

GENERATION AND DISPOSITION OF MSW IN MEXICO AND POTENTIAL
FOR IMPROVING WASTE MANAGEMENT IN TOLUCA MUNICIPALITY



María Gaviota Velasco Pérez Alonso

Advisor: Professor Nickolas J. Themelis

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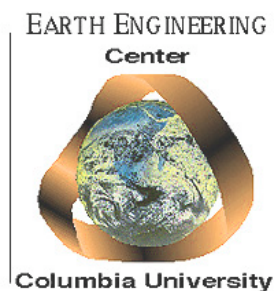
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EXECUTIVE SUMMARY

The purpose of this study was to examine the generation and disposition of municipal solid wastes (MSW) in Mexico and, particularly in Toluca (population 0.82 million), the capital city of the State of Mexico. Based on the results of this investigation, sets of actions are recommended for implementing a more sustainable management system in the municipality of Toluca.

The first part of this research was focused on quantifying the current MSW practice in Mexico. It was found that well developed processes such as recycling, composting and incineration with energy recovery have not generated the expected results in this country. Most of the treatment sites have stopped operating because of high capital and operating costs, or lack of markets due to the poor quality of the recovered materials and lack of source-separation programs. Also, in the case of recycling, one of the biggest challenges in Mexico and Toluca is educating citizens about the benefits of recycling and increasing their environmental awareness.

The analysis of Toluca's waste management system showed that it is far from the generally accepted hierarchy of waste management. Of the estimated 295,000 tons of MSW generated, 186,000 tons (63% of the total) are landfilled in two sanitary landfills outside the city that recover and flare landfill gas, 24,000 tons (8% of total) are recycled and an estimated 85,000 tons (29% of total) are disposed in non-regulated dumps ("tiraderos"). The municipality of Toluca is fully aware of this major environmental problem and is planning to increase collection coverage and proper disposal of MSW to 100% by 2012. There is no reported up-to-date information regarding composting. The small recycling activity is not part of the official municipal MSWM system. Actions such as the installation of collection centers are helpful but not part of the system.

In addition to collecting and analyzing information on the waste management of Toluca, the author carried out a survey in order to get a better insight of the perception of the MSW management system and waste treatment techniques by citizens of Toluca municipality. This survey was conducted from September to November 2010 and about 400 people responded, 60% living in Toluca, and the rest either working or studying in Toluca. Based on the collected information and the

results of this survey, the following measures are suggested for improving MSW management practices in Toluca:

- Include issues related to MSW management in school curricula at all levels.
- Support and legitimize informal recycling businesses, such as the ones carried out by itinerant buyers and scavengers.
- Since the municipality is already planning to build two waste transfer stations, it is recommended to use these sites also as material recovery facilities (MRFs).
- Due to the lack of a source-separation program and an appropriate infrastructure, landfilling of the MSW organic fraction (which comprises the largest share of Toluca's MSW composition) can be reduced by implementing windrow and household composting.
- Since there is not an appropriate site for building a sanitary landfill within the municipality of Toluca, it is recommended to take a regional approach, by building an inter-municipal infrastructure.
- Effective dissemination of information to the citizens regarding the benefits of recycling, composting, and sanitary landfilling over waste dumps.
- Remediate existing waste dumps and avoid creating new ones by increasing collection coverage from the present 63%.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	2
LIST OF FIGURES	6
LIST OF TABLES	9
ABBREVIATIONS	10
ACKNOWLEDGEMENTS	12
INTRODUCTION	13
CHAPTER 1: WASTE MANAGEMENT	15
1.1 DEFINITION OF WASTE	15
1.2 WASTE CLASSIFICATION	15
1.2.1 <i>Types by state</i>	15
1.2.2 <i>Types by origin</i>	15
1.2.3 <i>Types by handling</i>	16
1.3 SOLID WASTE MANAGEMENT	16
1.4 HIERARCHY OF WASTE MANAGEMENT	17
CHAPTER 2: WASTE MANAGEMENT SITUATION IN MEXICO	23
2.1 MEXICO: POPULATION, GEOGRAPHY AND ADMINISTRATION	23
2.2 WASTE MANAGEMENT HISTORY	24
2.3 REGULATORY FRAMEWORK	25
2.4 MSW IN MEXICO: MANAGEMENT SYSTEM AND CHARACTERIZATION	27
2.4.1 <i>Characterization</i>	27
2.4.1.1 Physical properties	27
2.4.1.2 Chemical properties.....	27
2.4.2 <i>MSWM system</i>	28
2.4.2.1 Generation of MSW in Mexico	29
2.4.2.2 Composition	31
2.4.2.3 Temporal Storage	33
2.4.2.4 Sweeping	35
2.4.2.5 Collection.....	35
2.4.2.6 Transportation and Transference	37
2.4.2.7 Treatment:	38
Recycling.....	38
Composting:.....	41
Incineration	41
2.4.2.8 Final Disposition	41
2.5 LANDFILL GAS (LFG) RECOVERY AND USE IN MEXICO	44
2.5.1 <i>LFG recovery</i>	44
2.5.2 <i>LFG utilization</i>	45
2.5.3 <i>LFG Recovery and Utilization potential in Mexico</i>	46
2.5.4 <i>LFG recovery and utilization sites in Mexico</i>	48
2.5.4.1 Salinas Victoria Sanitary Landfill	48
2.5.4.2 Merida Sanitary Landfill	51
2.5.4.3 San Nicolas de Arriba Sanitary Landfill.....	53
2.5.4.4 Chiltepeque Sanitary Landfill	54
2.5.4.5 Ciudad Juarez Sanitary Landfill	55
2.6 WASTE MANAGEMENT NATIONAL STRATEGIES: THE NATIONAL PROGRAM FOR THE PREVENTION AND THE INTEGRAL WASTE MANAGEMENT 2009-2012.....	57
2.6.1 <i>Implementation Advancements</i>	58
2.6.2 <i>Future Impacts</i>	59
CHAPTER 3: WASTE MANAGEMENT SITUATION IN TOLUCA	60
3.1 TOLUCA: POPULATION, GEOGRAPHY AND ADMINISTRATION	60

3.2 REGULATORY FRAMEWORK	62
3.3 MSW IN TOLUCA: MANAGEMENT SYSTEM AND CHARACTERISTICS	64
3.3.1 MSWM system	64
3.3.1.1 Generation	65
3.3.1.2 Composition	65
3.3.1.3 Temporal Storage	66
3.3.1.4 Sweeping	67
3.3.1.5 Collection and disposal of MSW	68
Collection Routes.....	69
3.3.1.6 Transportation and Transference	70
3.3.1.7 Treatment.....	73
Recycling.....	73
Composting.....	79
3.3.1.8 Final Disposition	79
Sanitary Landfill of San Antonio La Isla Municipality	81
Sanitary Landfill of Zinacantepec Municipality.....	84
3.4 MSWM SERVICES AND TREATMENT PERCEPTION SURVEY.....	88
3.4.1 Methodology	89
3.4.2 Sampling Procedure	89
3.4.3 Results.....	90
CHAPTER 4: POTENTIAL FOR IMPROVEMENT IN TOLUCA	100
4.1 PROJECTED MSW GENERATION AND COMPOSITION IN TOLUCA	100
4.1.1 Waste Prognosis Tool.....	101
4.1.2 Adapting the Waste Prognosis Tool to Toluca Municipality	103
4.1.3 Toluca MSW generation and composition: 2010 – 2015 Forecast.....	104
4.2 PREVENTIVE AND CORRECTIVE MSWM STRATEGIES IN TOLUCA	106
4.3 POTENTIAL FOR IMPROVEMENT IN TOLUCA	110
4.3.1 Waste Reduction Strategies	112
4.3.2 Recycling Strategies.....	113
4.3.3 Anaerobic digestion and Aerobic composting Strategies	115
4.3.4 Waste-to-energy Strategies.....	119
4.3.5 Sanitary landfill recovering and using or flaring CH ₄ Strategies.....	120
4.3.6 Non-regulated landfills Strategies.....	123
CONCLUSIONS AND FUTURE WORK	124
REFERENCES	127
INTERVIEWS	134
APPENDICES.....	135
APPENDIX I.....	136
APPENDIX II.....	141
APPENDIX III	142
APPENDIX IV.....	145
APPENDIX V	146
APPENDIX VI.....	148

LIST OF FIGURES

FIGURE 1: HIERARCHY OF WASTE MANAGEMENT	17
FIGURE 2: A TYPICAL WTE PLANT.	22
FIGURE 3: POLITICAL ADMINISTRATION MAP OF MEXICO	24
FIGURE 4: MSW FLOW SYSTEM	29
FIGURE 5: MEXICO MSW GENERATION BY STATE IN 2008.....	30
FIGURE 6: MSW GENERATION DISTRIBUTION IN MEXICO 2008,	31
FIGURE 7: MEXICO MSW COMPOSITION IN YEAR 2009	32
FIGURE 8: HISTORIC MSW COMPOSITION IN MEXICO.	32
FIGURE 9: HOUSEHOLD TEMPORAL STORAGE.....	34
FIGURE 10: CONTAINERS IN STREETS AND PUBLIC SPACES.....	34
FIGURE 11: SWEEPING SERVICES IN MEXICO.....	32
FIGURE 12: MSW COLLECTION DISTRIBUTION IN MEXICO 2008	36
FIGURE 13: MSW RECYCLED IN MEXICO 2008.	38
FIGURE 14: COMMERCE OF WASTE FOR RECYCLING BUSINESS IN MEXICO 2003.....	39
FIGURE 15: MSW DISPOSITION IN MEXICO 2008	43
FIGURE 16: MSW WITH ADEQUATE FINAL DISPOSITION IN MEXICO 2008.....	43
FIGURE 17: PASSIVE METHANE GAS VENTING SYSTEMS.....	44
FIGURE 18: ACTIVE (MECHANICAL) VENTING SYSTEM.	45
FIGURE 19: MSW ENERGETIC POTENTIAL 2000.....	47
FIGURE 20: SITES WITH BIOGAS-PROJECTS POTENTIAL IN MEXICO	48
FIGURE 21: BENLESA INTERNAL COMBUSTION ENGINE.....	49
FIGURE 22: BENLESA ESTIMATED CH ₄ PRODUCTION (BLUE LINE) AND CAPTURE (RED LINE).....	50
FIGURE 23: BENLESA PROCESS.....	50
FIGURE 24: MÉRIDA, YUCATÁN SANITARY LANDFILL	51
FIGURE 25: MÉRIDA SANITARY LANDFILL CH ₄ PRODUCTION ESTIMATE	52
FIGURE 26: MÉRIDA SANITARY LANDFILL CH ₄ RECOVERY ESTIMATE.....	52
FIGURE 27: SAN NICOLAS DE ARRIBA SANITARY LANDFILL INSTALLATIONS	51
FIGURE 28: SAN NICOLAS DE ARRIBA SANITARY LANDFILL LFG GENERATION AND RECOVERY PROJECTION	54
FIGURE 29: CHILTEPEQUE SANITARY LANDFILL INSTALLATIONS.....	53
FIGURE 30: CIUDAD JUAREZ SANITARY LANDFILL INSTALLATIONS	54
FIGURE 31: CIUDAD JUAREZ SANITARY LANDFILL LFG GENERATION AND RECOVERY PROJECTION,.....	57
FIGURE 32: GEOGRAPHICAL LOCATION OF TOLUCA, STATE OF MEXICO.....	60
FIGURE 33: TOLUCA RURAL AND URBAN ZONES.....	62
FIGURE 34: TOLUCA MSW COMPOSITION 2009.....	66
FIGURE 35: TEMPORAL STORAGE CONTAINERS IN TOLUCA	67
FIGURE 36: TOLUCA PREVIOUS TRANSFER STATION	70
FIGURE 37: REAR LOADER TRUCK FOR MSW COLLECTION IN TOLUCA.....	72
FIGURE 38: MSW TRUCK STORAGE	72
FIGURE 39: PLASTIC RECYCLING BUSINESS.....	74

FIGURE 40: RECYHUL'S TIRE RECYCLING PROCESS.....	75
FIGURE 41: ASPHALT RUBBER PRODUCTION PROCESS.....	75
FIGURE 42: CHILD SCAVENGER AT WORK, PETSTAR FACILITIES, AND SCAVENGER BEING INTERVIEWED IN THE FRAMEWORK OF THE NATIONAL RESEARCH STUDY.....	78
FIGURE 43: TOLUCA MSW FINAL DISPOSITION SITES.....	81
FIGURE 44: APPROXIMATE LOCATION OF SAN ANTONIO LA ISLA SANITARY LANDFILL.....	80
FIGURE 45: SAN ANTONIO LA ISLA SANITARY LANDFILL.....	83
FIGURE 46: ZINACANTEPEC SANITARY LANDFILL LOCATION.....	82
FIGURE 47: ZINACANTEPEC SANITARY LANDFILL ACCESS.....	85
FIGURE 48: ZINACANTEPEC SANITARY LANDFILL WEIGHTING SYSTEM.....	86
FIGURE 49: MSW DISPOSAL AND COMPACTING IN ZINACANTEPEC SANITARY LANDFILL.....	86
FIGURE 51: LEACHATE HOLDING TANK AND LFG EXTRACTION WELL.....	87
FIGURE 50: SCAVENGING IN ZINACANTEPEC SANITARY LANDFILL.....	85
FIGURE 52: ZINACANTEPEC SANITARY LANDFILL CHARACTERIZATION STUDIES.....	88
FIGURE 53: SOLAR PANELS PROVIDE ENERGY TO ZINACANTEPEC SANITARY LANDFILL.....	86
FIGURE 54: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - SEX.....	91
FIGURE 55: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - OCCUPATION.....	92
FIGURE 56: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - WASTE GENERATION.....	92
FIGURE 57: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - VDT HOUSEHOLD WASTE SEPARATION.....	93
FIGURE 58: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - REASONS FOR NOT SEPARATING WASTE IN TOLUCA VALLEY.....	93
FIGURE 59: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - REASONS FOR NOT SEPARATING WASTE IN TOLUCA.....	94
FIGURE 60: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - KNOWLEDGE ABOUT THE COMPOSTING PROCESS IN VDT.....	95
FIGURE 61: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - KNOWLEDGE ABOUT THE MSWM SYSTEM IN TOLUCA.....	96
FIGURE 62: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - COLLECTION FREQUENCY IN TOLUCA.....	96
FIGURE 63: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - WASTE DISPOSAL AND TREATMENT METHODS AVAILABLE IN TOLUCA.....	97
FIGURE 64: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - MSW COLLECTION SERVICE.....	98
FIGURE 65: PERCEPTION OF THE MSW MANAGEMENT IN TOLUCA - MSW FINAL DISPOSITION AND TREATMENT METHODS PERCEIVED RISK.....	99
FIGURE 66: MSW GENERATION.....	101
FIGURE 67: EXAMPLE OF FORECAST ERROR BY USING TREND EXTRAPOLATIONS.....	102
FIGURE 68: PROJECTED TOLUCA MSW GENERATION 2009 - 2015.....	104
FIGURE 69: PROJECTED TOLUCA MSW COMPOSITION 2015.....	105
FIGURE 70: TOLUCA MSW COMPOSITION TRENDS 2009- 2015.....	105
FIGURE 71: TOLUCA PER CAPITA WASTE GENERATION VS. POPULATION PROJECTED GROWTH 2009-2015.....	106
FIGURE 72: MEXICAN CARDBOARD COLLECTION.....	113
FIGURE 73: MRF, EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT - LOW TECHNOLOGY.....	115

FIGURE 74: MRF, EFFECT OF PLANT CAPACITY ON CAPITAL INVESTMENT - HIGH TECHNOLOGY.....	115
FIGURE 75: WINDROW COMPOSTING..	117
FIGURE 76: TOLUCA GREEN AREAS/GARDENS - ZONE 1.	117
FIGURE 77: TOLUCA GREEN AREAS/GARDENS - ZONE 2.	118
FIGURE 78: TOLUCA GREEN AREAS/GARDENS - ZONE 3.....	118
FIGURE 79: HIERARCHY OF WASTE MANAGEMENT IN SPANISH (JERARQUÍA DE LA GESTIÓN DE RESIDUOS)....	126

LIST OF TABLES

TABLE 1: ENVIRONMENTAL BENEFITS DERIVED FROM SUBSTITUTING SECONDARY MATERIALS FOR VIRGIN RESOURCES.....	20
TABLE 2: MSW CLASSIFICATION ACCORDING TO THEIR POSSIBLE USE.....	27
TABLE 3: TYPICAL CHEMICAL VALUES FOR WASTE IN MEXICO	28
TABLE 4: USES FOR LFG	46
TABLE 5: BIOGAS RECOVERY AND UTILIZATION PROJECTS IN MEXICO	48
TABLE 6: COLLECTION SYSTEM CHARACTERISTICS IN THE STATE OF MEXICO.....	69
TABLE 7: TOLUCA MSW VEHICLE INFRASTRUCTURE	71
TABLE 8: TRANSFERENCE STATIONS ESTIMATED COSTS FOR THE STATE OF MEXICO, 2007.	72
TABLE 9: MAIN MSW TREATMENT FACILITIES IN THE STATE OF MEXICO.	73
TABLE 10: AVANGARD'S SUPPLIERS.	76
TABLE 11: DISPOSITION SITES INVENTORY IN THE STATE OF MEXICO	80
TABLE 12: PROPOSED STRATEGIES FOR IMPROVING WM IN TOLUCA	111
TABLE 13: SAN ANTONIO LA ISLA AND ZINACANTEPEC SANITARY LANDFILL SPECIFICATIONS.....	122

ABBREVIATIONS

AD	Anaerobic digestion.
AR	Asphalt rubber.
BENLESA	Bioenergía de Nuevo Leon.
CDM	Clean Development Mechanism.
CFE	Federal Commission of Electricity.
COCEF	Border Environment Cooperation Commission.
CONAPO	National Council of Population.
DIF	Department for Integral Family Development.
ECOCE	Business Economy and Commitment.
FONADIN	National Infrastructure Fund.
GAIA	Global Anti-Incinerator Alliance.
GDP	Gross Domestic Product.
GHG	Greenhouse gases.
GIM	Growing Inclusive Markets.
GIS	Geographic information systems.
GTZ	German Society for Technical Cooperation.
IMSWM	Integrated municipal solid waste management.
INE	National Institute of Ecology.
INEGI	National Institute of Statistics and Geography.
IWM	Integral waste management.
JICA	Japan International Cooperation Agency.
LCA-IWM	Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies.
LFG	Landfill gas.
LGPGIR	General Law for the Prevention and Integral Management of Wastes.
M2M	Methane to Markets.
MRF	Materials recovery facility.

MSW	Municipal solid waste.
MSWM	Municipal solid waste management.
NOM	Official Mexican Standards.
NTEA	State Technical Environmental Regulations.
PASA	Promotora Ambiental / Environmental Developer.
PNPGIR	National Program for the Prevention and the Integral Waste Management.
RESA	Sanitary Landfills (company).
SEDESOL	Social Development Secretariat.
SEISA	International Energy Systems.
SEMARNAT	Ministry of Environment and Natural Resources.
SENER	Ministry of Energy.
SIMEPRODE	System for Ecological Waste Management and Processing.
UNEP	United Nations Environment Programme.
VDT	Toluca valley.
WM	Waste management.
WTE	Waste-to-Energy.
WTERT	Waste-to-Energy Research and Technology Council.

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INTRODUCTION

Mexico has a population of 111 million who in 2009 generated 38.3 million tons of Municipal Solid Waste (MSW), i.e., about 0.35 tons per capita. The generation of MSW has increased substantially in the last decade, due to urban growth, economic and industrial development, and changes in consumption patterns. Thus, over the last ten years, the total generation of MSW increased by 28%, in parallel with the Gross Domestic Product⁷⁰ and the growth of urban population.

The MSW composition has also changed. In the 1950s, the percentage of organic waste in MSW ranged from 65 to 70% of the total volume, by 2008, this share decreased to 52%. Of course, MSW composition depends on economic development of the nation, citizens' consumption patterns, etc.

Regarding the final disposition of MSW, it was estimated that 67%¹³ of the total MSW generated in Mexico was disposed in sanitary landfills and controlled sites, while the remaining 33% was discarded into uncontrolled and open dumps. Moreover, there is no precise and updated information available about recycling or any other kind of alternative final disposition methods. The last official record stated that in 2006, 10% of the recyclable material was recycled; this represented only 3.25% of the total MSW generated that year, while in 2008 this figure increased up to 3.6% (SEMARNAT, 2009). It is clear that the national and local government need to encourage both recycling and the appropriate final disposition and treatment of solid wastes in Mexico.

The first step towards creating and implementing an appropriate and integral waste management program, is to have on hand, and disseminate to the public, the necessary information for MSW management. Without it, it is impossible to evaluate the situation, to suggest a course of action or to take any kind of governmental, private or educational decisions. The last "National Program for the Integral Waste Management in Mexico: 2009 - 2012" proposed by the Government, stated that the available MSW information in the country is really scarce and is not standardized.

This study aims to help close this information gap by gathering all available and up-to-date information regarding MSW characteristics and management in Mexico, as presented in Chapter 2. Mexico's efforts for landfill gas recovery and use are also documented in Chapter 2, while Chapter 1 presents a brief overview of waste management definitions.

Additionally, due to Mexico's diversity and since MSW is managed at the municipal-level, the capital of the State of Mexico, Toluca municipality, was selected as a case study. Toluca's MSW management current situation is presented in Chapter 3. This Chapter also presents the results of a survey conducted by the author to obtain some insight of Toluca citizens' perception about the MSW treatment, final disposition and the municipal services provided.

Finally, on the basis of the information collected and analyzed for Mexico and Toluca, Chapter 4 suggests some strategies or lines of actions that follow the established hierarchy of waste management and may be used to improve MSW management in Toluca. This research can be considered as the first step towards implementing a more sustainable waste management system that is suitable to Toluca and Mexico's characteristics.

CHAPTER 1: WASTE MANAGEMENT

1.1 Definition of Waste

According to the General Direction of Public Services and Environment of Toluca municipality in Mexico, waste is any material that is not useful or does not represent an economic value to its owner, being the owner, the waste generator. From the legal standpoint, the most complicated issue of waste management is that it is a very subjective term, since it depends on the point of view of the people involved during its generation, handling and treatment.

1.2 Waste Classification

Wastes can be classified according to its state, its origin or its handling.

1.2.1 Types by state

Waste can be defined according to its physical state. Therefore, there are three types of waste: solid, liquid or gas. It is important to notice that the scope of this classification also includes the handling associated with a specific waste; for example, a container of used oil is intrinsically a liquid but it will be handled as a solid since it is transported by trucks instead of by a hydraulic system.

1.2.2 Types by origin

Waste can also be defined depending on the activity that originates it. The most important types are:

- Municipal wastes are generated by household, commercial and/or institutional activities and vary according to the consumption habits, income levels, and life standards, among others.
- Industrial wastes are generated by the industrial activity; it is a function of the technology used during the process, the quality of the raw materials, physical and chemical properties of the materials, fuels used and the necessary packing.

- Mining wastes, or also called tailings, include all the materials removed in order to gain access to an ore and the wastes generated during the mining process.
- Hospital wastes are produced by hospitals, and generally speaking, its handling depends on the generator rather than on a decentralized system. Its composition varies from household and industrial type of wastes up to medical waste containing hazardous substances.

1.2.3 Types by handling

Another way of classifying wastes is by the characteristics associated to its handling. Within this classification, three different groups can be defined:

1. Hazardous wastes are by nature inherently dangerous to handle and/or dispose, or if they are dangerous to the human health and the environment when handled in an inappropriate way.
2. Inert waste is a waste that becomes stable after a period of time and therefore, will not produce any considerable environmental impact.
3. Non-hazardous waste

1.3 Solid waste management

Solid waste management is the effort of removing and disposing all the unwanted material through a carefully, planned and judicious use of means. It comprehends the planning, financing, construction and operation of facilities for the collection, transportation, recycling and final disposition of solid waste. It is based on principles such as engineering, economics, public health, conservation, aesthetics, environmental considerations and social and ethical issues (Shah, 2000).

Basically, the solid waste management system is formed by the following subsystems, or elements:

1. Generation
2. Waste handling, separation and storage at site

3. Collection
4. Separation, processing and transformation of solid waste
5. Transfer and transport
6. Disposal

1.4 Hierarchy of Waste Management

The hierarchy of Waste Management (Figure 1) is a coordinated set of actions that classify WM strategies according to their desirability. However, the hierarchy of WM cannot be followed all the times and at every nation with the same approach. This should be adapted according to the specific characteristics and necessities of a particular location.

The hierarchy of waste management has the following structure:

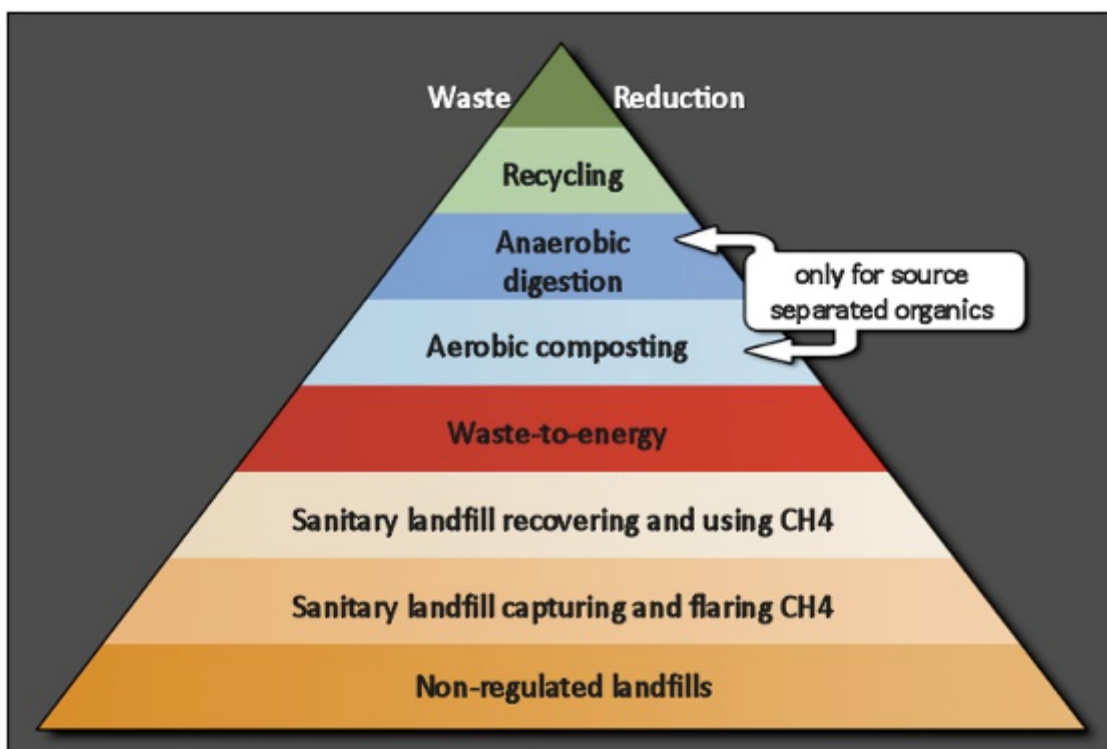


Figure 1: Hierarchy of Waste Management (WTERT, 2010)

Waste Reduction

The most effective way to reduce the quantity of MSW disposed is certainly reducing the quantity of MSW generated. It is a preventive action that can be

achieved by the generators by redesign of packaging, encouraging the use of minimal disposable material necessary to achieve the desired level of safety and convenience, increasing consumer awareness of waste issues, promotion of producer responsibility of post-consumer wastes (UNEP, 1996) and increasing the lifetime of a product, among others. These may be achieved by enacting public policies and the creation of economic incentives.

It is given the highest priority because some of the benefits of reducing the generated amount of waste include reduction of the number of collection vehicles needed, fewer and smaller waste handling facilities and with this, the extension of the landfill's useful life¹⁵.

Recycling

“Recycling is the next best thing to do after waste reduction”⁷¹; the best way to achieve this is through source separation, followed by material recovery and recycling¹. Also, waste-pickers or scavengers help recycling by removing valuable materials either on route or at the final disposition site. Recycling helps saving water, energy, and generates less contamination; it also reduces the amount of wastes to be collected, transported and disposed. “Recycling can result in a more competitive economy and a cleaner environment, and can contribute to a more sustainable development”¹⁵.

Supporting the recyclable products market is also key for advancing in this subject. If installing facilities to process materials and business for buying/selling them, is not economically justifiable, it is recommended to aloud and facilitate the private initiative participation. This is not only aimed for big businesses, but it is also important to support and legitimize the informal business such as the itinerant buyers and scavengers. Achieving this can be done through strategies such as micro-loans or some type of assistance provided by the municipality. When scavengers are supported jobs are created, poverty is reduced, the industrial competitiveness is improved and it saves the cities collection, transportation and disposal costs⁶⁵.

Some factors that affect the potential for resource recovery, and therefore the potential for recycling are:

- The cost of the separated material.
- The separated material purity.
- Separated material quantity.
- Separated material location.
- The market for recyclable products.
- Legislation policies.

Additionally, a research published by Alexis M. Troschinetz and James R. Mihelcic in 2009, summarized the factors acting as a barrier towards sustainable recycling of MSW in developing countries. The four biggest factors identified were: MSWM personnel education, waste collection and segregation, government finances and household education. By household education it is meant the extent of knowledge of WM methods and understanding the connection between human behavior, waste handling and health/sanitation/environment in households. “On the other hand, household economics is one of the smallest barriers (22% of the case studies), which indicates that socio-economic status is not the limiting factor to recycling in developing nations”².

Overall, recycling can provide social, economical and environmental benefits: “factories that consume recyclable materials can be built for a fraction of the cost of building plants that consume virgin materials”¹⁵, it saves energy, water, and generates less pollution, this translates into lower operating costs. Table 1 shows the environmental benefits derived from substituting secondary materials for virgin resources. Recycling also extends the life of disposal facilities, which also saves money to the municipalities.

Table 1: Environmental benefits derived from substituting secondary materials for virgin resources (Shah, 2000)

Reduction of:	% Reduction			
	Aluminum	Steel	Paper	Glass
Energy use	90 - 97	47 - 74	23 - 74	4 - 32
Air pollution	95	85	74	20
Water pollution	97	76	35	-
Mining wastes	-	97	-	80
Water use	-	40	58	50

Anaerobic digestion and aerobic composting

Anaerobic digestion and aerobic composting are used as composting techniques. They are practical only for source-separated organics, otherwise much of the compost “product” is not usable as soil conditioner and ends up in landfills (WTERT). The difference between these two is that anaerobic digestion (AD) is the degradation of organic material in the absence of oxygen, producing mainly 55 % CH₄, 45 % CO₂ and a compost product suitable as a soil conditioner⁴. CH₄ is typically formed by 93% of natural gas and may also be useful as the raw material for hydrogen production. “CH₄ thus has a great potential as an abundant and renewable energy resource”³, while in the aerobic process, microorganisms in an oxygen environment, decompose the organic waste producing compost (Shah, 2000).

Regarding the organic materials, it is important to know that organic components in waste streams present problems and opportunities (EPA, 2007). Some problems come when these components are landfilled, and LFG and leachate are produced. Leachate poses a threat to local surface and ground water systems while LFG contribute to the GHGs, and among its components; CH₄ is less easily broken down and it is considered 20 times more potent as a GHG (Johannessen, 1999). CH₄ concentrations can reach up to 50% of the composition of LFG at maximum anaerobic decomposition (Cointreau-Levine, 1996). “CO₂ is a second predominant gas in LFG; although less reactive, buildup in nearby homes could be a cause of asphyxiation”¹.

Composting can be implemented in 3 different levels: household level, community level and centralized large-scale level (municipality), where the larger the undertaking, the more capital investment is needed¹. The most common methods used for household, or backyard, composting are “pens”. The Pen method involves building a pile within a pen of woven wire where it can be easily mixed and allows good air circulation (Shah, 2000).

An example of an aerobic composting method is windrow composting, in here, the organic material is piled into heaps or windrows, these are turned periodically to aerate them and to avoid the development of anaerobic conditions. This method is labor-intensive and can help to create jobs for unskilled workers. “Windrow composting requires an extensive open land space, preferably over a paved surface with a slight downward slope and ditch to collect any excess runoff water”¹⁵.

Waste-to-energy (WTE)

Waste-to-energy “refers to the energy recovery through combustion of waste and possible material recovery after thermal processing”⁵. Since after the combustion process, there is still some ash to be disposed, it shouldn’t be considered a disposal option, “it should instead be considered more in terms of its waste-reduction potential, which can be 80-95% in terms of waste volume”¹.

