or similar institutions, or by public or private corporations, specialized enterprises or general government. Collection of municipal waste may be selective, that is to say, carried out for a specific type of product, or undifferentiated, in other words, covering all kinds of waste at the same time"(Organization for Economic Co-operation and Development, 2001).	**Collection and Transport** Describes the transport or conveyance of products (or wastes) from the user intefase to the other functional groups. Collection technologies are classified in primary and secondary collection, depending of to their carrying capacity and the distance coverage. Primary collection refer to smaller vehicles transporting the products at household or neighborhood level. Secondary collection are larger vehicles covering larger distances, and are used to transport the products to processing facilities or final disposal sites. The collection system can be carried out separately according product types, meaning that a specific type of product is collected separately (e.g. recyclables), or the system can be undifferentiated, meaning that all waste types are collected at the same time.

Conveyance "Describes the transport of products from one functional group to another. Although products may need to be transferred in various ways between functional groups, the longest, and most important gap is between User Interface or Collection and Storage/Treatment and (Semi-) Centralized Treatment. Therefore, for the sake of simplicity, Conveyance only describes the technologies used to transport products between these functional groups".	**Transfer and Transport** "Transfer systems include temporary waste storage and transfer points, vehicles and equipment for waste transfer, and the procedures for operating and maintaining these facilities and equipment" (Schübeler et al., 1996, p. 46). "This element involves the transfer of wastes from the smaller collection vehicles to the larger transport equipment and the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. The transfer usually takes place at a waste transfer station"(Williams, 2005, p. 369).	
(Semi) Centralized Treatment "Refers to treatment technologies that are generally appropriate for large user groups (i.e., neighborhood to city level applications). The operation, maintenance, and energy requirements of technologies within this functional group are generally higher than for smaller-scale technologies at the S level. The technologies are divided into 2 groups: T.1-T.12 are primarily for the treatment of Blackwater, Brownwater, Greywater or Effluent, whereas T.13-T.17 are mainly for the treatment of Sludge. Technologies for pre-treatment and post-treatment are also described (technology information sheets PRE and POST)".	**Treatment** "The recovery of separated materials, the separation and processing of waste components and transformation of wastes are elements which occur primarily in locations away from the source of waste generation. This category includes waste treatment at materials recycling facilities, activities at waste transfer stations, anaerobic digestion, composting and incineration with energy recovery" (Williams, 2005, p. 369).	**Treatment** Refers to treatment technologies that are generally appropriate for large user groups (i.e., neighbourhood to city level applications). The technologies within this functional group are generally used for processing or transforming waste products into more useful products or less hazardous products to be cycled back to other economic activities, and the residues or products that are no longer useful are prepared to be safely disposed. Here, technologies for energy recovery are included. The technologies of this functional group are divided in several categories, according to the characteristics of the processes or techniques that the technology uses to carry out its work (e.g. mechanical, biological, thermal, etc.).
Use and/or Disposal "Refers to the methods by which products are ultimately returned to the environment, either as useful resources or reduced-risk materials. Furthermore, products can also be cycled back into a system (e.g., by using treated Greywater for flushing)".	**Disposal** "Final disposal is usually landfill or land-spreading, i.e., the disposal of waste directly from source to a landfill site, and the disposal of residual materials from materials recycling facilities, residue from waste incineration, residues from composting or anaerobic digestion, etc., to the final disposal in landfill" (Williams, 2005, p. 369).	**Use and/or Disposal** Describes the methods to either use the recovered resources or to finally dispose the residues of the waste system.

	Reduction / waste minimization “Waste minimization refers to strategies that are aiming to prevent waste at source through upstream interventions. • On the production side, these strategies are focusing on optimizing resource and energy use and lowering toxicity levels during manufacture. • On the consumption side, waste minimization strategies aim to strengthen awareness and prompt environmentally conscious consumption patterns and consumer responsibility to reduce the overall levels of waste generation”	**Resource Recovery** Refers to the material recovery facilities prior treatment. It might include separation technologies or practices at the waste facilities, which allow removal of recyclable products from the waste stream. Technologies for energy recovery are not included.
	Reuse “Reuse of waste means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived”.	
	Recycling “Recycling of waste is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes”.	
	Recovery “Recovery of waste means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy”	

5.2. Identifying sanitation technologies

Having defined the New Functional Groups, it is time to find the technologies used in every functional group for solid waste management. To do that, the author sought the need to find out whether the functional groups might have some inner sub-categorization or not, to finally extract the sanitation technologies and sub-classify them if required.

The analytical process was carried out as follows:

To begin, an instrument for data gathering was built for every functional group. This instrument is divided into two parts: "sub-categorization" and "technologies". The first part seeks to identify any kind of sub-categorization if exists, in some cases several options for sub-categorization might be found so, every proposed sub-categorization should have a number (e.g. No. 1. None; No. 2. Primary and Secondary, etc.). Subsequently the most suitable categorization will be selected. The second part of the instrument aims to identify all the technologies that might be part of that functional group. In literature, technologies belonging to some functional groups may be quite homogenous in content and terminology yet, for some others that may not be the case. So, a posterior revision or screening may be needed in order to eliminate any overlapping contents and to discard the technologies that are not recommended nor sustainable. As result, the approved technologies will be reveled in the column "Final grouping of technologies".

Additionally, both parts of the instrument have a column called "sources" where the author should point out the exact location where the information was found. To do that, the Table 12. List of public reports or primary data, lists the primary data and assigns a letter from A to Q to every source. So using that code letter and a number, the author will refer the exact source or text and the page(s) where the contents exacted are located (e.g. A(74) = (United Nations Environmental Programme. International Solid Waste Association, 2015, s. 74)).
That information is required to validate the results, and it is a key to continue with the next step of the research, since in that point the author should review once again the sources to complete the information of every technology.

Using the ready instrument for data gathering, the author proceeded to analyze one by one the primary sources and organize findings in the instrument. The process was completed focusing on key words from the functional groups (e.g. collection, transportation, treatment, etc.) and then finding any technology suitable for that functional group and recording all the findings in the instrument. Once all sources were reviewed, all possible sub-categorizations and technologies were organized according to every functional group, the author proceeded to screen the results in order to produce a final list of technologies and select a suitable sub-categorization if needed. That step in qualitative content analysis is known as "grouping and categorizing" and belongs to the organizing phase (see Figure 16. Phases of the content analysis with deductive approach.Figure 16).

How to read the results: The tables 13 to 19 present the complete analytical process done to identify the sanitation technologies that are going to be part of the new compendium for solid waste management. The results are divided according to the active parts of the compendium, products and functional groups. The selected technologies appear in bold letters under the column "Final grouping of technologies". Moreover, the selected sub-categorization can be found in black font under the column "proposal of sub-categorization", the sub-categorizations in gray font were taken into consideration in the analytical process but were NOT selected.

Findings:

- The table 13 and 14 presents the initial products (inputs and outputs) found at this point of the research. However, it is expected that the biggest amount of products will be found during the defining phase, for that reason the final listing of products and their definitions can be found in the numeral 5.2.6. Compilation of products.
- User interface (Table 16) was perhaps the most homogenous content found in the literature, with a single categorization and quite clear structure of technologies.
- Collection and transport (Table 17) is the group with more options for subcategorization but the selection was quite straightforward since majority of authors agree that the most common classification is into primary and secondary collection. Despite the wide range of classification, the technologies found in literature were quite similar in almost all the sources, which facilitated the final grouping of technologies and their categorization.
- Resource recovery (Table 18) and Treatment technologies (Table 19) were the most challenging functional groups to separate. Therefore, it was necessary to follow strictly the definition of those functional groups in order to avoid overlapping technologies. So that, resource recovery comprises the facilities where waste arrives after being collected from the user interface before reach treatment or disposal. These facilities are used for temporary storage, separation and/or pretreatment. On the other hand, treatment comprises the technologies for fuel and energy recovery and organic recovery.
- In the last functional group Use and Disposal (Table 20), all the technologies for controlled final disposal were identified, including incineration. Even though, the author recognizes that incineration, is a costly method that not many developing countries can easily afford or implement, it is important that upper-middle income countries and emerging economies (e.g. Brazil, Russia, India, China and South Africa, etc.) begin or continue considering this method when suitable. Incineration can help to reduce significantly the increasing amount of wastes going to landfills and extend their operative life.
- The subcategory 'Use', which come along with 'disposal' remains untouched at this point. The category 'use' should be build analyzing all the resultant outputs of all the system, and then grouping them according to their final usage (e.g. products for agriculture use, for reuse in industry, for reprocessing, for up-cycling, or for landfill coverage, or for electric-energy usage etc.). So that, this part will be proposed at the very end.

Table 14. Inputs (part I)

	No.	Proposal of sub-categorization	Sources	Inputs	Sources
Inputs	1	▼ MSW ▼ Non-MSW	D(4), G(16), R(21-46), O(677)	Organic material/Biodegradable	S(57), D(8)
				Textiles and leather	S(57)
				Metals	S(57)
				Glass	S(57)
				Plastics	S(57), K(9,14)
		According to the contents resulting after technology gathering: Sub-categorization not required	Proposed by the author	Paper	S(57), Q(4-9)
				Other inert materials (ewaste, nano waste, hazardous waste, medical waste, C&D, WEEE, disaster waste, marine litter)	S(57-88,113), D(8-28,29), N(2E-waste), H(21)

Table 15. Outputs (part I)

	No.	Proposal of sub-categorization	Sources	Outputs	Sources
Outputs	1	▼ Secondary commodities ▼ Other waste streams	S(80) S(80)	Ferrous metals (Steel scrap)	S(81), F(12,14)
				Nonferrous metals (Aluminium, Cooper, etc.)	S(82,84)
		According to the contents resulting after technology gathering: Sub-categorization is not required	Proposed by the author	Recovered cellulose fibre	S(86), Q(4-9)
				Recovered Plastics	S(84,85), K(9,14)
				Textiles	S(88)
				Compost	H(7-9)
				Leachate	O(26), I(7)
				Landfill gas	O(26), I(4)
				Biogas	P(39,60)

Table 16. Technologies for user intefase

	No.	Proposal of sub-categorization	Sources	Technologies (gathered in final grouping)	Sources	sub-category
U **User Interfase**	1	▼ Household waste storage (Primary storage) ▼ Communal collection (Community waste storage)	D(13,14) P(60,71) C(40,49) Q(14-15*paper*)	**Set-Out containers (bags, pots, plastic/paper bags, concrete brick vats, or any other container available)**	D(13), P(34,36) C(41,42)	**Primary**
				Fixed community container	B(66), C(44)	**Communal**
				Wheeled containers/Portable bins emptied in situ	B(69), D(13), C(46)	
				Exchanged containers	B(68), C(47)	

Table 17. Technologies for collection and transport

	No.	Proposal of sub-categorization	Sources	Technologies gathered	Sources	Final grouping of technologies	Sub-category
C **Collection and Transport**	1	▼Separated or Combined Collection ▼Unseparated Collection	S(71) C(37) Q(14-15*paper*)	Cycle cart+Tricycle	S(64) C(66,68)	**Cycle cart**	**Primary**
	2	▼Primary (Smaller scale): Muscle-powered carts, Electric or propane-powered.	S(64) D(13) C(58,71-95) B(71,91)	Push cart	S(64) C(66,68)	**Push cart**	
				Animal transport	C(66)	(!) Not included: This is not a recommended practice nor acceptable from the point of view of animal protection and should be ban.	
		▼Secondary (Large scale)	S(64) D(15) C(71,94-95) P(71,91)	Motorcycle trailers	C(69)	**Motorcycle trailers**	**Primary**
				Two and Three wheeled motor powered vehicle	C(70)	**Two and Three wheeled motor powered vehicle**	
	3	According collection method: ▼ House-to-house ▼ Community bins ▼ Kerbside pick-up ▼ Self-delivered or drop-off Contracted/Delegated Service.	G(13) C(34.36)	Small truck/Micro-trucks	S(64) C(71)	**Small trucks**	
				Agricultural Trailers and tractors	C(71,73)	**Agricultural Trailers and tractors**	**Secondary**
				Close truck	S(64)	(!) Not included: the classification of trucks, tractors and trailers mentioned below provide better understanding of the wide range of transport technologies.	
				Open collection	S(64)		
				Truck collection	S(64)		
	4	According collection and transfer system: ▼Direct collection ▼Two stage collection ▼Tree stage collection	C(36,38)	Transfer tractor-trailers/Exchanged Container Systems	D(15) C(90,94)	**Exchange container systems**	**Secondary**
				Semi-compaction vehicles	C(80, 81)	**Semi-compaction vehicles**	
				Compacting trucks	D(15,16) C(82,89)	**Compacting trucks**	
				Non-compacting trucks/ non-compacting collection vehicle Bodies	D(16), C(74,80)	**Non-compacting trucks**	
				Bulk transportation	C(103,104)	**Bulk transportation**	
				Small Transfer stations and transfer systems:	D(15), C(97,102)	**Transfer systems:**	

