

Physical and Chemical Characteristics of Municipal Solid Waste in a Rural Locality- Study Case: Cosautlán De Carvajal, Veracruz, Mexico

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Abstract

To design and develop integrated waste management systems is necessary to have information of the physical and chemical characteristics of municipal solid waste (MSW), which is practically nil in Mexico. Therefore, this study was aimed to determine the physical (humidity, ashes, and specific heat) and chemical characteristics (pH, organic matter and sulfur) of MSW generated in the locality of Cosautlán de Carvajal, Veracruz, Mexico. A representative sampling of MSW was taken following the Mexican environmental regulations. The results revealed 65.9% of maximum humidity, 11 to 18.57% of ashes, and 1.008 to 1.53 cal/g° C of specific heat values for the MSW. Regarding its chemical characteristics, the MSW pH values were neutral, approximately 50% of the MSW corresponded to organic matter, and the maximum sulfur value was 1.862%. In conclusion, the results suggest that the MSW in the municipality of Cosautlán de Carvajal, Veracruz may undergo biological and thermal treatments. Thus, vermicomposting becomes as a suitable alternative as final treatment process to the organic fraction.

Keywords: Municipal solid waste, physical characteristics, chemical characteristics, semirural and rural localities.

1. Introduction

The Mexican legislation for the integrated management of MSW includes a considerable number of laws seeking to reduce the harmful effects caused by the improper handling of MSW. It also establishes that municipalities are responsible for performing integrated management of MSW (Ministry of Environment and Natural Resources, SEMARNAT by its Spanish Acronym, 2007), including a strategic planning, which considers not only information on the generation and composition of MSW but also their physical and chemical characteristics, and design systems to develop integrated waste management. To design an efficient management system, that consider the appropriate final treatment of MSW based on their physical and chemical characteristics, is important to consider the following basic parameters: volumetric weight, per capita generation, and composition of MSW (Tchobanoglous et al., 1994). In Mexico, however, the information regarding these parameters is vague and diffused, especially in semirural and rural localities, which according to the classification of the Ministry of Social Development (SEDESOL by its Spanish Acronym) are places with a population less than 15,000 inhabitants (Rosiles, 2008). Therefore, it became necessary to carry out this research to determine the physical (humidity, ashes, and specific heat) and chemical characteristics (pH, organic matter and sulfur) of MSW.

The study was performed in the locality of Cosautlán de Carvajal, Veracruz, Mexico, where currently there is no proper management of waste. The municipal authorities make only the MSW collection without considering an use or recovery. Once MSW are collected, they are transported to the disposal site, Pinoltepec, a municipality of Emiliano Zapata, located at approximately 70 km from Cosautlán de Carvajal.

1.1 Description of the study area

Cosautlán de Carvajal is located in the central highlands of the state of Veracruz in México, at coordinates 19° 20' north latitude and 96° 59' west longitude, to a height of 1,240 meters above sea level. It is located in the municipality with the same name, which bordered on the north with Teocelo and Ixhuacán de los Reyes, to the south and east with Tlaltetela and to the west with Ixhuacán de los Reyes and the state of Puebla, as shown in the figure 1 (INAFED, 2010).

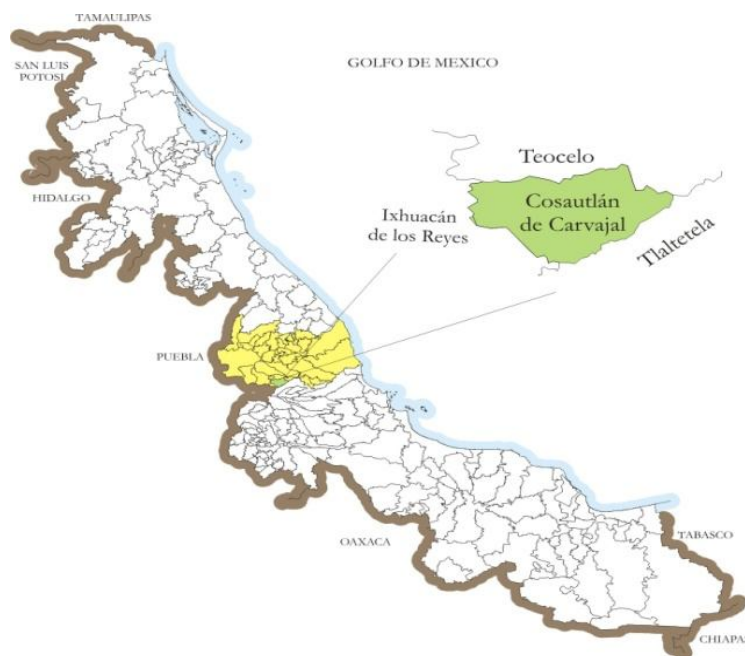


Figure 1. Map of the Locality of Cosautlán De Carvajal, Veracruz, Mexico INAFED, 2010

The approximate distance from the state capital, Xalapa, is 23.5 km. Its climate is temperate-humid-regular with an average temperature of 19.9 °C, and with an annual average rainfall of 2065.2 mm (SMN, 2013). The landform has basically two characteristic forms, hilly areas that are located to the north, south and east, and are composed by ravines and hills, and the half-planes which are located to the west and are formed by ridges of low slope (INAFED, 2010).