In a WTE plant, the heat produced by the combustion of non-recyclable MSW is used to produce steam that drives an electricity generator. A plant that provides a net electricity output of 550 KWh/ton of MSW is equivalent to saving 1.43 barrels (190 liters) of fuel oil per ton. For this process, “a sophisticated air pollution control system is used to remove particulate and gaseous pollutants before the process gas is released into the atmosphere”⁸⁷.

Typically, the basic components comprising a WTE plant are:

- Waste intake area, which usually includes a tipping floor, storage pit, and occasionally conveyors. It stores and sorts the incoming refuse.
- Crane to take the waste from the storage pit into the combustion chamber.

- Combustion chamber or furnace, where waste is introduced and combusted at high temperatures (over 1,000 °C). It consists of a grate system to move waste through the chamber.
- Heat recovery system, where the heat generated by the combustion process, is used to evaporate water into steam. This is done through heat exchanger tubes (waterwall) lining the combustion chamber. This steam is then superheated by superheater tubes, and sent to the electricity generator.
- Ash handling system, where ash is tested and sent to either a final disposition site or used in other processes such as road construction.
- Air pollution control system (APC) may include: activated carbon injection, electrostatic precipitators or baghouse filters and scrubbers.

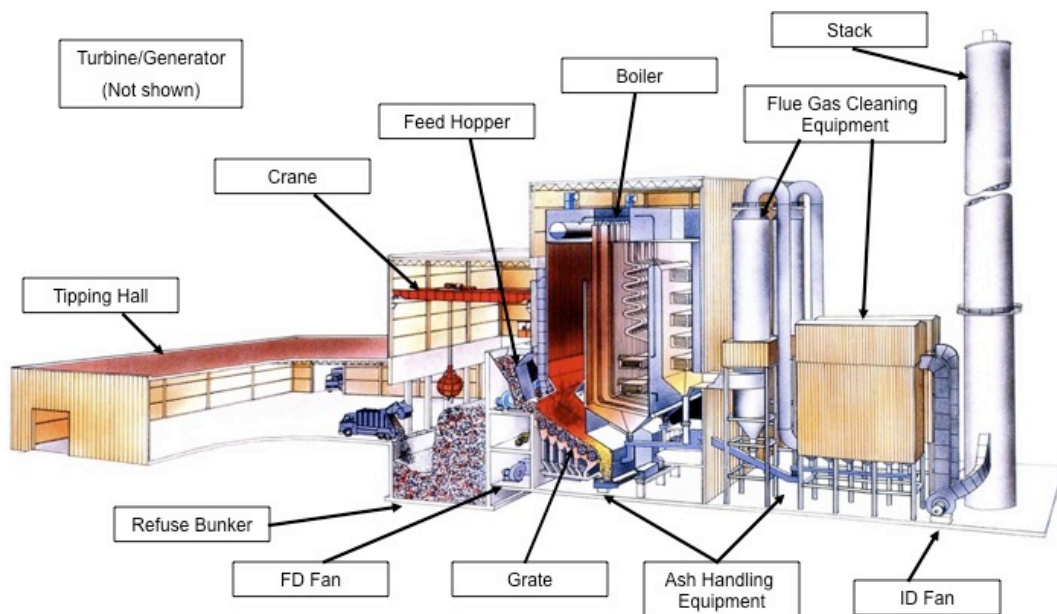


Figure 2: A Typical WTE plant. (Zannes, M.)

Landfilling

This final disposition method should be considered as the last option. “True sustainable development requires that only non-recyclable inorganic materials are landfilled”⁷¹. Landfilling is necessary for final disposal of the wastes that could not

be minimized, reused, recycled, composted, or combusted with energy recovery.

However, there is a hierarchy among landfilling, beginning with **sanitary landfills recovering and using methane (CH₄)**, followed by **sanitary landfills capturing and flaring CH₄** and **non-regulated landfills** are the last option in the hierarchy of WM. Even though landfilling is the less desired option, “until there is sufficient WTE capacity, it is necessary for all nations to construct sanitary landfills that prevent liquid effluents from contaminating ground and surface waters”⁷¹. Modern landfills also require high investments and additional efforts to collect LFG and use it to generate energy, consequently reducing the use of fossil fuels and with it, the GHG emissions that produces the climate change (WTERT)

CHAPTER 2: WASTE MANAGEMENT SITUATION IN MEXICO

2.1 Mexico: population, geography and administration

Mexico is the 13th largest country in the world with an area of 1.75 million square kilometers (761,404 mi²). It is well known for its topographic and climate diversity. The nation’s capital is Mexico’s Federal District, or better known as Mexico City, is considered to be the third largest city in the world, with a population of around 8.6 million. According to the last official survey in the year 2009, Mexico had a population of 111 million people, 76% of the population lives in urban areas. The population density is about 53 persons per km² (171 persons per mi²).



Figure 3: Political administration map of Mexico. (Geology.com, 2010)

Politically, the country is divided into 31 states plus the Federal District or the capital city. Each state is divided into municipalities.

2.2 Waste Management History

The management of MSW in Mexico began before Hernán Cortés arrived to conquer Mexico in 1519. The ancestors had an Aztec waste deity called “Tlazoltéotl: The Goddess of Filth” and a ritual where they were obligated to clean their entire city, each part of their home and temples. It is said that based on this history, originated the custom of sweeping the streets before sunrise. Some of their waste management systems consisted on using human wastes as fertilizers, while some other waste was buried.

At the Spaniards arrival, they established different and fewer customs, it is said that this translated into diseases due to the lack of hygienic systems, which were even opposite to those of the Aztecs. It took until July 15th 1891, when the Health Council created the first Sanitary Code in Mexico⁷.

During this time, MSW in Mexico was usually disposed at uncontrolled open-air dumps. It was not until the 60’s, when the first sanitary waste landfill in the whole country was designed and began to operate in the city of Aguascalientes, this

landfill was followed by MSW collection and disposal management plans in the principal capital cities.

During the decade of 1970's, nationwide interest on environmental issues began to spring, which led to the creation of the Environment Improvement Undersecretary in 1972. This agency started a nationwide program that resulted in the executive MSW management and disposal projects for some of the major cities in Mexico. Based on this program, at the end of these years and up until 1982, a series of projects were carried out along with the creation of MSW technical regulations.

One year later, the RS100 program was created in 1983 with the objective of creating executive projects for landfills in cities with a population larger than 100,000 citizens. Finally, the Secretariat of Environment, Natural Resources and Fishing was created in 1994 incorporating other organisms which took care of all environmental matters.

2.3 Regulatory Framework

Waste management (WM) in Mexico is regulated by laws established in the Constitution of the United Mexican States: The General Law for the Ecologic Equilibrium and Environment Protection, the Official Mexican Standards and the General Law for the Prevention and Integrated Management of Wastes.

The Constitution of the United Mexican States specifies in its 115th Article that the municipalities will be responsible of the sweeping, collection, transportation, treatment and final disposition of solid wastes. Hereby, it is clear that each municipality has the freedom to institute its own waste management system. However, the 73th Article declares that the Federal Congress has the ability to issue laws that help the Federal, State and Municipal Governments to manage effectively all their environmental protection matters. Also, based on this Article, legislators created the "Ley General del Equilibrio Ecológico y la Protección al Ambiente" (General Law for the Ecologic Equilibrium and Environment Protection) that created the Official Mexican Standards (Normas Oficiales Mexicanas, NOM) for

controlling the location, design, construction and operation of the different landfills used for MSW final disposition.

Specifically, the NOM concerned with the management of municipal solid wastes at a Federal level are:

NOM-083-SEMARNAT-2003: It regulates the final disposition of MSW, stating that everything concerned with these final disposition sites (location, construction, operation, closing, monitoring and complementary works) should be carried out according to technical guidelines that guarantee environmental protection and minimize pollution effects related to inappropriate waste management.

NOM-098-SEMARNAT-2002: This NOM makes reference to waste incineration, stating that incineration of any kind, including hazardous waste, has toxic effects that pollute the environment, damaging the ecosystems and the human health, which is why preventive actions must be adopted in order to achieve acceptable level of emissions. About the preventive actions, it also states that these have to consider the integral control of the emissions into the air, as well as management of ash.

The General Law for Health favors the prevention and control of the toxic effects of environmental factors to the public health, however, there is not a single article that makes reference to any specific type of wastes and its effect on the public health.^(8,9)

On October 8 2003, the General Law for the Prevention and Integral Management of Wastes (Ley General para la Prevención y Manejo Integral de Residuos, LGPGIR) was published in the Official Federal Journal (Diario Oficial de la Federación), filling in many of the regulation gaps regarding Municipal Solid Waste Management (MSWM). This Law considers waste from two points of view; first, as a potential contaminant that must be avoided, reduced and managed in an environmentally adequate manner, including a payment for this; and second, as material endowed with a value, that could be employed through reuse, recycling or by recovering the energy contained in it—as long as this is done in an environmentally adequate manner.⁹

2.4 MSW in Mexico: management system and characterization

2.4.1 Characterization

2.4.1.1 Physical properties

The NOM-AA-22-1985 standard describes how to identify and separate MSW sub-products. This methodology is useful in studies for classifying MSW materials according to their usage, based on their physical characteristics. As an example of this characterization, a study made in Mexico City showed the following classification results:

Table 2: MSW classification according to their possible use. (Pacheco, 2004)

Recycling	Alternate Manufacture	Use of Food Wastes (Composting)	Energy Recovery	Final Disposition
Cardboard Cartons Cans Ferrous material Non ferrous material Bond paper Newspaper Plastic wrap Plastic Glass (color) Glass (transparent)	Crockery Ceramics Construction Material Bond Paper Newspaper Plastic wrap Tires Plastic	Bones Food wastes Garden wastes	Cotton Cardboard Leather Cartons Synthetic fibers Plant fibers Fat Rubber Wood Tissue paper Polyurethane Expandable Polystyrene (EPS)	Tongue depressors Disposable syringes Radiographs Sanitary pads Tights Others

2.4.1.2 Chemical properties

For different kinds of waste treatment, different chemical properties of the waste are important. In the case of waste recovery, some main properties to be taken into account are: humidity, upper and lower calorific value. For composting, some fundamental properties are: pH, nitrogen/carbon ratio, dissolved oxygen, total nitrogen and humidity.

Table 3 shows the typical values for some chemical properties in Mexico.

Table 3: Typical chemical values for waste in Mexico. (Pacheco J, 2004)

Waste Sub products	Humidity %	Calorific Value kJ/kg	Carbon %	Hydrogen %	Oxygen %	Nitrogen %
Cotton	10.00	16,049	55.00	6.60	31.20	4.12
Cardboard	5.00	16,282	44.00	5.90	44.60	0.38
Leather	10.00	17,445	60.00	8.06	11.61	10.00
Small wastes	3.20	8,555	20.62	2.57	4.00	8.58
Vegetable fiber	12.00	15,119	43.40	6.10	43.70	0.10
Synthetic fiber	15.00	17,445	46.19	6.41	41.05	2.10
Bone	0.00	16,282	41.72	5.75	27.62	2.97
Rubber	2.00	23,260	77.65	10.35	0.00	2.00
Can	3.00	698	4.47	6.00	4.30	0.05
Crockery & ceramics	8.00	6,978	26.30	3.00	2.00	0.50
Wood	20.00	18,608	43.50	6.00	42.70	0.20
Construction materials	8.00	6,978	26.30	3.00	2.00	0.50
Ferrous material	3.00	698	4.54	8.63	4.20	0.05
Non ferrous material	2.00	698	4.47	6.00	4.36	0.05
Paper	6.00	16,747	43.50	6.00	44.00	0.30
Disposable diapers	3.00	32,564	60.00	7.20	22.00	0.00
Plastic wrap	3.00	32,564	67.21	9.72	15.02	0.46
Plastic	0.20	45,769	84.54	14.10	8.00	0.86
Polyurethane	0.20	26,256	63.27	6.26	17.65	5.99
Expandable Polystyrene (EPS)	0.20	38,146	87.10	0.45	3.96	0.21
Food waste	70.00	4,652	40.00	6.00	37.68	2.60
Garden waste	60.00	4,652	47.00	6.00	38.00	3.40
Carton	1.45	26,284	59.10	9.25	30.13	0.17
Cloth	10.00	16,049	55.00	6.60	31.28	4.12
Glass	2.00	140	0.52	0.07	0.36	0.03
Others	4.34	698	4.54	0.63	4.28	0.05

2.4.2 MSWM system

In Mexico, municipal authorities have the responsibility of planning, financing, building and operating the handling of MSW at their jurisdiction. The majority of the municipalities manage these services directly, while the rest do it through municipal autonomous organisms, as is the case for SERVILIMPIA in Mérida⁸⁵. During the last years, both types of administrations have started to give concessions to operate some stages of the MSW management system, like in the case of the sanitary landfill in Queretaro⁸⁵.

As mentioned earlier, in the majority of the cities in Mexico, there is no specific cost for the waste management services. The authorities have the responsibility of financing them through taxes instead of direct fees, same as is done in most Latin American countries¹⁰. Nevertheless, the principal problem is that either by a direct fee or through taxes; there is not enough money to pay such services. This can have a big effect on the quality and quantity of services provided, forcing the authorities to apply measures such as extending the usage of vehicles far over their standard lifetime, hiring the services of the private sector, using collection methods not as efficient but that require less capital, etc.

According to the National Institute of Ecology (INE), the Mexican WM process can be represented through a flow diagram:

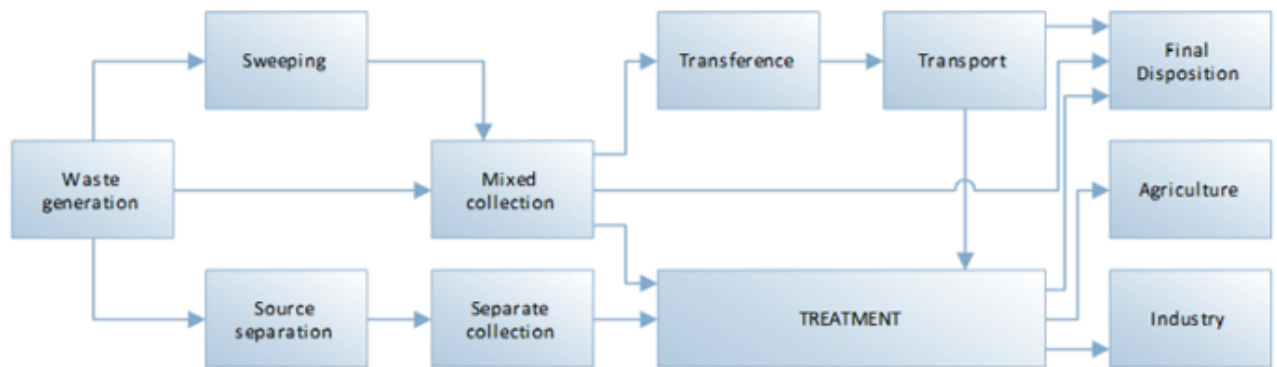


Figure 4: MSW flow system (Weherpohl, G., 2004)

2.4.2.1 Generation of MSW in Mexico

According to the Ministry of Environment and Natural Resources (Secretaría de Medio Ambiente y Recursos Naturales, SEMARNAT), in the year 2009, the total MSW generation was of 38.3 million tons, from which 77% came from households and the rest from any other sources¹¹. The yearly average MSW generated per capita was 0.35 tons in 2009. The SEMARNAT indicates that the production of MSW per person increased by a 200% in the last four decades, while the tendency in the increase of waste generation is projected to vary for different areas, in the range of 1% and 3.5% per year.

The amount of waste per citizen that is generated has a direct correlation to the size of a city. Of the total MSW generated daily about 87% belongs to

communities of over 15,000 inhabitants¹², and only 13% to small communities (semi-rural and rural areas); these are widely spread all over the country and are sometimes difficult to reach, making it laborious to deal and to establish an adequate WM strategy. According to the National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía, INEGI), 24% of the total population lives in rural areas, and based on this data, the calculated per capita MSW generation in rural areas is of 0.08 tons, and 0.27 in urban ones.

In a state-by-state level for year 2008, the State of Mexico, had the largest MSW generation, with over 6 million tons (Figures 5 and 6), followed by Mexico City with 4.7 million tons. However, the per capita yearly generation for Mexico City in 2008 is larger (0.55 tons) when compared to that of the State of Mexico (0.44 tons).

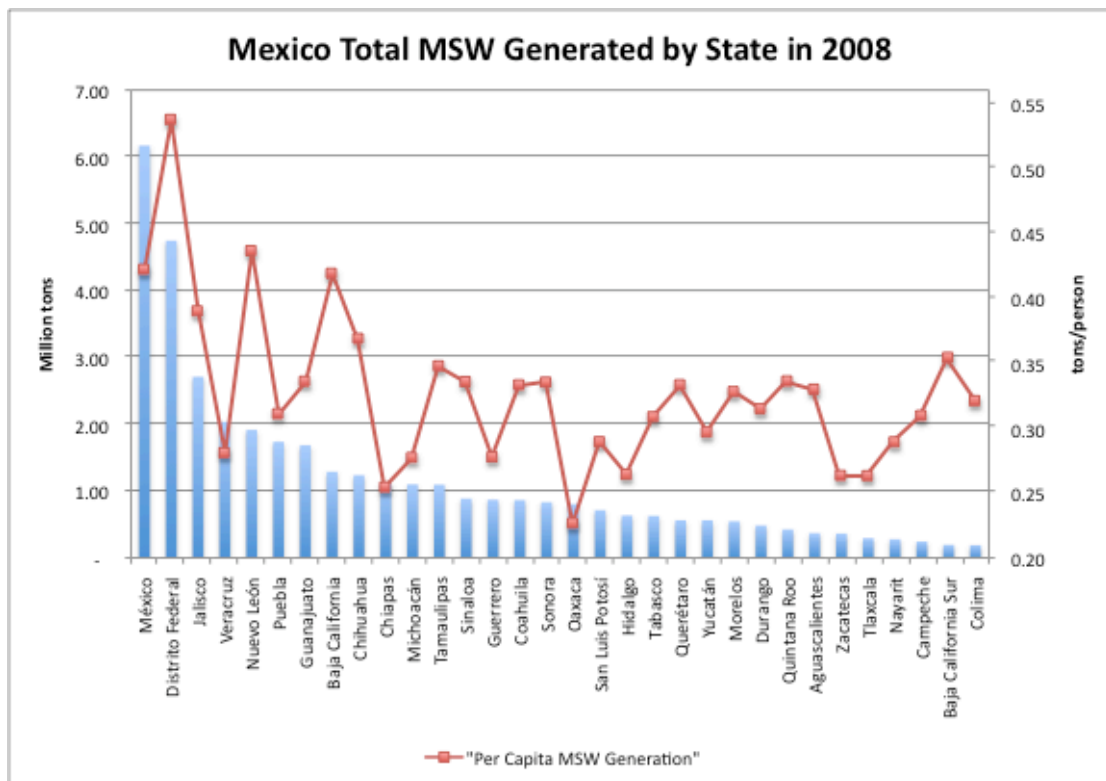


Figure 5: Mexico MSW generation by state in 2008 (INEGI & CONAPO, 2009)

MSW Generation Distribution in Mexico , 2008

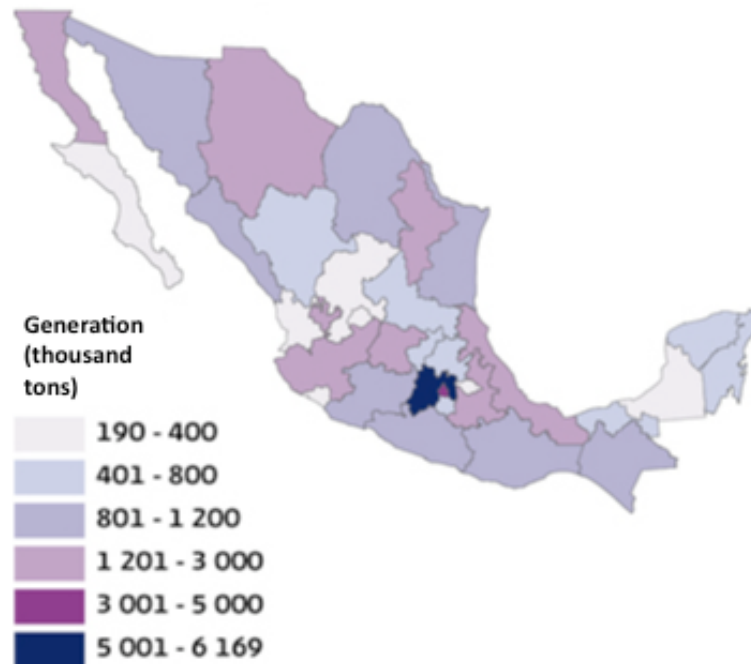


Figure 6: MSW Generation Distribution In Mexico 2008, (SEMARNAT, 2009)

2.4.2.2 Composition

There is different data concerning MSW composition in Mexico. It was found that some of them are not in agreement, even for studies performed for the same year. This lack of homogeneity can be due to the technique used or to the time or season in which the waste study was performed. Also, the composition of municipal solid waste is not the same throughout the country because it strongly depends on income and consumption habits: in the southern zone of Mexico, there is a greater content of gardening waste, whereas in the largest urban zones this same waste appears in a smaller proportion⁹.

According to the official source SEMARNAT (2009), MSW in Mexico is composed as follows:

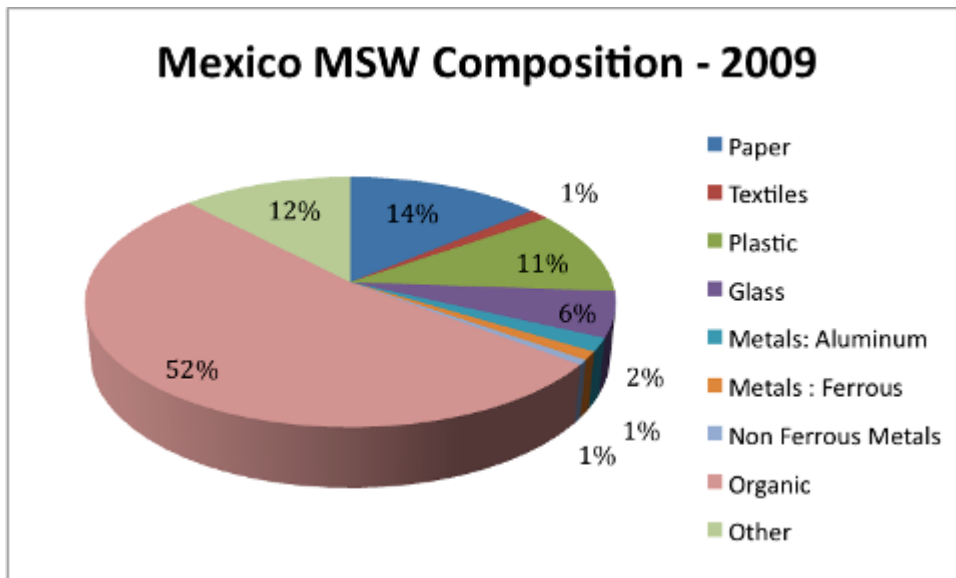


Figure 7: Mexico MSW composition in year 2009 (SEMARNAT, 2009)

As it can be seen, organic matter is the most frequent type of waste in Mexico's MSW; however, when comparing to historic data, we can observe how there has been a gradual change in the MSW composition: plastic and paper have increased their share, while organic waste decreased. Several authors related this to the increasing use and consumption of disposable goods.

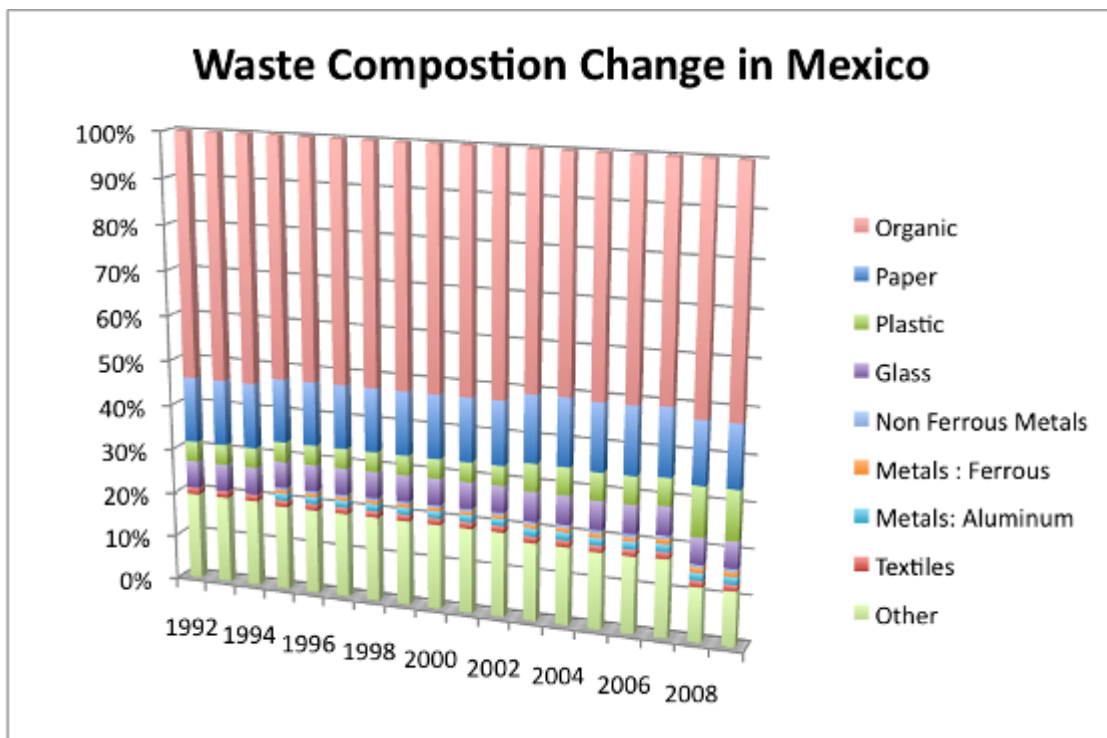


Figure 8: Historic MSW composition in Mexico. (SEMARNAT , 2009)

2.4.2.3 Temporal Storage

The temporal storage stage is a responsibility of the waste generation source and its objective is to keep the waste temporally stored in ways that it does not present a threat to the public health or the environment, until the wastes are collected by the local WM system. In Mexico, since this stage looks very simple, it has been neglected regularly, leading to a lack of good storage practices in most of the cities.

The storage containers and their locations should be designed in accordance to the waste characteristics, rate of generation, volumetric weight and frequency of collection. In reality, most storage locations in Mexico are not well designed, especially for sources with a high generation rate like markets, convenience stores or public spaces, thus creating all kind of health risks.

The most widely storage containers used in households are polyethylene bags provided by stores (convenience stores, clothing stores, etc.). However, other kinds of containers such as wooden, cardboard boxes or paper bags are also common. This kind of containers are one of the main operational problems of the WM systems: due to their low resistance, they end up breaking while being collected, which decreases the efficiency, increases the costs, causes pollution and leaves a bad municipal image. Some waste generating sources are using black polyethylene bags and plastic or metal containers that are specifically designed for waste storage and tend to be more resistant. This is the case especially for higher socioeconomic classes.



Figure 9: Household temporal storage.

Actions towards MSW source separation are established according to the different laws issued by the state and municipal authorities, along with the programs and actions developed in educational and non-governmental institutions.

Another important part of MSW storage are waste repositories or containers for the waste generated on the street or at public spaces like parks, schools, beaches, recreational centers, archeological zones and other kind of meeting places. These places have their own special waste containers, nevertheless, it is very common to see a lot of garbage not properly disposed or even scattered around these sites, and this probably dates from the lack of public participation, infrequent collection and/or not enough containers.



Figure 10: Containers in streets and public spaces.

Also, as private companies start being a part of the collection system, it becomes more frequent to observe containers that are taken by special collection vehicles that pick them up completely, which are known as roll on, roll off vehicles.

2.4.2.4 Sweeping



Figure 11: Sweeping services in Mexico (SEMARNAT, 2009)

Municipal Government is responsible for sweeping public spaces and streets while the citizens are responsible of sweeping the sidewalks in front of their respective households. The majority of these services are done through manual sweeping; while on main avenues, mechanical techniques are used. According to the INE, the cost of the manual sweeping varies from \$1.6 to \$24.3 USD* per kilometer (\$ 20 to \$ 305 MXN).

2.4.2.5 Collection

According to the SEMARNAT database, the amount of waste collected by collection services in the year 2008 was of 90% of the total generated. High collection figures are found mainly in metropolitan areas, where coverage's is up to 98%. For medium sized cities, it varies between 75 and 85%, for small urban cities, the coverage is between 60 to 80%. On a state-by-state level, the MSW collection distribution is shown in Figure 12:

* Mexican Peso to US Dollar exchange rate on August 4th 2010 was used: 1MXN= 0.0796 USD. (http://www.exchangerates.org.uk/MXN-USD-04_08_2010-exchange-rate-history.html)

MSW Collection Distribution in Mexico , 2008

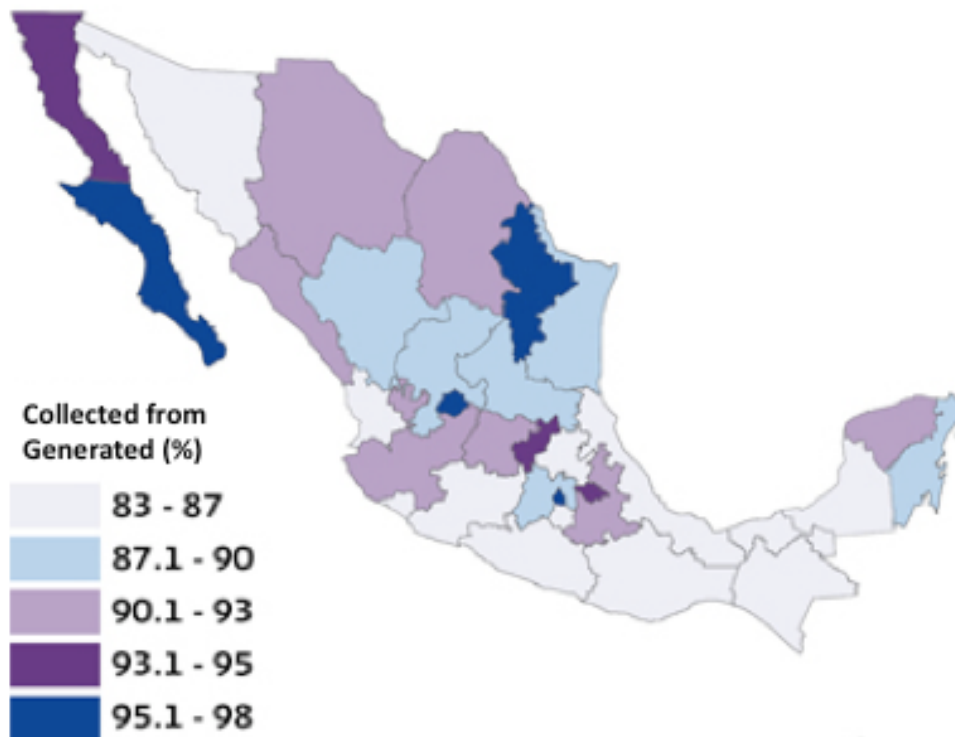


Figure 12: MSW collection distribution in Mexico 2008 (SEMARNAT , 2009)

Regarding the collection management system, SEDESOL in its “Technical Manual for MSW Generation, Collection and Transference” mentioned that only 75% of the cities in Mexico are divided in different areas or operative sectors, in order to be properly served, and only 43% of the cities use route optimization methods to design the proper collection route. Most municipalities have their own collection systems; however some cities have chosen to use private collection systems.

Recently, due to the change in laws in some cities like Mexico City and Jalisco State, selective collection of compostables has been applied. This was implemented by using different collection days or special vehicles. In the case of Mexico City, the 2009 online version of the newspaper “La Jornada”, published 5 years after this law came into effect, reported that only 5 out of the 16 delegations (political divisions, similar to boroughs) applied it.

The vehicles used for the collection are compactor trucks, with capacities varying from 10m³ up to 15m³, which can usually collect between 4 to 8 tons per

trip. Collection costs in medium-sized cities start from approximately \$2 up to \$51 USD per ton (\$30 up to \$640 MXN) (INE, 2006); depending on the population density, total collected waste, filling efficiency of the vehicle, truck maintenance and route design.

