Waste Management 29 (2009) 2018–2024

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico

Guadalupe Gómez [a,b], Montserrat Meneses [a], Lourdes Ballinas [b], Francesc Castells [a,*]

[a] Departament d'Enginyeria Química, Universitat Rovira i Virgili, 43007 Tarragona, Spain
[b] Facultad de Ciencias Químicas, Universidad Autónoma de Chihuahua, 31310, México

ARTICLE INFO

Article history:
Accepted 2 February 2009
Available online 20 March 2009

ABSTRACT

Management of municipal solid waste (MSW) has become a significant environmental problem, especially in fast-growing cities. The amount of waste generated increases each year and this makes it difficult to create solutions which due to the increase in waste generation year after year and having to identify a solution that will have minimum impact on the environment. To determine the most sustainable waste management strategy for Chihuahua, it is first necessary to identify the nature and composition of the city's urban waste. The MSW composition varied considerably depending on many factors, the time of year is one of them. Therefore, as part of our attempt to implement an integral waste management system in the city of Chihuahua, we conducted a study of the characteristics of MSW composition for the different seasons. This paper analyzes and compares the findings of the study of the characterization and the generation of solid waste from households at three different socio-economic levels in the city over three periods (April and August, 2006 and January, 2007).

The average weight of waste generated in Chihuahua, taking into account all three seasons, was 0.592 kg capita^{-1} day^{-1}. Our results show that the lowest income groups generated the least amount of waste. We also found that less waste was generated during the winter season. The breakdown for the composition of the waste shows that organic waste accounts for the largest proportion (45%), followed by paper (17%) and others (16%).

1. Introduction

The world's population consumes ever-increasing amounts of all types of products. This leads to large amounts of solid waste in diverse forms. Technologically developed countries have implemented waste treatment systems of varying degrees of sophistication. However, less developed countries deposit their waste in landfills with no environmental controls or in open spaces.

Landfills generate gas emissions and leaching that affect the air, soil and water. Preventing or reducing environmental emissions is a challenge for the environmental agencies of any country. However, defining a sustainable strategy for urban waste treatment that can be applied to a city is a particularly difficult task, since geographic location, climate, demographics and socio-economic factors determine the amount and composition of waste.

In order to identify a more sustainable waste management system for a city like Chihuahua, we elaborated a characterization procedure which would allow us to determine the amount and composition of municipal solid waste (MSW) generated in households. The study focused on three different periods of the year so that any seasonal differences could be identified. This paper presents the background, methodology and outcome of this characterization. In a previous paper (Gómez et al., 2008), we reported on an initial characterization of MSW in Chihuahua during one period of the year; the present study is a continuation of that work. Previous studies conducted on urban waste characterization are reported in Gómez et al. (2008).

1.1. Description of the MSW collection system in Chihuahua

Approximately 1000 tons per day of MSW is generated in the city of Chihuahua, over the period of this study. Sixty percent of this waste is collected by the Municipal Sanitation Service system and the remainder of the work is contracted out to various private organizations (Garay, 2006). Fig. 1 shows the city of Chihuahua's collection system. Collection trucks leave the transfer facility to collect waste. Service operators collect urban solid waste generated from the houses along their designated route. Waste is emptied into the truck and then taken directly to the landfill site or to the transfer unit, depending on the location where the collection service is provided (Reglamento de Limpia, 2007).

Chihuahua does not currently have a waste sorting system. However, people known as "garbage pickers" sort through and separate materials which they later sell on the sidewalks. The same happens with the collection trucks (the collection workers them-

* Corresponding author. Tel.: +34 977559644; fax: +34 977559621.
E-mail address: francesc.castells@urv.cat (F. Castells).