In 2005, the National Institute of Statistics, Geography and Informatics (INEGI by its Spanish acronym), reported in its Second Census of Population and Housing that this locality had 4,429 inhabitants (INEGI, 2013). In the same year, the National Population Council (CONAPO by its Spanish acronym) reported that the degree of marginalization of this municipality was high with an index of 0.4123 (CONAPO, 2013), establishing this locality in the place 87th in the state and 803 nationwide (SEDESOL, 2013).

2. Materials and Methods

2.1 Determining the composition of the sample

The methodology for determining the composition of domestic solid waste, was based on the Mexican reference standard NMX-AA-022-1985 "Environmental protection, soil contamination, municipal solid waste selection and quantification of products" (SECOFI, 1985a).

2.2 Sample collection for laboratory analysis

The method used to obtain a representative sample of household waste for physical and chemical analysis, was established based on the Mexican standard NMX-AA-015-1985 "Protecting the environment-soil contamination-municipal solid waste-sampling-quarantining method" (SECOFI, 1985b). Sampling was carried out during 5 days, taking a sample daily for a total number of 5. The analysis of each sample was performed in duplicate and the results were averaged, for a total of 5 mean values for each parameter. Therefore, this study was descriptive. Physical and chemical analyses were performed in the laboratory of the School of Chemistry Science, Universidad Veracruzana, campus Xalapa, Veracruz, Mexico, within a maximum period of one hour.

2.3 Sample preparation for analysis in the laboratory

The preparation of the sample for analysis in the laboratory was made according to the provisions of Mexican reference standard NMX-AA-052-1985 "Protecting the environment-soil contamination, municipal solid-waste sample preparation in the laboratory for analysis" (SECOFI, 1985c). First, the MSW were crumbling to a maximum size of approximately 5 cm. Only glass and metals were not included, since they interfere with thermal treatment or biological determinations.

Subsequently, MSW were homogenized and a sample of about 1 kg was obtained, which was placed in a roller mill to obtain a more homogeneous product and a size similar to coarse sand. All determinations were performed in this final product. This procedure was carried out daily during the five days of sampling. Every day samples were tested in the laboratory for humidity, ashes, specific heat, pH, organic matter and sulfur.

2.4 Laboratory tests

The physical and chemical tests of MSW were performed in the laboratory as detailed below:

Determination of humidity. It was determined following the Mexican reference standard NMX-AA-016-1984 "Protecting the environment-Soil contamination MSW humidity-determination" (SECOFI, 1984a).

Determination of ashes. This test was performed by applying the Mexican reference standard NMX-AA-018-1984 "Protecting the environment-Soil contamination MSW ashes-determination" (SECOFI, 1984b).

Determination of the specific heat. The specific heat is defined as the amount of heat required to raise the temperature of one gram of a substance by a degree (Armijo and Armijo, 2006). In this case was used the Dulong and Petit technique (Gray and Haight, 2003), which uses a calorimeter to obtain the specific heat value of the sample. To perform this technique, 20 grams of MSW was carefully introduced in 200 ml of boiling distilled water, and was held with a wire. Sample was heat and expose to water vapor for 15 minutes. Then, the sample was dried with filter paper, waiting for the time when the highest temperature was registered to the contact point. Finally, the sample was introduced directly to the calorimeter and the temperature and the level of water contained in it were registered. Calculations were performed according to the expression 3.

$$C_{esp} = \frac{m_2 (T_2 - T_1)}{m_1 (T_3 - T_2)} \text{----- (3)}$$

Where:

C_{esp} = Specific heat (g/cal °C)

m₁ = Weight of the simple (g)

m₂ = Total equivalent of the water (g)

T₁ = Initial temperature of the water (°C)

T₂ = Final temperature of the water (°C)

T₃ = Temperature of the sample (°C)

Determination of pH. We used the Mexican reference standard NMX-AA-25-1984, "Environmental protection, soil contamination municipal solid-waste-determination of pH-potentiometric method" (SECOFI, 1984c). The potentiometer used was Hanna Instruments pH 211.