	No.	Proposal of sub-categorization	Sources	Technologies gathered	Sources	Final grouping of technologies	Sub-category
				Rendezvous system, loading from the ground, Split-level transfer stations, Pit and Hoist type small transfer station. Lastly, Container-to-container transfer system		**- Loading from the ground - Split level transfer stations - Pit and Hoist type small transfer stations - Container-to-container transfer system**	

Table 18. Technologies for resource recovery

	No.	Proposal of sub-categorization	Sources	Technologies gathered	Sources	Final grouping of technologies	Sub-category
R **Resource Recovery**	1	According to waste composition and resultant waste properties: ▼ Material Separation Technologies(MST) ▼ Organic recovery(OR) ▼ Fuel and Energy Recovery (FER) (!) Not used at this point: for having overlapping aspects with treatment technologies.	S(72) D(24) P(94,107-131,165) R(22)	Material Recovery Facilities (MRFs)	S(74), Q(21), J(4,16)	**Material Recovery Facilities (MRFs)**	**NONE**
				Waste sorting centers (manual sorting)	S(74), Q(21), J(15,16)	**Waste sorting centers (manual sorting)**	
				Mechanical biological treatment facilities (MBTs)	S(74), K(16,18),	**Mechanical biological treatment facilities (MBTs)**	
				Integrated Resource Recovery Centres (IRRCs)	S(133)	**Integrated Resource Recovery Centres (IRRCs)**	
	2	According to the contents resulting after technology gathering: Sub-categorization not required	Proposed by the author	Manual dismantling/sorting of fractions	N(3,6) R(22) pre-treatment processes for e-waste or WEEE	(!) Not included: The number of mentions are low and the contents lack of depth, which may not facilitate the completion of the upcoming steps in this research. Besides that, e-waste or WEEE is hazardous waste and it should be managed separately from the MSW stream.	
				De-gassing of CFC, HCFC			
				Semi-automatic cut and cleaning			
				Integrated smelter for non-ferrous (pyro-metallurgical methods)			
				Aluminium remelter/refiner			

Table 19. Technologies for treatment

	No.	Proposal of sub-categorization	Sources	Technologies (gathered in final grouping)	Sources	Sub-categorization
Treatment	1	▼ Fuel and Energy Recovery (FER) ▼ Organic Recovery (OR)	S(72-76), P(131-Part II), H(22-51)	**Combustion with ER as electricity and/or heat (Incineration)**	S(76-78), D(25), G(29), R(50), P(9,10-19,22)	FER
				Co-combustion in an industrial facility: Refuse-derived fuel (RDF) /Solid Recovered Fuel (SRF)	S(76-78), D(50)	FER
				Gasification: updraft gasification, downdraft gasification, fluidized bed, entrained flo gasification and rotatory kiln gasification.	S(76-78), P(259,292), T(337,346)	FER
				Pyrolysis: Carbonization, conventional, flash-liquid, flash-gas, Ultra. Other types: vacuum, hydropyrolysis, and methanolysis.	S(76-78) T(326,337)	FER
				Landfill gas(LFG) utilization. LFG emission control, Leachate	S(76), E(2,3-all) I(3,6-7)	FER
				Composting: (enclosed and open system) OR (Residential composting, decentralized Community composting, centralized large-scale composting)	S(75-77), D(18-20) P(216-225), H(3,6)	OR
				Biogasification/Anaerobic digestion: Fixed-dome digester, Floating-drum digester, tubular digester, garage type digester.	S(75-77) Q(32,39), D(21)	OR
				▼ **Animal feeding** ▼ **Vermicomposting** ▼ **Black Soldier Flies** ▼ **Inoculums** (!) Not included: This treatment is used in composting when there is lack of microorganisms, yet in the majority of the cases is not necessary (United Nations Environment Programme & CalRecovery Inc., 2005, p. 199).	S(75) D(20), P(198,199)	OR

Table 20. Technologies for disposal

D

Use and/or Disposal

No.	Proposal of Sub-categorization	Sources
1	▼ Controlled ▼ Uncontrolled Disposal	S(65) R(22), E(1) P(323 – Part III)
2	▼ Incineration ▼ Landfill ▼ Non-landfilling disposal	D(25.26)
3	**- Controlled disposal** **- Use*** (*) The category USE was not included: Technical definitions are not enough to structure this part. The components of this category can be set up only after the technology information sheets are ready.	**Proposed by the author**

Technologies (gathered in final grouping)	Sources	sub-categorization
Upgraded dumpsite/Semi-controlled dump	S(65), D(27), G(29)	Controlled disposal
Controlled dump	G(29)	
'Intermediate' engineered dumpsite/Engineered landfill	S(65), G(29)	
Sanitary landfill	D(26), G(29), O(5,40), I(3,7)	
Incineration	D(25), G(29), R(50), L(9,10-19,22)	(!) Included in the treatment module as "Combustion with ER and heat". Following the waste hierarchy guidelines.
Open burning	S(65)	(!) Not included: these disposal methods are harmful for the environment and are mayor source of pollution.
Open dumping	S(65)	
Disposal into farmland	D(27)	
Disposal into water bodies	D(27)	

5.3. Defining sanitation technologies and products

The present subchapter presents the definitions of the selected technologies and lists all the products (input/output) moving throughout the entire system. These definitions lay the basis to begin the "Technology Information Sheets", and provide the total overview of the new compendium and its parts.
Here, the functional groups, subcategories and sanitation technologies are structured. The definitions were completed using only the primary sources selected for the research (see Table 12. List of public reports or primary data). Moreover, each technology was identified with a letter and a number, the letter points out the functional group where it belongs, and the number refers to the position within the functional group.

5.3.1. User Interface

- **Household waste storage**

U.1: Set-out containers: The majority of waste systems begin with some type of set-out containers, where householders dispose their wastes awaiting for collection. Several kinds of waste containers are used for that purpose, often they rank from simple plastic bags placed in the curbside to standardized plastic-wheeled-containers. Set-out containers can include as well boxes, pots, baskets, clay jars or basically any container available (Eawag/Sandec, 2008, p. 13). In order to select a suitable, affordable and effective method is important to consider that, the containers should facilitate collection and should resist outdoor conditions (e.g. protect waste from rain and animals) (Coffey & Coad, 2010, p. 41). An organized collection service should aim to promote the usage of affordable, durable and large waste containers, such as: light weight plastic containers with handles (e.g. bins made of old tyres or plastic bin with liner), or light weight metal containers with handles (e.g. halved oil drum, recycled steel drum, etc.) (Coffey & Coad, 2010). Quantitative methods and instruments for assessing the characteristics of waste containers are close related with waste composition/generation data (Coffey & Coad, 2010, p. 36).

- **Community waste storage:** Refers to containers that stores waste for several dwellings. They can be filled directly by the residents or by primary collection vehicles (e.g. push cart, cycle carts, etc.)(Coffey & Coad, 2010, p. 43).

U.2: Fixed community container: Fixed storage facilities with an average capacity of 1-5 m3. Often this type of storage containers are simply a concrete/steel pipe or concrete bunker. This type of units are often problematic because often wastes are disposed out of the container making it look untidy and aesthetic, secondly, it does not provide protection against rain or animals, and thirdly, it should be emptied by hand using baskets to carry the waste to the collection vehicle. Due to those reasons, it is recommended to use closed units that can be open in the top surface, which serves to facilitate filling and prevent residents to dispose waste out of the containers. As well as provide them with a simple shelter to protect waste from rainfall (Coffey & Coad, 2010, pp. 44-45).

U.3: Wheeled containers/Portable bins emptied in situ: These containers are mostly made of plastic and sometimes made from galvanized steel sheet. There are three types of portable containers: two-wheeled containers, four-wheeled containers and non-wheeled-containers that can be picked up by a crane. Their capacity ranges between 80 to 1500 liters (Coffey & Coad, 2010, pp. 45-47).

U.4: Exchanged containers: Refers to large containers that once filled are transported directly to the transfer station or waste facility. This storage system requires special vehicles for handling, reason why it facilitates greatly loading and empting the waste. Often it is a matter of 1-2 minutes that trucks can unload an empty container in situ, and pick up the filled container that is now ready to be transported, so that, the productivity of this storage system is maximized (Coffey & Coad, 2010, pp. 47-48). Exchangeable containers are mostly suitable for areas where waste affluence is great (e.g. markets or secondary collection of household waste), and for non-biodegradable waste (e.g. industrial and institutional wastes) (Coffey & Coad, 2010, p. 48).

5.3.2. Collection and transport

▼ **Primary collection:** Refers to the collection service at a relative small scale, carried out either by public, private or informal sector or even NGO's. The main characteristic of this categorization is that, vehicles of small capacity pick up the waste from households and small commercial establishments to transport them to a community waste storage or to small transfer stations, where secondary collection takes place. Often vehicle operators perform some waste sorting at this point (D. Wilson et al., 2015, pp. 62-63). The vehicles used for primary collection are suitable for highly populated areas and areas that tend to have heavy traffic congestion (Coffey & Coad, 2010, p. 66).

C.1. Pushcart: Also known as handcart. This small wheeled-vehicle, human powered, covers an area not larger than one kilometer in a flat ground (Coffey & Coad, 2010, p. 66). The design of pushcarts has a great similarity to carts used for street sweeping, however when residents bring their wastes is necessary to use containers with bigger capacity (Coffey & Coad, 2010, p. 67).

C.2. Cycle cart: These vehicles are bicycles or tricycles, human powered, which covers up to a two kilometers route from the picking up area to the secondary collection point. There are several variations of this type of vehicles, often they are operated by single man, however if the load interfere with pedaling, an extra man is needed. The main factors affecting efficiency of the service are firstly the distance from the picking-up point to the small transfer station or rendezvous point, and the vehicle's design. A small tricycle covering a route of 1km to the small transfer station is able to make several trips collecting in total 2,200 kg a day. Whereas, a vehicle with big load of 1.5 m3 (approx. 721.5kg) is able to make a single trip a day, and due to the heavy load pedaling becomes too difficult slowing down the process (Coffey & Coad, 2010, p. 68). Tricycles with small load combined with effective small transfer stations can benefit the collection service in high-populated areas and make easier and more effective the operator's tasks (Coffey & Coad, 2010, p. 68).

C.3. Motorcycle trailers: These motorcycles are equipped with a small two-wheeled trailer. Due to their speed and the small trailer body, these vehicles can cover longer distances and can move quickly in heavy traffic. These vehicles suit best for low housing density areas (Coffey & Coad, 2010, p. 69).

C.4. Two and three-wheeled motor powered vehicles: there are two main types of vehicles in this category two-wheeled tractors and three-wheeler auto-rickshaw. Small tractors can cover a distance until 8km to the secondary collection point, and due to the small engine this vehicle has long operative life and very low fuel consumption, its maximum speed is 20 km/hr. This vehicle can transport in one-trip 8-10 bins of 100-120 liters each, whose are quickly emptied by two men (Coffey & Coad, 2010, p. 70). Now then, auto-rickshaw are mostly used as taxis in Asian countries, however with a small modification this vehicle has a carrying capacity of one cubic meter of MSW. Due to their small compact design, these vehicles are suitable for high-populated urban centers and can cover distances up to 5km to the transfer point, and its maxim speed is 30 km/h. This vehicle has a relative high fuel consumption and causes pollution problems, but newer models are being improved (Coffey & Coad, 2010, p. 70).