Also, there are some “roll on, roll off” trucks, which are commonly used in the industry or for wastes with high volumetric weight. In some areas, it is also common to find that dump trucks are used, especially in rural areas. In general, these have a capacity of 6 and 8 m³ and can collect from 1.2 up to 8 tons per trip, depending on the type of truck. From the total vehicles used in the country, it is estimated that due to overuse and lack of maintenance, 25% of them are in good condition, 50% in mediocre and 25% in bad condition. The average service life of these trucks in Mexico is between 8 and 12 years, which is larger than the average life expectancy of a truck (7 years),

The driver and two workers usually form the collection-services staff of an urban city such as Mexico City. Sometimes more people are part of the staff but usually, they are scavengers and are not employed by the municipality. These scavengers typically work with help of the staff, they share the earnings received from separating and later selling glass, cardboard, aluminum, mattress and other materials found in the garbage. All of this results into an inefficient collection system, due to the fact that they need more time to complete the route.

2.4.2.6 Transportation and Transference

Once collected, MSW may either be transported directly to the final disposition/treatment site, or to a transference station. According to the INE, in Mexico there are 42 transfer sites. In metropolitan areas, 75% of the waste goes through transfer stations. Transference costs represent approximately 29% of the total costs, varying between \$1.7 and \$10.2 USD per ton (\$22 and \$145 MXN).

Transfer stations help to bridge the large distances that often exist between the cities and the final disposition sites. In addition, they help to decrease collection times, reduce fuel consumption and increase the efficiency of the service. This helps to decrease the operation cost of the WM system.

2.4.2.7 Treatment:

In general terms, treatment processes such as incineration, energy-recover, and the utilization of sub-products for recycling and composting, have not generated the expected results in this country. Most of the treatment sites have stopped operating due to lack of market, high operation and capital costs or to the poor quality of the finished product. Recycling, composting and incineration will be reviewed next.

Recycling

According to the SEMARNAT, only 3.6% of the total MSW generated was recycled in 2008, this compared to the reported data of 2.4% in 1998, represents an increase of only 1.2 percentage points in 10 years, i.e., 0.12% yearly. Of this amount, paper and cardboard represent the largest proportion (42.1%), followed by glass (28.7%) and metals (27.8%), the rest is plastics (1.3%) and textiles (0.2%).¹³

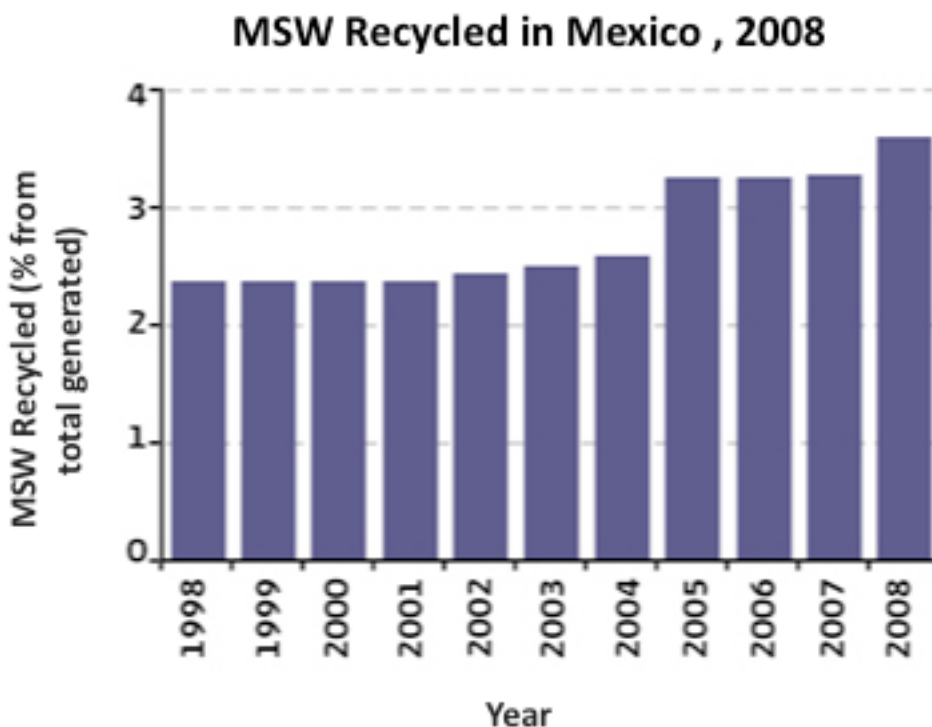


Figure 13: MSW recycled in Mexico 2008. (SEMARNAT, 2009)

The National Institute of Statistics and Geography (Instituto Nacional de

Estadística y Geografía INEGI) reported that in 2003 there were 4,024 registered businesses concerned with the commerce of waste material recycling, 42% less business than in 1998. The different economic sectors are shown in Figure 14.

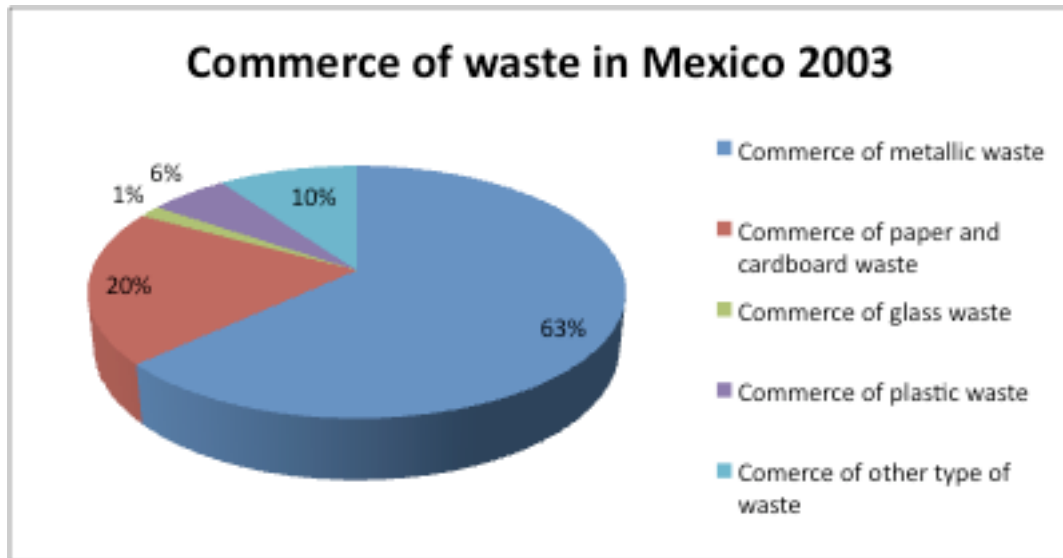


Figure 14: Commerce of waste for recycling business in Mexico 2003. (INEGI, 2003)

An analysis of the recyclable market in Mexico¹⁴ showed that there exist more collection centers than businesses dedicated to actually recycling, using or transforming these wastes. Furthermore, businesses, that could use the recycled products, require materials that are cleaner and of a higher quality than what recycling stations are able to provide. This is one of the reasons why they choose to use “virgin” materials, rather than recycled ones, because since standards are very high, it is even more expensive to treat recycled materials. The most demanded materials are: paper, cardboard, aluminum, glass, plastic, rubber, ferrous and non-ferrous materials.

According to SEDESOL data, the economic potential for recovery and recycling in Mexico is over \$1.34 million USD daily (\$16.8 million MXN) (the calculation was made based on the recoverable materials from the MSW generated). Data provided by INEGI shows that in comparison; the existing recycling businesses generated \$229.9 million USD (\$2,800 million MXN) in 2003, i.e., about \$630,119 USD per day (\$7.9 million MXN), representing only 47% of its full potential. This huge gap indicates that there is potential for increasing the rate of recycling in Mexico.

Scavengers

An important contributor to waste management in Mexico, as in many other developing countries, is the informal separation of recyclable wastes by scavengers. This takes place everywhere but more often in urban areas, where there is a bigger market for selling recovered products. Sometimes, scavengers also provide the collection system for municipalities that cannot afford it. An example of this can be found around Mexico City, in the suburbs of Ciudad Nezahualcoyotl, Chalco and Iztapaluca, where hundreds of informal collectors use pick-up trucks, push carts and horse carts to collect the garbage¹⁵. Scavengers can work either individually or in very well organized groups, and sometimes operate collection centers.

In Mexico, depending on the site and type of waste collected, scavengers go by different names: Dumpsite scavengers are “pepenadores”, cardboard collectors are “cartoneros”, aluminum can collectors are “buscabotes” and rag collectors are known as “traperos”.

Scavengers work under very non-sanitary conditions, exposed to the risk of diseases or accidents, especially due to the smells, toxic gases, burns, violence, drugs, conflicts and lack of proper equipment. According to one study, in Mexico City, dumpsite scavengers have a life expectancy of 65 years, compared to the average age of 75 for the general population¹⁶.

In Mexico City alone, there are approximately 25,000 to 30,000 scavengers, including many children. The recyclable materials range in value between \$0.08 (\$1 MXN) for a kilogram of cardboard, \$1.11 (\$14 MXN) for a kg of aluminum and up to \$7.96 (\$100 MXN) for a used perfume bottle. A typical scavenger can earn up to \$24 USD (\$300 MXN) per day¹⁷, which is practically 5 times more than the average official minimum daily wage in México of \$4.45 (\$55.92 MXN).¹⁸

Scavengers are typically very well organized groups, formed even by whole families, headed by a leader. However, they operate in a very competitive environment, leading to a lack of sense of community among different groups.

It is very common for scavenger leaders to sell the recycled material to intermediaries or to the operators of the collection trucks, who also separate the already collected MSW, and sell it afterwards. This can be done at collection centers close to the transference sites or at the final disposition sites. Intermediaries in the recycling business are a typical part of the recycling chain in Mexico; in such chains of up to 3 or 4 intermediaries, the first collector earns the least amount of money while working under the worst conditions. After the first collector, usually a scavenger, the next intermediaries in the chain usually have more monetary capacity and their own small infrastructure and means of transportation.¹⁴

Composting:

The National Institute of Ecology (INE), identified 61 composting plants in the year 2005 that were either operating or had operated in the past.

The first composting facility was built and operated in Toluca city (the capital city of the State of Mexico), but was closed in 1969. A second facility opened in 1972 in Guadalajara, with a total capacity of 500 tons per day but was also closed. The same happened in other cities such as Monterrey and Mexico City. On 2006, 6 composting facilities close to Mexico City were identified, with a total capacity of approximately 6,600 tons per year, that is less than 0.02% of the total MSW generated on that year in this country or 0.14% of the generated in Mexico City that year.

Incineration

In Mexico, incineration is not applied as a MSW treatment method, however, there are 43 incinerators for hazardous wastes, 85% of which are used for biologic and infectious wastes and 15% for industrial wastes (INE, 2007).

2.4.2.8 Final Disposition

According to NOM-083-SEMARNAT-2003, landfills are divided as follows:

- Sanitary landfill: Infrastructure that applies engineering methods for the final disposition of MSW with the objective to control the environmental impacts through compacting, impermeability and any other necessary infrastructure.

These disposal sites have to comply with NOM-083-SEMARNAT-2003, which establishes the conditions required by the sites meant for final disposal; including restrictions to avoid affecting construction sites and protected natural areas, required minimal distance from airports, roads, railroads and hydrological, geological, hydro-geological aspects.

- Controlled dump: This site meets with the specifications of a sanitary landfill regarding operation and infrastructure for a sanitary landfill but does not comply with the impermeability specifications.
- Uncontrolled dump: These are sites where different types of MSW are disposed and mixed without any control.
- Open dump: These are illegal dumps where MSW is disposed and accumulated illegally without any type of control. These sites can be deserted terrains, ravines, rivers, creeks or other bodies of water.

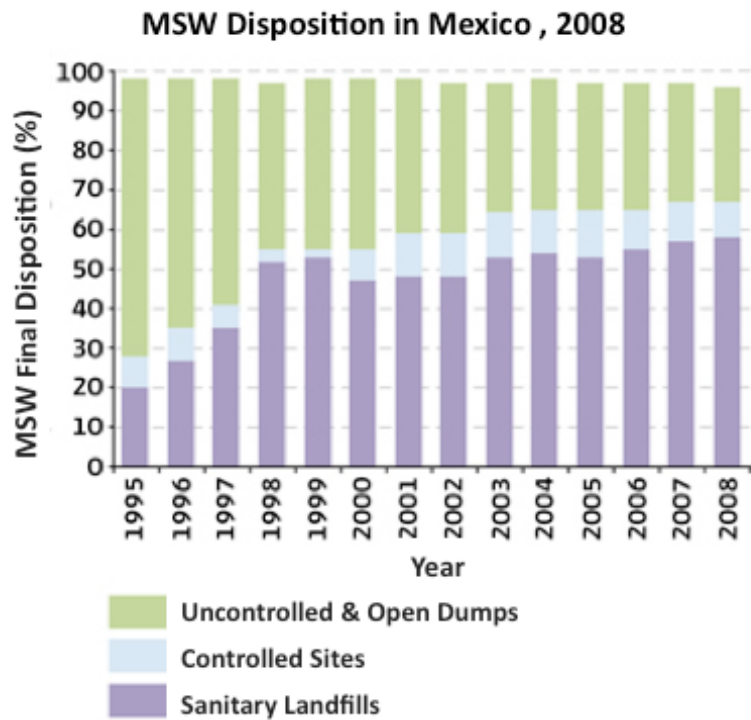
For the year 2008, it was estimated that 67% of the total MSW generated in Mexico was disposed in sanitary landfills and controlled sites, while the remaining 33% went to uncontrolled and open dumps¹³. It is believed that the cause of these uncontrolled dumps is either inadequacy of waste collection services in the area or simply trying to avoid the costs of proper disposal in a controlled landfill.

According to the SEMARNAT¹³, in 2009 there were 137 sanitary landfills and 185 controlled sites. On the other hand, INE³ states that there are 40 sanitary landfills located in mid-sized cities and metropolitan areas and 13 in small cities operating in a satisfactory way; the rest of the sites in the country do not comply with the minimum standards.

In 2010, SEMARNAT published a list of the 12 best sanitary landfills in Mexico; from which only one of these is operated by the Municipal Government (San Nicolás de Arriba, Aguascalientes), and the rest by private companies. Among the private companies operating the 12 best sanitary landfills in Mexico, a private company called PROACTIVA Medio Ambiente, is in charge of 5 of them.

Finally, in metropolitan zones, that represent 56% of the population of Mexico, 80% of the collected MSW was disposed on either sanitary landfills or controlled sites, while in semi-urban and rural cities; this share is barely 3.2%¹³.

Additional information regarding the final disposition of MSW in Mexico is provided in Figures 15 and 16 by SEMARNAT.



Note: Total percentage does not add 100 due to the fact the the recycling share is considered

Figure 15: MSW Disposition in Mexico 2008. (SEMARNAT, 2009)

MSW with Adequate Final Disposition in Mexico, 2008



Figure 16: MSW with adequate final disposition in Mexico 2008. (SEMARNAT, 2009)

2.5 Landfill gas (LFG) recovery and use in Mexico

2.5.1 LFG recovery

Landfill gas (LFG) results from the biological decomposition of organic components contained in MSW. It consists mostly of equal amounts of carbon dioxide (CO_2) and methane (CH_4), and contains a variety of trace amounts of organic compounds such as hydrogen sulfide (H_2S), which can cause odor problems (Shah K., 2000).

The generated gases escape then to the atmosphere, or migrate to the surrounding soil or leak into the groundwater and can result into serious environmental problems as well as safety and health hazards (Shah K., 2000). This is the reason why LFG control and recovery are receiving significant attention. To recover and/or control LFG, several methods are available:

Passive venting system: This system consists of a series of isolated wells or gas vents, which allows the gas to escape. In passive-control systems, the generated gas pressure drives the movement of the gas. Additionally, a trench filled with granular backfill or with gravel and a membrane intercepts the migrating gas, and allows it to escape by diffusing upwards through the trench into the atmosphere. These systems are used where gas generation is low and off-site migration is not expected.

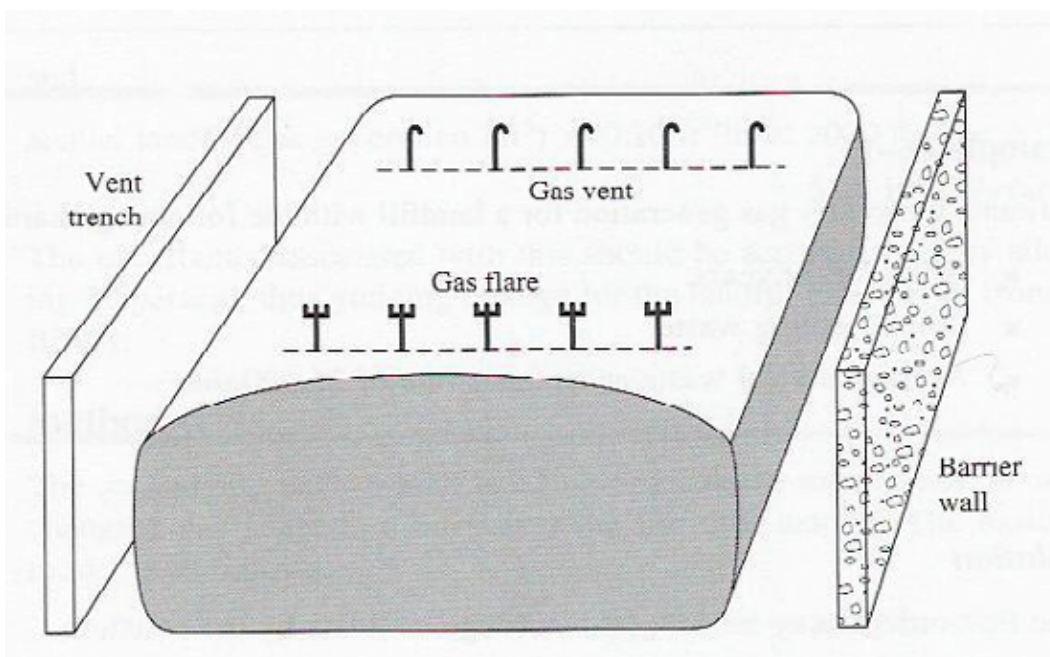


Figure 17: Passive methane gas venting systems. (Shah, K. ,2000)

Active (mechanical) venting system: this system consists of a series of deep extraction wells that are connected by a header pipe to a blower that may deliver the gas for energy recovery to an on-site burner or to the atmosphere. In addition, when sanitary landfills have energy recovery systems, most of them have a flare for the combustion of excess gas and for usage during equipment downtime.

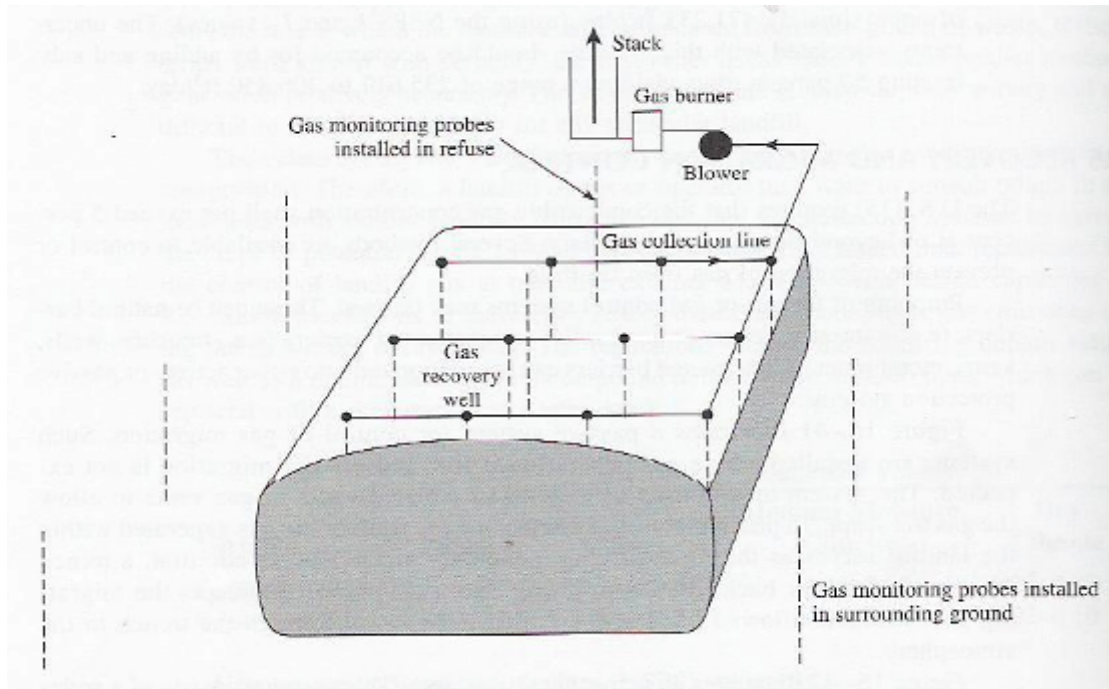


Figure 18: Active (mechanical) venting system. (Shah, K., 2000)

2.5.2 LFG utilization

The heat value of raw LFG is between 400 and 600 Btu/ft³, depending on the material deposited on site¹⁹. LFG utilization has the purpose of converting this gas into useful energy such as electricity, steam, boiler fuel, vehicle fuel or pipeline-quality gas.

Once LFG is collected, it can be used in a conversion process, where first, it is necessary to remove any impurities such as particulates. The treatment process depends on the end-use application, for example, when gas is going to be used in boilers, minimal treatment is required, but for injection into a gas pipeline, CO₂ needs to be previously removed. The most common usage for LFG is as a fuel for power generation, where the electricity is then sold to a utility company. A list of LFG uses is shown in Table 4.

Table 4: Uses for LFG (Shah K, 2000)

Medium-Energy Use (Gas includes CO ₂)	High-Energy Use (CO ₂ needs to be removed)
Internal-combustion engine	Sale to gas companies
Gas turbine	CO ₂ recovery
Power Generation	For vehicles
Steam production	
Sale to industries	

2.5.3 LFG Recovery and Utilization potential in Mexico

The SENER stated that in the year 2000, proper final disposition of all MSW generated (30.7 million tons in 2000) in sanitary landfills would generate between 1.25 and 1.75 million tons of usable CH₄ per year, and an electric potential ranging between 500 to 700 MW per year from LFG recovery, better known as biogas in Mexico. Additional to this, SENER also presented the thermal treatment electric potential. “Thermal treatment with energy recovery is the application of heat under controlled conditions to extract energy from organic wastes, its primary objective is to reduce the volume of MSW, and with the recovered energy being a by-product”²⁰. This thermal treatment electric potential ranges from 1,212 up to 1,460 MW per year, twice as much the potential generated from biogas. These potentials are schematized on a regional level in Figure 19.



	MSW Generation 2000 (thousand tons/year)	CH ₄ Generation Potential (thousand tons/year) ¹	Biogas Generation Electric Potential (MW) ²	Thermal Treatment Electric Potential (MW) ³
	0 – 550	0 – 25	0 – 10	0 – 20
	550 – 1,000	25 – 50	10 – 20	21 – 50
	1,000 – 2,000	50 – 100	20 – 35	51 – 80
	2,000 – 2,500	100 – 150	35 – 50	81 – 120
	2,500 – 5,000	150 – 300	50 – 110	120 – 270
Total	30,733	1,250 – 1,725	500 – 700	1,212 – 1,460

^{1 y 2} Landfill Gas-to-Energy Project Opportunities, EPA 430-K-99-002, 1999

³ Dhussa, A.K., Vashney, A.K. (UNDP, 2000). Energy Recovery from Municipal Solid Waste
<http://www.undp.org.in/programme/GEF/march00/page7-8.htm>

Figure 19: MSW Energetic Potential 2000 (SENER, 2003)

As it can be seen in Figure 19, the majority of the MSW (57%), and therefore the largest electric potential is found in 6 States: Mexico City, State of Mexico, Puebla, Veracruz, Guanajuato, Nuevo León and Jalisco.

Additionally, the Company International Energy Systems (Sistemas de Energía Internacional, SEISA) presented during the XIII Energy Forum in Nuevo Leon (Rumbo al XIII Foro de Energía) a figure showing the sites where biogas-recovering facilities could be developed in Mexico:

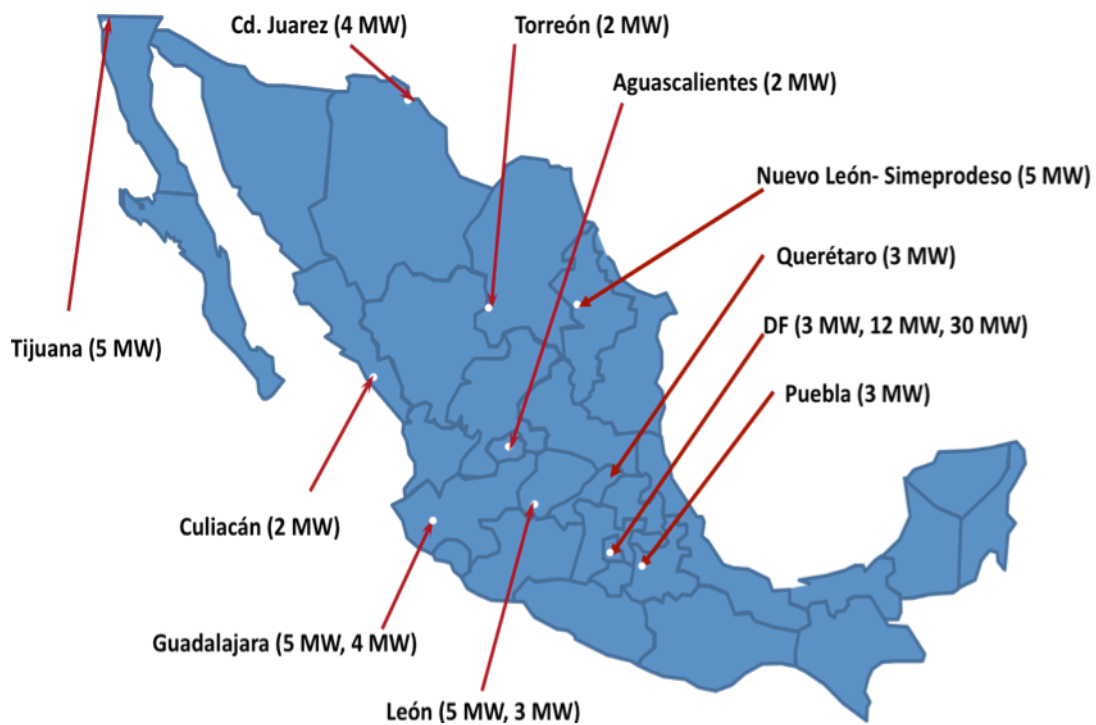


Figure 20: Sites with Biogas-Projects Potential in Mexico (SEISA, 2006)

2.5.4 LFG recovery and utilization sites in Mexico

In Mexico not everything is a potential only, there are already LFG recovery success histories. Based on a list of the best landfills in Mexico published by SEMARNAT, the following, most successful projects of biogas recovery and utilization were chosen and will be explained subsequently:

Table 5: Biogas recovery and utilization projects in Mexico

Sanitary Landfill Location	Operated by	Business in charge of the LFG Project
Salinas Victoria, Nuevo Leon	SIMEPRODE	BENLESA
Mérida, Yucatan	SETASA	ProActiva
San Nicolas de Arriba, Aguascalientes	Municipal Government	EcoMethane
Chiltepeque, Puebla	RESA	RESA
Ciudad Juarez	PASA	Biogas de Juarez

2.5.4.1 Salinas Victoria Sanitary Landfill

The Salinas Victoria (Nuevo León) sanitary landfill was rated #1 by SEMARNAT. It is operated by SIMEPRODE (System for Ecological Waste Management and Processing) and was the first site in Mexico to recover LFG and

use it as fuel. This project is the result of an alliance between the government of the state of Nuevo León, through SIMEPRODE, and the private company Bioeléctrica de Monterrey, forming Bioenergía de Nuevo Leon (BENLESA)

BENLESA was the first renewable energy project in Mexico and Latin America using the biogas from a landfill as fuel²¹. The plant started operating on September 19th 2003.



Figure 21: BENLESA internal combustion engine²²

During the day, this facility is able to satisfy the daily energy needs of the general offices of the Government of the state of Nuevo León, the public transportation system of the city of Monterrey, Monterrey's water utility and the Department for Integral Family Development (DIF) of the same state. During the night, the electricity is distributed for usage into other municipalities (i.e. for public lighting).

To supply the energy to the grid, an interconnection agreement was concluded between BENLESA and Mexico's electric utility: The Federal Commission of Electricity (Comisión Federal de Electricidad, CFE), along with other contracts such as backup in case of failure or maintenance or sale in case of energy surplus.

The plant generation capacity is of 12.72 MW, enough to supply energy for around 25,000 small houses or for the whole Monterrey City public lighting²¹; and "up until February 2010, the emission of 81,000 tons of CH₄ have been avoided, this is equivalent to an abatement of 1,718,000 tons of CO₂" (SIMEPRODE, 210). Estimations made by the World Bank Argentina predicted that over the lifetime of the project (until 2021), assuming a capture rate of 70%, 313 million m³ of CH₄

would be produced, from which 214 million m³ could be captured due to the project.

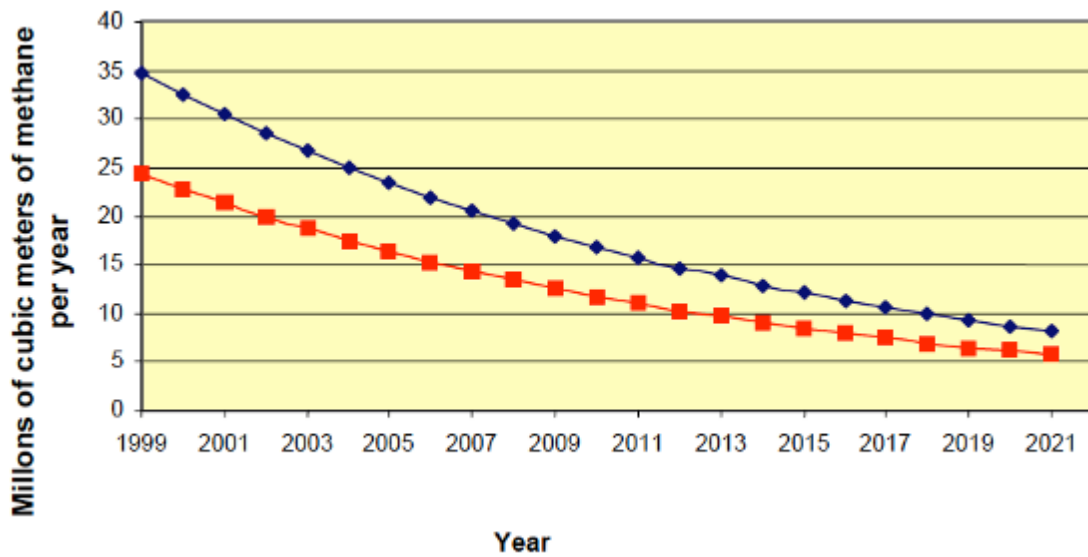


Figure 22: BENLESA Estimated CH₄ Production (blue line) and Capture (red line). (World Bank Argentina)

At the Salinas Victoria sanitary landfill, the process starts with the biogas- or LFG extraction through wells. These wells are connected through a piping system towards a central branch, which leads to internal combustion engines. The engines are connected to generators that transform the mechanical energy into electricity. Since the original conception of the project, the engines were designed to be integrated modularly. Independent systems facilitated maintenance and provided flexibility for further expansion.²²



Figure 23: BENLESA process (SIMEPRODE, 2010)

The plant was designed to operate for 25 to 30 years, depending on the lifetime of the sanitary landfill ²². In a planned expansion phase called Monterrey III, its capacity will be increased up to 17MW; this will abate 530,000 tons of CO₂ per

year, which corresponds to a removal of 200,000 cars from traffic (SIMEPRODE, 2010).

2.5.4.2 Merida Sanitary Landfill

Since 1997 in service, Merida sanitary landfill is operated by Environmental Technology Services (Servicios de Tecnología Ambiental, SETASA), a fully owned company of Proactiva Medio Ambiente. Proactiva, who is also the biogas project developer, is a Mexican subsidiary of Proactiva Medio Ambiente, a Spanish company. Even though this project does not produce electricity for commercial purposes or for internal use, it stands out from the rest because “it is equipped with safe and modern systems for treatment and final disposal of solid waste: liner systems, storm water drainage, leachate collection and treatment and best practices for passive landfill gas venting and monitoring of both surface and groundwater”.²³



Figure 24: Mérida, Yucatán Sanitary Landfill (M2M, 2009)

The objective of this LFG recover project, initiated 10 years after the sanitary landfill started operating (2007), is to maximize the LFG capture and flare it to reduce emissions of CH₄ and other greenhouse gases (GHG).