0956-053X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.wasman.2009.02.006

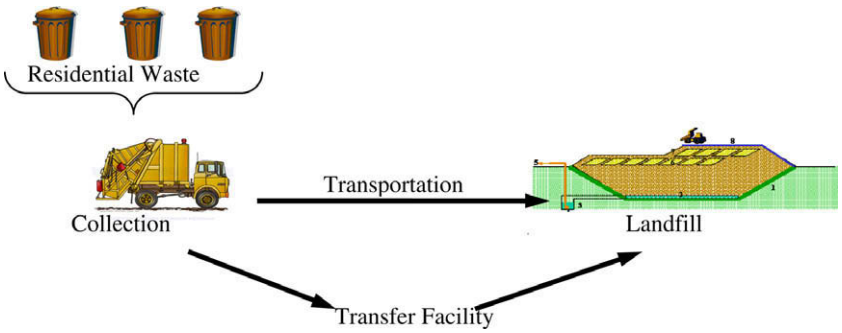

Fig. 1. Waste collection system in the city of Chihuahua.

selves separate things) as the waste is being taken to the landfill. This reduces the amount of waste which reaches the landfill and the fractions separated by the garbage pickers are taken to receiving sites.

2. Objective

The purpose of this paper is to characterize the MSW generated in households in the city of Chihuahua at three socio-economic levels and at three different times of the year. The socio-economic levels studied were: level I: households with 1–2 minimum wages (lowest socio-economic level); level II: households with 2–5 minimum wages; and level III: households with more than 5 minimum wages (highest socio-economic level). The periods studied are: one week in April, 2006, one week in August of the same year and another week in January, 2007, representing three different seasons: spring (change temperature), summer (high temperature) and winter (low temperature).

3. Methodology

The methodology employed in this paper was also applied in Gómez et al. (2008), which concerned an initial MSW characterization in Chihuahua for only one period of the year.

The methodology chose involved collecting solid waste directly from the houses where it was generated. This is an established method used in characterizing solid waste (Tchobanoglous and Kreith, 2002). The process consisted of the following stages:

(1) Classifying the population by socio-economic levels.
(2) Selecting the neighborhood for sample collection.
(3) Determining the number of samples.
(4) Collecting the samples.
(5) Classifying and quantifying the fractions.
(6) Analyzing the results.

3.1. Classifying the population by socio-economic levels

The city of Chihuahua has a population of 758,791 inhabitants (INEGI, 2005) and 194,562 households distributed among 525 neighborhoods (SCINCE, 2000). The secondary and tertiary sectors account for most of the city's economic activity.

According to SCINCE (2000), 37% of the population of Chihuahua is economically active. They classify this active sector of the population by number of minimum wage earners, identifying several minimum wage ranges. In line with this approach, our study classifies its subjects based on income. Table 1 shows the minimum wage ranges and classification by levels. Three percent of households within the active population category earned one minimum wage and were classified as level 0 (see below), those earning 1–2 minimum wages were classified as level I, those earning 2–5 minimum wages as level II and households earning more than 5 minimum wages were classified as level III. This study incorporates socio-economic levels I, II and III. People at level 0 are not included because this population is not stable, there being a tendency to switch jobs or migrate to the United States.

Table 1
Classification of levels according to the income range for the economically active population in Chihuahua.

Minimum-wage range[a]	Active population (%)	Level (self-classified)
1 wage	3	0
1–2 wages	19	I
2–5 wages	54	II
>5 wages	24	III

In 2007, the minimum salary in Chihuahua was US$4.3 per day.
[a] SCINCE (2000).

3.2. Selecting the neighborhood for solid waste sample collection

The neighborhoods to be sampled for MSW were chosen by applying data obtained from SCINCE (2000). This approach makes it possible to locate neighborhoods on a map of the city and provides statistical information about each neighborhood.

Neighborhoods were selected for the study according to the largest percentage of residents earning the required range of minimum wages necessary for the study. Neighborhoods that were easy to get to and where residents were willing to participate in the collection of their waste were considered. Fig. 2 shows a map of the city of Chihuahua and the location of the neighborhoods selected for the study.

3.3. Determining the number of samples

Solid waste is a heterogeneous material and the amounts generated and the compositions vary from place to place and from season to season (Gidarakos et al., 2006; World Resources Institute, 1996). Due to the heterogeneity and variability of MSW, a statistical tool is required to estimate the number of samples to be analyzed. From a statistical viewpoint, the accuracy in determining these parameters will increase as the number of samples to be analyzed increases. At the same time, the number of samples should be manageable, taking into account the resources available.

The method used is the same as in Gómez et al. (2008) which is an adaptation of the one reported by Abu Qdais et al. (1997). This method is based on the central limit theorem, with the hypothesis that sample composition follows a normal distribution. The sample was estimated to a 99% confidence interval and a 10% error of the