C.5. Small trucks: Are four-wheeled micro-trucks equipped with a tipping refuse body with a maximum carrying capacity of one and a half cubic meters (Coffey & Coad, 2010, p. 71). Usually these vehicles can have open top or hinged lids, and its tipping refuse system can be manufactured locally. These vehicles are very reliable and relatively inexpensive to maintain and operate even though micro-trucks have gasoline engines, yet in the coming years is expected that diesel engine micro-trucks are available in order to offer a more cost-effective transport solution (Coffey & Coad, 2010, p. 71).

▼ **Secondary collection**: refers to large-scale collection, which is often part of an integrated collection system across the city (D. Wilson et al., 2015, p. 63).

C.6: Agricultural trailers and tractors: Agricultural tractors are widely used in developing countries since they are affordable, have a long economic life, and lower fuel consumption and maintenance costs. For collection of MSW, these agricultural tractors are equipped with a detachable open trailer, and hydraulic systems to operate their rear lift arms and to handle tipping trailer or other similar loads (Coffey & Coad, 2010, p. 71). Since tractors are relatively low-speed vehicles and sometimes the trailer's design can shorten their maneuverability, these vehicles are usually suitable for distances between 20 km and 40 km to the waste facility. In order to make a tractor a cost-effective transport solution the power-to-weight ratio should be taken into consideration, this to determine fuel consumption, speed and acceleration(Coffey & Coad, 2010, p. 72). Besides that, the trailer's body size should be appropriated as well, often a standard truck trailer has a carrying capacity of 3 m^3, but an improved waste trailer can increase the capacity to 5 m^3 or more (Coffey & Coad, 2010, p. 73). Now, tractors have not been used to its full potential in the MSW collection service mostly because they should be customized in order to extend their capacity and improve maneuverability, but that can be easily achieved for an inexpensive cost. If compare the cost of a tractor with a tipping truck of the same capacity, the tractor costs 50% less and its operating annual costs are 60% lower than the tipping truck (Coffey & Coad, 2010, p. 72).

C.7: Exchanged container systems: There are several types of vehicles used for picking up containers. In MSW, the most common vehicles are tractors, trucks and customized small construction site dumpers (Coffey & Coad, 2010, pp. 90-94). Besides the vehicles characteristics, this chapter covers the systems used for lifting and picking up containers in situ. In case of the tractors, two systems are used for container pick up: a) Standard lift arms located on the very back of the tractor, which are used for picking up small containers by the roadside of narrow streets/roads. b) A hydraulic system that serves for both picking up and tipping the wastes automatically without work force. This system is often used in bigger tractors ranging between 40-60 hp or larger, which can handle a trailer with loads between 10 m3 to 20 m3 or even more (Coffey & Coad, 2010, p. 90). In the case of trucks, two types of "skip-lifting hydraulic systems" are used to handle waste containers. The first system is known as "bucket lift" or "load lugger", in which the vehicle is equipped with lifting arms able to lift the container and place it on the top of the vehicle for either transporting the container, or tipping the wastes into another larger container located in the back of the vehicle (Coffey & Coad, 2010, pp. 92,89). The second system can be divided into two systems "roll-on" and "hooklift systems. Both of these systems use hydraulic-operated arms that are meant to pull and roll the container until the container reaches the vehicle's deck; then to empty the container, the vehicle's arms lift and tip the load (Coffey & Coad, 2010, p. 92). Roll-on and hook systems can handle much larger capacities than skip-lift systems, reason why they are especially suitable for large cities or municipalities (Coffey & Coad, 2010, p. 93).

Lastly, "customized small construction site dumper" is meant to carry small containers called "micrabin" for short distances. Due to its small and compact design this small vehicle needs a very small area to lift the micrabin containers, reason why is very suitable for difficult conditions such as challenging roads or congested areas. The vehicle has about 9 hp and its maximum speed is 20km/h. The micrabins have a capacity of 2 m3 tops (Coffey & Coad, 2010, p. 94).

C.8: Non-compacting trucks: This section more than describe the mechanical characteristics of the vehicles, it is destined to describe features of non-compacting vehicle's bodies. The body types described here do not have any waste compression system, their most important feature is the loading-unloading systems, which can either facilitate or inhibit an efficient collection service while resulting time and cost effective. Non-compacting body vehicles result often suitable for developing countries because the waste density is already quite high, making unnecessary the use of compression (Coffey & Coad, 2010, p. 74). Besides that, the waste composition in many developing countries includes abrasive and corrosive wastes, which are problematic for compaction. Other advantage of non-compacting vehicles are the lower costs throughout their operative life, since they require less capital, less maintenance and lower operative costs than compaction vehicles (Coffey & Coad, 2010, p. 75). There are several designs used for MSW, the main difference between them is the way the waste is loaded and unloaded, some are equipped with automatic systems and others require manual load/unload. According to Coffey et.al. (2010, pp. 75-80), the main non-compacting body types can be categorized as follows: high-sided open-top vehicles; side loading "roll-top" vehicles; front-loading high-sided enclosed vehicles; Fore-and-aft tipping bodies; side loading binlift system; crane-tipper system; and side-loading, moving-barrier, semi-compaction vehicles.

C.9: Semi-Compacting Vehicles (SCV): Vehicles are those whose body is equipped to compact waste and reduce its volume in a little percent. Compared with compaction vehicles, SVCs have simpler systems for compaction and less force to compress the waste. Those features make semi-compaction vehicles a suitable option for developing countries where the waste density is middle to high, because they powerful enough to eliminate the air between the waste items and to compress cardboard boxes making more room within the body. Besides that, they are less costly than a compaction vehicle and maintenance can be done locally (Coffey & Coad, 2010, p. 80). The most common SCVs are: a) Side-loading, moving-barrier SVC; b) Fore-and-aft SCV; c) side-loading-hopper SCV (Coffey & Coad, 2010, pp. 80-82).

C.10: Compaction vehicles: According to Coffey et.al. (2010), there are five types of compaction vehicles: Rear-loading compaction plate compactor; screw compactor; rotation drum compactor; paddle compactor; front loading compactor. Each of these vehicles are equipped with an specific hydraulic compaction system and loading mechanisms, which can be either for "continuous-loading" or "intermittent-loading", depending of the amount of time that waste remains awaiting for compaction (Coffey & Coad, 2010, p. 89). Compactor vehicles are very common in industrialized countries, and several main cities in developing countries have been acquiring this kind of vehicles as well. However, the suitability of this kind of trucks in developing countries unfortunately is not the best in terms of operative life costs and sustainability in general. The suitability of compaction systems shall be determined according to waste density and composition. Very low waste densities (100-150kg/ m3 as seen in developed countries) often require compaction in order to optimize the cost per load; yet a high waste density (250-400 kg/ m3 as is the case of developing countries) would not require that because it would cause overload (Coffey & Coad, 2010, pp. 82,83). Because of the constant overload, the vehicle will be soon worn-out, and will require special maintenance and replacement parts coming from overseas (Coffey & Coad, 2010, p. 82). For that reason, besides the technical information, it seems important to discuss in detail the criteria for selecting compactor vehicles, as well as their advantages and disadvantages for developing countries.

C.11: Bulk transportation: Refers to large and big secondary collection vehicles that transport large amounts of waste from the collection point to the waste disposal/treatment facility when this last is located is far away (e.g. off city limits). Coffey and Coad (2010, pp. 103,104) classify these type of vehicles into the following six categories:

- Agricultural tractors with large trailers (e.g. carrying capacity: 20 m3)
- Large truck with open bodies (e.g. three to four axle chasis)
- Hooklift trucks (the container capacity cannot exceed the power of the hooklift system)
- Combination of truck and simple light containers used in pit and hoist small transfer stations (e.g. capacity 3000 kg per trip).
- Large compactor trucks
- Articulated trucks. Loading options: open top trailer or rear open for compacting the waste inside. Unloading options: multistage hydraulic rams, conveyor belts or walking floors.

C.12: Transfer Systems: In waste collection, transfer systems are used to direct the waste collected at small scale (primary collection) into larger vehicles (secondary collection) for transportation to the waste treatment/disposal facility. The places where waste transference happens are known as "transfer stations or transfer points". These points serve as a short term storage, and some serve for recycling, separation of some waste streams and even offer some preprocessing (e.g. compaction, drying/wetting)(Eawag/Sandec, 2008, p. 15). This section shall discuss firstly, the features, advantages and drawbacks of a small transfer station, and secondly, shall discuss the transfer systems. Coffey and Coad (2010) list the transfer systems as follows:

- *Rendezvous system:* At particular location and time, a collection vehicle is placed to load the waste collected by primary collectors (e.g. pushcarts, wheeled vehicles, etc). Then, the collectors themselves load the waste into the truck, and once the vehicle is loaded it leaves to the waste facility, meanwhile the remaining collectors will have to wait for the next truck to deliver their load. This system do not use any infrastructure, no capital is needed, yet it generates several issues with the traffic and results problematic for primary collectors(Coffey & Coad, 2010, pp. 97,98).
- *Loading from the ground:* This type of transfer only needs a flat area where, primary collectors dump the waste and then, the secondary collection vehicle is loaded manually for operators or by a crane. This system can only be taken into consideration for emergencies, because it results inefficient, unhygienic and chaotic when waste remains longer than a day and piles up (Coffey & Coad, 2010, p. 98).
- *Split level transfer stations:* In this stations the primary collection vehicle is placed in a high ramp or elevator, then the waste is discharged by gravity into a large trailer, some systems can use compaction if needed(Coffey & Coad, 2010, pp. 98,99).
- *Pit and Hoist type small transfer stations*: It consist in a small facility installed at the ground level of city centers or even business buildings. This facility require a small area to operate (e.g. dimensions: 16 m x 8 m), results hygienic and minimizes odors. The facility consists in a pit where a large waste container is placed, then primary collectors discharge their waste within the container without using any special platform, only lifting the front side of their vehicle or waste bins. Once the waste container is full it is ready to be removed from the pit and loaded to the secondary collection vehicle for transportation. To do so, this facility has a hoist system that lifts the waste container and place it automatically over the secondary collection truck, or place it a side of the pit to wait for transport, then another waste container is placed into the pit to provide a continuous service (Coffey & Coad, 2010, p. 100).
- *Container-to-container transfer systems*: It refers to a waste transference from small agricultural tractors (primary collection) to larger containers transported by bigger tractors (secondary collection). It does not require manual loading, the truck are equipped with simple hydraulic systems to facilitate the waste transference to other containers. This system has been used in East Africa and has shown positive results for a low cost (Coffey & Coad, 2010, p. 102).

5.3.3. Resource recovery and recycling

This section refers to the technical components of 'recycling' and 'recovery', which are two of the 4R's of the waste system elements within ISWM' framework. Recyclables or valuable materials present in the MSW stream are recovered at two instances, either are segregated at the user interface or after collection in waste management facilities. In some countries a considerable amount of dry recyclables (e.g. metals, glass, cardboard, paper, etc.) never entry to the waste system, because informal sector remove them at the user interface (D. Wilson et

al., 2015, p. 67). Therefore, in this section only recyclables entering to the waste system will be taken into consideration.
Recycling and resource recovery in this document covers, the facilities in which separation of waste streams happens after collection, and these facilities are known as 'sorting facilities'. A sorting facility is meant to segregate the waste streams and recover the valuable materials, to do so some facilities only separate and clean the recyclables, and others include some kind of treatment (Neidel & Jakobsen, 2013, p. 5). Here, the biggest emphasis will be done regarding technologies for segregation, the treatment technologies are explained in the 'Treatment' section. A sorting facility uses different separation technologies or a combination of them to effectively separate the waste streams, depending on the input material and the quality of the recyclable that is desired to produce. The main types of separation technologies are: by sizing; by gravity or density; metal separation; using optical or sensors; and manual separation that is often used for quality control as well (Neidel & Jakobsen, 2013, pp. 5, 6)

R.1. Material Recovery Facilities (MRFs): MRFs may use manual and automated sorting systems. MRFs facilities are classified into three groups according to input materials that can manage. The first are called "Clean MRFs", because clean input material is classified, cleaned and prepared for recycling or for fuel production. In developing countries, these facilities often handle a mixture of clean recycling materials. The second are known as "Dirty MRFs" because uses mixed waste as input material, and separates dry recyclables and organic fraction, but since the input materials are mixed in the first place, low quality recyclables are expected. The third and last is "Specific purpose MRFs", which manage an specific waste stream (e.g. e-waste, C&D or plastic) (D. Wilson et al., 2015, p. 74)

R.2. Waste sorting centers: Refers mainly to facilities in which waste is sorted manually, and it is often carried out by the informal sector in official waste management facilities. However, in practice these centers include a large variety of sorting methods, making difficult to differentiate from a MRFs plant (D. Wilson et al., 2015, p. 74).