The extraction system consists of a gas wells network that is connected to the main collector. The LFG is extracted from the wells by a blower through the collector and delivers it to the flare for full combustion. It is estimated that the enhanced collection and flaring capacity of the project will be translated in a yearly capture and combustion of approximately 70% of the generated LFG. The estimate of total emission reductions of CO₂eq during the first crediting period (January 1st 2008 and ending December 31st 2014) is 744,383 tons of CO₂eq.²³. Estimations for

CH₄ generation and recovery are shown in Figure 25 and Figure 26.

Estimation of the production of methane from the landfill

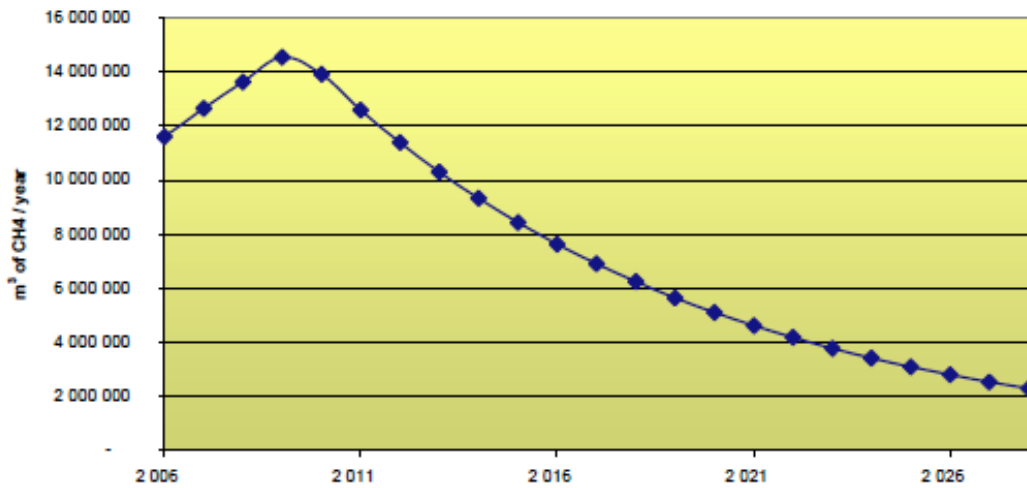


Figure 25: Mérida sanitary landfill CH₄ production estimate ²³.

Estimated recoverable quantity of methane.

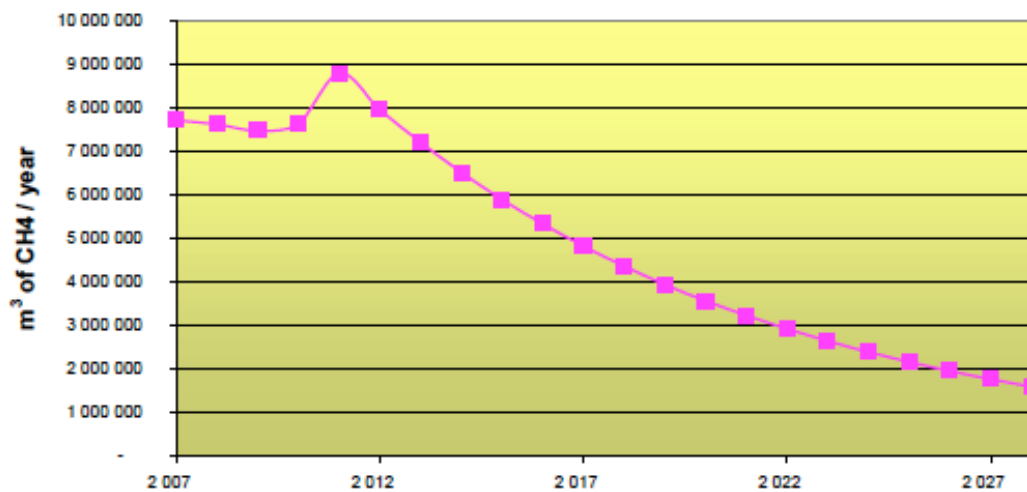


Figure 26: Mérida sanitary landfill CH₄ recovery estimate ²³.

The reason why they didn't implement electricity generation in this project was due to "the lack of maturity of these technologies in Mexico and an insufficient financial incentive"²³ when this project was created.

In 2010, Mérida sanitary landfill reached its full capacity (2.6 million tons). A second sanitary landfill, built close to the old one, is expected to start operations at the beginning of 2011 and will have 8 cells with a capacity of 5 million tons and an

useful life of 18 years, this represents a capacity of approximately 0.28 tons per year.²⁴

2.5.4.3 San Nicolas de Arriba Sanitary Landfill

The San Nicolas landfill was opened in 1999 and is projected to close in 2010. It is owned and operated by the municipal government of Aguascalientes. Prior to the Aguascalientes LFG project, there were no systems for capturing or flaring LFG in México. Furthermore, in that time, there was no economic incentive or support to develop LFG projects in this country, mainly due to high cost of construction.²⁵

The LFG to Energy project was developed, financed, built and operated by EcoMethane, a joint business enterprise between EcoSecurities and Biogas Technology. It was registered on April 23rd 2005 as a Clean Development Mechanism (CDM) and started its operations on June 15th 2006. The infrastructure was planned to consist of a highly efficient gas collection system, flaring equipment, and a modular electricity generation plant, with an installed capacity between 2 and 4 MW, for combusting the LFG to supply electricity to the grid.



Figure 27: San Nicolas de Arriba sanitary landfill installations (M2M, 2009)

The total emission reduction of the project during its crediting period (10 years) is estimated to be 1.625 million tons of CO₂eq. Additional to this, it has a gas collection efficiency of 70% and a flare efficiency of 98%²⁶. An LFG generation and recovery projected by Methane to Markets (M2M) can be seen on Figure 28.

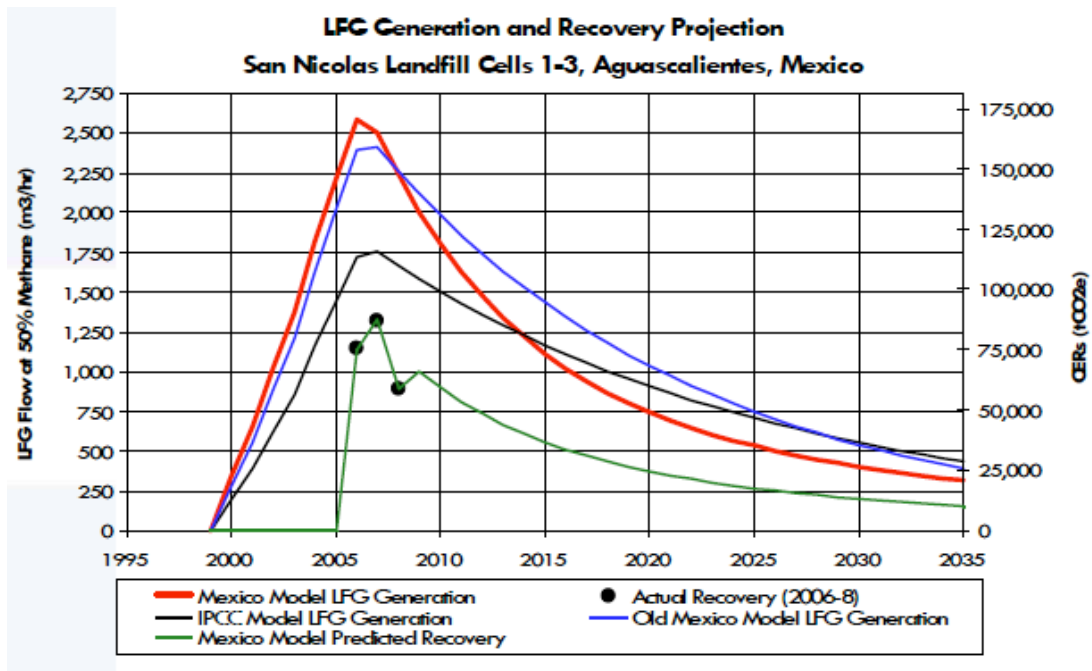


Figure 28: San Nicolas de Arriba sanitary landfill LFG generation and recovery projection, (M2M, 2009)

Until today, the site is only collecting and flaring the generated LFG due to the fact that a power purchase agreement has not been concluded yet. Once the project places a power purchase contract, a modular electricity generation plant will be installed on site.

2.5.4.4 Chiltepeque Sanitary Landfill

Owned and operated by Sanitary Landfills (Rellenos Sanitarios S.A. de C.V., RESA), Chiltepeque Landfill started operating in 1995 and accepts an approximate of 593,500 tons of MSW per year; it is expected to close in 2022 with approximately 14 million tons of deposited waste then.²⁷

The Puebla LFG to Energy project, promoted by RESA, has the purpose to develop LFG recovering techniques within the Chiltepeque landfill, to utilize the collected LFG to generate electricity. The project is divided in two phases: The first is for the LFG collection and flaring and the second, for implementing the electricity generation. Phase one began on 2010, while phase two is expected to begin operation in January 2011. The project infrastructure includes a gas collection system, a flaring system, leachate drainage system, electricity generation plant and a grid connection system. The projected reduction in CO₂eq is of approximately 2.02 million tons during the next 10 years, while the expected electric capacity will be up

to 5 MW²⁸. It is estimated that due to the used technology of LFG compression and the drying systems (to remove dust and moisture from the LFG) a CH₄ collection efficiency of over 50% will be ensured.



Figure 29: Chiltepeque sanitary landfill installations (Cruz,M. and Paredes, J)

Estimates provided by Environment Canada indicate that on average 1,825 m³/hour of LFG is available to fuel this project per year, and assuming that a gas collection and flaring system is installed in 2010, this landfill capture project has the potential of collecting an average of 2.5 million cubic meters of methane per year, during the next 10 years²⁷.

2.5.4.5 Ciudad Juarez Sanitary Landfill

Ciudad Juarez sanitary landfill will provide the necessary biogas for the “LFG to Energy” project developed by “Biogas de Juarez S.A. de C.V.” This site started operating in 1995, it has a capacity of 5.6 million tons of MSW and is expected to be open until 2010.

During the project, it is considered to install a collection system connecting the extraction wells with the flare station, a LFG control plant, leachate de-watering pumps in selected extraction wells, a condensate management system, an enclosed flaring station a blower. The electricity generation plant will have a generator with an installed capacity of 6.4 MW (from four generator engines), a 13.8 to 115 kVA transformer and a transmission line for connecting to the local grid. It will be prepared for an expansion during phase two with more horizontal extraction wells, as well as a new generator of 14.4 MW (from 9 generator engines).²⁹



Figure 30: Ciudad Juarez sanitary landfill installations (M2M, 2009)

The project is currently in the phase I, which includes the capture and flaring of the LFG produced by one cell containing approximately 4.98 million tons of waste. Even though the original plan stated that an electricity generation facility of 6.4MW would be installed in January 2008, there will be no electricity generation in the near future due to a so-called “on-the-ground” delay, but as well because the power measurement device to properly monitor electricity consumption was installed not until June 9th 2010.³⁰

The estimated total CO₂eq reductions are 1,193,490 tons for the first crediting period (7 years), and it is expected to add up to 2,639,496 tons of CO₂eq for a 14-years period and 3,908,248 tons of CO₂eq for a 21-years period. The flare efficiency is expected to be of 97%²⁵, while the estimated capture efficiency will be approximately 65%⁸⁹.

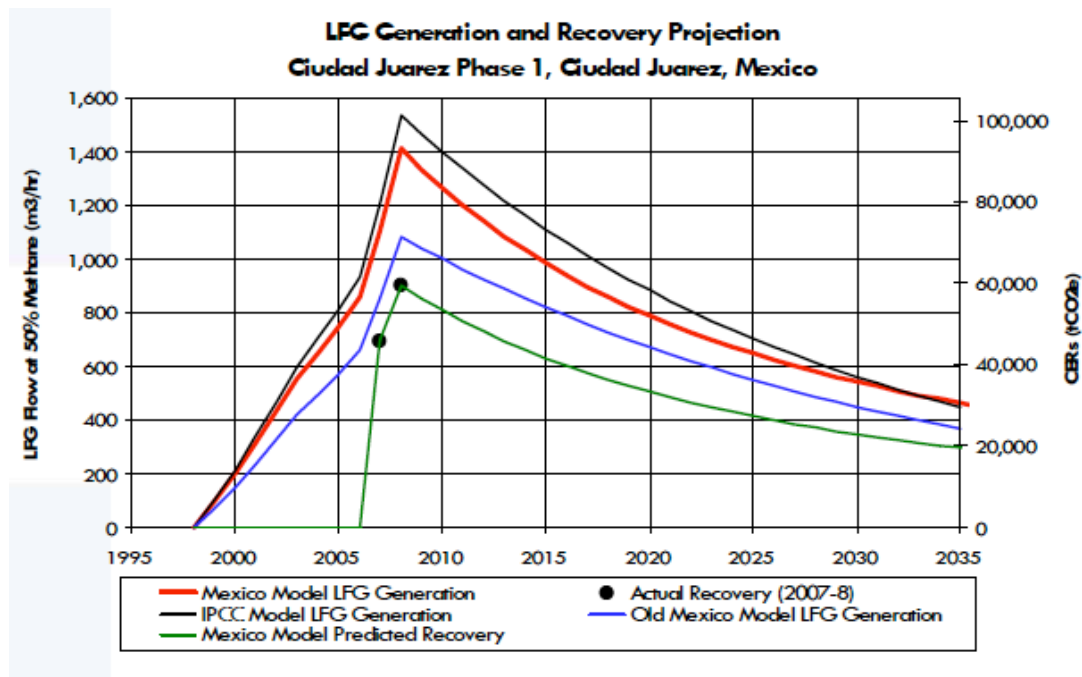


Figure 31: Ciudad Juarez sanitary landfill LFG generation and recovery projection, (M2M, 2009)

2.6 Waste Management National Strategies: the National Program for the Prevention and the Integral Waste Management 2009-2012

In March 2007, the SEMARNAT presented the Politics and Strategies for the Prevention and Integral Waste Management in Mexico, and in year 2009 it published the National Program for the Prevention and the Integral Waste Management 2009-2012 (Programa Nacional para la Prevención y Gestión Integral de Residuos, PNP GIR) to accomplish the required actions mentioned in the Politics and Strategies for the advancement of IWM in Mexico.

The program is based on the principles of reduction, reuse and recycling of waste in a framework of IMSWM, where responsibilities are shared and differentiated among the different social and productive sectors, and the three government systems.

The PNP GIR is strictly attached to the politics and guidelines established in the National Development Program 2007 – 2012 and in the National System of Democratic Planning and especially to the article 20, which establishes that different groups and actors will participate and will be consulted for its creation. Also,

according to this last article, the Sub secretary of Environmental Foment and Regulation is in charge of this program, with the help and collaboration of the Sub secretary of Environmental Planning and Politics, the Sub secretary of Environmental Management Protection, the INE, Japan International Cooperation Agency (JICA) and the German Society for Technical Cooperation (GTZ).

One of the first actions to be done for implementing the PNP GIR is the collection of all MSW generated, this should be done and guaranteed by all collection systems in the country. Added to this, all source-separation actions should be done simultaneously with activities focused on training and educating the responsible authorities, the citizens and the businesses.

Overall the Federal Government will promote the cyclic use and proper waste disposition through:

1. Prevention and minimization of waste generation.
2. Reuse.
3. Recycling.
4. Treatment.
5. Restricted and appropriated final disposition according to the particular circumstances of each locality and based on the priority order described by the Law.

The PNP GIR 2009-2012 strategies can be found in Appendix I.

2.6.1 Implementation Advancements

In Mexico City, June 2010, during the V Seminar of Sustainable Housing and Climate Change, the SEMARNAT presented some of the PNP GIR advancements³¹:

- 12 states signed treaties to implement the PNP GIR in projects evaluated on 2008 and the first part of 2009 (42 projects with a total investment of 17.4 millions USD, approx. 219 millions MXN).
- 6 treaties signed by 5 States to implement PNP GIR projects.
- 3 State Programs for Prevention and Integral Waste Management were completed: Mexico City, State of Mexico and Quintana Roo, and an inter-municipal program was also completed: Mazamitla, Jalisco.

- Organization of the information related to waste in the National System of Environmental Information (Sistema Nacional de Información Ambiental)
- Expansion of financial options: National Infrastructure Fund (Fondo Nacional de Infraestructura, FONADIN), Fondo Metropolitano, Border Environment Cooperation Commission (Comisión de Cooperación Ecológica Fronteriza, COCEF), SEDESOL, and SEMARNAT to support with research, equipment, infrastructure and cleaning services. Private sector participation is now possible.

2.6.2 Future Impacts

If properly implemented, in year 2012, the National Program for Prevention and Integral Waste Management will have the following impacts in MSWM:³²

- ⇒ Up to 213,000 tons per year of inadequately disposed MSW will be reduced.
- ⇒ The final disposition of MSW in sanitary landfills will increase up to 82% from the total generated.
- ⇒ Between 3,000 and 4,000 tons per day (between 11 and 15%) of MSW will be recovered from materials recovery facilities (MRF).
- ⇒ 50% increase of the actual installed capacity of organic waste treatment plants, from 61 up to 93 composting facilities.
- ⇒ The reuse of glass, cardboard, metals and plastics will increase up to 11%.
- ⇒ Reduction of approximately 9.5 million tons of CO₂eq annually

CHAPTER 3: WASTE MANAGEMENT SITUATION IN TOLUCA

3.1 Toluca: population, geography and administration

Toluca is one of the 125 municipalities of the State of Mexico, the most populous state in Mexico with 14 million citizens. It is located in the central part of the State of Mexico, 45 miles away from Mexico City (72 km), at an average elevation of 1.63 miles over sea level (2,600 m.), making it the highest urban city in the country. Due to this high elevation, the yearly average of Toluca's weather is about 54 °F (12°C).

It is the capital city of this state and its official name is "Toluca de Lerdo". It has an area of 162.16 mi² (420 km²), which corresponds to 3% of the total area of the state. According to the last official INEGI survey, in the year 2005, 747,512 people were living here (17th most populated city in Mexico), from which 93% of it lived in urban areas. However, Toluca's municipal government estimates for 2009, a population of 815,000 citizens and a population density with approximately 5,025 people per mi² (1,940 people per km²).

Mexico City has a considerable impact on Toluca due to its close proximity. This turns Toluca into a very cosmopolitan and industrialized city. Some of the most important Mexican industries can be found here, like textiles, automobiles, beverages, and pharmaceutical.



Figure 32: Geographical location of Toluca, State of Mexico. (Based on Valle de Bravo-Rodavento localization map)

For complying with its political and management functions, Toluca has a territorial division of 24 delegations. These 24 delegations are also divided in sub-delegations, neighborhoods and districts (Refer to Appendix II to see Toluca's delegation structure). The population is accentuated in the municipality seat, or main district, (the place where the administrative authorities are held), with 65.28% of the population.

It is important to mention that what is considered to be the main district, is integrated for census purposes by the following delegations: Santa Cruz Atzacapotzaltongo, San Cristóbal Huichochitlán, San Mateo Oxtotitlán, Santiago Tlaxomulco, Santiago Miltepec, San Lorenzo Tepaltitlán, Santa Ana Tlapaltitlán, Santa María Totoltepec, San Buenaventura and Capultitlán. The rest of the delegations are: San Pablo Autopan, San Pedro Totoltepec, San Mateo Oztacatipan, San Andrés Cuexcontitlán, Santiago Tlacotepec, Tlachaloya, Cacalomacán, Calixtlahuaca, San Felipe Tlalmimilolpan, San Juan Tilapa, San Martín Toltepec, San Antonio Buenavista, San Marcos Yachihuacaltepec and Tecaxic. Figure 33 shows a map of what is considered as urban and rural zones in Toluca.

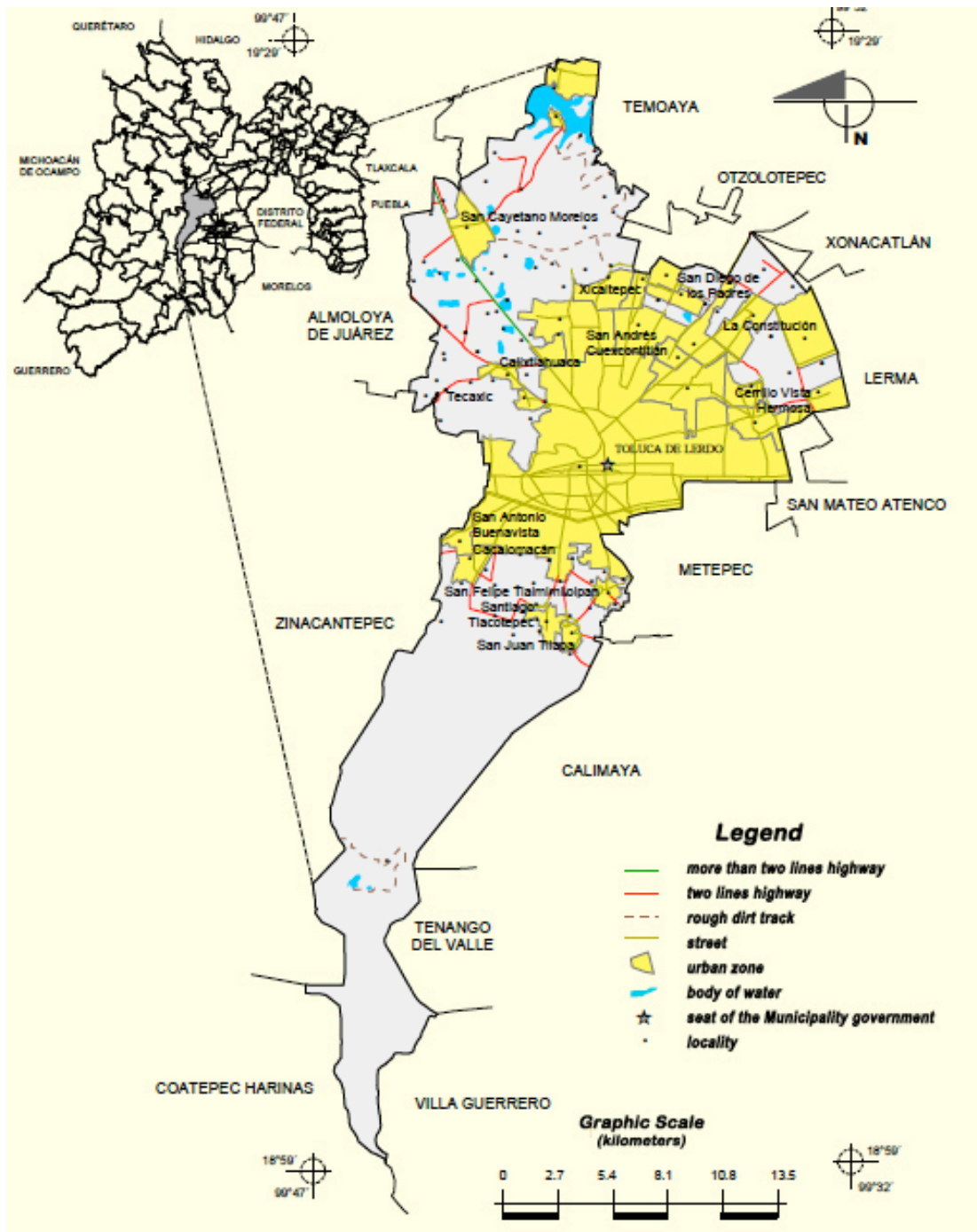


Figure 33: Toluca rural and urban zones (INEGI, 2008)

3.2 Regulatory Framework

Along with the federal WM laws and regulations, each state and municipality has their own regulatory framework. In the State of Mexico these are: Code for the Biodiversity of the State of Mexico (Código de Biodiversidad del Estado de México), Program for the Prevention and Integral Waste Management of Municipal Solid Wastes and Special Wastes of the State of Mexico (Programa para la Prevención y Gestión Integral de Residuos Sólidos Urbanos y de Manejo Especial del Estado de

México), Municipal Organic Law of the State of Mexico (Ley Orgánica Municipal del Estado de México) and Law for the Protection of the Environment and the Sustainable Development of the State of Mexico (Ley de Protección al Ambiente para el Desarrollo Sustentable del Estado de México). Additional to these laws, Toluca is regulated by the Municipal Code 2010 (Bando Municipal).

The Code for the Biodiversity, through its articles and specifically in its Fourth Book, states that it is the states and the municipalities' obligation to formulate programs oriented on the prevention and integral waste management (IWM). This book includes the basic outline for planning and implementing these programs, stating that the implementation must be gradual.

In order to comply with the Code for Biodiversity, the Program for Prevention and Integral Waste Management was published in April 2009. It has the objective of establishing specific programs, priorities and actions towards IWM in the State of Mexico. Some of the actions proposed in this document are: the support of new waste treatment and waste re-use technologies that are feasible, economical and socially accepted, MSW source-separation, separate collection and differentiated treatment. Also, this program mentions that the SEMARNAT has the responsibility to coordinate those activities³³. The main strategies of this program can be consulted in Appendix III

However, the municipal authorities must implement all these actions, programs, strategies and the waste management system itself. This is established in the Municipal Organic Law Articles 31 and 125, along with other obligations conferred on the municipalities.³⁴

The Law for the Protection of the Environment and the Sustainable Development of the State of Mexico is, in most of its articles, focused on the promotion of recycling and re-use of MSW, and the installation and operation of facilities or any other actions required for these purposes, such as the encouragement of the citizens participation in the planning, execution and evaluation of the environmental policies.

Finally, regarding Toluca's Municipal Code, its 17th article establishes that it is an obligation for all the citizens to hand over the solid wastes properly separated into organic and inorganic. The 77th article classifies as an infraction non-compliance with this obligation. Nevertheless, none of these two articles are really implemented.

3.3 MSW in Toluca: management system and characteristics

3.3.1 MSWM system

In Mexico, every municipality has its particular way to provide the MSW management (MSWM) service. However, in general the main structure of larger municipalities is similar to the one in Toluca. It consists of an elaborate MSWM structural organization. The Municipal President, who designates Directors in charge of the Public Services and Environment Areas, is in charge of forming this organization. Within it can be found a Sub secretary of Solid Waste, who is in charge of managing personnel and every stage related to MSWM.

According to the Biodiversity Code of the State of Mexico, in its article 4.56, the public service of sweeping and collection of MSW provided by the municipalities must cover the following stages:³⁵

- Sweeping of common areas, streets, roads and any other type of public spaces.
- Collection and transportation of MSW to transference stations.
- Temporal storage of MSW within selection plants for distributing materials to composting, re-usage, recycling, thermal treatment or any other treatment used for its reduction, re-use or elimination.
- MSW elimination through final disposition technologies or through sanitary/controlled landfills.

In Toluca, this service is provided to streets, houses, schools, some institutional offices and public roads, even those under the state jurisdiction such as: Solidaridad Las Torres, East Paseo Tollocan and the access to the capital of the State of Mexico. Additionally, they have special operatives to address manifestations, meetings, celebrations, civic, cultural and sports events.

3.3.1.1 Generation

In the 50's, Toluca's per capita MSW generation was only 0.11 tons. By 2009, this rate increased by 200% to an average per capita generation oscillating from 0.32 tons to 0.37 tons. The total generation of MSW in Toluca was estimated at 295,000 tons, which corresponds to about 0.36 tons per capita. The city proper generates about 60% of this amount.³⁶

3.3.1.2 Composition

The MSW composition is evaluated through a characterization study described in the NOM NMX-AA-22-1985: Selection and quantification of sub products. Such study was carried out in 2004 and showed that in this municipality, 60% of the MSW was organic, and the rest, inorganic¹⁵. For the year 2009, official information from municipal authorities showed a decrease from 60% to 50% in the share of organic waste. Based on this fraction, it can be concluded that by means of organic waste composting, a large part of the problems related to MSW generation in this city could be avoided. Figure 34 show the MSW composition for the year 2009.

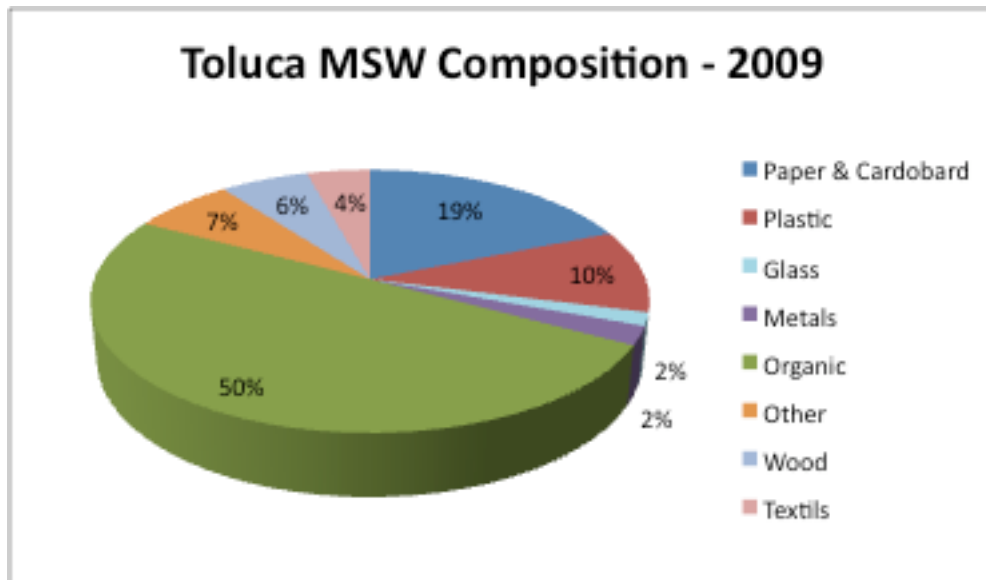


Figure 34: Toluca MSW Composition 2009. (Toluca General Direction of Public Services and Environment, 2010)

3.3.1.3 Temporal Storage

As in all cities of Mexico, MSW temporal storage stage is responsibility of the MSW generators. The responsibility for the public courses is of the municipal authorities.

In the urban areas, black polyethylene bags designed especially for this purpose are used, along with plastic containers. On the other hand, rural areas tend to use less resistant plastic bags as containers, like the ones provided by supermarkets or any other type of store. In May 2010, in order to provide other waste disposal options and avoid uncontrolled disposition, municipal authorities installed special high-capacity containers in at least 4 different neighborhoods.³⁷



Figure 35: Temporal Storage Containers in Toluca .³⁷

At Toluca, even though MSW separation at the source is considered as an obligation in the Municipal Code, and even though some programs have been implemented, the inadequate infrastructure and not enough dissemination of information to the public have undermined this project.

At public spaces, metal containers are used, but they are usually not designed for sorting the waste. This decreases the public awareness about the importance of separating the waste at its origin.

3.3.1.4 Sweeping

While municipal authorities are in charge of sweeping the public spaces, the Code for Biodiversity in the article 4.44 states that it is the responsibility of every waste-generator to sweep everyday the sidewalks in front of their houses, businesses or any other land of their property.³⁵ The service provided by the authorities on streets is usually done through manual sweeping, while mechanical service is used only for main streets during nights.

In Toluca, the manual sweeping is done by 86 workers, from which almost 70% work during the morning shift and the rest during the afternoon shift, from Monday to Saturday, sweeping a daily average of 112 miles (180 km). On Sundays, only 35 workers are available for both shifts. The manual service at Toluca has a daily cost of \$2,642 USD (\$33,190.13 MXN), which takes into account the labor,

equipment such as brooms and vehicles, and the transport and final disposition of an average of 20 tons daily.

Regarding the mechanical sweeping, the Municipal Development Plan 2006 – 2009 states that from 7 mechanical sweepers available, only 3 are in use; which is due to the high repairing costs. Mechanical sweeping is done mostly at nights to avoid vehicle traffic. On a state-level average, the mechanical service is provided 340 days of the year, which costs approximately \$13,850.4 USD daily (\$174,000 MXN)³³.

3.3.1.5 Collection and disposal of MSW

In October 2009, The General Direction of Public Services and Environment of Toluca reported in its Municipal Development Plan 2010 – 2012 that an average of 510 tons of MSW are collected daily, i.e. about 186,000 tons per year.