Determination of the organic matter. For this we applied the Mexican reference standard NMX-AA-021-1985 "Protecting the environment-Soil contamination municipal solid waste organic matter- determination" (SECOFI, 1985d).

Determination of sulfur. NMX-AA-92-1984, "Environmental protection-Soil contamination MSW sulfur-determination" (SECOFI, 1984d).

3. Results and Discussion

The results revealed the following composition distribution of the MSW: food waste (51.41 %), garden waste (8.31 %), clear glass (6.84 %), rigid plastic (6.55 %), paper (6.06 %), plastic film (4.31 %), fiber (3.37 %), metals (1.43%) and others (11.42 %).

Table I shows the results of the physical and chemical tests conducted on the household waste.

Determination	Unit	Sampling day				
		1	2	3	4	5
Humidity	%	65.9	51.3	68.5	41.05	38.65
Ashes	%	18.57	11.13	ND	ND	ND
Specific Heat	cal/g °C	1.52	1.008	1.13	1.53	1.33
pH	UpH	7.6	7.4	7.1	7.2	ND
Organic Matter	%	53.38	57.51	54.34	ND	ND
Sulfur	%	0.17	1.86	1.74	ND	ND
ND= Not determined because of external causes of the project						

Table I. Summary of Results of Physical and Chemical Tests on Municipal Waste

Determination of humidity

Analogous to what has been reported in the literature (Llauró, 1999), we found that the MSW humidity feature was between 30 to 70%, fulfilling the required values for fuel incineration without auxiliary, which should not exceed 50%. It also fulfills the requirements for composting or vermicomposting, which need an optimal humidity of 40 to 60% (Dios, 2008). The high humidity values may be explained by the high percentage of organic matter (food and yard waste) in the samples, which is common in semirural and rural localities.

Determination of ashes

The ashes value was lower than 50%, which is considered optimal and it is possible to use incineration techniques, without the use of auxiliary fuels, as final treatment (Llauró, 1999).

Determination of specific heat

We did not find any reference values for this parameter in the literature. Therefore, it was only possible to compare the results of this determination with the specific heat of wood, a component present in the samples, which according to the literature (SEMARNAT, 2005) is 0.284 cal/g°C. Table 1 shows the specific heat determined in this study. The results suggest high values of specific heat in the MSW samples, which are advantageous, since this property is directly related to the thermal treatments, through the thermal inertia in the incineration furnaces. This is important because calorific irregularities cause distortions in the distribution of temperatures, causing poor performance and insufficient quality of destruction. Therefore, it is necessary to have the higher specific heat value, because of the greater thermal inertia (Castells, 2005) and greater thermal stability (Alvarez and Alvarez 2008).

Determination of pH

The pH values obtained in this study were between 5 and 7, which are optimal for biological treatment (Dios, 2008).

Determination of organic matter

We found 50 to 55 % of organic matter in the MSW, similarly to values reported for other localities (Esquer, 2009). These results may be due to the prevailing habits of organic food in the semirural and rural localities, a situation that contrasts with the highly industrialized countries, which have organic matter values of approximately 10% (Tur Chabalina and Perez, 1996).

Determination of sulfur

In the literature concerning waste elemental analysis, sulfur data is near 0.1% (Hurst et al., 2006); however, the results of the second and third day of analysis are extremely high, approaching 2%. This situation may be due to high content of vegetables and legumes present in the samples, which were possibly sprayed with pesticides or fertilizers with sulfur.

4. Conclusions

In Mexico, the information of the physical and chemical characteristics of MSW is scarce and does not consider semirural and rural localities; this situation difficult the establishment of programs for integrated waste management.

The determination of the physical and chemical characteristics of MSW should be considered because their importance in the biochemical transformation and final treatments, such as incineration or energy recovery. Based on the results of specific heat and ashes, incineration could become a good choice for the final treatment of MSW in the municipality of Cosautlán de Carvajal, Veracruz; nevertheless, due to the high cost of this technique is not recommended for semirural and rural localities. However, the results of humidity, organic matter, pH and sulfur, present in MSW from this locality suggest that have optimum values for biological treatment. Additional characterization of other parameters to confirm the suitability of this type of treatment, such as phosphorus and nitrogen, should be performed.

Thus, the vermicomposting is suggested as the best treatment, not only because it is exploited the weather conditions of the region (optimum to develop this technique), but also because the high levels of organic matter found favor this practice, besides considered an appropriate procedure for waste recovery.

In summary, this research contributes and promotes the integration of a national database for decision making in the analysis of alternatives regarding to the more efficient types of treatment for semirural and rural localities.

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