R.3. Mechanical biological treatment facilities (MBTs): MTBs are waste processing facilities that combine several sorting methods with some form of biological treatment (e.g. composting, anaerobic digestion, etc.). These facilities accept several unsegregated input materials, for instance mixed MSW from households, commercial establishments and even some industrial waste. MBTs are designed a planned for processing an specific waste stream and produce desired outputs such as dry recyclates, organic-rich (e.g. compost-like output CLO) and fuel-rich fractions (refuse derived fuel RDF/ solid refused fuel SRF) (D. Wilson et al., 2015, p. 75). The organic treatments used in a MBT plant are further explained in the following chapter titled "Treatment", under the classification "Organic recovery".

R.4. Integrated Resource Recovery Centers (IRRCs): In Asia, United Nations Economic and Social Commission has largely promoted a type of waste sorting centers called 'Integrated Resource Recovery Centers' which works very similarly to an MBT plant (D. Wilson et al., 2015, p. 74)

5.3.4. Treatment

▼ **Organic Recovery (OR) :**

T.1. Composting: Biological process in which biodegradable solid waste discompose mainly under controlled aerobic conditions, to generate *compost* material to be used as soil amendment, fertilizer or growth medium (Eawag/Sandec, 2008; United Nations Environment Programme & CalRecovery Inc., 2005, p. 197). The feedstock that can be used for composting covers a wide range of organic waste such as wood waste, yard/garden waste and food waste. In developing countries, nearly 50 to 70% of the MSW is compostable (D. Wilson et al., 2015). Some of the advantages for developing countries are its inexpensive costs, that it contributes to the reductions of GHG, and that it improves recycling, incineration and landfill's capacity (Daniel. Hoornweg et al., 1999). Despite of its mayor advantages, composting in developing countries has faced mayor challenges. Many composting plants of mixed waste have failed or are working at 30% of their full capacity. The main reasons are that the costs (mainly transportation and operative costs) exceed the profits; the compost product is not always the best quality due to poor sorting; lack of knowledge in the process; and high competition in the market because chemical fertilizers are affordable and often are subsidized (Eawag/Sandec, 2008, p. 17). The composting systems that have succeed in developing countries are the ones which uses only source-separated feedstock (e.g. market waste, restaurant waste, yard waste, etc.).

Composting technologies are mainly two, enclosed and open systems. Enclosed systems (or in-vessel) refers to a technical system enclosed into a building consisting on a drum and agitated bed technologies. These systems produce compost in shorter time span and uses less land, yet it might be costly for some developing countries especially if the system is automated, costs range from $40USD/ton to $100USD/ton (Eawag/Sandec, 2008, p. 17). There are many types of enclosed systems, some of them are: dano drum, other horizontal drum systems, naturizer system, channel-type, and fairfield reactor (United Nations Environment Programme & CalRecovery Inc., 2005).

Open systems are the simplest composting technologies since decomposition happens naturally in controlled conditions (e.g. temperature, moisture and aeration are constantly monitored), but it takes more time (Eawag/Sandec, 2008, p. 17). There are mainly two open systems 'static windrow' and 'turned windrow' (United Nations Environment Programme & CalRecovery Inc., 2005). These systems are very affordable since they do not require specialized machinery, operational costs and energy consumption are low. For instance, operative costs may range between $5USD/ton and $20USD/ton. The system is labor intensive and uses larger amounts of land, so it can be suitable for countries that cannot afford big capital investments and have considerable amount of land and workforce available (Eawag/Sandec, 2008, p. 17).

Composting activities can be carried out at different scales, from smallest to the biggest they are: backyard composting, decentralized community-scale composting, centralized municipal composting, and composting at landfill or incineration sites.(Eawag/Sandec, 2008, pp. 18-20)

T.2. Vermicomposting: Also known as vermiculture, it consists basically on breaking down organic material using the natural digestion of redworms and earthworms, the output product is *vermicast* (or worm castings) which is the worms' excreta and eggs and the actual worms. The worms are rich in protein and can be sold for fish or animal feed, and the vermicast can be used as fertilizer for agriculture since it contains high concentrations of nitrates, calcium, phosphorous and magnesium (Daniel. Hoornweg et al., 1999, p. 35).
This process is more suitable for small-scale or pilot projects, for instance for micro enterprises or for small communities like a village (Eawag/Sandec, 2008). A basic production can have about 60 000 worms, in an area of 2mx1m and can produce about 800kg of vermicast in 3 months (United Nations Environment Programme & CalRecovery Inc., 2005, p. 199). Vermiculture needs considerable care so that it is labor intensive. Vermin conditions such as moisture, temperature and feedstock should carefully monitored, in order to assure a healthy environment to foster growth, and to minimize the presence of pathogens in the end product and reduce heavy metals in the worms' tissue (Eawag/Sandec, 2008; Daniel. Hoornweg et al., 1999).

T.3. Black Soldier Flies: It is another animal-based method which uses the life cycle of the Hermetia illucens fly to decompose organic waste. It consist on feed the larva with organic material then when larva has feed its last stage as larva before become fly, it will be harvested, this life stage is known as prepupae. The output product are the *prepupae*' bodies that can be used for fish and poultry feed, for their rich content of protein and fat. With this method organic matter is reduce by 40-50% in mass, so that it is as effective as composting or a biogas unit (Eawag/Sandec, 2008).

T.4. Animal feeding: Refers to direct use of clean food waste that has been segregated at the source for animal feeding. This practice is popular in countries such as Japan and the Republic of Korea and is regulated by the law(D. Wilson et al., 2015, p. 75). The recycling of food waste for animal feeding is a whole business industry in Japan, where food recyclers turn waste into animal feed following strict industrial processes. The law of "Promotion of Recycling and Related Activities for the Treatment of Cyclical Food Resources (2001; revised 2007)" regulates recycling of waste generated along the value chain (food-business and consumers) in order to ensure a safe, clean and stable supply food waste for the big recycling industry in the country. In EU and UK, this ancient practice has been banned because it might spread pathogens and diseases to the animals (D. Wilson et al., 2015, p. 140). Animal feeding in the waste hierarchy ranks higher than composting due that the full nutritional value of the food waste is used (Eawag/Sandec, 2008).

T.5. Biogasification: Also known as Anaerobic Digestion (AD), biomethanisation or methane fermentation. Biogasification refers to the biological decomposition of complex organic matter by various bacterial activities under anaerobic conditions, in order to produce *biogas*, and *digestate* which is a mixture of biomass and inert organics (Vögeli, 2014, s. 24; United Nations Environmental Program (UNEP), 2005). The resultant biogas is mainly methane (40-70%) and carbon dioxide (30-60%), the remaining percentage is composed by water (2-7%) and other gases such as H2S, N, O, H and NH3 (1-5%) (Vögeli, 2014; Hemkendreis;Güdel;Vögeli ;& Peter, 2008). The quality of biogas produced is determined by the efficiency of the burners or appliances used in the process, however it has been estimated that in average, biogas has calorific value of 6 kWh/m3 which is equivalent to half litre of diesel (Eawag/Sandec, 2008).

Biogasification presents optimal results treating wet wastes such as sewage sludge, livestock wastes, food waste and night soil. Yet not all organic wastes can be easily treated with this method as is the case of, lignin-rich waste (woody waste, rice hulls and straw) and wastes with high content of ammonia (poultry manure) (D. Wilson et al., 2015). Other substances considered as Ad inhibitors are oxygen, hydrogen sulfide, organic acids, heavy metals and other hazardous substances like disinfectants, contaminated soil, or herbicides and pesticides (Vögeli, 2014). In the case of MSW, biogasification is recommended for clean source-segregated wastes preferably. Mixed organic wastes can be problematic for this method due to its high solid content, large particle size and the difference in chemical composition (D. Wilson et al., 2015).

The technologies used for AD are diverse and range in complexity, some can be simple cylindrical digesters with no moving parts and others can be fully automated units or industrial facilities. Often these technologies are classified according the type of digested used and some operational features of the biogas system. AD systems are categorized for instance depending of the total solid content of the feedstock (wet vs. dry systems), or according to the feeding mode (continuous vs. batch), or according to the operating temperature (mesophilic vs. thermophilic), and according to number of stages of the biochemical reactions (single-, two-, and multi-stage systems) (Vögeli, 2014).

In developing countries, the most common AD systems used are wet digestion systems working under mesophilic conditions in continuous feeding mode. The most used digesters types are: fixed-dome digester, floating-drum digester, tubular digester, and garage type digester (Vögeli, 2014).

These type of digesters are affordable, have simple non-automated systems and can be built with local materials, therefore less likely to fail. Nevertheless, it would be recommended to consider the addition of other digester types that could suit the local conditions of emerging economies as well.

- ▼ **<u>Fuel and Energy Recovery (FER)</u>**

T.6. Gasification: This process was originally used to recover energy from solid fuels (e.g. coal), but recently has been successfully used for MSW waste and it has showed great potential to be a better environmental and economic alternative for waste-to-energy

(Bacher et al., 2012; D. Wilson et al., 2015). Waste gasification is mainly suitable for refused fuels (RDF/SRF), and some other organic waste with high carbon content as wood waste, sewage sludge, agricultural residues and plastics (D. Wilson et al., 2015). The process consists in partially combust the waste in the presence of limited amounts of oxygen in the form of air, steam or pure oxygen to make it react with the carbon present in the waste, that reaction produces as result *gas, ash* and *tar*(Williams, 2005). The reaction occurs at different temperatures depending on the oxygen' form, e.g. air gasification happens at 800-1000°C, with oxygen happens at 1000-1400°C, or with steam happens at 700-900°C (Williams, 2005). In all gasification processes, the resulting gas is a mixture of carbon dioxide, carbon monoxide, hydrogen and methane, the only difference is that with air gasification the resulting gas has nitrogen as a mayor component (Williams, 2005, p. 138). There are different types reactor systems used for waste gasification, the main types are: updraft gasification, downdraft gasification, fluidized bed, entrained flow gasification and rotatory kiln gasification (Williams, 2005).

T.7. Pyrolysis: Likewise gasification, pyrolysis is a viable alternative for waste treatment in the future (Bacher et al., 2012; D. Wilson et al., 2015)**.** The process of pyrolysis works similarly to gasification but without the presence of oxygen. Pyrolysis is a thermal method in which organic waste is ignited in the absence oxygen to produce char, oil and flammable gases (Williams, 2005). Pyrolysis has been used to treat cellulose waste (wood, paper, cardboard), tyre, RDF, plastics (including composite plastics) and textile waste, and sewage sludge. In the process, the temperatures used are relatively lower than other competitive thermal processes (e.g. gasification or combustion), often it ranges between 400-800 °C. The heating rate used in pyrolysis among other considerations, can be adjusted to the desired output or end-product, so that controlling the heating rate is possible to control the amount produced of *oil, char* or *gas* (Williams, 2005). The types of pyrolysis can be classified according to the heating rate. According to Williams (2005, p. 330), the most common pyrolysis processes with their heating rates are: Carbonization (very low), conventional (low-moderate), flash-liquid (high), flash-gas (high), ultra (very high). Other types: vacuum (medium), hydropyrolysis (high), and methanolysis (high).