As will be shown in the Recycling section (3.3.1.7), the estimated recycling rate in Toluca is 24,000 tons per year. Subtracting this number and also the amount landfilled in sanitary landfills (186,000 tons) from the estimated total generation of 295,000 tons shows that 85,000 tons of MSW are not accounted for and must be disposed in uncontrolled dumps ("tiraderos"). This represents about 29% of the total MSW generated in the year 2009. The municipality of Toluca is fully aware of this major environmental problem and they are planning to increase collection coverage and proper disposal of MSW to 100% by 2012. Sixty collection trucks are used at the present time, each manned by one driver and two assistants (vehicle specifications are shown in Table 7).

This service is provided through the Direction of Solid Wastes to 90 sectors of the city distributed in 9 out of the 24 delegations. The rest, that is to say 15 delegations, are addressed by the company "Servicio de Transporte S.A. de C.V.", to whom these services have been granted since 2004.

From the state point of view, the State of Mexico collection system in the year 2004 had the following characteristics:

Table 6: Collection system characteristics in the State of Mexico.³³

Type of Municipality	# Reported Municipalities	# Municipalities with Collection	# Vehicles	Collection Staff Personnel	Municipalities with Separated Collection
Rural	57	53	149	618	11
Semi-urban	16	16	121	471	2
Urban	5	5	57	70	-
Metropolitan	15	15	675	4,084	3
Total	93	89	1,002	5,243	16

A highlight in this information is the number of municipalities with separated collection, as it exhibits that only 20% of the metropolitan cities implemented this service even though it is already stated as an obligation in the Biodiversity Code of the State of Mexico. As mentioned before, in Toluca, due to the lack of cultural acceptance, programs and proper infrastructure, separated collection has been unsuccessful. However, this stage of the collection is being applied regularly after the actual collection of the waste, through scavenging and in designated facilities for the collection and separation of MSW with recycling and composting potential. In 2008, the Director of Solid Wastes in Toluca declared that during the collection, the crew separated approximately 35 to 40 tons of recyclable material.³⁸

According to Toluca’s Municipal Development Plan 2003- 2006, some of the problems faced by the collection service are the irregular urban design in the south part of the city, which makes it very difficult to design collection routes and the rapid grow of several zones in the municipality.

Collection Routes

There are 193 routes to provide household MSW collection services, from which 148 correspond to urban and sub-urban zones, and 45 to rural zones. The Direction of Public Service of Toluca is in charge of planning these routes. Appendix IV shows an example of these routes, where neighborhoods, collection days and final disposition sites can be found.

The service starts at 7:00 am up until all assigned routes are covered, afternoon shifts are only used when the service couldn’t be provided or finished during the morning shift due to operative situations or transportation problems.

3.3.1.6 Transportation and Transference

Along with many other municipalities in the State of Mexico, Toluca does not have a transference station. A couple of years ago, Toluca used to have a transference center, but it was decommissioned, due to the following reasons:

- A commitment previously made with neighbors of this zone to use the area of the center for a local park and a chapel.
- Since the station was located within an urban zone, this created environmental pollution such as volatile organic compounds.
- A transference station needs space exclusively for this usage. The previous site was used not only as transference station but as well as a municipal workshop, general warehouse, and public offices, which produced overcrowding.

Today, the transference station is a public park including a chapel, as can be seen in the pictures below. However, at the time of the visit, no containers for disposing waste within this park or its surroundings could be found.



Figure 36: Toluca previous transfer station

Due to the lack of a transference center, all collected waste is directly transported to the final disposition site once the collection route is completed, or if the vehicle is full. Regarding the infrastructure for transportation, for this purpose 75 vehicles are available; Table 7 shows the type, number and capacity of those vehicles owned by the municipality, as well as the ones used for sweeping and collection.

**Table 7: Toluca MSW vehicle infrastructure
(Toluca General Direction of Public Services and Environment, 2010)**

Type of Unit	# of Units	Sweeping & Collection	Transportation & Transference	Volume Capacity					
				#	m3	#	m3	#	m3
Front Loader	1		1	1	64				
Side Loader	4	3	1	4	14				
Rear Loader	65	35	30	51	19	14	21		
Roller Compactor	9	9		3	15	6	17		
Compactor	20	9	11	7	20	5	18	8	10
Rectangular	5	4	1	5	18				
Container Chassis	19		19	19	5				
Roll-off Truck	3		3	3	17				
Dump Truck	9		9	9	6				
Total	135	60	75						

It is important to mention that according to the Municipal Development Plan 2009 – 2012 of Toluca, from the 135 units available in total, 20 units are broken, 4 will be shut down soon and some others were in operation for more than 20 years, which makes them highly unreliable. In total, only 111 units are active.

Also, there are 11 new units that were given by the State Program “Clean City” (Ciudad Limpia), but they have not been used for operations because the donation process is not finished yet.



Figure 37: Rear loader truck for MSW collection in Toluca



Figure 38: MSW truck storage

According to the Prevention Program for the Integral Management of MSW in the State of Mexico, the estimated costs for operating a transference station within the State of Mexico are:

Table 8: Transference stations estimated costs for the State of Mexico, 2007. ³³

Unit	Estimated Costs 2007	
	USD	MXN
\$/ton	21	263
\$/container	128	1,609
\$/km	25	312
\$/1,000 citizens	4	48

Using the estimated costs in Table 8 and assuming a collection of 510 tons of MSW daily, an approximate of \$10,710 USD (\$134,130 MXN) would be spent everyday to operate such transference station in Toluca.

3.3.1.7 Treatment

In the State of Mexico, little information regarding MSW treatment has been collected. From the 125 municipalities, only 13% reported any kind of MSW treatment, and 73% of those are in rural or semi-urban municipalities:

Table 9: Main MSW treatment facilities in the State of Mexico.³³

Type of Municipality	# Reported Municipalities	# Municipalities with Composting	# Municipalities with Mechanic/Biologic Treatment	# Municipalities with other Treatment
Rural	57	5	0	0
Semi-urban	16	3	0	0
Urban	5	0	1	0
Metropolitan	15	3	0	0
Total	93	11	1	0

Recycling

In 2001, it was estimated that approximately 1% of the MSW generated in Toluca was recycled³⁹. Even though no further information is available for Toluca city, on a state level, INEGI reported that in 2003 there were 814 registered businesses concerned with the commerce of waste material for recycling in the State of Mexico. Specifically in Toluca or in communities very close to it, according to the business directory, there are 14 businesses listed as “Waste Recycling”. However, practically all of those are dedicated to the collection and recycling of industrial, commercial, hazardous and biologic wastes, and some of them do not have proper facilities.

As in the rest of Mexico, scavengers play an important role in recycling in Toluca, but even so, they barely collect 8% of the total MSW generated³⁸, while the rest ends up in sanitary landfills and waste dumps. Also, in Toluca, it is very common to see people going house by house asking if somebody wants to sell any kind of paper, cardboards, or any other objects with metal parts in it.



Figure 39: Plastic recycling business

For the purposes of this study, it was assumed that the total recycling in Toluca amounted to 8% of the total MSW, that is 24,000 tons. Two of the MSW recycling businesses in Toluca are the Recyhul Group and Petstar that are described in the following sections.

Recyhul Group

Recyhul Group is a business dedicated to recycling tires. From the 1 million of tires recycled yearly by Recyhul, they create nylon, synthetic “grass” covering, hoses and shoe soles, among other products. This facility has a capacity to process up to 5,500 car tires daily, or 1,600 truck tires. The process is mostly mechanic, including some sort of thermal treatment process. Materials from the tire are extracted and recycled, such as the steel. In 2008, Goodyear and Recyhul signed an agreement to process all the collected used tires from Goodyear’s distributors through Recyhul’s facility.



Figure 40: Recyhul's tire recycling process. (Portal Automotriz, 2010)

Also, Recyhul is partner in a pilot project in Toluca where asphalt rubber (AR) is produced. Phoenix Industries, a U.S. Company that builds waste tire recycling plants and AR blending equipment, developed this project. In this project, Recyhul provides the crumb rubber and “Mezcla Asfáltica de Alta Calidad” contributes with the hot mix production and paving. This pilot project was developed with the objective of giving the road authorities in Mexico a way to evaluate this product in order to implement it in further projects.



Figure 41: Asphalt rubber production process. (Phoenix Industries, 2010)

Petstar

Petstar “is the first bottle-to-bottle recycling facility with this sophisticated technology in Latin America”¹⁷ and the third in the world. Its objective is not only to generate a profit from the sale of the recycled material, but also to improve scavengers working conditions¹⁷. Environmental Developer (Promotora Ambiental, PASA), a leading Mexican environmental service business that offers services such as waste collection, and Avangard, the largest post-consumer plastic collector in Mexico, formed Petstar.

In the Petstar case, a study carried out by Growing Inclusive Markets (GIM) mentioned that one of the challenges faced by PASA was the promotion of recycling. They also found that recycled plastic bottles come in at very low quantities (8 – 12% of the estimated total in the MSW stream), which makes processing unprofitable. This would not be the case if citizens could be persuaded to separate their waste at the source, thus increasing the feedstock to the plant to 80%, turning recycling of plastic wastes into a profitable business. However, due to the lack of environmental awareness and the informal nature of waste collection in Mexico, this is a difficult scenario to achieve. As a result, Avangard appeared as a possible partner, since it collects approximately 100,000 tons of PET per year in Mexico and also maintains very good relations with scavengers.

Subsequently it was shown that this very particular relationship of Avangard, contributes significantly to its business. Avangard is supplied with PET through a network formed by four different types of suppliers, with plastic waste coming from about 1,300 sites in 22 states (Table 10).

Table 10: Avangard's Suppliers. ¹⁷

Type of suppliers	Supply Sites %	Supply Volume %
Suppliers who separate PET at source	67	3
Suppliers who separate PET at collection	7	26
Scavengers	14	27
Intermediates who collect PET from the 3 previous groups	12	44

In Table 10, the importance of the scavenger's participation can be seen. Avangard buys directly from the leaders of the group, and it is estimated that in total, around 2,600 people, 10 to 25% of them children, contribute to PET collection.

With these alliances, Petsar was born. The plant needed an investment of approximately US \$28 million and started operations in April 2009. The facility has an area of 269,097 ft² (25,000 m²) and thanks to high-tech machinery it is operated by only 65 employees on a 24/7 schedule all year round. It has a capacity of 32,000 tons of PET per year, all of which is supplied by Avangard.

The recycling process is carried out once the plant receives the PET in bales, which is processed for washing and segregation (the extraction of the contaminating elements such as labels, caps, dirt, non PET bottles, etc.) and then crushed, creating a "flake". Next, the flake is extruded into a pellet and de-contaminated and re-polymerized through a thermal process. This creates a food-grade resin known as post-consumer regrind (PCR), which can be sold to bottling companies. It is reported that 35 bottles of PET represent 1 kg. of PET, of which 800 grams of resin can be obtained. The process last around 9 to 12 hours and requires approximately 1 liter of water per kg of PET. This is the reason why the plant considered the inclusion of a water treatment facility, which enables its reuse.

Along with the environmental and economical benefits brought by recycling, Petstar helps to reduce the gap between scavengers and the final product by eliminating all the intermediaries. It is planning to use these additional resources, usually owned by intermediaries, in developing programs that improve scavengers' life and job quality. One of these planned programs focuses on reducing child labor by creating Centers of Community Education and childcare facilities. On the other hand, scavengers' life conditions will be improved by creating segregation centers that will include a roof, cafeteria, restrooms and electricity services. Additionally, adults working here will have the opportunity to sign an official contract that includes benefits such as social security.

Finally, Petstar is also committed to increase the environmental awareness in Mexico. Working together with the Business Economy and Commitment (ECOCE, Economía y Compromiso Empresarial) and schools, Petstar will encourage children

to recycle by rewarding them with “eco-points” for every kilogram of PET they separate at home for recycling, which then can be exchanged for presents such as balloons, computers, DVDs and bicycles. Additionally, they plan to give guided tours and build an auditorium to give conferences to explain the importance of recycling.



Figure 42: Child scavenger at work, PETSTAR facilities, and scavenger being interviewed in the framework of the national research study.¹²

Collection centers

To promote recycling among the citizens, Toluca municipal authorities created “collection centers” that collect all non-organic wastes that citizens separate at their homes. Up until now, Toluca has established 12 collection centers distributed within different convenience stores and neighborhoods, where accepted materials are: cardboard, paper, glass, plastic, metal, aluminum, batteries, tetra-pak and wood. For every kilogram of recycled material, citizens receive in exchange coupons called “Ecos”, which function as money because a numeric value is assigned to them. These can be used to purchase some basic products such as rice, beans, detergent, and soap, among others.³⁸

In addition to this program, the Environmental Direction advice schools to create collection centers among their institutions. So far, 16 schools are participating in this environmental project, where they receive certificates by selling all recyclable waste to specialized recycling-facilities. These certificates can be used to acquire educational material or to improve their facilities. An important part for the appropriate operation of these centers is the creation of Vigilance Council to

guarantee the transparency in the application of the revenues, so that they will only benefit the students.⁴⁰

Composting:

The only official data found regarding composting activities in Toluca was published on December 2006 in the Municipal Development Plan 2006- 2009. This Plan mentions that in 2006, 8% of the MSW was composted, however it was not specified whether this figure represented the MSW collected, generated or from the organic fraction. On the other hand, for the entire State of Mexico, data shows that in the year 2000, 23 tons of organic waste per day was used for this process, resulting in 11 tons per day of compost. Based on a state average, these 23 tons represent less than 0.17% of MSW generation daily in the year 2000. Regarding composting costs, for the year 2007 they were calculated to be \$38.5 USD per ton (\$483.43 MXN)³³ in the State of Mexico.

The INE published in 2007 a list of identified composting facilities focused in Mexico City, Morelos and State of Mexico. In the case of Toluca, only one facility was identified, classified as active in that time⁴¹, but no further information was provided, and the plant could not be located during the time of this research.

3.3.1.8 Final Disposition

The Biodiversity Code, in its article 4.91 states that the final disposition of MSW in the State of Mexico in sanitary landfills is the least preferable. First, other options have to be considered like re-usage, recycling, treating the wastes or if applicable composting. In this way, the Code states that a maximum of 10% of MSW with the proper composting characteristics can be landfilled. Also, it states that whenever waste is landfilled, these sites must have leachate treatment systems and gas extraction mechanisms for collecting and flaring it or using it to produce electricity or as an alternative fuel.³⁵

The State of Mexico final disposition sites information can be summarized in Table 11:

Table 11: Disposition sites inventory in the State of Mexico.⁴²

Type of Disposition Site	# Disposition Sites	Tons per day	%
Sanitary Landfill	10	5,871	39%
Controlled Site	37	4,282	29%
Uncontrolled Site	52	1,605	11%
Wastes not disposed		3,112	21%
Total	99	14,870	100%

Since December 20th 2004, when NOM-083-SEMARNAT-2003 came into effect, all municipalities must review and evaluate their final disposition sites in order to define whether or not they fulfill this standard. At the end of 2009, 59 municipalities had started their regularization procedures, 32 handed in their regularization plans and 27 the verification list only. Toluca is not specifically mentioned in this list, however some municipalities that share the same disposition sites are listed.⁴²

The General Direction of Public Services and Environment reported a daily cost per collected, transported and disposed ton of MSW of \$51.71USD (\$649.73 MXN). If as reported, approximately 510 tons of MSW are collected daily in Toluca, this means that the daily cost of collecting, transporting and disposing the total MSW are \$26,372 USD (\$331,623 MXN).

Toluca has no final disposition infrastructure within the city; this is why they do not exhibit any costs for maintenance, machinery, wages, fuels, or any other kind of actions related to the management of these sites. However, Toluca must pay for disposing and transporting the MSW in sites located in other municipalities. Currently, the MSW collected by the municipality (estimated at 186,000 tons) is disposed in two sanitary landfills; half of the collected MSW is disposed in San Antonio la Isla and the other half in Zinacantepec. Both of these landfills collect landfill gas and flare it. Regarding the collection routes, 42% of the routes have San Antonio la Isla as their final disposition site and they cover the northern part of Toluca. The rest of the collections routes dispose the collected MSW in the Zinacantepec landfill, and serve mainly the southern part and most of downtown. This is because the municipality of Zinacantepec borders the southwest of Toluca

(Figure 43).

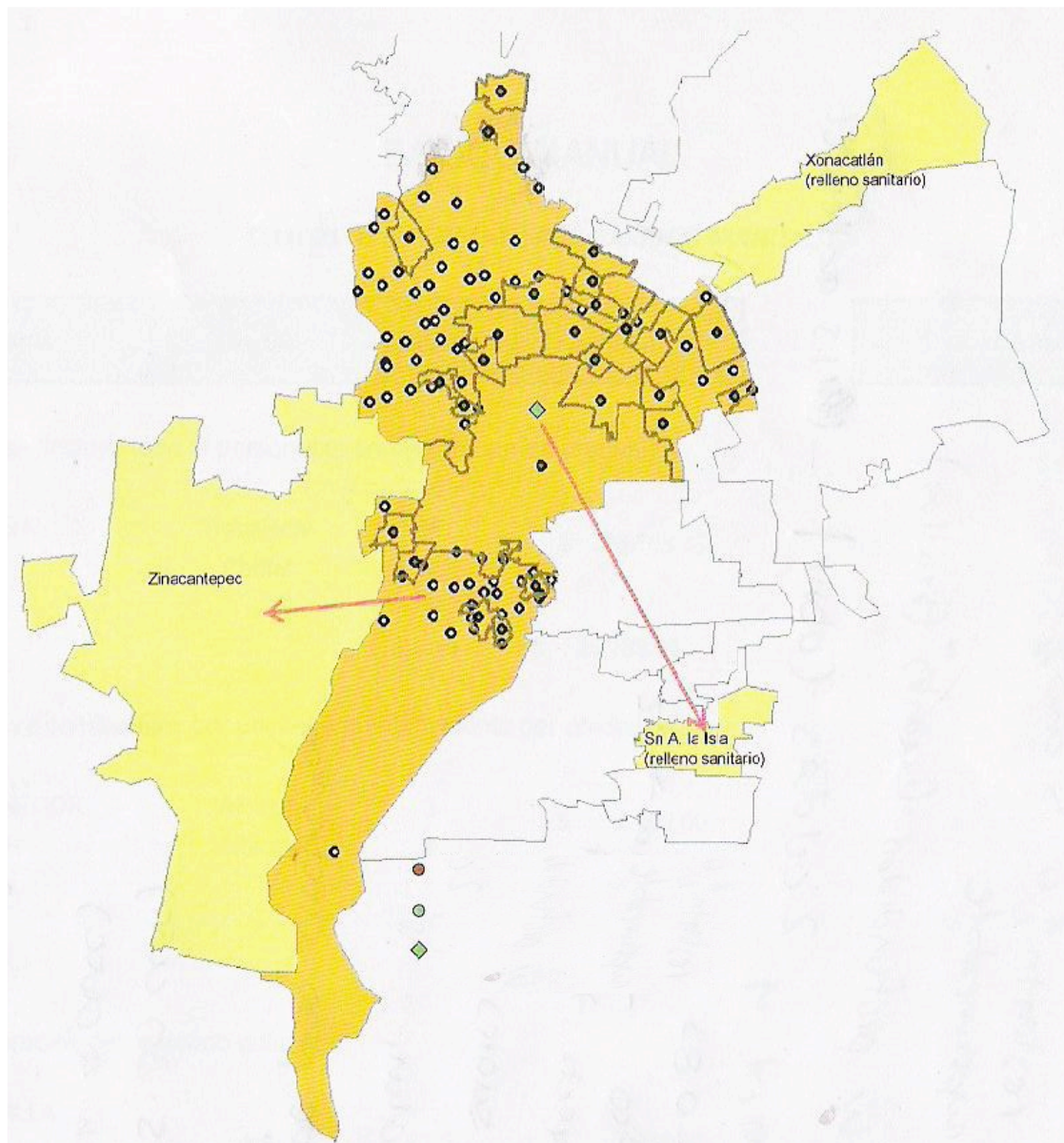


Figure 43: Toluca MSW final disposition sites. (Toluca General Direction of Public Services and Environment, 2010)

Sanitary Landfill of San Antonio La Isla Municipality

Also known as “The Station” (La Estación), it is located between the municipalities of San Antonio La Isla and Calimaya, at an average distance of 10.7 miles (17.3 km) from downtown Toluca*. It complies with all the environmental standards of NOM-083-SEMARNAT-2003. It is operated by a private company called: La Estación de San Antonio, S.A. de C.V and has a total area of 1,131,788.2 ft²

* Google/INEGI Maps calculations.

(105,146.56 m²), from which 753,574.48 ft² (70,009.36 m²) is designated for MSW disposal. It has an estimated useful life of 13 years, with a total capacity of 2.287 million tons⁴³.



Figure 44: Approximate location of San Antonio La Isla sanitary landfill (Google Maps, 2010)

Toluca is not the only city that uses this site, “The Station” receives MSW from five other municipalities: Lerma, Malinalco, Metepec, Tenancingo and Zumpahuacan, and some private collectors. This landfill was authorized and started operating on May 2007, and has an authorized reception of 1,000 tons/day, however, according to the Secretary of Environment of the State, in October 2010, the average reception of MSW is of 850 tons/day⁴³. A study carried on 2007⁴³, estimated that during the first 3 years of this sanitary landfill, it would receive approximately 400 tons/day, and 800 tons/day the rest of its useful life. When compared to the real reception, this quantity doubled, at least within its third year of operation. According to this study, up until the year 2010, this site would have received 506,500 tons. Based on the total land surface used of this sanitary landfill (105,146.56 m²) and its total capacity, it was calculated a total capacity of 21.7 tons/m².

In order to last approximately 13 years, data about MSW reception estimates, final compacted size and cover material, was used to calculate its necessary size. Based on these, the site was designed with a volumetric capacity of 3.9 million m³

Regarding its operation, in this site, scavenging or any kind of separation or recycling is prohibited. The operation stages are as followed:

- Access control: all vehicles must be registered along with information such as vehicle characteristics, access time, origin and type of wastes.
- Waste weighting: vehicles with a maximum capacity of 80 tons are weighted in a special scale, the information is registered and the vehicles move towards the unloading area.
- Waste disposition: two methods are used during this stage: the trench method for the first cells and the area method. In the trench method, a trench is excavated and MSW is placed and then compacted in there, after this, all or some of the soil that was taken out is used to cover the waste and compacted. In the area method, MSW is deposited, compacted and then cover material is used and again compacted.
- Cells coating: once disposed and compacted, MSW is covered with material extracted from the same site. This material is a sandy loam soil and the average thickness of the coating will be 0.65 ft (20 cm).
- Closure: is formed of several steps and actions. The most important are: preliminary environmental diagnostic, site evaluation, design of control infrastructure, design of the final coating, environmental supervision, final use of the landfill and subsequent monitoring after closure.



Figure 45: San Antonio la Isla sanitary landfill. (SEMARNAT, 2010)

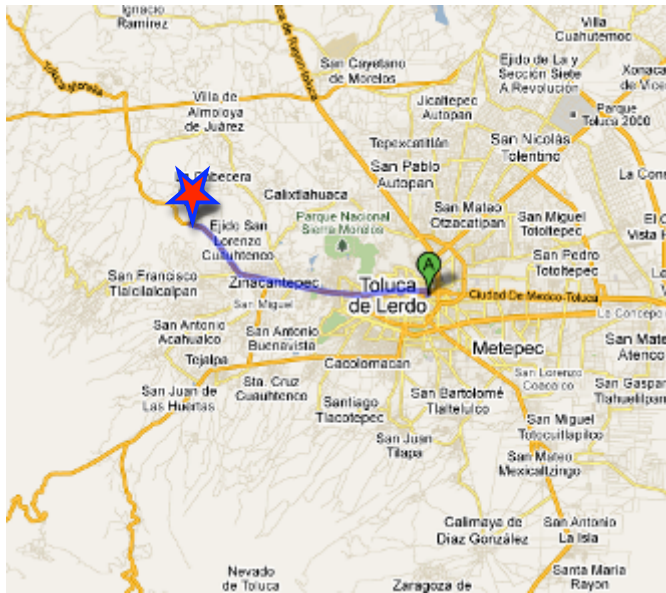


Figure 46: Zinacantepec Sanitary Landfill Location (Google Maps, 2010)

This site is located on the highway Toluca – Zitácuaro, at an average distance from downtown Toluca of 9.3 miles (15 km)*. Just like “The Station”, this sanitary landfill complies with all the regulations and standards required from the NOM-083-SEMARNAT-2003. A private company operates it: “Mantenimientos y Servicios

Ambientales S.A. de C.V.”

This sanitary landfill has been in operation since 2007, and according to the staff, during these 4 years it has received a total tonnage of 600,000 tons treated adequately. However, 20 years ago this site was an open-air dump, and therefore, “Mantenimientos y Servicios Ambientales S.A. de C.V.” had the task of not only building up a sanitary landfill in accordance with the NOM-083-SEMARNAT-2003, but as well cleaning up the site, which was necessary for its operation and for repairing the environmental damages caused by the dump. This task took them 1 year and a half.

This sanitary landfill has two cells with a surface area of 3.8 hectares (38,000 m²), while the site has an approximate total surface area of 8.5 hectares*. The staff mentioned that it has a calculated lifetime of 4 more years. This is expected to change, as there is a cell reserved for extending the site. This extension has a land surface of 107,339 ft² (10,000 m²) where an additional 225,000 tons of MSW can be disposed. This extends the useful life to 5 years when considering an average daily

* Google/INEGI Maps calculations.

reception of 350 tons/day.

The average MSW received per day is 600 tons, but personnel from the staff mentioned that there are peak days with tonnage of up to 1,700. Besides Toluca, Zinacantepec sanitary landfill receives MSW from private collection companies and other municipalities in the State of Mexico such as: Zinacantepec, Amanalco de Becerra, Almoloya de Juárez, Almoloya de Alquisiras and Sultepec.

Since this site complies with the NOM-083-SEMARNAT-2003, its daily operation is very similar to “La Estación”: access control, waste weighting, waste disposition by the area method and cell coating with an average thickness of 1.15 ft (35 cm). The difference is that here scavenging is allowed, as it is the only available way to separate recyclables materials in the site. When asked about the possibility of implementing composting to process the MSW organic fraction, the staff mentioned that it was not feasible because the organic waste arrives very mixed with the rest of the waste making it impossible to separate the necessary amount to carry out this process.



Figure 47: Zinacantepec Sanitary Landfill Access (Google Maps, 2010)

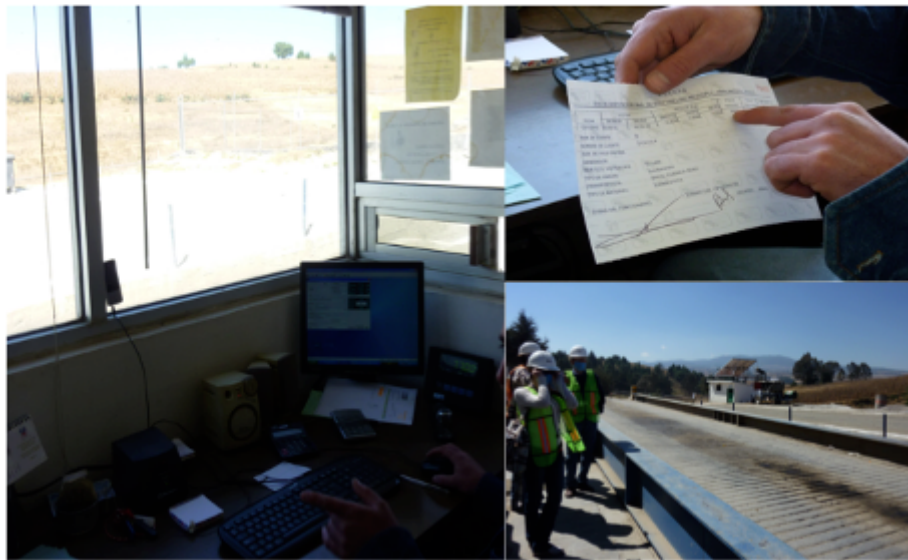


Figure 48: Zinacantepec Sanitary Landfill Weighting System.



Figure 49: MSW disposal and compacting in Zinacantepec sanitary landfill.

As mentioned earlier, scavenging activities are allowed in this site. Since scavenger groups have been working in this place since it was an open- air dump, the operating company decided to let them carry out separation activities as long as they work under the company guidelines. These guidelines include the usage of a safety helmet and a vest, no women or children are allowed, and to work on their own responsibility. Additionally, a first aid kit and vaccinations are offered every year for both, the scavengers and the operating staff.



Figure 50: Scavenging in Zinacantepec sanitary landfill.

Regarding its infrastructure, a grid of drainpipes that conduct the produced leachate to a holding tank, controls the leachate. The holding tank has a collection capacity of 600,000 liters (600 m³). To treat the collected leachate, this is either evaporated or recycled through the landfill; this permits further removal or stabilization of contaminants and facilitates the decomposition process. In the case of LFG, this is recovered through 14 extraction wells that deliver the gas to the surface and is then burned in the same wells.



Figure 51: Leachate holding tank and LFG extraction well.

The site conducts periodic soil, leachate and MSW characterization studies In order to comply with the NOM-083-SEMARNAT-2003. Additional to this, an on-site chemist opens random plastic bags when deposited to ensure that the received waste is composed of MSW only.



Figure 52: Zinacantepec Sanitary Landfill Characterization Studies

Finally, an important characteristic of this sanitary landfill is its commitment towards sustainability. For this, they have implemented solar panels that provide the energy for their installations and lighting, LED light bulbs, reforestation plans for areas surrounding the site and an adobe blocks production using the clay found in the site, among other actions.



Figure 53: Solar Panels Provide Energy to Zinacantepec Sanitary Landfill

3.4 MSWM services and treatment perception survey

Some key factors for a successful implementation and planning of any MSW management strategy are the willingness of the citizens to actively participate, their perception towards the quality of the services provided and their knowledge about waste treatment methods. To quantify and acquire a general idea of Toluca's citizens MSWM perception, the author carried out a questionnaire survey.

3.4.1 Methodology

The survey involved questions that covered the following topics:

- General perception of the risks related to waste.
- Knowledge of per capita waste generation.
- MSW source-separation.
- Satisfaction and knowledge of the MSWM system provided by Toluca Municipal Government.
- MSW treatments and final disposition risk perception

The survey had 10 questions* related to one or several of the different aspects mentioned before and a section for gathering data such as gender, age, occupation, neighborhood and zip code. The zip code provided information regarding whether or not the interviewed person lived in Toluca municipality, as it is common to find people working or studying in Toluca city but living in other neighbor municipalities.

To quantify subjective attitudinal data such as risk perception and satisfaction, questions were designed using a five point Likert-scale. Surveys were offered online as well through printed copies, distributed at schools and businesses of different economic levels in the municipality of Toluca.

This survey can be found in Appendix V for its Spanish version and Appendix VI for its English version.

3.4.2 Sampling Procedure

The determination of the sample size was done based on the level of precision, desired confidence, time and application feasibility. The level of precision, or sampling error, “is the range in which the true value of the population is estimated to be”⁴⁴; it is expressed in percentage points (e.g. +/- 5%). “The confidence level represents how often the true percentage of the population who would pick an answer lies within the confidence interval”⁴⁵.

* Some of the questions were based on a proposed survey by: *The Use of Life Cycle Assessment Tool for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies, Deliverable Report on D5.1 and D5.2: Social Sustainability Criteria and Indicators for waste management*, (<http://www.iwar.bauing.tudarmstadt.de/abft/Lcaiwm/Project/TheResults.htm>)

The equation used to determine the sample was the one developed by Cochran (1977), for large populations (greater than 50,000⁴⁶):

$$n_o = \frac{Z^2 pq}{e^2}$$

Equation 1: Sample size equation for large populations.⁴⁴

Where:

n_o = Sample size.

Z = Abscissa of the normal curve that cuts off an area at the tails.

e = Desired level of precision.

p = Estimated proportion of an attribute that is present in the population.

q = 1 – p

Assuming typical values: a confidence level of 95% (Z value of 1.96), a precision level of +/- 5% and a maximum variability p= 0.5, the necessary sample size determined was 385 surveys.