T.8. Landfill gas (LFG) utilization: LFG is a mixture of gases produced by microbes when waste decays in anaerobic conditions. This gas is mainly composed by ~40-60% methane and the remaining percent is carbon dioxide. LFG also contains ~5% nitrogen, hydrogen and oxygen, and about 1% contains NMOCs (non-methane organic compounds) which is a mixture of hundreds of pollutants like GHG, VOCs, and HAP (EPA U.S. Environmental Protection Agency, 2008; Johannessen, 1999).
LFG collection systems are basically a set of perforated pipelines placed horizontally and vertically surrounding and connecting the landfill' cells where the LFG is collected. There are two collection systems known as active and passive. Active systems come equipped with a vacuum system in which mechanical blowers or compressors are used to optimize

the process. Passive systems use merely natural pressure (atmospheric pressure)(EPA U.S. Environmental Protection Agency, 2008)

Once LFG is collected, the gas can be combusted with or without energy recovery or upgraded to be used as fuel or to put directly into the gas pipeline. Some combustion techniques without energy recovery are for instance flares (burner design either closed or enclosed) and thermal incinerators. Other combustion techniques with energy recovery to produce *electricity* are gas turbines, reciprocating engines and boilers. Regarding to upgrading techniques or purification techniques there is two categories: (1) techniques to produce *medium-BTU gas* (industrial fuel): dehydration and filtration. (2) Techniques to produce *high-BTU gas* (gas for pipeline): adsorption, absorption and membranes(EPA U.S. Environmental Protection Agency, 2008, p. 2).

T.9. Combustion with energy recovery as electricity and/or heat: Combustion of MSW is a well-known method to reduce significantly the waste volume in a 70-75% and its weight up to 90% (Eawag/Sandec, 2008; Daniel Hoornweg & Bhada-Tata, 2012). Combustion or incineration with energy recovery facilities are usually known as "waste-to energy plants". In these plants, the calorific content of waste is ignited in the presence of oxygen to heat up a water boiler where steam is produced. Then, the steam can be directly used for heating (e.g. district heating) or used to power turbines to generate electricity for sale, or the combination of both for heat and power systems (CHP)(Eawag/Sandec, 2008; Williams, 2005). The most common combustion systems suitable for MSW are: travelling grate, rotary kilns and fluidized beds (Bacher et al., 2012, p. 50). Waste incineration is a costly treatment because they are not only equipped with a burning unit but, it also has to have an expensive highly efficient gas-clean up system, in order to control the air emissions, acid gases, heavy metals and dioxins (Williams, 2005; D. Wilson et al., 2015). The most important factor to consider a incineration plant is the waste composition and its calorific value; the waste can be used as fuel only when its average calorific value during is at least 7MJ/kg, and it is never less than 6 MJ/kg in any period of the year (Rand et al., 2000, p. 6). In developing countries, MSW has a high moisture and low calorific value, perhaps due to the fact that useful waste for incineration (e.g. paper, cardboard and some plastics) are removed by informal waste collectors, and the majority of the waste stream is composed by organic material that does not burn without auxiliary fuel (Rand et al., 2000). In those cases, MSW can be mix with institutional, industrial and commercial waste in order to increase the overall calorific value (Rand et al., 2000). Therefore, the suitability of waste-to-energy plant in developing countries does not only depend on technical and financial aspects, but social impacts must be carefully consider as well.

T.10. Co-combustion in an industrial facility: This is another method for combustion of MSW, in which the segregated high calorific content of the waste is combusted in an industrial facility (Leavens, ym., 2003), for instance in cement kilns, paper mill furnaces, small plants for district heating, industrial boilers or power plants (Williams, 2005; D.

Wilson et al., 2015). Co-combustion is suitable for RDF and SRF produced in MTB plants because, many of these industrial facilities are already equipped with special air pollution systems, so ash and hazardous gases that the refused fuel may contain will not be released into the atmosphere (D. Wilson et al., 2015). The most common combustion system used for waste fuel is 'fluidized bed', in which the fuel is placed into a bubbling bed of hot sand and heated up at 800°C until reach the combustion point (Williams, 2005). Co-combustion in cement kilns has been already tested and proven to work in several developing countries such as, Brazil, Sri Lanka, Ecuador, Malaysia, Pakistan, Tanzania and Vietnam (D. Wilson et al., 2015).

5.3.5. Disposal and/or use

▼ **Controlled disposal**

In developing countries, proper landfilling is still a challenge due to the availability of open dumping as an accepted way to manage MSW. Therefore, in this section the disposal options cover the progress moving towards totally controlled disposal, starting from less controlled option (D.1) until the most environmentally sound manner (D.4.).

Controlled disposal implies the proper management of landfill gas and leachate among other managerial considerations, in order to protect the environment from the negative impacts of waste degradation (Hoornweg D. B., 2012). The disposal options here included gradually increase control measures and implement the use of engineer solutions to manage the processes and its emissions.

D.1. Semi-controlled dump: Refers to a dumpsite with few controls in place, in which waste is placed directly in the site with certain level of organization but without compaction. Informal waste pickers often collect recyclables directly from the site. Yet, no engineering measures are in place so there is no control of the contaminants released (Hoornweg D. B., 2012).

Due to the lack of engineering solutions in this site, it would be recommended to describe the legal aspects in which this site operates, in order to clarify the all the controls that can be implemented and clearly explain the difference between this type of dumpsite and open dump.

D.2. Controlled dump: Refers to a registered dumpsite that complies with national legislation and has permit to operate. Controlled dumps count with waste compaction and surface water monitoring, yet no other engineering measures are in place and contaminants are freely released into the environment (Hoornweg D. B., 2012). Like suggested for D.1., controlled dump should be explained including the clear legal framework in which it should operate.

D.3. 'Intermediate' engineered dumpsite/Engineered landfill: Refers to an engineered pit lined at the bottom, in which layers of mixed solid waste are placed, compacted and covered daily with blockage material. The site counts with ground water monitoring and some level of leachate treatment that mostly rely on the containment of leachate using the daily coverage. It has some kind of landfill gas management that mostly rely on flaring or a passive ventilation system (Hoornweg D. B., 2012).

D.4. Sanitary landfill: Refers to a site where waste is safely disposed isolated from the environment in cells underground. There, waste remains until it completely degrades biologically, physically and chemically (Thurgood, Rushbrook, & Pugh, 1998).

5.3.6. Compilation of products

- **Animal food:** "Organic waste reused directly for animal feeding, with or without processing." (D. Wilson et al., 2015, p. 75)
- **Ash:** waste product generated after combustion of MSW.
- **Biogas:** "A mixture of gases, predominantly methane and carbon dioxide, produced by the process of anaerobic digestion." (Vögeli, 2014, s. 5)
- **Biowaste:** "Organic Fraction Of Municipal Solid Waste (OFMSW): The biodegradable fraction of municipal solid waste." (Vögeli, 2014, s. 6)
- **Char:** "The chars may be used directly as fuels, briquetted to produce solid fuels, used as adsorptive materials such as activated carbon, upgraded to produce a higher grade activated carbon, or crushed and mixed with the pyrolysis oil product to produce a slurry for combustion. The calorific value of the chars are relatively high, char derived from municipal solid waste has a calorific value of about 19 MJ/kg, tyre char about 29 MJ/kg and wood waste produces a char of calorific value about 33 MJ/kg. As such, the chars could be used as a medium grade solid fuel." (Williams, 2005, p.331)
- **Compost:** "Compost is the output of a biological process that converts biodegradable waste to a humus-like material. The principal use is to improve soil quality, as compost improves its biological and physical properties, for example enhancing water retention and resistance to erosion, which is particularly valuable in arid climates. It also has some value as fertilizer"(D. Wilson et al., 2015, p. 75)
- **Digestate:** "The solid and/or liquid material remaining after undergoing anaerobic digestion; often still high in nutrient content (see effluent).(…) Effluent: The liquid that remains after a treatment or separation process; it refers to liquid which has gone through some type of clarification, settling, or biological process, flowing out of the digester." (Vögeli, 2014, s. 5;6)
- **Electricity:** out-put product resulting from waste treatment technologies with energy recovery.
- **Ferrous metals** (Steel scrap): metals containing iron.
- **Gases:** all type of gases produced during waste treatment and disposal, except biogas and landfill gas.

- **Glass waste:** "Bottles, broken glassware, light bulbs, colored glass" (Hoornweg et al., 2012, p. 16)
- **Heating:** out-put product resulting from waste treatment technologies with energy recovery e.g. CHP plants.
- **High-BTU gas:** Gas resulting after purification of LFG, "by removal of inert constituents using adsorption, absorption, and membranes." (EPA U.S. Environmental Protection Agency, 2008, p. 2).
- **Inorganic matter:** "Material, such as grit, inorganic salts, metals, glass etc., which is not degraded by microorganisms." (Vögeli, 2014, s. 6)
- **Landfill gas (LFG):** "A mixture of gases (predominantly methane and carbon dioxide) produced through microbial activity in anaerobic conditions during the degradation of waste that is landfilled or dumped." (Johannessen, 1999, p. 8)
- **Leachate:** "Polluted liquid produced as a result of rain or other water percolating through waste that is landfilled or dumped."(Johannessen, 1999, p. 8)
- **Medium-BTU gas:** Gas resulting after purification of raw LFG using dehydration and filtration (EPA U.S. Environmental Protection Agency, 2008, p. 2).
- **Metal waste:** "Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles" (Hoornweg et al., 2012, p. 16).
- **Mixed waste:** mixed and unsorted MSW.
- **Nonferrous metals**: "copper, brass, stainless steel, aluminium, zinc, etc." (Neidel et al., 2013, p. 15)
- **Oil:** (output of solid waste combustion) "the properties of the pyrolysis oil fuel may not match the specifications of a petroleum-derived fuel and may require modifications to the power plant or upgrading of the fuel. In some cases the oil product is described as a liquid but, depending on the feedstock and the pyrolysis process conditions, it may represent either a true oil, an oil/ aqueous phase, separated oil and aqueous phases or, for some waste feedstocks, a waxy material. (…) The oil may be used directly as a fuel, added to petroleum refinery stocks, upgraded using catalysts to a premium grade fuel, or used as a chemical feedstock. The composition of the oil is dependent on the chemical composition of the feedstock and the processing conditions." (Williams, 2005, p. 332)
- **Organic matter:** "Material from animal and vegetable sources which can be degraded by microorganisms." (Vögeli, 2014, s. 7)
- **Other inert materials**: ewaste, nano waste, hazardous waste, medical waste, C&D, WEEE, disaster waste, marine litter.
- **Paper and cardboard:** "Paper and cardboard are sheets of cellulose fibres with a number of chemicals, added to modify the properties and quality of the sheet. (…) for paper recycling it is important to distinguish between types of paper, which are final use products such as newspapers, magazines, corrugated medium, tissue paper, and grades, a term used for waste paper. (…) Paper grades are classes of waste paper that define their quality and for recycling and facilitate its trade, and effectively organizing its collection, sorting, and preparation as feedstock in papermaking." (Villanueva & Eder, 2011, p. 9; 13).

- **Plastic waste:** refuse material made of "highly polymerized compounds consisting of carbon and hydrogen, made from substances such as petroleum and natural gas."(P.W.M.I. Plastic Waste Management Institute, 2009, p. 10) Categorization of plastic waste: bottles and tubes; packs and cups; trays and blister pact; bags; caps and stoppers; cellophane and film; boxes and cases; and others. (P.W.M.I. Plastic Waste Management Institute, 2009, p. 9)
- **Prepupae:** the last larval stage of the Black Soldier Fly, "in which their bodies are rich in protein and fat, thus making them an excellent component of animal feed" (Eawag/Sandec, 2008, p. 20)
- **Recovered cellulose fibre:** Recovered cellulose from paper waste.
- **Recovered Plastics:** preprocessed or processed clean plastic material ready to be remanufactured or reused.
- **Recyclables:** dry waste that can be recycled e.g. paper and cardboard (no contaminated with organic waste), plastics, metals, etc.
- **Refuse derived fuel RDF/SRF:** "RDF usually refers to the segregated high calorific fraction of municipal solid waste (MSW), commercial or industrial process wastes. Other terms are also used for MSW derived fuels such as Recovered Fuel (REF), Packaging Derived Fuels (PDF), Paper and Plastic Fraction (PPF) and Process Engineered Fuel (PEF). REF, PDF, PPF and PEF usually refer to a source-separated, processed, dry combustible MSW fraction (e.g. plastics and/or paper) which are too contaminated to be recycled. It has a higher calorific value, lower moisture content and lower ash content (on combustion) than RDF derived from mixed waste fractions." (Gendebien et al., 2003, p.22)
- **Slurry:** "A semi-liquid mixture of organic material, microorganisms and water." (Vögeli, 2014, s. 7)
- **Tar:** "A dark, thick flammable liquid distilled from wood or coal, consisting of a mixture of hydrocarbons, resins, alcohols, and other compounds. It is used in road-making and for coating and preserving timber." (Oxford University Press, 2017)**.**
- **Textiles and leather waste**
- **Vermicast:** "Worm castings containing high concentrations of nitrates, potassium, calcium, phosphorous, and magnesium and can be applied instead of chemical fertilizers in some agricultural practices. Castings also contain many worm eggs which continue to enrich the soil when it is applied." (Hoornweg et al., 1999, p. 35)

5.4. Final structure of the new compendium for ISWM

The following table summarizes the new structure of the compendium for solid waste management and presents the most important concepts structured, identified and defined in this research.

Table 21. Structure of the new Compendium for ISWM.

Functional Groups	Technologies
User interface	▼ Household waste storage
	U.1: Set-out containers
	▼ Community waste storage
	U.2: Fixed community container
	U.3: Wheeled containers/Portable bins emptied in situ
	U.4: Exchanged containers
Collection and transport	▼ Primary collection
	C.1. Pushcart
	C.2. Cycle cart
	C.3. Motorcycle trailers
	C.4. Two and three-wheeled motor powered vehicles
	C.5. Small trucks
	▼ Secondary collection
	C.6: Agricultural trailers and tractors
	C.7: Exchanged container systems
	C.8: Non-compacting trucks
	C.9: Semi-Compacting Vehicles (SCV)
	C.10: Compaction vehicles
	C.11: Bulk transportation
	C.12: Transfer Systems:
	Rendezvous system, Loading from the ground, Split level transfer stations, Pit and Hoist type small transfer station, Container-to-container transfer systems
Resource recovery and recycling	R.1. Material Recovery Facilities (MRFs)
	R.2. Waste sorting centers
	R.3. Mechanical biological treatment facilities (MBTs)
	R.4. Integrated Resource Recovery Centers (IRRCs)
Treatment	▼ Organic Recovery (OR
	T.1. Composting

Inputs and Outputs
Animal food
Ash
Biogas
Biowaste
Char
Compost
Digestate
Electricity
Ferrous metals
Gases
Glass waste
Heating
High-BTU gas
Inorganic matter
Landfill gas (LFG)
Leachate
Medium-BTU gas
Metal waste
Mixed waste
Nonferrous metals
Oil
Organic matter
Other inert materials
Paper and cardboard
Plastic waste
Prepupae
Recovered cellulose fibre
Recovered Plastics
Recyclables
Refuse derived fuel RDF/SRF

	T.2. Vermicomposting T.3. Black Soldier Flies T.4. Animal feeding T.5. Biogasification ▼ Fuel and Energy Recovery (FER) T.7. Pyrolysis T.8. Landfill gas (LFG) utilization T.9. Combustion with energy recovery as electricity and/or heat T.10. Co-combustion in an industrial facility	Slurry Tar Textiles and leather waste Vermicast
Disposal and/or use	▼ Controlled disposal D.1. Semi-controlled dump D.2. Controlled dump D.3. 'Intermediate' engineered dumpsite D.4. Sanitary landfill ▼ Use	

6. DISCUSSION & CONCLUSIONS

ISWM has been adopted in the national waste strategies of many developing countries during the last three decades. Yet, many countries still seems to struggle with uncontrolled dumping, low service coverage, and expensive collection services that consume the majority of the total budget leaving little capital to invest in recovery, pretreatment, treatment, or safe disposal. All that signs evidence that many waste management systems in developing countries are not being effective. Besides that, when looking at predictions of the waste statistics worldwide, developing countries will double the amount of waste produced by the year 2025, some due to overall increase in economic wealth and others due to population growth. So that, combining a current non-efficient waste management system with the imminent increase of MSW (in so short time-span), the problem is evident and require immediate action.

Waste managers and policy makers in developing countries have been working hard to find suitable technical solutions to improve their waste systems, but in many cases the technologies has not meet their expectations and unfortunately had been likely to fail. This because many developing countries have been acquiring technology that has been successful in developed countries, expecting that it will solve the local problems, yet in many cases that has not been the result. A successfully implemented technology should fit properly the local conditions of climate, economy, socio-cultural, education, labor and level of expertise; if any of those components fail the technology is very likely to fail as well.

Main findings

The author of the present research studied the implementation of the technological component of ISWM in developing countries and proceeded to adjust the planning tool "Compendium of Sanitation Systems and Technologies" (Tilley et al., 2014) for the management of solid wastes. Extended literature can be found for planning ISWM systems, majority of the technical planning tools contain complex loads of information comprised into a set of books or volumes dedicated to the various activities or components of ISWM, which often result overwhelming to the reader. This thesis however adjusted a rather simple planning tool that highlights the integration of waste services within a single compressible structure, which serves for configuring sanitation systems for solid waste management in developing countries.

The research was carried out using as a research method 'qualitative content analysis', whereby 19 public reports issued by relevant international organizations in the field of waste management were analyzed to construct the structure of the new compendium of ISWM.

As result, the new compendium of ISWM contains a robust structure containing: five (5) functional groups (or waste services), thirty-tree (33) sanitation technologies and thirty-five (35) products (inputs/outputs) (see Table 21). Every active part of the structure was defined following the same criteria of the original CSST.

Applications of the new compendium of ISWM

The findings of this study gives to sanitation field a complete conceptual structure of how the technical components of ISWM should harmonically work in the waste chain in order to promote equity, effectiveness, efficiency and sustainability in this important service.

The adoption of the new Compendium of ISWM serves for three purpouses to three different target groups. Firstly, it can be used as a tool for homogenization of waste data regarding waste management systems, so that members of the academy can analyze and compare in an easier way the waste management systems and the way they operate in different municipalities, cities or even countries. Secondly, it serves as a planning tool that planners and decision makers can use to configure their waste systems. Third and lastly, it can be used as a communication tool to transmit valuable information to the other stakeholders that are not involved in the decision making (e.g. community leaders, service users, etc.) regarding changes or improvements made in the system.

As a tool for homogenization of waste data, the compendium provide a clear and versatile structure that can serve to the academy to study and compare different management systems. During the development of the present research and taking into consideration all the literature cited and analized, this is the only structure in ISWM that truly show the integration of waste services in a single matrix. Several studies found have tried to compare different solid waste management systems, a punctual example of this type of study is the document "Solid waste management in the world's cities" (UN-HABITAT - United Nations Human Settlements Program, 2010). The document successfully explains and present valuable data regarding the differences about waste management in the world, but still it seems that the researchers had to rely on very detailed textual descriptions to perform the comparisons due to the fact that, WM data is not homogenous and waste definitions varies greatly.

Besides that, the 20 cities compared in that document have different visual representation of how their management systems work, making very difficult to the researcher and the readers to see and compare the systems. With the adoption of The compendium of ISWM, the field could benefit of a homogenous structure, clearly defined and very versatile to configure any management system for solid waste, and simplify the comparison among them. The comparison of management systems could provide valuable insights and promote learning and innovation in this field.

As a planning tool, the Compendium of ISWM provides planners with a drawing tool that can be used the same that CSST to draw and configure an entire solid waste management system. With the knowledge here compiled, users can contemplate the different technology options that every functional system has to offer and consider which one could suit better to their needs. At this point, the structure has only the definitions of the technologies, but still only with these elements, the users can build their own sanitation systems. Hopefully in the future, the adaptation of the compendium can be completed and offer even more knowledge to the users.

As communication tool, the Compendium of ISWM serves to illustrate graphically how a management system works. This could serve well to spread information to other stakeholders which are not involved in the decision making such as community leaders, service users and other service providers, regarding changes made in the waste systems and how that changes require as well of their collaboration to the successful adoption or improvement of the new technology or practice.

Other findings

During the complexion of the new compendium, the researcher found out important evidence pointing out reasons why some technologies or practices have not been successful in developing countries. According to the findings, one of them is that not always the adoption of the most cutting-edge technology is the solution to the waste related problems. In many cases, simple solutions and small scale technologies can result much more efficient because they adjust better to the local conditions. A predominant example of this issue was found when reviewing the solutions for *collection*. Many capital cities in middle-income countries have been acquiring expensive compactor trucks imported from developed countries, yet according to the findings, that has not improve the collection service, indeed it has make it less cost effective and less versatile.

Other reason found in the data is that, a technology should be adopted only when the whole system can support it. Waste management is chain of reactions in which, the success of a technology depends on the right output coming from other technology or waste service. Virtually all the treatment technologies are designed to handle and specific type of feedstock and produce an specific amount of a desired product or products; but if the flow of the feedstock changes anyhow for instance if it is not available any more or its chemical composition changes, etc., the technology might run into technical or financial problems. A clear example of this issue are the composting plants for mixed waste. Despite its many advantages, it has face failure in many developing countries because the feedstock has a poor sorting and as result compost is not the best quality. Besides that, the transportation and operative cost exceed the profits, because the end product has to face fearless competition in the market with inexpensive and subsidized chemical fertilizers.

Other valuable lesson learned from the data analysis is that, when selecting the technologies suitable for developing countries it is challenging to decide whether costly technologies such as controlled combustion should be recommended or not. Because the author recognizes that many low- and middle-income countries cannot probably afford it, but emerging economies such as BRICS and other countries that are experiencing an economic and industrial burst could and probably should contemplate the adoption of more specialized technology in their waste strategies when suitable.

Findings in comparison with prior literature

Famous environmental organizations had developed very technical and complete managerial tools for implementing ISWM, yet not easily comprehensive or easily adaptable for the complex situation in developing countries. Just to mention couple of examples, The United States Environmental Protection Agency (US EPA), in 1995 published a complete guide called "Decision-Makers' Guide To Solid Waste Management, Volume II", and ten years later United Nations Environmental Program (UNEP) compiled into a series of 4 documents in a training manual called "Developing Integrated Solid Waste Management Plan". Those documents comprise very valuable methods/tools to implement a more sustainable waste management at municipal or even national level. However, they are very detailed and technical oriented, that they do not facilitate the selection of technology for all the stakeholders. These manuals seems to be written by engineers to engineers, and other parties that may not have strong background in engineering might find the information either difficult to understand or too long.
According to the findings of the present research, the adoption of new technology in developing countries have had hard times not because of the technology itself, but because it does not always suit perfectly to the local conditions. Therefore, it seems that ISWM in developing countries has a need of a more fact-based information regarding other managerial considerations besides the technical component.
The definitions included in the new compendium of ISWM, were completed in such a way that economic, environmental and social considerations were mentioned. The structure is rather easy to understand because the information is compiled in a single matrix that works in the very same way that wastes move through the waste chain. So in that sense, the findings of this research contributes with its simplicity to the earlier literature found in ISWM for developing countries.

Limitations of the study

The present research tried to cover a very broad concept with many dimensions, which is often not an easy task. For that reason, the author acknowledges that there were some limitations related mainly to the methodology.
In qualitative studies, the sample sizing is often smaller than in quantitative studies, in this research the data selected seemed to be large and permeated enough to perform the research task. However, when analyzing the data some topics were difficult to cover due that the topic heavily overlapped with others or in other cases, there were lack of information. This happened mostly when separating the technologies for sorting and resource recovery with the treatment technologies, because both of these activities often occur in the same facility or are part of a same process. Because of this, the author decided to be as close as possible to definitions of original CSST in order to minimize the overlapping concepts in the final structure.

Other limitation was the lack of previous studies regarding the implementation of a centain type of technologies in developing countries. It would have been beneficial to have more access to this type of information so that, more practical information could have been added to the

results. Yet in this case, that information was not so mandatory since only the structure and definitions were required. Nevertheless, in case of further research this lack of information can affect greatly the upcoming results.
Other shortcoming was that in WM many concepts are so obvious that is not easy to find complete definitions (e.g. "collection" or "transportation"), that is why was required to complement the primary data (public reports) with educational books that are not so old. Indeed, majority of the textbooks in the field are quite outdated.

Suggestions for further research

With this initial adjustment of the compendium, the author lays down the path for the adoption of a new tool to facilitate the integration of waste services in developing countries. The structure here presented is an invitation to other professionals of the field of waste management and sanitation to continue with the adjustment of CSST. So that planners, engineers, policy makers, regulators and other stakeholders involved in the decision making process can access to a brief fact-based information that not only includes technical features of a wide range of waste technologies, but other important managerial considerations such as: costs, requirements for implementation, maintenance, advantages, disadvantages, health and safety, and stakeholder management factors.