3.4.3 Results

600 surveys were given away in different schools, businesses and public spaces in Toluca. From these, 403 were returned and after doing a cross-reference check with the provided zip codes, 60% corresponded to people living in Toluca. The reason of this might be that since Toluca is the capital city of the state, many people living in nearby municipalities come here to work and/or study. In fact, due to the closeness of some municipalities, these are considered as a region called “Toluca Valley” (Valle de Toluca, VDT). Other municipalities considered as part of the VDT metropolitan area include Metepec, Calimaya, Almoloya de Juárez, San Mateo Atenco, Lerma, Lago, Temoaya and Xonacatlán⁴⁸.

For the purpose of this research, information collected from questions 7, 8 and 10, that have to do with the collection frequency, knowledge about the service, MSW treatment/final disposition sites in Toluca, and the overall perception of the collection service, will be considered only for the fraction of the sample that lives in the neighborhoods pertaining to Toluca municipality. Therefore all percentages and information provided of these 3 questions were calculated based on a sample of 241

surveys. Even so, when necessary and for comparison purposes, some results will be presented for both, Toluca and the VDT, especially in case of large discrepancies.

Since the rest of the questions regard citizen's perceptions and habits, and due to the fact that these municipalities are considered to pertain to the same region, the whole sample will be used for the rest of the questions.

From the total sample, 53% males and 47% females answered the survey. 81% of those polled range between 18 and 29 years, 14% from 30 to 39, only 2% from 40 to 50, the rest were either older than 50 or younger than 18. Since the highest response rate from all delivered surveys was obtained from schools, the occupation statistics showed that from those polled, 57% were students. Sex and occupation charts are depicted in Figures 54 and 55.

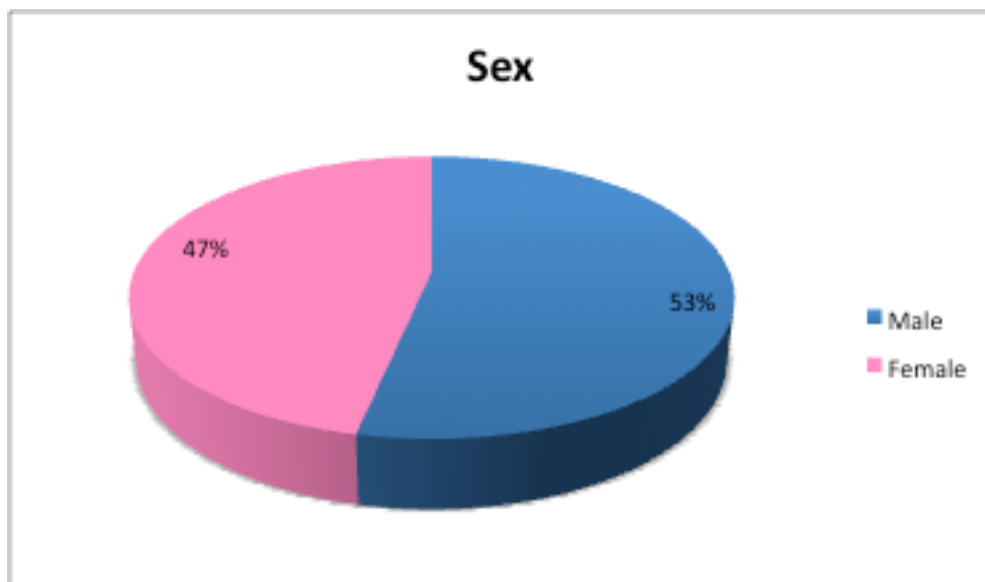


Figure 54: Perception of the MSW management in Toluca - Sex

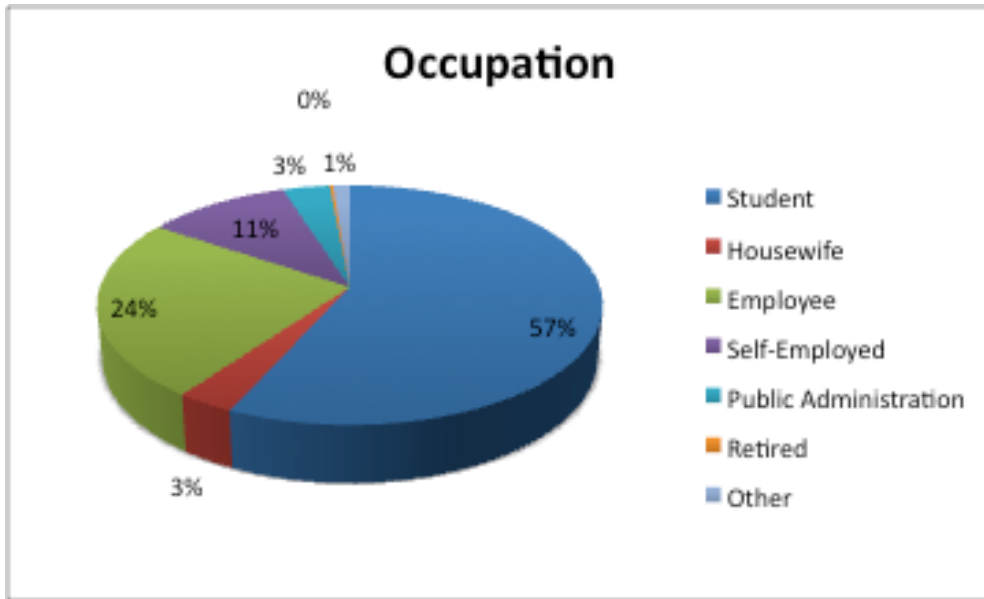


Figure 55: Perception of the MSW management in Toluca - Occupation

Regardless the age, sex or occupation, those polled ranked water pollution as the environmental problem that represents a bigger treat to the human life, followed, by air pollution, waste and finally, noise.

When asked if they had an idea of how much waste they generate every day, 83% answered they didn't know. The remaining 17% calculated an overall average of 2 kg of waste generated daily, twice as much as the daily MSW per capita generation in Toluca.



Figure 56: Perception of the MSW management in Toluca - Waste generation

Regarding waste separation at home (organic and inorganic), 57% answered that they separate it. When isolating these results for Toluca citizens only, the share of people that separates slightly decreases to 54%. Also when analyzing the sample of Toluca-citizens only, it can be seen that employees of any kind are more prone to separate the waste, 65% of employees do it. When compared to the students, 44% declared to carry out this task.

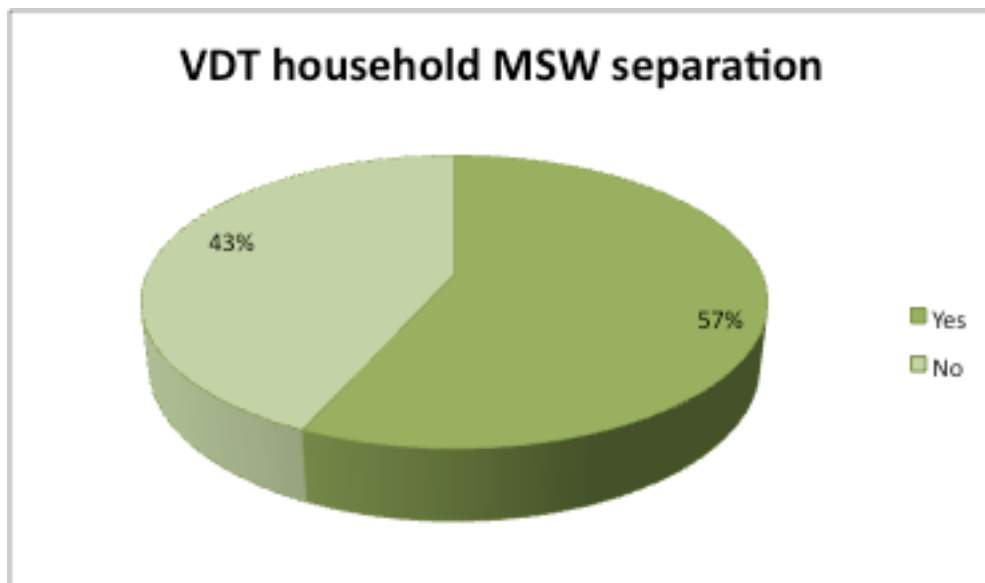


Figure 57: Perception of the MSW management in Toluca - VDT household waste separation

The reasons given for those who don't separate the waste are displayed in Figures 58 and 59 for VDT and Toluca respectively.

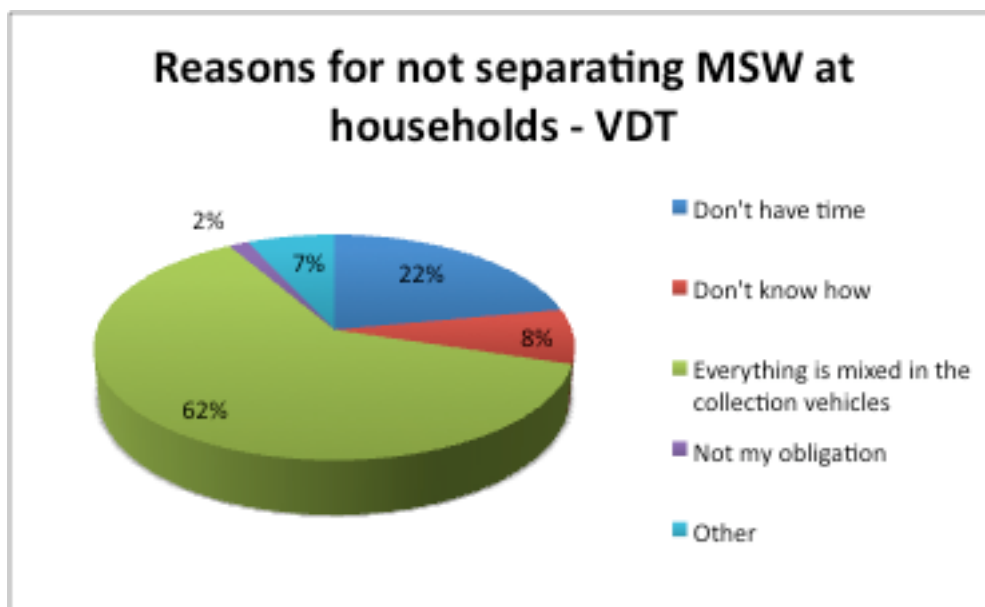


Figure 58: Perception of the MSW management in Toluca - Reasons for not separating waste in Toluca Valley

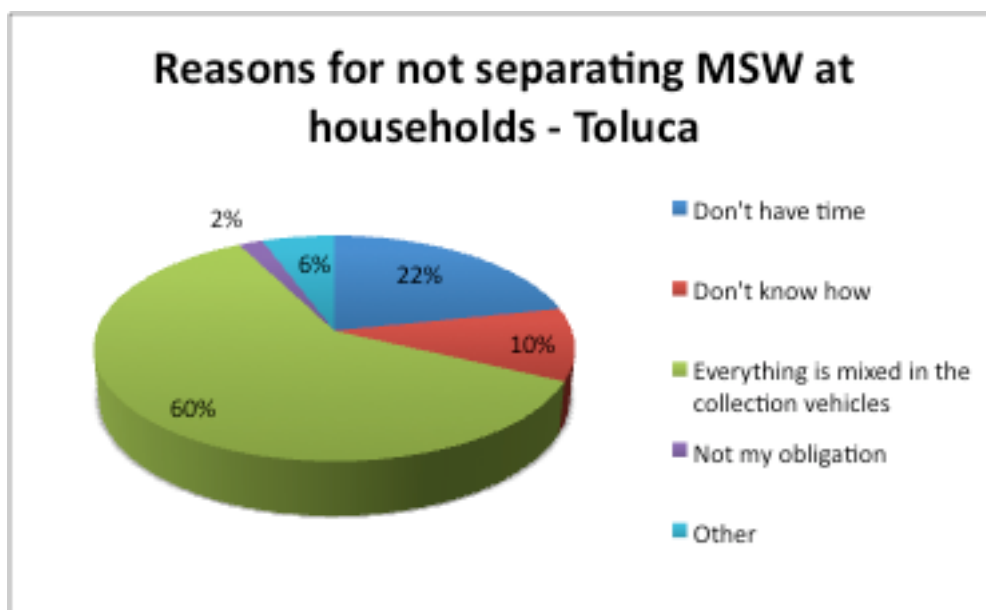


Figure 59: Perception of the MSW management in Toluca - Reasons for not separating waste in Toluca

When comparing these last results, it can be seen how the percentages from Toluca citizens do not differ widely from those living in Toluca and in nearby municipalities. The largest differences can be seen in the share of people that do not separate because they do not know how (62% in VDT vs. 60% in Toluca) and because everything is mixed again in the collection vehicles (8% in VDT vs. 10% in Toluca). In both cases, the majority of those polled agreed that they don't do it because it seems senseless if everything is mixed again during collection.

Due to the large organic fraction contained in Toluca's MSW composition, the different options for composting can play an important role towards implementing an IMSWM. Concerning composting, 60% of the people know the basics about this process, 17% understand the process and know about the different existing composting methods and 22% know nothing about it. From the people that know at least something about composting, 36% have used compost, and as it was expected, the majority of these people (73%) that have used compost were the ones that answered that have a better knowledge about the composting process and techniques.

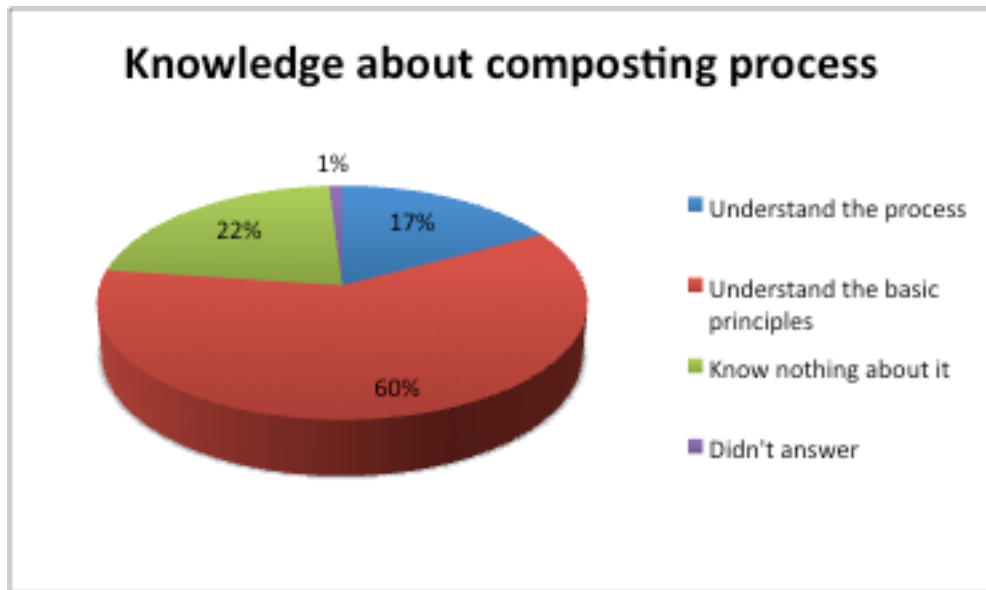


Figure 60: Perception of the MSW management in Toluca - Knowledge about the composting process in VDT

In the MSWM service survey section, when questioned how much they know about the services provided in their neighborhood, 71% from those polled living in Toluca, chose answers ranging from no idea to an average knowledge, 29% of the people have no idea. On the other side, only 7% know everything about this service. Occupation statistics shows that this might have some influence because students tend to know less, since most of the times; they are not in charge of taking out the waste when the collectors arrive. From the students, 13% of them declared to know a lot or completely about the MSWM service. In the case of the employees (including independent and public administration), almost twice as much (25%) declared to have a lot or complete knowledge about this service.

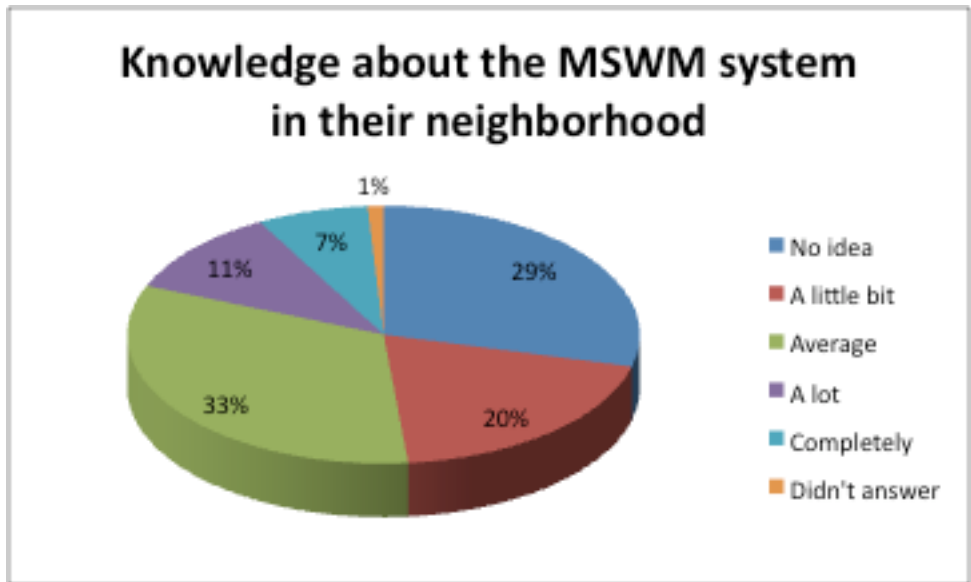


Figure 61: Perception of the MSW management in Toluca - Knowledge about the MSWM system in Toluca

Regarding the frequency collection, the results for Toluca only, showed no trends towards a specific answer. When standardizing all the different questions provided, it was identified that the most common provided answers could be grouped as: specific days and time, specific days with no time and an interval of days (i.e. 2 times per week). This shows the lack of knowledge and/or the lack of consistency in the collection routes.

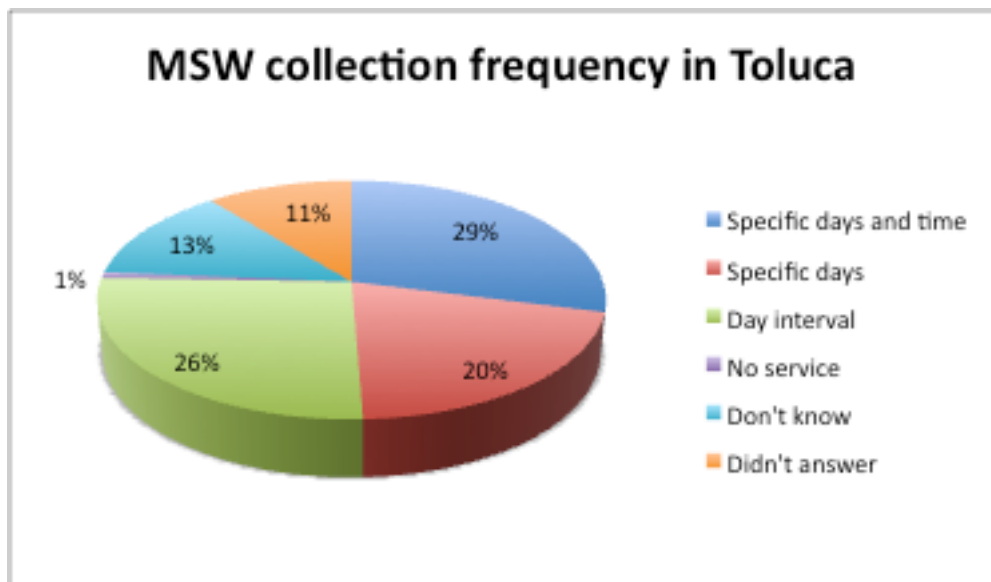


Figure 62: Perception of the MSW management in Toluca - Collection frequency in Toluca

Another data that showed the lack of consistency in the routes and/or the lack of information was found when cross referencing the neighborhoods and the data provided the General Direction of Public Services and Environment (Appendix

IV). Only 3 neighborhoods were found where more than 6 who people that live there answered this survey and that provided answers with specific collection-days, the neighborhoods were: San Lorenzo Tepaltitlán, Morelos 2nd section and Seminario. Form these, in the case of Morelos 2nd section and Seminario, no more than 33% mentioned the same days as indicated by the official routes. In the case of the other neighborhood (San Lorenzo Tepaltitlán), no one provided the same collection days. Even so, in some cases one or two days form the official ones were mentioned, but answer could not be standardized due to the different answers provided.

Regarding the number of collection days per week, the official collection routes have an average collection frequency of 3 days/week. The surveys indicated an average of 2 days/week. At a neighborhood-level, the average number of collection days/week of 83% of them, reported less collection days than the official number of days reported by the Municipal Government*.

Additional to collection, the waste disposal and treatment methods available in Toluca were also asked. The results are shown in Figure 63, were it can be seen that more people believe that in Toluca, MSW is disposed in waste dumps, rather than in sanitary landfills.

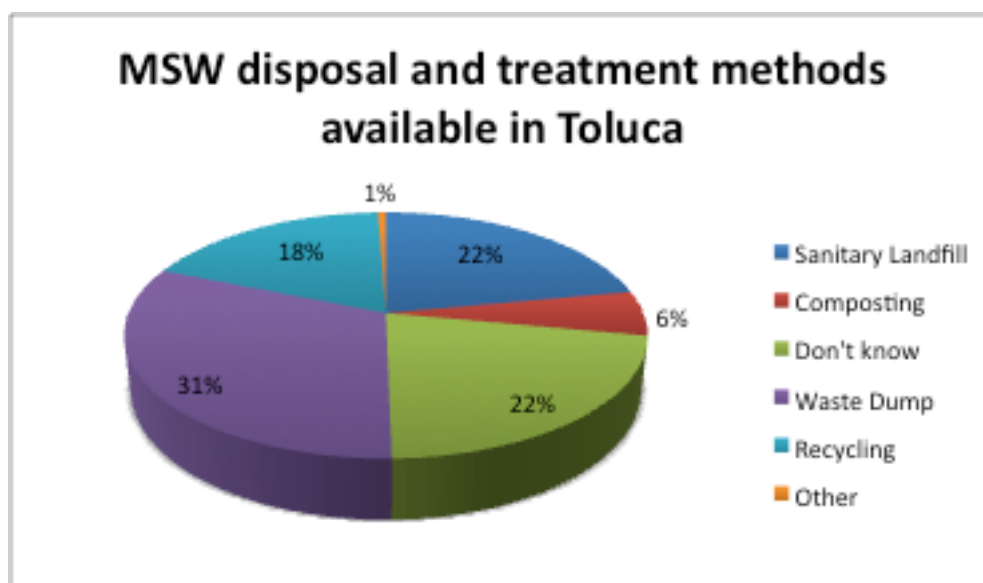


Figure 63: Perception of the MSW management in Toluca – Waste disposal and treatment methods available in Toluca

* Only neighborhoods with at least 6 answered surveys were considered.

Overall, the MSWM system in the municipality of Toluca was qualified as average (2.7 in a scale of 1 to 5). Only 20% of those polled described it as either good or very good

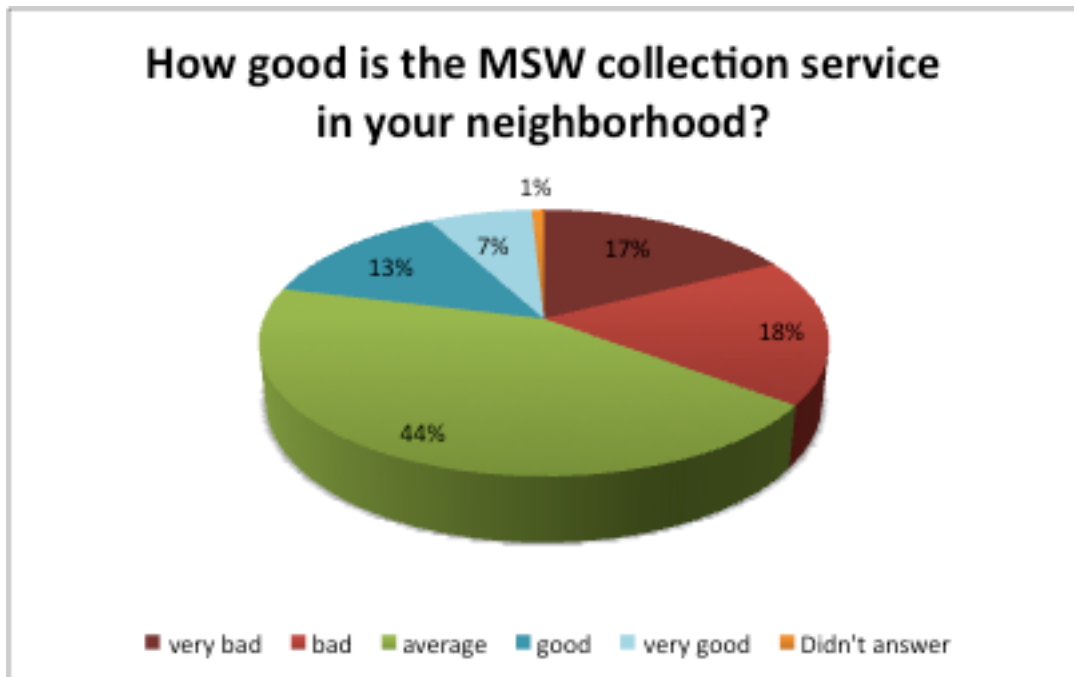


Figure 64: Perception of the MSW management in Toluca – MSW collection service

As a final point, those who answered the survey (total sample considered), assigned a numeric value to represent the perceived risk for each of the following final disposition and treatment methods: sanitary landfill, waste dump, composting, recycling, incineration and mechanic or biologic treatments. Recycling is perceived as the least risky method, as opposed to waste dumps. Results are depicted in Figure 65.

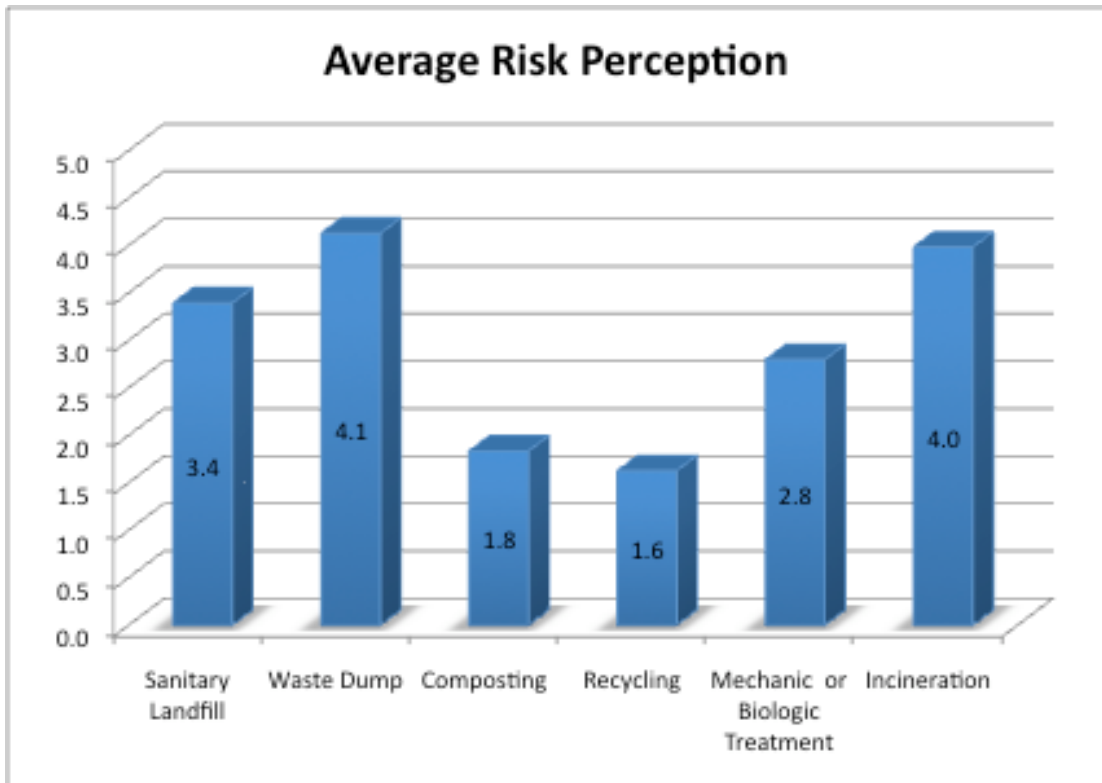


Figure 65: Perception of the MSW management in Toluca - MSW final disposition and treatment methods perceived risk

CHAPTER 4: POTENTIAL FOR IMPROVEMENT IN TOLUCA

4.1 Projected MSW Generation and Composition in Toluca

Every stage of MSWM requires knowing the actual MSW generation quantities in order to operate properly. But of even more interest is the future MSW generation since its estimate is an important prerequisite for an adequate planning for any WM system ⁴⁵, inappropriate projections can lead to increased costs due to capacity overestimations.

The amount of MSW generated per capita has as input, the set of products that are bought or acquired to be used, transformed or stored, while the output is the waste fractions generated by the disposal of these products. The generation and waste fractions strongly depend on social and economic conditions. This process can be illustrated in Figure 66.

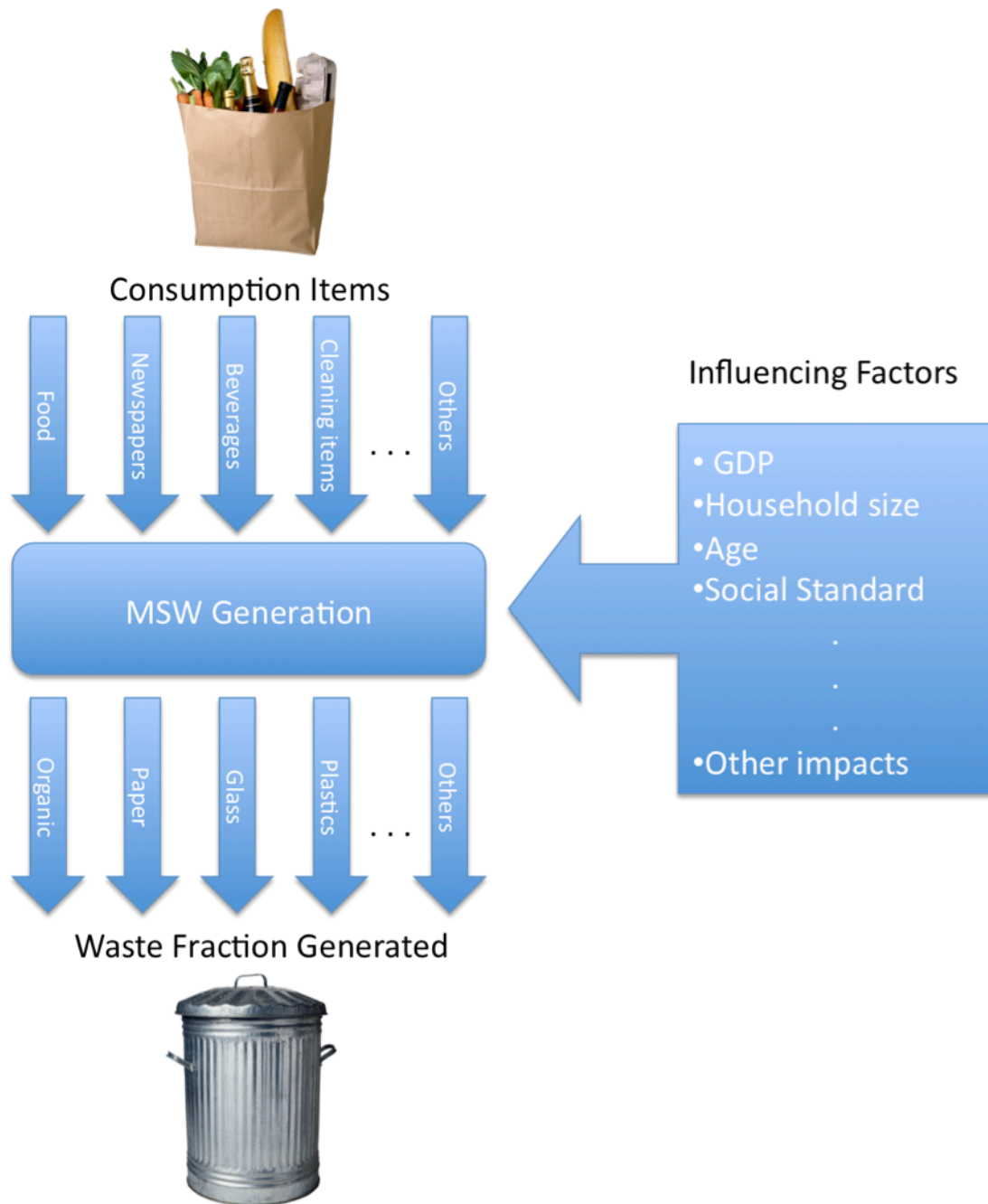


Figure 66: MSW Generation. (Based on LCA-IWM)

4.1.1 Waste Prognosis Tool

Some MSW forecasts consider factors such as population growth and per-capita generation, which are then, extrapolated over time, however, these techniques neglect other important social and economic indicators, leading to mislead calculations. An example of this error is shown in Figure 67:

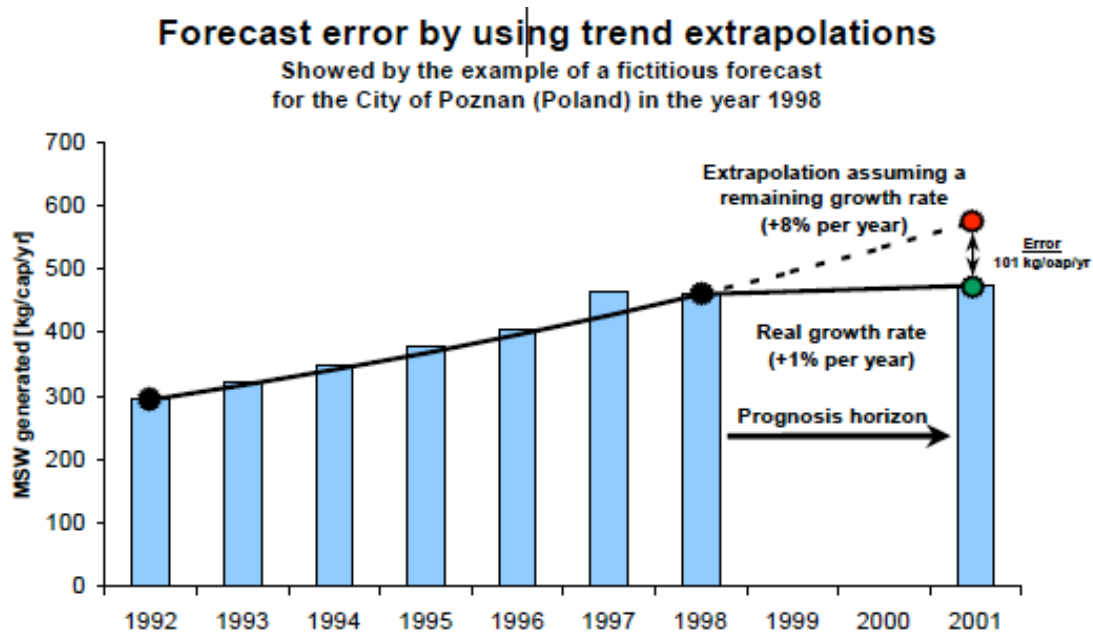


Figure 67: Example of forecast error by using trend extrapolations (LCA – IWM , 2003)

For Toluca’s MSW generation and composition, it was projected using a decision tool developed by “the Use of Life Cycle Assessment Tools for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies” project (LCA-IWM), the Waste Prognosis Tool⁴⁵. Since it is focused on cities with rapidly growing economies, like southern and eastern European countries and due to its friendly interface and data availability for the country and the municipality, it was selected for its application in a developing country such as Mexico, and therefore for Toluca city.

The LCA-IWM project carried out a European-wide set of investigations in order to identify relationships between potential influencing factors and MSW generation. These investigations resulted in the identification of a set of significant influencing factors:

- **Gross Domestic Product (GDP)** is employed to assess the development of the waste stream.
- **Social indicators**, such as infant mortality rates, life expectancy and the percentage of persons employed in agriculture were shown to have considerable impact, particularly in rapidly growing countries in Easter Europe.

- **Age:** previous experiences confirm the relationship between the group of people aged 15 to 59 years (the age group with highest economic activity), and the amount of generated waste.⁴⁵
- **Household size** has a direct correlation with waste production.

The mentioned relationships have been used in this model, which contains a set of formulas. The model used in this tool, “enables the prediction of the per capita MSW generation with an accuracy of 8% ($R^2= 0.65$), this error is significantly lower than the achieved with similar models (compared with 14% prediction error for German cities or and $R^2= 0.49$)”.⁴⁵

4.1.2 Adapting the Waste Prognosis Tool to Toluca Municipality

For the proper use of the Waste Prognosis Tool for Toluca MSW projections, the following assumptions were made:

1. Assessment year: 2015. Since the Municipal authorities are chosen every 3 years, 2015 was chosen to cover the whole next administration period (2012-2015).
2. The Institution in charge of providing municipality’s population projection, National Council of Population (Consejo Nacional de Población “CONAPO”), provided the projections for age group 15 – 64, therefore this was used as the group with the highest economic activity in Mexico (instead of the suggested 15 – 59 age range).
3. No separate collection exists; all collected waste is residual waste.
4. Due to the lack of separate collection target values, it is assumed that there won’t be a separate collection program implementation.
5. The composition of the organic waste is 100% Bio-waste.
6. Public/internal waste prevention measures are not considered.

All national and some municipal indicators were provided by the INEGI. The Municipal Development Plan provided the rest of the municipal indicators. For all projections, the information was provided by the CONAPO.

It is important to mention that year 2009, was used as reference year for all required data and indicators.

4.1.3 Toluca MSW generation and composition: 2010 – 2015 Forecast

According to the prognosis tool, Toluca MSW generation in 2015 is expected to increase to 416,000 tons. This represents an average increase of 5.8% per year.

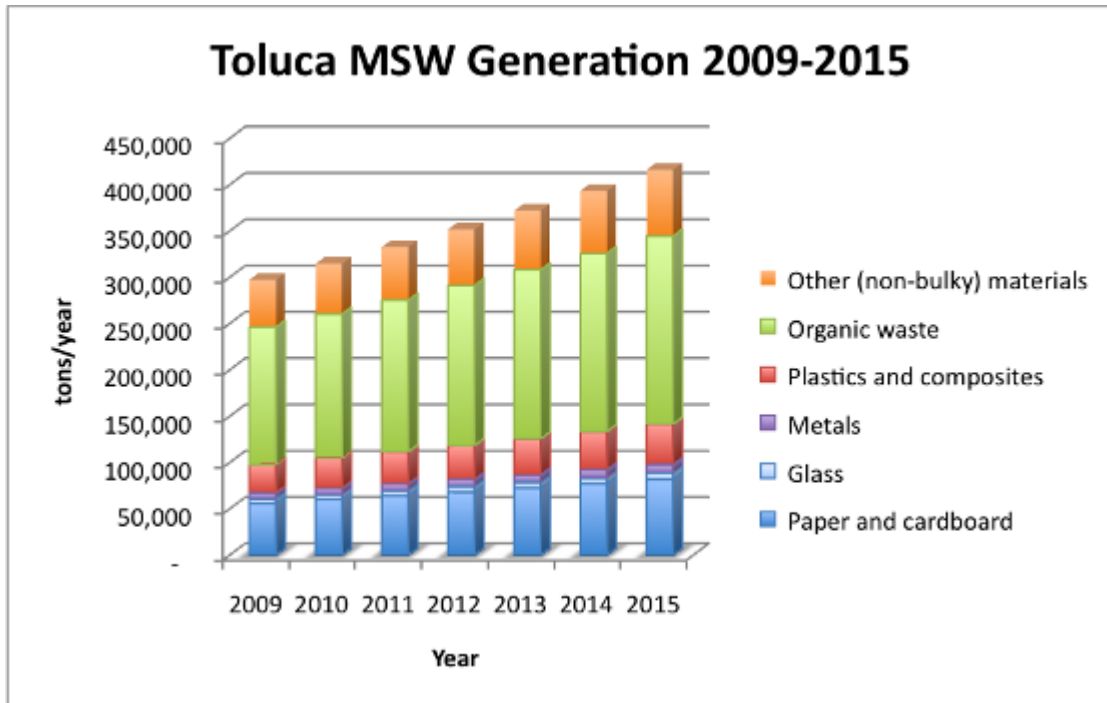


Figure 68: Projected Toluca MSW Generation 2009 - 2015

Regarding its composition, the most significant change is in the paper and cardboard share; it is expected to increase from 18.8% to 19.70%. The plastic and composites waste fraction presented a slight increase from 10.20% to 10.50%. In the other hand, metals and organic waste decreased from 2.30% to 2.20% and from 49.9% to 48.8% respectively. Organic waste continues being the largest component.

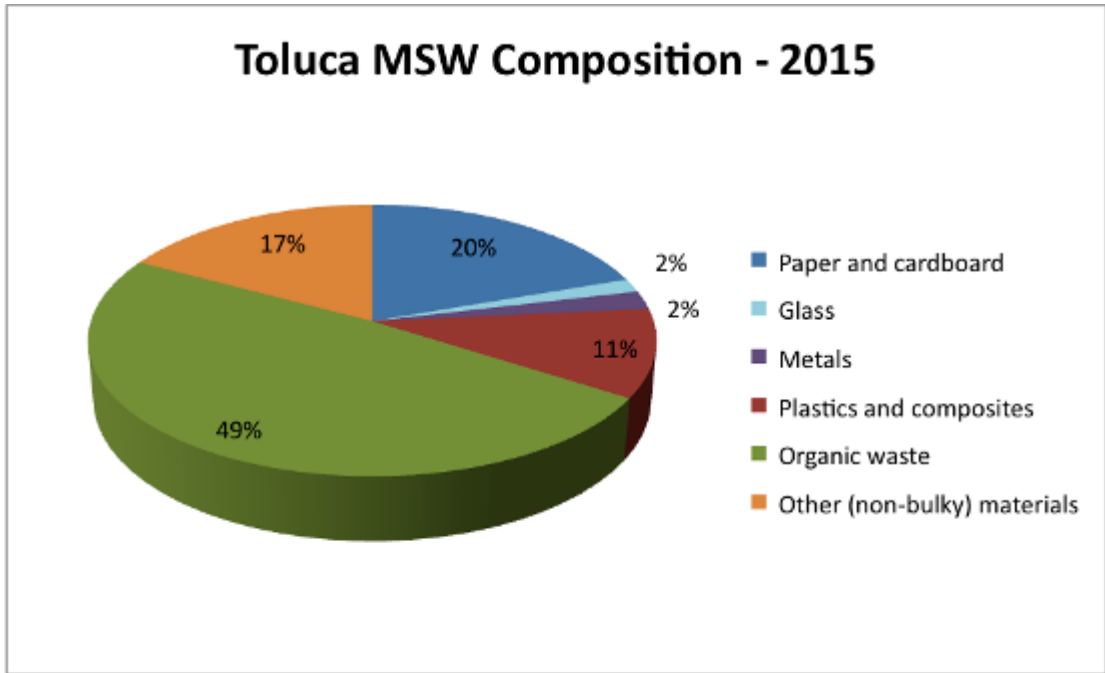


Figure 69: Projected Toluca MSW Composition 2015

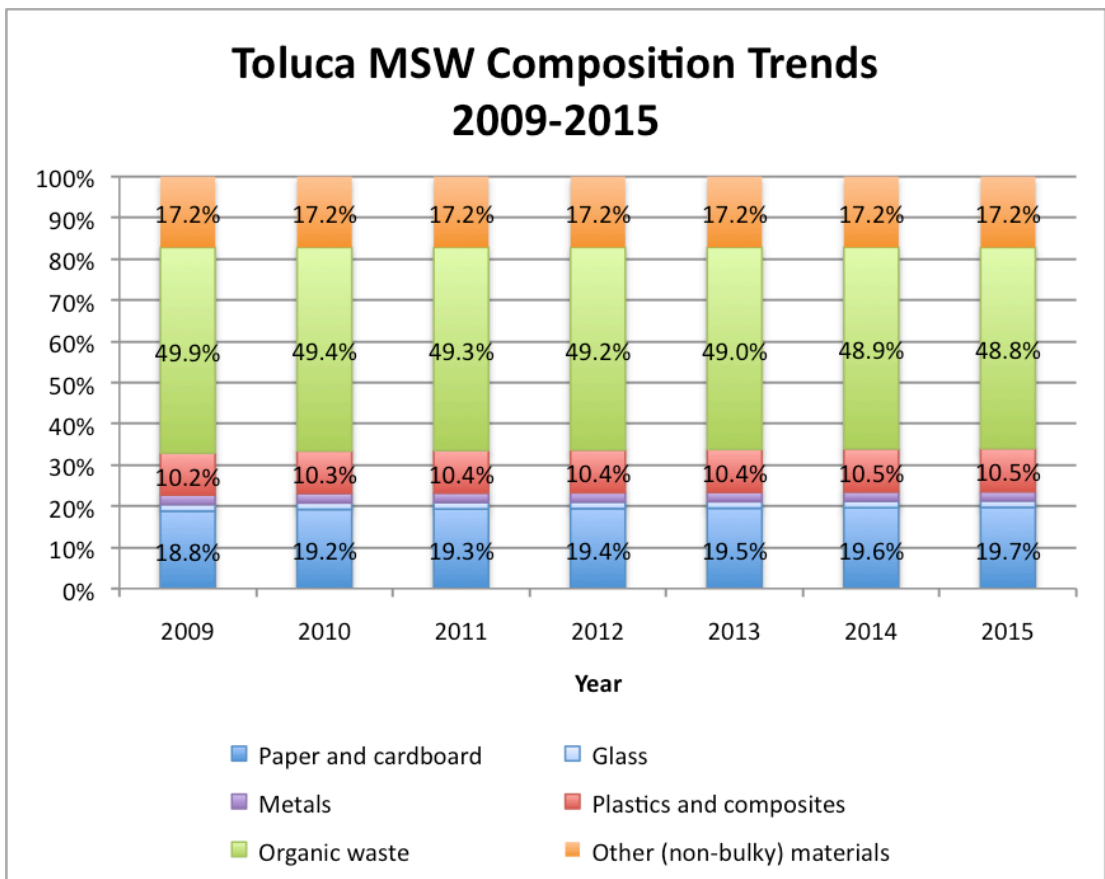


Figure 70: Toluca MSW Composition Trends 2009- 2015

The average per capita waste generation in 2015 is expected to increase from 0.36 tons/year in 2009 up to 0.45 tons/year, which represents an average growth rate of 3.7% per year. When compared this growth rate with Toluca's population average yearly growth (2.0 %) we can appreciate how as in other

developing countries, consumerism and industrialization affects the MSW generation patterns, not only by increasing consumption itself but by slightly shifting its waste composition: increasing the paper, cardboard and plastic disposal while decreasing the organic waste.

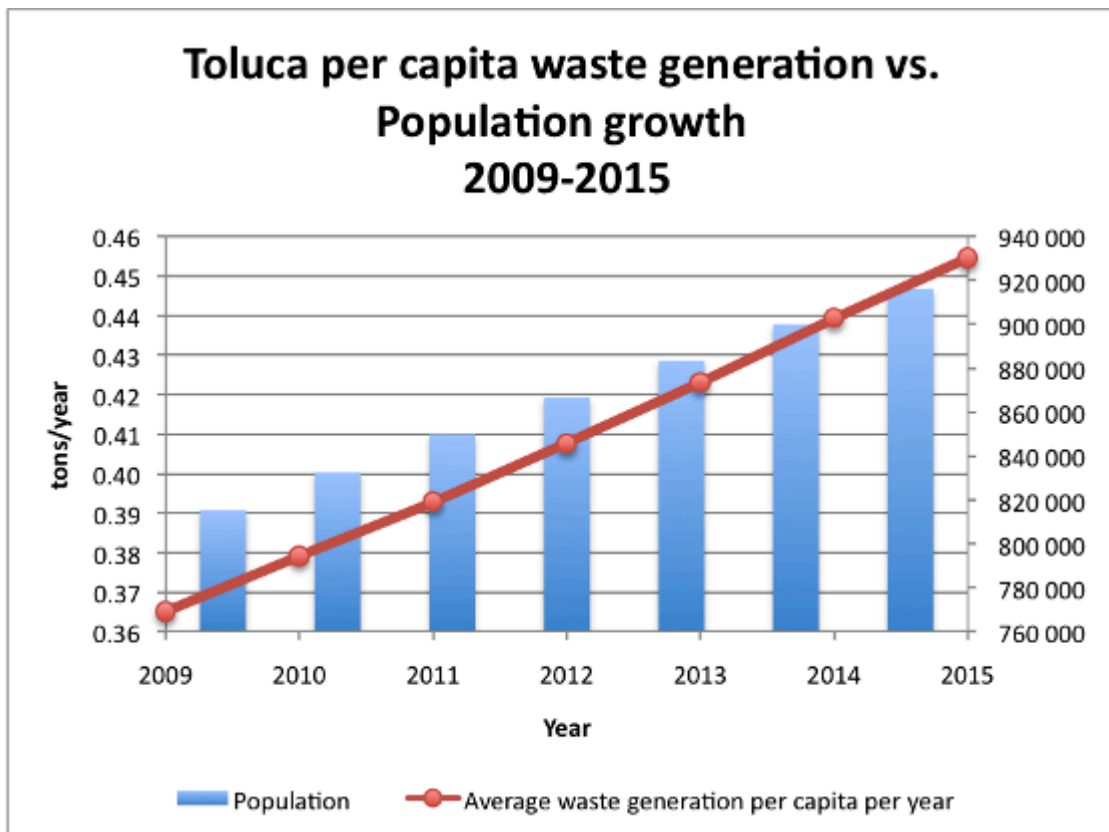


Figure 71: Toluca Per Capita Waste Generation vs. Population Projected Growth 2009-2015

4.2 Preventive and corrective MSWM strategies in Toluca

Toluca municipality understands the necessity of creating strategies and actions focused on the improvement on the actual MSWM system. This is not only because during the last year, the MSW generation dramatically increased, but also because there is an urgency of covering 100% of the demand for service. On year 2009, only 63% of the total MSW generated was collected, added to this, Toluca needs to create the necessary conditions to have an efficient collection system, handling, treatment and final disposition of the MSW, always attached to the environmental regulations. With the purpose of contributing with the development of MSWM in Toluca and in Mexico, preventive and corrective measures have been planned at a municipal level

According to the Municipal Development Plan 2009 – 2012, the planned strategies are:

A. Installation of Infrastructure for Sweeping and Collection: Due to the necessity of collecting MSW 365 days in public spaces and urban zones in Toluca, it is necessary as a first stage, to acquire 2,500 litter bins with a capacity of 50 liters and 100 containers of 3,000 liters installed in strategic places. Added to this, 35 sweeping cars will be acquired to support the sweeping and collection service downtown. The total investment will be of \$ 724,933 USD (\$ 9,107,195 MXN).

This strategy had a programmed implementation time during the months of March to May 2010 and no reports of its advancement have been published.

B. Total collection coverage: The active vehicles for MSW collection and transportation are not enough to cover the daily demand of this municipality, since only 510 tons out of the 815 tons generated are collected daily (63% coverage). Therefore, it is imminent and necessary to expand the already existing routes and institute new ones, increasing the collection frequency to achieve the 100% collection coverage and avoid the proliferation of illegal dumps. Added to this, another objective of this strategy is to acquire 12 new MSW collection units, 10 motorcycles for routes supervision, and the use of 2 used units that will act as tow trucks.

The total investment will be of \$ 1,189,859 USD (\$ 14,947,976 MXN).

This strategy has a programmed implementation time during the months of March to December 2010. When compared to the latest information provided by the General Direction of Public Services and Environment, the vehicle infrastructure increased from 134 up to 135 and collection routes increased from 180 up to 193.

C. Permanent Maintenance in the Historic Center: One of the sites that attracts large crowds is the Historic Center of Toluca, this produces a large quantity of MSW accumulation daily, it is then necessary a large staff of people and 3 shifts per day to keep this site clean. Maintaining the Historical Center clean is a key factor to attract more tourists and therefore more money to the municipality, this is why for this purpose, this strategy aims to acquire 2 mechanical sweepers and 1 floor scrubber.

The total investment will be of \$ 403,970 USD (\$ 5,075,000 MXN).

This strategy has a programmed implementation time during the months of March to December 2010.

D. Long term productive infrastructure: The actual offices and warehouses occupied by the directive, administrative and operating staff that make up the Direction of Public Services, are in terrible state. This resulted from the rushed change of location after taking the decision of transforming what used to be the transference center into a public park (Parque Centenario). The offices are now scattered in different buildings and are provisional. Some offices don't have the minimum electric, hydraulic or sanitary requirements (lockers, dressing rooms, asphalt parking lots, necessary illumination, etc.), even the Sub direction of Solid Wastes offices have leaks during rain seasons, and the manual sweeping offices are in danger of falling ceilings and walls, endangering the staff working there. For solving this situation this strategy will plan and build one building with all offices and warehouses contained in it and one office for the manual sweeping staff in a strategic part of the municipality.

The total investment will be of \$ 1,219,815 USD (\$ 15,324,315MXN).

This strategy has a programmed implementation time during the months of March to December 2010.

E. System for controlling, evaluating and monitoring MSW collection units: Due to the large number of complains regarding the continuity of the collection system, the municipality recognized the necessity of a control system for the units. Reality is that collection trucks are usually used for purposes other than those specified by the Municipal Government. This situation is in part caused by the clause of the Collective Contract of Work that grants the ownership of MSW to the operators and assistants of the collection trucks. With this, the staff uses some of the already programmed time for collecting, for scavenging and selling cardboard, glass, plastic, paper, aluminum, etc. To promote a more efficient service, the municipality plans to buy 163 global positioning systems (GPS) and rent the monitoring system and software, which will allow them to control:

- Trajectory.
- Collection points in each neighborhood.
- Traveled distance.
- Fuel performance.
- Time used for scavenging
- Time used for disposing the waste in the landfills.

The total investment will be of \$ 90,600 USD (\$ 1,138,196.4 MXN) per year, with a minimum contract with the supplier of 3 years. This would add up to an investment of \$ 271,800 USD (\$ 3,414,589.2 MXN) in 3 years.

This strategy has a programmed implementation time during the months of March to May 2009, but won't be operated until August 2012.

F. Installation and Operation of MSW collection and transference sites in the North and South zone: Due to the frequent closures of landfills that don't fulfill the NOM-083-SEMARNAT-2003 requirements, it is necessary to start turning to new technologies for the treatment and final disposition of solid wastes. This new measures will create new jobs, increase the life of sanitary landfills, create additional revenues for the municipality and reduce operation costs. Saying this, the objective of this strategy is to build collection and transfer sites to mechanically and manually classify and separate the inorganic MSW portion, to process the organic portion through biotechnology (not specified) into high quality fertilizer and to sell recyclable products.

The total investment will be of \$8,756 USD (\$ 110,000 MXN).

This strategy has a programmed implementation time during the months of March to May 2009, and the operation will begin until August 2012.

4.3 Potential for improvement in Toluca

In order to improve MSWM practices in Toluca municipality, it is important to adopt and adhere to the integrated waste management hierarchy previously presented. Adopting and applying this hierarchy must be done according to the circumstances and resources available at this municipality and not forgetting the guiding principle. The guiding principle is that “responsible management of wastes must be based on science and best available technology at a particular location and not what seems to be inexpensive now but can be very costly in the future” (WTERT, 2010). Based on this, Table 12 summarizes the proposed strategies by the author to be applied in this municipality, and therefore it could be used as a guideline to improve MSWM in Toluca. The next sections will explain in detail these proposed strategies.

Table 12: Proposed strategies for improving WM in Toluca

Integrated Waste Management Hierarchy Concept	Strategies for improving WM in Toluca, México
Waste Reduction	<ul style="list-style-type: none"> • Public programs and campaigns that promote awareness and waste reuse. • Include MSWM issues in all-levels school curricula. • Enact public policies and creation of economic incentives to discourage usage of unnecessary packaging materials.
Recycling	<ul style="list-style-type: none"> • Collection centers. • Promote collection centers along with the benefits of recycling. • Build MRFs in the planned transfer stations. • Support and legitimize the informal business such as the itinerant buyers or scavengers.
Anaerobic digestion	<ul style="list-style-type: none"> • Still not suitable for Toluca’s economic and MSW service conditions.
Aerobic digestion	<ul style="list-style-type: none"> • Windrow composting • Household/backyard composting. • Strengthen the compost market.
Waste-to-energy	<ul style="list-style-type: none"> • Still not suitable for Toluca’s current situation.
Sanitary landfill recovering and using CH ₄	<ul style="list-style-type: none"> • Develop a regional approach, by building an inter-municipal landfill infrastructure. • CH₄ use should be evaluated through a feasibility study.
Sanitary landfill recovering and flaring CH ₄	<ul style="list-style-type: none"> • Disseminate the benefits and the difference between waste dumps and sanitary landfills.
Non-regulated landfills	<ul style="list-style-type: none"> • Eradicate and avoid the proliferation of waste dumps through the increase of collection coverage and by providing MSWM system information to the citizens.

4.3.1 Waste Reduction Strategies

At national level, the PNP GIR 2009-2012 already considers this as an important preventive measure, by having among its plan a strategy towards waste prevention and minimization. This strategy focuses on creating programs and campaigns that educate people to avoid the unnecessary generation of waste under the criteria of rational consumption.

In Toluca, as we could see through the surveys conducted by the author, 83% of the people have no idea about how much waste they generate. Additionally, the knowledge about what happens after their garbage is collected is not very high; percentages lower than 33% were assigned to each one of the waste treatment facilities/treatments that people believe exist in Toluca while 18% don't know. Based on this, some additional preventive measure for this municipality could include the incorporation of MSW management, issues and information in all-levels of school programs of study to encourage awareness, eradicate the "out of sight, out of mind" way of thinking and to make them realize that they can be part of the problem, or of the solution.

The campaigns, programs and school programs can also achieve waste reduction through reuse. Reuse consists in the recovery of items that are considered as "waste" to be used again, probably after some cleaning and/or refurbishing. Some reuse ideas are: reuse plastic or glass food containers for storing, reuse plastic grocery bags or bring your own, write on the back of used paper, among others.

Enacting public policies and the creation of economic incentives to discourage usage of unnecessary packaging materials during production is another strategy that could be applied. However, this strategy might not have a reduction potential as the previous proposed strategy. This is due to Toluca's MSW composition, since what is considered as packaging material: glass, aluminum, plastics, steel and other metals, and paper and paperboard (EPA, 1992) has a share of 33%, and is expected to increase up to 34% in 2015^{*}, and still does not represent the largest share of the MSW composition. In Europe, almost half of the generated municipal solid waste originates from packaging material⁴⁹. Therefore priority

* Projected using the LCA-IWM Prognosis tool

should be given to the programs and campaigns that focus on the reduction of total MSW generated, rather than just a part of it.

4.3.2 Recycling Strategies

In the year 2001, Toluca recycled only 1% of the MSW generated, and even though no further official data is available for more recent years, in 2008 it was published that the staff from the collection vehicles reported a recovery of 30 to 40 tons daily during their scavenging, this represents approximately 8% of the generated MSW in that year³⁸. Nevertheless, Toluca MSW is composed of approximately 33% recyclable material, which includes glass, paper, cardboard, metal and plastic. In the other hand, according to the surveys, recycling is perceived as the MSW treatment with the lowest risk (1.6 in a scale of 1 to 5). This shows the big potential of recycling in Toluca.



Figure 72: Mexican cardboard collection (EPA, 2007)

In Toluca, recovery and recycling of generated MSW is mostly done by the informal sector, itinerant buyers, and scavengers or by the same staff from the collection vehicles. This activity is characterized for being very labor-intensive, with poor labor conditions, low incomes and for not being recognized by the municipal authorities.

Due to the absence of appropriate curbside separate collection, an already implemented strategy in Toluca to support waste separation and recycling is the creation of drop-off or collection centers, as described in Section 3.3.1.7. These collection centers not only receive the recyclable material, but it gives people on exchange a money replacement to trade them for products from the basic basket. During the inauguration of a collection center in November 2010, the Major mentioned that Toluca is the only municipality in Mexico that has a program like this, which promotes recycling awareness, and that even her commitment at the beginning of her administration in 2009, was to install 4 collection centers, and now the objective is to install a collection center in each sub-delegation.⁵⁰

It is suggested to carry out promotion campaigns through different media to spread the information about these centers, how they work and the benefits of recycling. During a study of reuse and recycling behavior in Mexico, (Corral-Verdugo, 1997) it was observed in the case of recycling, one was more likely to recycle waste when fully understanding the proper way and the reasons to do it as opposed to one simply desiring to recycle.

Toluca Municipal Development Plan 2009 – 2012 also contains another recycling-encouraging action: the installation and operation of MSW collection and transference sites in the North and South zones. Its purpose is to work not only as a transfer station, but also as a site to mechanically and manually classify and separate the inorganic MSW portion. This is clearly a potential for increasing Toluca's recycling rate, by building sites that work as a transfer station and as a MRF. It is important to determine if the planned total investment of \$ 8,756 USD (\$ 110,000 MXN) will be enough for building this transfer station/MRF, based on the planned capacity and the type of technology to be used. According to the Division of Pollution Prevention and Environmental Assistance of North Carolina, the capital cost of an MRF, with an average capacity of 89 tons per day, is approximately \$26,000 USD per ton of design capacity per day. Figures 73 and 74 show the range of capital costs for existing low-tech and high-tech MRFs that sort reusable materials, whether mixed or separately collected.⁵¹

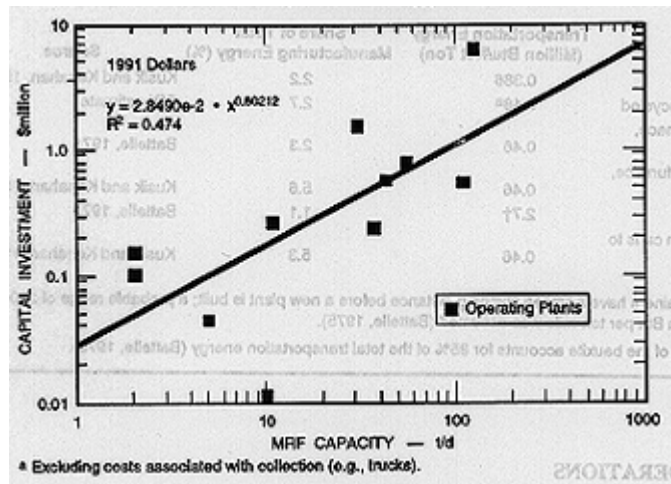


Figure 73: MRF, effect of plant capacity on capital investment - Low Technology.⁵¹

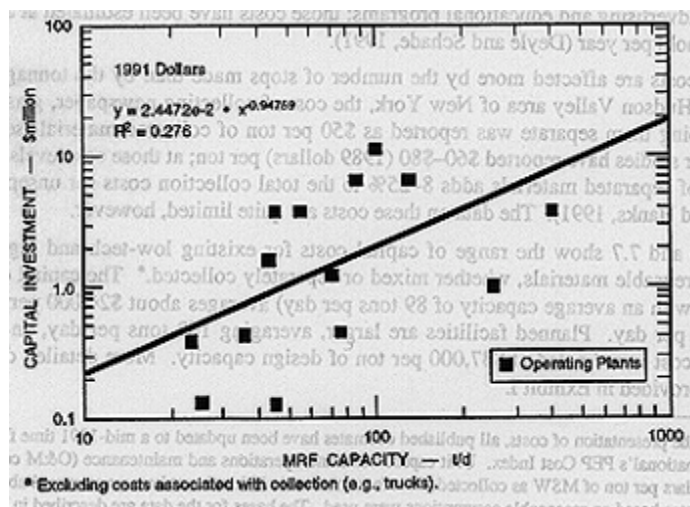


Figure 74: MRF, effect of plant capacity on capital investment - High technology.⁵¹

Also, it is important to support the recyclable products market in Toluca. As discussed in Section 1.4, this can be done through strategies such as legalizing scavenging activities, micro-loans or some type of assistance provided by the municipality, and by allowing and facilitating the private initiative participation in this market

4.3.3 Anaerobic digestion and Aerobic composting Strategies

Even though AD is a promising and integral technology, these systems need high up-front capital investment and to process many thousands of tons of MSW per year to have a reasonable treatment cost per ton⁵². AD cannot compete from the cost point of view with traditional composting methods⁵³. Due to this, AD is not suitable for Toluca's economic and MSW collection conditions; where not all households separate their wastes and separate collection is not provided, making it

difficult to achieve high levels of organic waste to be treated. Therefore only aerobic composition will be considered for implementing in this municipality.