Until this point, the compendium has only structure and conceptual definitions. The author identified three paths for further research towards the full adjustment of the tool.
The first could be the complexion of the *technology information sheets,* which contains all the relevant information regarding every technology (see numeral 3.2.3). The second could be, the configuration of the *system templates,* which are the most common system configurations used in developing countries (see numeral 3.2.2). And the third could be to study the new technologies for solid waste handling in order to explore the potential that they may have in developing countries and contemplate the addition of those technologies in the compendium. The author recommends that every path is studied separately considering the large amount data that they require.

Final remarks
Waste management in developing countries needs to adopt new managerial visions and implement new technical solutions to provide a more sustainable and effective service. To do so, governments, waste managers, policy makers need to focus all their efforts in doing very well informed decisions when planning or improving their waste strategies. The compendium of ISWM is a conceptual tool for planning sanitation systems for solid waste that is especially dedicated to developing countries. This tool contains a wide range of technologies within a single structure that can be used either as a planning tool, communication tool or as a simple source of inspiration to contemplate the most suitable technological options and what they have to offer. With the ultimate goal of reducing pressure on landfill sites, having more efficient system for waste treatment and resource recovery and to provide a cleaner, healthier and more pleasant urban environment to the citizens.

APPENDICES

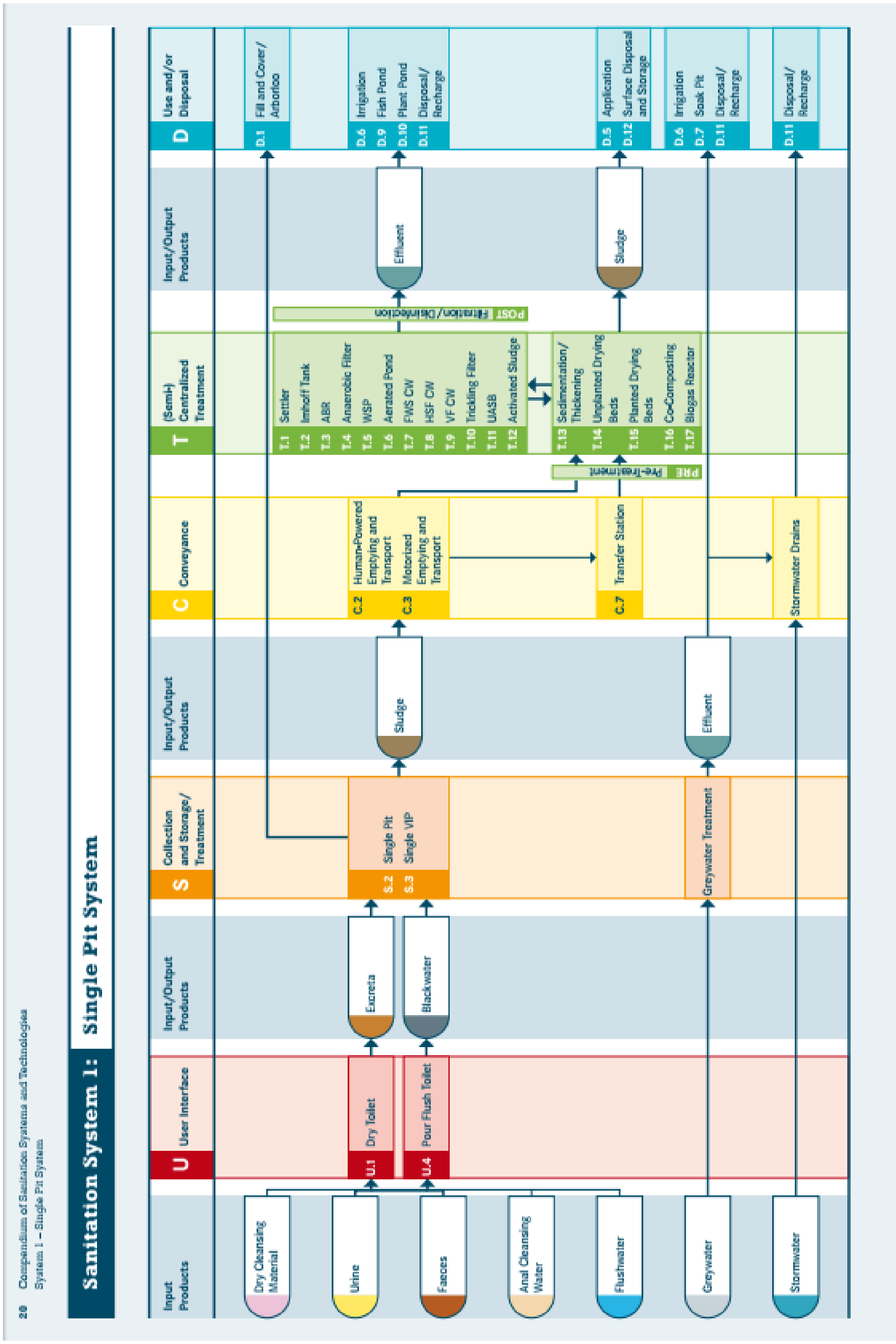
ANNEX 1. European List of MSW
Extracted from: Chapter 20: Classification Of Municipal Waste Including Separately Collected Fractions. (The European Commission, 2000, Pp. 30-31)

▼M1

20	**MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS**
20 01	**separately collected fractions (except 15 01)**
20 01 01	paper and cardboard
20 01 02	glass
20 01 08	biodegradable kitchen and canteen waste
20 01 10	clothes
20 01 11	textiles
20 01 13*	solvents
20 01 14*	acids
20 01 15*	alkalines
20 01 17*	photochemicals
20 01 19*	pesticides
20 01 21*	fluorescent tubes and other mercury-containing waste
20 01 23*	discarded equipment containing chlorofluorocarbons
20 01 25	edible oil and fat
20 01 26*	oil and fat other than those mentioned in 20 01 25
20 01 27*	paint, inks, adhesives and resins containing dangerous substances
20 01 28	paint, inks, adhesives and resins other than those mentioned in 20 01 27
20 01 29*	detergents containing dangerous substances
20 01 30	detergents other than those mentioned in 20 01 29
20 01 31*	cytotoxic and cytostatic medicines
20 01 32	medicines other than those mentioned in 20 01 31
20 01 33*	batteries and accumulators included in 16 06 01, 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries
20 01 34	batteries and accumulators other than those mentioned in 20 01 33
20 01 35*	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components [6]

20 01 36	discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35
20 01 37*	wood containing dangerous substances
20 01 38	wood other than that mentioned in 20 01 37
20 01 39	plastics
20 01 40	metals
20 01 41	wastes from chimney sweeping
20 01 99	other fractions not otherwise specified
20 02	**garden and park wastes (including cemetery waste)**
20 02 01	biodegradable waste
20 02 02	soil and stones
20 02 03	other non-biodegradable wastes
20 03	**other municipal wastes**
20 03 01	mixed municipal waste
20 03 02	waste from markets
20 03 03	street-cleaning residues
20 03 04	septic tank sludge
20 03 06	waste from sewage cleaning
20 03 07	bulky waste
20 03 99	municipal wastes not otherwise specified

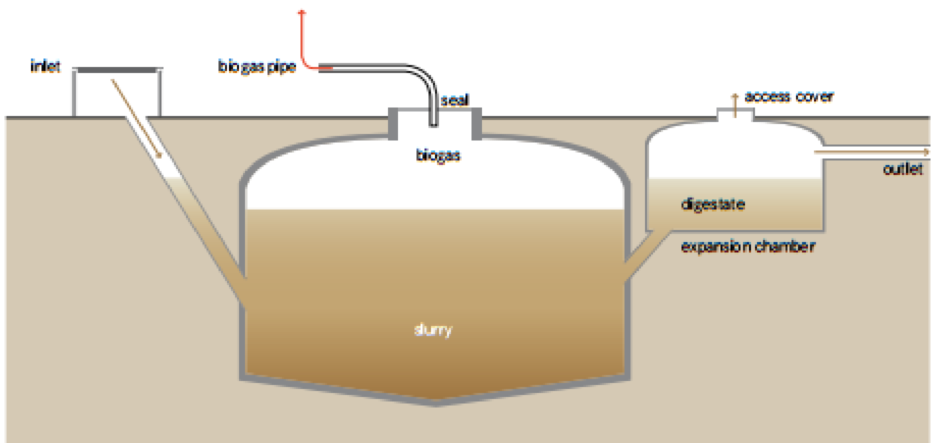
ANNEX 2 Example of a System Template. Sanitation System 1: Single Pit System.
Extracted from: Compendium of Sanitation Systems and Technologies 2nd Edition (Eawag Aquatic Research, 2016)



T.17 Biogas Reactor

Applicable to:
Systems 1, 6-9

Application Level:	**Management Level:**	**Inputs:** Sludge, Blackwater, Brownwater, Organics
** Household	** Household	**Outputs:** Sludge, Biogas
** Neighbourhood	** Shared	
** City	** Public	



A biogas reactor or anaerobic digester is an anaerobic treatment technology that produces (a) a digested slurry (digestate) that can be used as a fertilizer and (b) biogas that can be used for energy. Biogas is a mix of methane, carbon dioxide and other trace gases which can be converted to heat, electricity or light.

A biogas reactor is an airtight chamber that facilitates the anaerobic degradation of blackwater, sludge, and/or biodegradable waste. It also facilitates the collection of the biogas produced in the fermentation processes in the reactor. The gas forms in the slurry and collects at the top of the chamber, mixing the slurry as it rises. The digestate is rich in organics and nutrients, almost odourless and pathogens are partly inactivated.

Design Considerations Biogas reactors can be brick-constructed domes or prefabricated tanks, installed above or below ground, depending on space, soil characteristics, available resources and the volume of waste generated. They can be built as fixed dome or floating dome digesters. In the fixed dome, the volume of the reactor is constant. As gas is generated it exerts a pressure and displaces the slurry upward into an expansion chamber. When the gas is removed, the slurry flows back into the reactor. The pressure can be used to transport the biogas through pipes. In a floating dome reactor, the dome rises and falls with the production and withdrawal of gas. Alternatively, it can expand (like a balloon). To minimize distribution losses, the reactors should be installed close to where the gas can be used.

The hydraulic retention time (HRT) in the reactor should be at least 15 days in hot climates and 25 days in temperate climates. For highly pathogenic inputs, a HRT of 60 days should be considered. Normally, biogas reactors are operated in the mesophilic temperature range of 30 to 38 °C. A thermophilic temperature of 50 to 57 °C would ensure the pathogens destruction, but can only be achieved by heating the reactor (although in practice, this is only found in industrialized countries). Often, biogas reactors are directly connected to private or public toilets with an additional access point for organic materials. At the household level, reactors can be made out of plastic containers or bricks. Sizes can vary from 1,000 L for a single family up to 100,000 L for institutional or public toilet applications. Because the digestate production is continuous, there must be provisions made for its storage, use and/or transport away from the site.

Appropriateness This technology can be applied at the household level, in small neighbourhoods or for the stabilization of sludge at large wastewater treatment plants. It is best used where regular feeding is possible. Often, a biogas reactor is used as an alternative to a Septic Tank (S.9), since it offers a similar level of treatment, but with the added benefit of biogas. However, significant gas production cannot be achieved if blackwater is the only input. The highest levels of biogas production are obtained with concentrated substrates, which are rich in organic material, such as animal manure and organic market or household waste. It can be efficient to co-digest blackwater from a single household with manure if the latter is the main source of feedstock. Greywater should not be added as it substantially reduces the HRT. Wood material and straw are difficult to degrade and should be avoided in the substrate.
Biogas reactors are less appropriate for colder climates as the rate of organic matter conversion into biogas is very low below 15 °C. Consequently, the HRT needs to be longer and the design volume substantially increased.

Health Aspects/Acceptance The digestate is partially sanitized but still carries a risk of infection. Depending on its end-use, further treatment might be required. There are also dangers associated with the flammable gases that, if mismanaged, could be harmful to human health.