As mentioned in Section 1.4, AD and aerobic composting are practical only for source-separated organics; otherwise, the final product will not have the desirable quality and cannot be used as soil conditioner. Toluca does not provide curbside separate collection of organic wastes and this is a barrier towards proper implementation of composting, although as previously mentioned, surveys showed that 54% of the people in Toluca separate waste at home (organic and non-organic). For the 46% of the people that do not separate their waste, the main reason (60%) was that they find it pointless since everything ends up mixed in the collection truck. Also, in November of 2008 a local online newspaper published an article stating that the Director of the Solid Wastes Department of Toluca recognized that separation efforts at home were futile because waste arrives mixed to the final disposition sites.³⁸

As noted earlier, in 2009, 50% of Toluca's MSW was composed by organic waste and represents the largest fraction of the MSW generated by this municipality. This means that providing separate curbside collection of organic wastes represents a big opportunity for advancing IMSWM in Toluca.

Even though there is no official, updated data regarding the existence of composting practices in Toluca (facilities, campaigns, etc.), its MSW composition is theoretically ideal for composting; in fact, Municipal Government included the use of biotechnology (the type of technology was not specified in the Municipal Development Plan 2009 – 2012) to process the organic portion into high quality fertilizer in the two transfer stations that are planned during 2009 – 2012. However, as mentioned above, it is necessary to educate citizens and also to install the appropriate infrastructure, including special bins for public spaces, vehicles for curbside separate collection or the creation of different collection days for organic waste only.

Regarding composting the source-separated organic wastes, the least costly processing method that can be considered as the most appropriate to the socioeconomic conditions of Toluca is windrow composting¹⁵.



Figure 75: Windrow composting. (Washington State University, 2000).

Besides this, section 1.4 mentioned that composting could be done at three different levels: At households, by the community and at a centralized large scale, level serving an entire city. The last two proposals are considered as large scale; nevertheless, “most developing countries, which have found success with composting, have found it works best when implemented at the household level”¹.

Household level composting has potential for success especially where small agriculture is found close to urban areas, or those areas where gardens are found within the city ¹. According to the INEGI (2008), 60% of Toluca’s surface comprises land appropriate for agriculture, from which 88% was sown during 2008. Additional to this, since majority of the people in Toluca live in houses, it is common to find small gardens in each neighborhood, making it a suitable strategy for this city. Figures 76, 77 and 78 show 3 randomly chosen areas in Toluca where green areas or gardens are highlighted.



Figure 76: Toluca green areas/gardens - Zone 1. (Google Earth, 2010)



Figure 77: Toluca green areas/gardens - Zone 2. (Google Earth, 2010)



Figure 78: Toluca green areas/gardens – Zone 3. (Google Earth, 2010)

Based on the surveys, since 54% of people are already separating and the majority of the people that don't do it is due to the lack of an appropriate separate collection system, household level composting can compensate for this lack of service, while taking advantage of the effort already done by some citizens.

Also, the key for successful implementation of any composting method is to find a useful destination for the final product, either by selling to regional farmers, gardeners, and public parks or using it for the household's own plots and garden. At a national level, the creation and strengthening of the compost market is already planned. Strategies towards developing this means of waste management would

also be beneficial at the municipal- level, by means of policies, regulations, and some financial assistance.⁵⁴

Again, education is a key factor to promoting this project. According to the Toluca surveys, 77% of the people know at least the basic concepts of composting, and of these people, 36% have used it at least once. Furthermore, the citizens from the population sample assigned it a low risk perception of 1.8 (in a scale of 1 to 5). After recycling, composting is seen as the least risky MSW treatment. It is important to educate people, through programs and workshops about how to make their own compost and the benefits of producing a fertilizer and reducing landfilling.

4.3.4 Waste-to-energy Strategies

There are no records of WTE facilities in Toluca or in Mexico. In December 2009, an electronic newspaper reported that a business called Integramex of the “Grupo Business Internacional”, is planning to create the first facility in Mexico that will generate electricity and produce diesel, through waste incineration; the project would be completed in one year and a half. The total investment would be 100 million USD, for a capacity to treat 1,000 tons of waste daily generating up to 20 MW per hour.⁵⁵ However on November 2010, the department of Solid Wastes of Toluca stated to the author that they knew nothing about this subject; no further information could be found in electronic sources regarding the project or this company.

There is no doubt that Waste-to-energy is the proven means for replacing landfilling around the world. However, its implementation in Toluca must be preceded by increasing recycling and composting to at least 30% of the MSW that is presently generated in this municipality.

Also, “experience with incineration in developing countries has been mostly negative”¹⁵. A paper published by Medina Martínez in 2002, pointed out that because of climate and the high humidity of the MSW, it must be dried in the sun for days, and even then, fuel would be needed to maintain combustion. This increases the cost of an already expensive technology. In 2003, Olar Zerbock¹, wrote that additional to high capital costs, specific technical expertise and related general repair and maintenance technology are often not present in developing nations,

Therefore, the additional level of infrastructure and planning required to implement such a method is usually not available in most developing nations, and that arguments for the implementation of these projects should not rely on potential energy generation as the main “sales pitch”. “High costs and environmental problems have led to incinerators being shut down in many cities, among them Buenos Aires, Mexico City, Sao Paulo and New Delhi “ (UNEP, 1996).

Another reason why this technology is still not suitable for Toluca is the current social and cultural environment. In the Toluca survey, incineration is still perceived as one of the most harmful MSW treatment techniques, just after waste dump. Apparently, this social perception prevails in the rest of the country; two WTE projects were stopped in Guanajuato and Aguascalientes in the last two years, in part due to public opposition from groups like Greenpeace Mexico, Global Anti-Incinerator Alliance (GAIA), the Argentinean Anti-Incineration Coalition and even a political party, arguing that this process is risky for the environment and the people (56,57,58,59).

This does not mean that there is no potential for WTE in Toluca. Since Toluca does not have MSW final disposition sites within the city (all MSW collected is transported to other municipalities), a WTE facility is a promising technology that helps reducing hauling costs, provides an alternative source of energy, while avoiding the environmental impacts related to landfilling, among other benefits. Additional to this, options for building sanitary landfill sites will start to decrease, and it is imminent that Toluca will need an alternative option for replacing landfills and reducing the quantity of landfilled MSW. WTE is the most appropriate and suitable technique for achieving this, and it must be considered in a nearby future, after implementing the recycling and composting strategies in this municipality.

4.3.5 Sanitary landfill recovering and using or flaring CH₄ Strategies

As noted earlier, all the MSW collected in Toluca is deposited in two sanitary landfills located in Zinacantepec and San Antonio la Isla municipalities, 15 and 17.3 kilometers from Toluca, respectively. Both of these landfills capture and flare CH₄.

The possibility of building a sanitary landfill in Toluca was considered in 2001, when the Mayor proposed the construction of a sanitary landfill at the south of

Toluca, in “San Juan Tilapa” neighborhood. This project failed due to pressure from the opposition to his political party³⁸.

In November 2008, the Milenio electronic newspaper⁸⁶ reported that two environmental engineers hired by them, determined that with about less than the half of the money used in 2007 for transporting the MSW to out-of town landfills (Tecamac, Tlalnepantla and Tultitlán), Toluca could build a sanitary landfill of their own. They mentioned that in 2007, about \$6 million USD (\$76 million MXN) were used to landfill 500 daily tons of MSW in Toluca, while the average cost of a 40-hectare sanitary landfill would cost \$3.2 million USD (\$40 million USD).

Even though the construction of a sanitary landfill seems logical from the economic point of view, Maass (2004) used the Geographic Information Systems (GIS) tool for evaluating this problem based on Toluca’s land information and regional characteristics according to the NOM-083-SEMARNAT-2003 standards. The first finding in this analysis was that there were no appropriate landfill sites in Toluca. Some of the limiting aspects were the environmental and geo-hydrologic criteria. Most of the municipal land is connected to an aquifer, while the most suitable permeability conditions are found in a National Park.

Maass concluded from this study that it is better to develop a regional approach, by building an inter-municipal infrastructure that includes the beneficial use of landfill gas. In recent years, Toluca has been disposing their MSW in different landfills in the State of Mexico, but as their useful life comes to an end, the options for building a sanitary landfill close to Toluca and in accordance with the NOM-083-SEMARNAT-2003, are decreasing. Regarding the two sanitary landfills used by Toluca now (Zinacantepec and San Antonio la Isla) and according to the information of Section 3.3.1.8, the calculated available capacity from 2011 onwards is shown in Table 13:

Table 13: San Antonio la Isla and Zinacantepec sanitary landfill specifications

	San Antonio la Isla	Zinacantepec
Distance from Toluca center, (km)	17.3	15
Landfill total area, (hectares)	10.5	8.5
Operation start date	2007	2007
Average MSW received (tons/day)	850	600
Total capacity (million tons)	2.287	1.476*
Tons/m2 at full capacity	21.7	17.4
Useful life (years)	13	8
Remaining capacity (million tons)	1.78	0.88

In order to calculate the remaining useful life based on Toluca’s projected MSW generation, the following assumptions were made:

- Constant MSW daily reception.
- All of the received waste comes from Toluca* (an average of 177,285 tons/year sent to each sanitary landfill)
- As declared by the Office of Public Services, 50% of MSW collected in Toluca is deposited in Zinacantepec and 50% in San Antonio la Isla.
- A planned expansion from Zinacantepec sanitary landfill was not taken into account.
- Reduction, recycling or composting strategies are not implemented.
- 100% collection coverage.
- Yearly MSW generation projections were made using the Prognosis Tool .

The author’s own calculations showed that the San Antonio la Isla landfill would be able to fully operate up until the year 2015 (4 year less than expected), and Zinacantepec up until the year 2013 (1 year less than expected). When

* Calculated based on the average MSW received and the site operations start date.

collection coverage is considered to be 63% (as in 2010 provided data) instead of 100%, this would provide one extra year, at most, for both sites.

Public opinion is also an important factor that must be taken into account in selecting landfill sites. The Toluca survey applied by the author showed that this practice is rated as the third most dangerous MSW treatment method. Local opposition has represented an obstacle for sanitary landfills construction during the last years, making it harder to find adequate sites located at reasonable distances from the collection areas. “Building landfills at greater distances to the central collection areas implies higher transfer costs as well as additional investments in the infrastructure of roads hence intensifying the financial problems of the responsible authorities”¹. Thus, providing information to the public as to the difference between waste dumps and sanitary landfills is absolutely necessary.

4.3.6 Non-regulated landfills Strategies

Finally, the least desired option, non-regulated landfills or waste dumps, are still a reality in this municipality. It was reported that at least 10 non-regulated sites were found in Toluca, three of which were cleaned in May 2010. Since Toluca has a big potential for reducing, recycling and composting, and also two sanitary landfills where MSW can be properly disposed, waste dumps should be totally eradicated. A strategy already being implemented consists in providing high-volume containers in strategic places that provide a healthier alternative for the citizens to dispose their wastes⁶⁰.

Other approaches to eradicate waste dumps include increasing the collection coverage and providing the citizens with more information about the MSWM system (collection days, hours, and final disposal sites). Collection coverage can be increased with the two planned transfer stations, due to the fact that now the city collection trucks will not have to transport the collected MSW all the way to the sanitary landfills. Also, in the Municipal Development Plan 2009 – 2012 it is planned to increase to collection coverage by expanding the routes, acquiring new vehicles and using GPS to track and control the continuity of the route.

Conclusions and Future Work

The information presented above provides an overview of the MSW situation in Mexico and in Toluca, and the potential for improving the MSW situation in Toluca municipality. In general terms, it was found that well developed processes such as recycling, composting and incineration with energy recovery have not generated the expected results in this country. Most of the treatment sites have stopped operating due to high capital and operating costs or lack of markets due to the poor quality of the finished product. This last one is also due to the lack of source-separation programs. Also, in the case of recycling, one of the biggest challenges in Mexico is to educate citizens about the benefits of recycling and to increase their environmental awareness.

The analysis of Toluca's waste management system showed that it is far from the generally accepted hierarchy of waste management. Of the estimated 295,000 tons of MSW generated, 186,000 tons (63% of the total) are landfilled in two sanitary landfills outside the city that recover and flare landfill gas, 24,000 tons (8% of total) are recycled and an estimated 85,000 tons (29% of total) are disposed in non-regulated dumps ("tiraderos"). The municipality of Toluca is fully aware of this major environmental problem and they are planning to increase the collection coverage and proper disposal of MSW to 100% by 2012. There is no reported up-to-date information regarding composting. The small recycling activity is not part of the official municipal MSWM system. Actions such as the installation of collection centers are helpful but not a fundamental part of the system.

For improving the Waste Management of Toluca, efforts should be placed on recycling and composting. The Toluca MSW consists of, 33% recyclable materials and about 50% of organic waste. However, recycling requires source separate collection and processing systems to be provided by the municipality. Composting of organic waste also requires an adequate MSW source-separation system.

Additionally, the author ran a survey in order to get a better insight of the perception of the MSWM system and waste treatment techniques in Toluca municipality. This survey was carried out from September to November 2010. About

400 people answered it, from which 60% corresponded to people living in Toluca, while the rest lived in nearby municipalities but were working or studying in Toluca.

From this survey, it was found that 54% of the people already separate waste at home, even though this municipality does not provide separate collection. In fact, the lack of this service was the main reason for not separating waste. This demonstrates that the municipality should see this as an opportunity area, by providing a separate collection service and/or by supporting household composting.

Also, this study brought out a very important fact: that all the proposed strategies in the hierarchy of waste management have as common factor that in order to guarantee a successful implementation, it is necessary to increase the citizens' awareness and education on this subject. It is not enough to tell people what to do; it is necessary for people to understand why they should do it. Understanding the benefits of sustainable waste management will create long-term and more efficient solutions; because it will also reduce the quantity of waste generated and motivate people to re-use.

This study is just a first step towards the implementation of an IMSWM in Toluca. Future work may include:

- Carrying out a study to determine the feasibility of building a MRF within the proposed transfer stations.
- A Feasibility study to evaluate the possibility of using the captured CH₄ from Zinacantepec and San Antonio la Isla landfills.
- Evaluate the possibility of establishing “gate fees” for the provided MSW service.
- A Life cycle assessment (LCA) of the current MSWM system and of alternate MSWM scenarios in Toluca.
- Waste-to-energy is the proven means for replacing landfilling around the world. However, its implementation in Toluca must be preceded by increasing recycling and composting to at least 30% of the MSW that is presently generated in this municipality.

Finally, it is clear that implementing any of these strategies requires money and effort from the society as a whole, not only from the municipal government. Still, it is more expensive and unsustainable to keep on handling MSW by just disposing it in landfills and waste dumps. Both, from the economic and the environmental points of view, the inflicted damage on soil, water, air, and on people is much more costly than the cost of proper management of the generated MSW. As a small contribution to advancing sustainable waste management in Toluca and Mexico, the author has translated the hierarchy of waste management (Figure 1) into Spanish, as shown below.



Figure 79: Hierarchy of Waste Management in Spanish (Jerarquía de la Gestión de Residuos)

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- C.P. J. Jesús Herrera Silva. Mantenimiento y Servicios Ambientales S.A. de C.V.
- Lic. Francisco Guajardo Ramírez. DDSA Environment General Manager. DDSA Renewable Energies General Manager.
- Staff from Zinacantepec sanitary landfill.
- Staff from the collection vehicle from the Universidad collection-route

APPENDICES

APPENDIX I

NATIONAL PROGRAM FOR THE PREVENTION AND THE INTEGRAL WASTE MANAGEMENT 2009 - 2010

Preventive Strategies

A. To promote the creation, modification and application of legal instruments to strengthen the IMSWM by all government sectors.

Indicator	Target
Reform proposal	Reform the Article 115 th in the Political Constitution of the United Mexican States, and if necessary the LGPGIR and its regulations.

B. Formulate a NOM that establishes the criteria to determine the MSW quantity and type that will be subject to handling plans, including a list of them, and the elements and procedures for elaborating those plans.

Indicator	Target
NOM creation	NOM published

C. Reevaluate the appropriateness of the specifications for the environmental protection during the construction and operations of MSW final disposition sites contained in the NOM-083-SEMARNAT-2003.

Indicator	Target
Reviewed NOM-083-SEMARNAT-2003	Published NOM-083-SEMARNAT-2003 with its modifications.

D. Promote, through technical assistance, the actualization and publication of the municipal legal framework for the Prevention and Integral Waste Management

Indicator	Target
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Municipalities with legal framework aligned with the LGPGIR and with the Municipal Program for the Prevention and Integral Waste management	Promote, in 32 municipalities, the actualization and publication of the legal framework for the Prevention and Integral Waste Management.
	Promote, in 32 municipalities, the creation and publication of the legal framework for the Prevention and Integral Waste Management.

E. To prevent and minimize waste generation, it is necessary to promote the education among the citizens in order to direct them towards consuming products that generate the less waste, under the criteria of rational consumption, avoiding the unnecessary generation of waste and when necessary, only disposing the waste that produces less environmental negative effects.

Indicator	Target
Programs or campaigns of environmental education.	Design and implement a national diffusion campaign concerning the MSW and of special handling

F. Develop systems of IMSWM that are environmentally suitable for small localities with difficult access to sanitary landfills or with deficient collection services

Indicator	Target
IMSWM systems	Collection and transference schemes to sanitary landfill for small localities.

G. Encourage the creation of a value chain of MSW recyclable sub products, through legal, fiscal and economic instruments

Indicator	Target
Action towards strengthening the value chain of MSW sub products.	Develop a study that allows identifying the economic instruments and the incentives needed to strengthen the IMSWM.

H. Develop an IMSWM environmental performance evaluation system in all States, with the help of Superior Education Institutions and integral certifying processes.

Indicator	Target
Efficiency in the Municipal IMSWM	Design, elaboration and pilot program of an evaluation system for the IMSWM performance.

I. Evaluate, and if necessary, promote the establishment of sustainable rates for the public sweeping service or the collection services, that promote the waste generation reduction, reflect the cost of the service and match with the generators affordability.

Indicator	Target
Sustainable rates	Study that evaluates the feasibility of rates implementation in some municipalities.

Integral Management

J. Based on the Municipal and State Programs for Prevention and Integral Waste Management, support the gradual implementation of MSW source separation programs, taking into account its separate collection and the necessary infrastructure for its use.

Indicator	Target
Localities with MSW separation programs	Support 100% of municipalities that have MSW separation programs, signing a collaboration agreement with the Federation

K. Promote the efficiency and professionalization of municipal sweeping services, through the creation of Decentralized Operator Organisms with trained staff and the participation of private initiatives to provide these services.

Indicator	Target
Municipalities with IMSWM Governmental Organisms	10 Decentralized Operator Organisms for IMSWM either regional or municipal, with inter-municipal cooperation schemes.
	Promote the inclusion of the informal sector in activities oriented to the adequate handle of wastes,

according to environmental laws in this subject.

L. Promote the use of the MSW organic fraction through the creation of composting facilities and strengthening the compost market, without limiting other usage alternatives that are economic and suitable, such as fertilizers, for the governmental and the agricultural level. This will be based on the projects mentioned in the Kyoto's Protocol CDM.

Indicator	Target
Organic waste treatment or composting facilities.	1 organic waste treatment or composting facility per State.

M. Promote the use of alternative or complementary technologies for the treatment and final disposition of MSW.

Indicator	Target
Type of evaluated technology	Evaluate 5 different technologies that promote its application accordingly to the social, economic, technical and environmental conditions.

N. Promotion of the construction of new solid waste infrastructure under the criteria of regionalization and economies of scale

Indicator	Target
Investment projects for new infrastructure.	Promote the construction of 50 sanitary landfills in medium size cities (10 in main touristic destinations), 50 selection plants, 50 transfer stations and vehicles.
	Promote the construction of 2 materials recovery facilities.
	Promote the construction of 2 solid waste thermal treatment facilities.
	Identify the necessary actions to promote the construction of the necessary infrastructure for waste separation, recycling and treatment under the 3R'S strategy

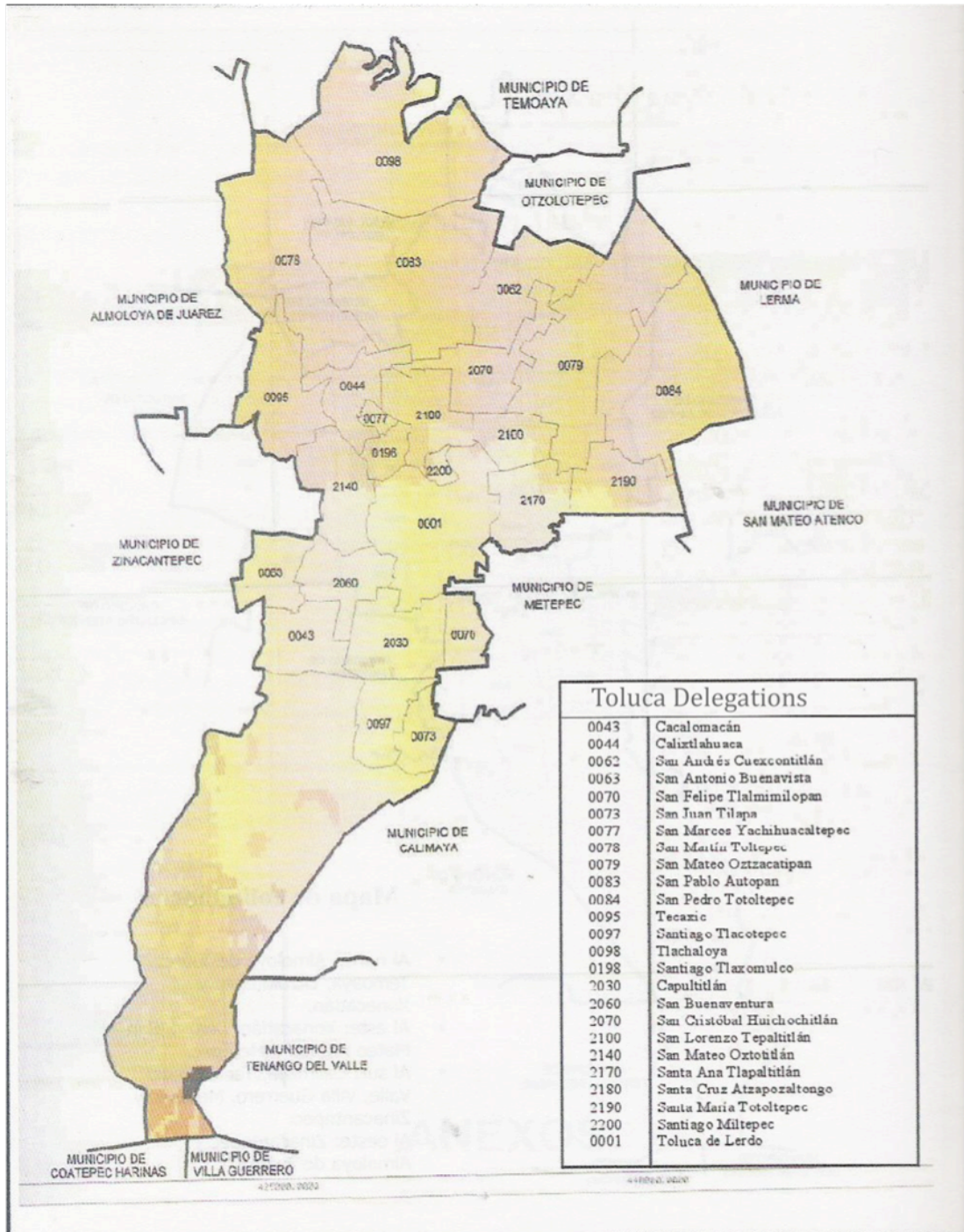
Implement 20% of the necessary actions identified in the previous target.

O. Increase the environmental control and protective measures in the already existing facilities used for waste handling, treatment, usage or final disposition.

Indicator	Target
Technical guide.	Devise a technical guide that considers the necessary measures to control and reduce the impact on the environment from waste handling, treatment, usage or final disposition facilities.

APPENDIX II

TOLUCA'S DELEGATION STRUCTURE



APPENDIX III

PROGRAM FOR THE PREVENTION AND INTEGRAL WASTE MANAGEMENT OF MSW AND SPECIAL WASTE OF THE STATE OF MEXICO 2009 - 2012

A. Information System: This action, seeks the implementation of the State System of Public Environmental Information for the Integral Management of MSW and of Special Handling. This system is formed by the records of generators, handling businesses, infrastructure, along with information provided by municipalities regarding their programs for IMSWM. All this information is saved in a database that allows the development of a waste and infrastructure inventory in the State of Mexico

Indicator	Target (2011)
Total number of entries of solid waste generators	300
Total number of entries of solid waste handling, treatment and final disposition service providers.	40 entries
Total % of accomplished goals concerning the Municipal Programs for Prevention and IMSWM	40%.

B. Technical assistance, training and research: Factors such as the change of municipal authorities every 3 years, seriously affect the institutional learning from the municipal governments. Acquired knowledge is not permanent and all associated actions cannot be sustained. This strategy allows the propagation of already acquired experiences.

Indicator	Target (2011)
Number of consultancies, workshops or courses for Municipal training	50
Number of attendants to the biannual fair of technologies for waste management.	More than 300
Registered students impacted with environmental education actions in solid waste topics	> 80%

Number of held meetings to promote intergovernmental and/or non governmental coordination to encourage the participation of the different sectors of society	12
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C. Integral Management: The management of solid waste is attributed directly to the municipalities in consistency with the state regulations. This strategy proposes different programs that support the IMSWM such as source separation, separated collection, differentiated treatment, promotion of the sub products market, promotion of compost elaboration and usage and increased capacity of final disposition sites.

Indicator	Target (2011)
Quantity of MSW collected separately (ton/day)	1,000 tons/day
Quantity of recycled wastes	600 tons/day
Total quantity of organic wastes processed in composting facilities (ton/day)	500 tons/day
Total authorized capacity for final disposition (ton/day)	12,000 tons/day

D. Regulations and Environmental Impact: The lack of attention to any of the everyday MSWM processes, might create important impacts in the environment, for this it is necessary the constant verification of these activities. This strategy will create legal instruments in order to establish the line between the allowed and the not allowed actions in MSWM matter. The lines of action in this strategy will be: vigilance of waste treatment facilities, creation of State Technical Environmental Regulations (Normas Técnicas Estatales Ambientales, NTEA), tax incentives and review of regulatory instruments.

Indicator	Target (2011)
Visited waste management facilities per year	50
Total number of valid regulations (less than 5 years old)	> 4

Number of meetings with the involved people/institutions for the tax incentive promotion	3
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APPENDIX IV

EXAMPLE OF TOLUCA COLLECTION ROUTES AS OF OCTOBER 2010

RUTA	Delegation / Neighborhood	Frequency						Final Disposition	
		M	T	W	T	F	S		S
1	Downtown	1	1	1	1	1	1	1	Zinacantepec
2	Barrio de Santa Clara Poniente	1		1		1			Zinacantepec
3	Barrio de Santa Clara Oriente		1		1		1		Zinacantepec
4	Colonia 5 de Mayo Poniente	1		1		1			Zinacantepec
5	Colonia 5 de Mayo Oriente		1		1		1		Zinacantepec
6	Colonia Francisco Murguía Oriente (El Ranchito)	1		1		1			Zinacantepec
7	Colonia Francisco Murguía Poniente (El Ranchito)		1		1		1		Zinacantepec
8	Barrio de la Merced (Alameda)	1	1	1	1	1	1	1	Zinacantepec
9	Barrio de el Cópore	1		1		1			Zinacantepec
10	Barrio de Santa Bárbara	1		1		1			Zinacantepec
11	Barrio de Zopilocalco Sur y Colonia Niños Héroes (Pensiones) y Fraccionamiento Lomas Altas	1	1	1	1	1	1	1	Zinacantepec
12	Barrio de Zopilocalco Norte	1		1		1			Zinacantepec
13	Barrio de Huitzila y Colonia Doctores		1		1		1		Zinacantepec
14	Colonia Los Ángeles, Santiago Miltepec y Colonia las Imágenes	1		1		1			Zinacantepec
15	Colonia Reforma y Ferrocarriles Nacionales (Barrio de San Juan Bautista) Oriente	1		1		1			Zinacantepec
16	Colonia Reforma y Ferrocarriles Nacionales (Barrio de San Juan Bautista) Poniente		1		1		1		Zinacantepec
17	Barrio de San Sebastián y Fraccionamiento Vertice Oriente	1		1		1			San Antonio La Isla
18	Barrio de San Sebastián y Fraccionamiento Vertice Poniente		1		1		1		San Antonio La Isla
19	Colonia Las Américas Oriente	1		1		1			Zinacantepec

APPENDIX V

QUESTIONNAIRE USED IN TOLUCA SURVEY

ENCUESTA: PERCEPCIÓN DEL MANEJO DE LA BASURA EN LA CIUDAD DE TOLUCA

Sexo : Masculino Femenino

Edad : Menor de 18 18-29 30-39 40-50 Mayor de 50

Ocupación: Estudiante Ama de casa Empleado Trabajador Independiente

Administración Pública Jubilado Otra

Colonia: Código Postal:

1. Asignar a los siguientes problemas ambientales, valores del 1 al 4, de acuerdo a los que consideres presentan mayor riesgo para la vida humana (1 = menor riesgo, 4 = mayor riesgo).

Contaminación del aire Contaminación del agua Basura
 Ruido

2. ¿Sabes cuánta basura produces al día? No Sí,
¿Cuánta?:

3. ¿Separas la basura en casa (orgánico, inorgánico)? No Sí

4. Si respondiste **NO** a la pregunta 3, ¿Cuál es la razón/razones por la que no separas la basura?

No tengo tiempo
 No sé cómo separar los residuos
 Todo termina revuelto nuevamente en el camión de la basura
 Considero que no es mi obligación
 Otra:

5. ¿Qué tanto sabes acerca de el proceso de compostaje?

Entiendo el proceso y conozco diferentes tipos de compostaje
 Entiendo los principios básico
 No conozco nada acerca de este proceso

6. En caso de conocer la composta, ¿alguna vez la has utilizado? No Sí
No aplica

7. ¿Qué tanto sabes acerca del servicio de recolección de basura de tu colonia?

muy poco 1 2 3 4 5 mucho
Frecuencia de recolección (día de la semana y hora):

8. ¿Qué tipos de tratamiento y eliminación de basura existe en tu ciudad?

Relleno sanitario Tiradero

- Compostaje
- Desconozco

- Reciclaje
- Otra:

9. De acuerdo a tu percepción, califica el riesgo asociado con cada uno de los siguientes tratamientos de basura(1= menor riesgo, 5 = mayor riesgo)

Relleno Sanitario	1	2	3	4	5	.
Tiradero	1	2	3	4	5	.
Compostaje	1	2	3	4	5	.
Reciclaje	1	2	3	4	5	.
Tratamientos mecánicos o biológicos	1	2	3	4	5	.
Incineración	1	2	3	4	5	.

10. ¿Cómo calificarías el servicio de recolección de basura en tu colonia?
 muy malo 1 2 3 4 5 muy bueno

APPENDIX VI

TRANSLATION OF SURVEY OF WASTE MANAGEMENT PERCEPTION IN TOLUCA

Sex: Male Female

Age: Less than 18 18-29 30-39 40-50 More than 50

Occupation: Student Housewife Employee Self-employed
 Public Administration Retired Other

Neighborhood: _____ Zip Code: _____

1. Rank the following environment problems using values from 1 to 4, in terms of the threat they pose on human life (1 = lowest risk, 4= highest risk)

Air Pollution Water Pollution Waste Noise

2. Do you know how much waste you produce every day? No Yes, How much?

3. Do you separate waste at home (organic, inorganic)? No Yes

4. If answer to question 3 was **NO**, What is the reason(s)?

- I don't have time
- I don't know how to do it
- Everything ends up mixed again in the collection trucks
- I believe this is not my obligation
- Other:

5. How much do you know about the composting process?

- I thoroughly understand the process and know about the different types of composting
- I understand the basic principles
- I know anything about this process

6. In case you know the compost, have you ever used it? No Yes Non applicable

7. How much do you know about the waste management system of your city?

no idea 1 2 3 4 5 completely
Collection frequency (Day(s) of the wee and time):

8. How waste is treated and eliminated in your city?

- Sanitary Landfill Dump
- Composting Recycling
- No idea Other:

9. According to your perception, rank how high is the risk associated with the following waste treatment and final disposition methods (1= lowest risk, 5= highest risk)

Sanitary Landfill	1	2	3	4	5	.
Dump	1	2	3	4	5	.
Composting	1	2	3	4	5	.
Recycling	1	2	3	4	5	.
Mechanic or biological treatments	1	2	3	4	5	.
Incineration	1	2	3	4	5	.

10. How would you rate the collection service in your neighborhood?

very bad 1 2 3 4 5 very good