Operation & Maintenance If the reactor is properly designed and built, repairs should be minimal. To start the reactor, it should be inoculated with anaerobic bacteria, e.g., by adding cow dung or Septic Tank sludge. Organic waste used as substrate should be shredded and mixed with water or digestate prior to feeding.
Gas equipment should be carefully and regularly cleaned so that corrosion and leaks are prevented. Grit and sand that have settled to the bottom should be removed. Depending on the design and the inputs, the reactor should be emptied once every 5 to 10 years.

Pros & Cons
+ Generation of renewable energy
+ Small land area required (most of the structure can be built underground)
+ No electrical energy required
+ Conservation of nutrients
+ Long service life
+ Low operating costs
- Requires expert design and skilled construction
- Incomplete pathogen removal, the digestate might require further treatment
- Limited gas production below 15 °C

References & Further Reading

_ CMS (1996). *Biogas Technology: A Training Manual for Extension.* FAO/TCP/NEP/4451-T. Consolidated Management Services, Kathmandu, NP.
Available at: www.fao.org

_ GTZ (1998). *Biogas Digest. Volume I-IV.* Information and Advisory Service on Appropriate Technology (ISAT). Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, DE.
Available at: www.susana.org/library

_ Mang, H.-P. and Li, Z. (2010). *Technology Review of Biogas Sanitation. Draft – Biogas Sanitation for Blackwater, Brown Water, or for Excreta Treatment and Reuse in Developing Countries.* Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, DE.
Available at: www.susana.org/library

_ Ulrich, A. (Ed.), Reuter, S. (Ed.), Gutterer, B. (Ed.), Sasse, L., Panzerbieter, T. and Reckerzügel, T. (2009). *Decentralised Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries. A Practical Guide.* WEDC, Loughborough University, Leicestershire, UK.

_ Vögeli, Y., Lohri, C. R., Gallardo, A., Diener, S. and Zurbrügg, C. (2014). *Anaerobic Digestion of Biowaste in Developing Countries. Practical Information and Case Studies.* Eawag (Department Sandec), Dübendorf, CH.
Available at: www.sandec.ch

REFERENCES

Anschütz, J., Ijgosse, J., & Scheinberg, A. (2004). *Putting Integrated Sustainable Waste Management into Practice*. Retrieved from Gouda, The Netherlands:

B.I.R. Bureau of International Recycling. (2016). *World steel recycling in figures 2011 – 2015*. Retrieved from http://www.bir.org/assets/Documents/publications/brochures/160160-Ferrous-report-update-FIN-4-WEB.pdf

Bacher , J., Laine-Ylijok, J., Wahlström, M., Jermakka, J., Teirasvuo, N., Kuosa, H., . . . Luoranen, M. (2012). Directions of future developments in waste recycling. 2012.

Berelson, B. (1952). *Content Analysis in Communication Research*. Glencoe, Ilinois: The Free Press.

Coffey, M., & Coad, A. (2010). *Collection of Municipal Solid Waste in Developing Countries*. Retrieved from Malta:

Downe-Wamboldt, B. (1992). Content analysis: Method, applications, and issues. *Health Care For Women International Vol:13*, 313-321.

Eawag. (2008). *Global Waste Challenge - Situation in Developing Countries.* Swiss Federal Institute of Aquatic Science and Technology. Retrieved from: http://www.pseau.org/outils/ouvrages/eawag_global_waste_challenge_situation_in_developing_countries_2008.pdf

Eawag. (2016). *Compendium of Sanitation Systems and Technologies 2nd Edition. Sanitation System Drawing Tool*. Retrieved from http://www.eawag.ch/en/department/sandec/publications/compendium/

Eawag/Sandec. (2008). *Sandec Training Tool 1.0 – Module 6: Solid Waste Management*. Retrieved from Dübendorf:

Ellen Macarthur Foundation. (2016). *Circular Economy System Diagram*. Retrieved *www.ellenmacarthurfoundation.org//circular-economy/interactive-diagram*.

Elo, S., & Kyngäs, H. (2007). The qualitative content analysis process. *Journal of Advanced Nursing*, 107-115.

Elo, S., Kääriinen, M., Kanste , O., Pölkki, T., Utriainen, K., & Kyngäs, H. (2014). Qualitative Content Analysis: A Focus on Trustworthiness. *SAGE Open*, 1-10.

EPA U.S. Environmental Protection Agency. (2002). *Solid Waste Mangement: A Local Challenge with Global Impacts.* EPA530-F02-026.

EPA U.S. Environmental Protection Agency. (2008). Chapter 2: Solid Waste Disposal. Sectional 2.4 MUNICIPAL SOLID WASTE LANDFILLS *AP-42: Compilation of Air Emission Factors* (Fifth Edition ed., Vol. I, pp. 30).

EUROSTAT. (2015, 10 1). Waste stadistics. European Union. Retrieved 10 25, 2015, from http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation

European Environmental Agency. (2013). *Managing municipal solid waste: A review of achivements in 32 European Countries*. Retrieved from Copenhagen:

Gendebien, A., Leavens, A., Blackmore, K., Godley, A., Lewin, K., Whiting, K., Davis, R., Giegrich, J., Fehrenbach, H., Gromke, U., del Bufalo, N., & Hogg, D. (2003). *Refuse Derived Fuel, Current Practice and Perspectives (B4-3040/2000/306517/Mar/E3). WRc Ref: CO5087-4.*

WRc plc. Retrieved 10 17, 2015, from http://ec.europa.eu/environment/waste/studies/pdf/rdf.pdf
Global Waste Challenge - Situation in Developing Countries. (2008). *Eawag Aquatic Research*. Retrieved from http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/General_Overview/Eawag_Sandec_2008.pdf
Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today Ed:24*, 105-112.
Health topics. (2016, 8 8). *Sanitation*. Retrieved from http://www.who.int/topics/sanitation/en/
Health topics - Sanitation (2016, 04 12).
Hoornweg, D., & Bhada-Tata, P. (2012). What a Waste : A Global Review of Solid Waste Management. *World Bank, No. 15*, 116.
Hoornweg, D., Thomas, L., & Otten, L. (1999). *Composting and Its Applicability in Developing Countries*. Retrieved from Washigton DC: http://documents.worldbank.org/curated/en/483421468740129529/Composting-and-its-applicability-in-developing-countries
Hsieh , H., & Shannon, S. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research Vol.15*, 1277-1288.
Johannessen, L. M. (1999). *Guidance note on recuperation of landfill gas from municipal solid waste landfills* (19791). Retrieved from Washington D.C.: http://documents.worldbank.org/curated/en/892171468766767158/Guidance-note-on-recuperation-of-landfill-gas-from-municipal-solid-waste-landfills
Krippendorff, K. (1980). *Content Analisis: An Introduction to its Methodology*. Newbury Park: Sage Publications.
Kyngäs, H., & Vanhanen, L. (1999). Content analysis. *Hoitotiede 11*, 3-12.
Letcher, T. M., & Vallero, D. A. (2011). *WASTE - A handbook for management*. Burlington, MA 01803, USA: Academic Press - Elsevier.
Mushtaq M., & Surya C. (2016). Integrated Solid Waste Management: Process to develop a ISWM plan. Osaka, Japan: UNEP: International Environemental Technology Center.
Neidel, T. L., & Jakobsen, J. B. (2013). *Report on assessment of relevant recycling technologies*. Retrieved from http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=PLASTIC_ZERO_annex_d32_action4.2_report_on_assessment_sept2013_final.pdf
Organization for Economic Co-operation and Development. (2001). Glossary of Statistical Terms: Waste Collection. Retrieved 19.10.2016 https://stats.oecd.org/glossary/detail.asp?ID=2897
P.W.M.I. Plastic Waste Management Institute. (2009). *An Introduction to Plastic Recycling*. Retrieved from https://www.pwmi.or.jp/ei/plastic_recycling_2009.pdf
Rand, T., Haukohl, J., & Marxen, U. (2000). *Municipal Solid Waste Incineration - A Decision Maker's Guide* (21091). Retrieved from Washington D.C.:

http://documents.worldbank.org/curated/en/206371468740203078/Municipal-solid-waste-incineration-a-decision-makers-guide
Rothenberger, S., Zurbrügg, C., Enayetullah, I., & Sinha, A. H. M. M. (2006). *Decentralised Composting for Cities of Low- and Middle Income Countries - A Users' Manual*. Duebendorf, Switzerland: Waste Concern and Eawag.
Schluep, M., Hagelüken, C., Meskers, C. E. M., Magalini, F., Wang, F., Müller, E., . . . Sonnemann, G. (2009). *Market potential of innovative e-waste recycling technologies in developing countries.* Paper presented at the R'09 World Congress, Davos, Switzerland.
Schübeler, P., Wehrle, K., & Christen, J. (1996). *Conceptual Framework for Municipal Solid Waste in Low-Income Countries - Working Paper No.9*. Retrieved from St. Gallen, Switzerland:
Solid waste magement: a local challenge with global impacts. (2016, 05 03).
Spuhler, D., & Gensch, R. (Producer). (2016, 04 12). Sanitation systems. *Sustainable Sanitation and Water Management (SSWM)*. Retrieved from http://www.sswm.info/category/implementation-tools/wastewater-collection/hardware/introduction/sanitation-systems
Statistics Finland, O. S. o. (2015, 10 27). Waste statistics [e-publication]. *Statistics Finland.* Retrieved from http://www.stat.fi/til/jate/kas_en.html

The World Health Organization (WHO). (2016). Health topics - Sanitation . Retrieved from: http://www.who.int/topics/sanitation/en/

Thurgood, M., Rushbrook, P., & Pugh, M. (1998). *Decision-maker's guide to solid waste landfills - Summary*. Retrieved from Washington DC: http://documents.worldbank.org/curated/en/814611468765273519/Decision-makers-guide-to-solid-waste-landfills-Summary
Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrügg, C. (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition*. Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).
UNEP & CalRecovery (2005). *Solid Waste Management* (Vol. I). California, United States: United Nations Environmental Program UNEP.
UNEP. International Environmental Technology Center. (2009). *Developing Integrated Solid Waste Management Plan. Vol 4: ISWM Plan*. Retrieved from Osaka/Shiga, Japan:

UNDESA. United Nations Department of Economic and Social Affairs. (2012). *Shanghai Manual - A Guide for Sustainable Urban Development in the 21st Century*. Chapter 5 - Municipal Solid Waste Management: Turning Waste Into Resources. Retrieved http://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/shanghaimanual/Chapter%205%20-%20Waste_management.pdf
United Nations Environment Programme. (2011). *Waste - Investing in energy and resource efficiency*. Retrieved from
United Nations Environment Programme, & CalRecovery Inc. (2005). *Solid Waste Management*: United Nations Environment Programme.

United Nations Human Settlements Programme. (2010). *Solid Waste Management in the world's cities*. London: Earthscan 2010.
van de Klundert, A., & Anschutz, J. (2001). *Integrated Solid Waste Management - the concept*. Retrieved from Gouda, the Netherlands:
Waste stadistics. (2015, 10 1).
Weber, R. P. (1990). *Basic Content Analysis*. Newbury Park: Sage Publications, Inc.
Villanueva, A., & Eder, P. (2011). End-of-waste criteria for waste paper: Technical proposals. *European Commission - Joint Research Centre Institute for Prospective Technological Studies*, 101. doi:10.2791/57814
Williams, P. T. (2005). *Waste treatment and disposal 2nd edition*. England, West Sussex: John Wiley & Sons, Ltd.
Wilson, D., Rodic, L., Modak, P., Soos, R., Carpintero, A., Velis, C., . . . Simonett, O. (2015). *Global Waste Mangement Outlook* (David C. Wilson Ed.). Viena, Austria: United Nations Environment Programme.
Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C., & Alabaster, G. (2012). Comparative Analysis of Solid Waste Management in 20 cities. *Waste Management & Research*, 30(33),237-225.
Wilson, D. C., Rodic, L., & Velis, C. A. (2013). Integrated sustainable waste management in developing countries. *Proceedings of the Institution of Civil Engineers: Waste and Resource Management Vol. 166*, 52-68.
Vögeli , I., Riu, C., Gallardo, A., Diener, S., & Zurbrügg, C. (2014). *Anaerobic Digestion of Biowaste in Developing Countries*. Dübendorf: Eawag – Swiss Federal Institute of Aquatic Science and Technology / Department of Water and Sanitation in Developing Countries (Sandec).