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Municipal Solid Waste Management in a Municipality of Chiapas, Mexico

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Abstract: This document provides a comprehensive review of the municipal solid waste management in the municipality of Villaflores, Chiapas, specifically the municipal seat and nearby towns. The main waste management problems were identified. Derived from the study, it was found that currently 0.707 kg/per capita day of solid waste are generated, equivalent to 59 tons/day, which are handled with limited equipment and personnel, leading to difficulties, specifically as regards final disposal. It was found that, despite the limited number and inferior characteristics of the existing collection vehicles, waste collection is moderately efficient (78%). Final disposal shows serious deficiencies, such as ruptures of cell geotextile liners, clogging of rainwater drain channel, neglected leachate evaporation pond, among others. To improve solid waste management at municipal level, the Department of Public Services in conjunction with the legal areas of the municipal council, and other external factors, such as academia and civil society organizations, should promote awareness strategies and waste separation at the source.

Keywords: Collection, Disposal, Generation, Sub-Products

1. Introduction

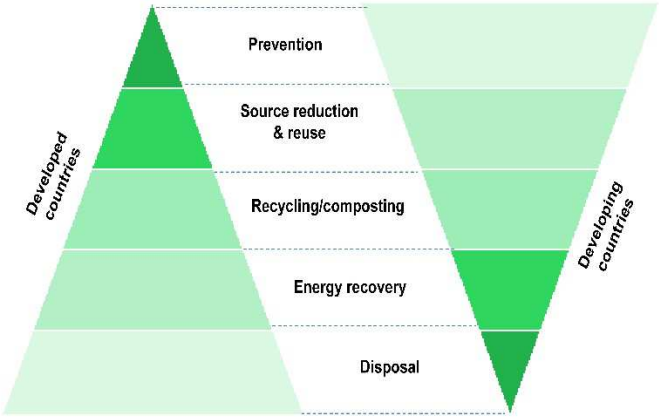
According to Tchobanoglous et al. (1993) and Worrel and Vesilind (2002) [1, 2], Municipal Solid Waste (MSW) generation is related to lifestyle. The high rates of MSW production, their constant increase and their impact on the environment, are the result of multiple factors, such as population growth, changes in consumption habits and purchasing power, migrations or new habits, as well as poor management by municipal agencies [3, 4, 5].

In developed countries, per capita MSW generation rates are generally above 1.00 kg/day (1.30 kg/day in Europe and 2.00 kg/day in the USA), and waste management policies are oriented towards waste generation reduction through the establishment of a disposal hierarchy in which landfill is considered the least recommendable option (LF) [6, 7].

Although waste generation rates in Latin America and the Caribbean are not as high as in developed countries, local policies operate in the opposite direction (see Figure 1), i.e., conventional collection systems prevail, and wastes are mixed and deposited in Landfills (LF) or Open Dump Sites (ODS), waste reduction through recycling and waste treatment being neglected [8, 9, 10].

In Mexico, the situation does not differ greatly from the Latin American context, and the efforts made by the Secretary of the Environment and Natural Resources (SEMARNAT) to promote integrated management schemes in the municipalities and towns of the country have been insufficient to date. In the period from 1950 to 2010, the average daily national generation of MSW increased almost 13-fold, from 8,200 tons/day, equivalent to about 300 g/per capita-day, to more than 109,000 tons/day, i.e., 900 g/per

capita-day. However, the problem lies not only in the large quantities generated, but also in the work required at municipal and state levels to handle them [12, 13].



Source: Adapted from [11].

Figure 1. *Hierarchy in solid waste management.*

According to the National Institute of Ecology and Climate Change (INECC), it is estimated that, in Mexico, collection covers only 83.93% of Municipal Solid Waste, this figure falling to 23.43% in places with fewer than 10,000 inhabitants. Moreover, only 60.54% of the collected MSW is deposited in Final Disposal Sites (FDS) that comply with Mexican regulations, while the remaining 39.46% is deposited in ODS or unknown places [14].

In the state of Chiapas, MSW handling is worrying, especially in small towns which are located in remote places that are difficult to access because of the rough topography of the zone, which leads to deficient basic services, especially waste collection and final disposal [15].

This paper presents a review of MSW management in the Municipal Seat of Villaflores, Chiapas, analyzes current waste generation, and identifies the main problems affecting each stage of waste management.

2. Methodology

2.1. Study Area and Context

This study was performed in the municipal seat of Villaflores, Chiapas, located at 16° 14' N and 93° 16' O (Figure 2). Villaflores is the third largest municipality of the Frailesca region, with a territorial extension of 1,901.82 km^2. In 2010, its population was 98,618 inhabitants, distributed in 1,058 localities. Only the municipal seat and 8 localities are considered urban settlements, concentrating 68.28% of the total population [16].

In recent years, the population of the municipal seat of Villaflores has grown notably, to a great extent because of the construction of new residential complexes, and this situation has an impact on the generation of MSW, because, in addition to population increase, the number of commercial establishments and services has also expanded.

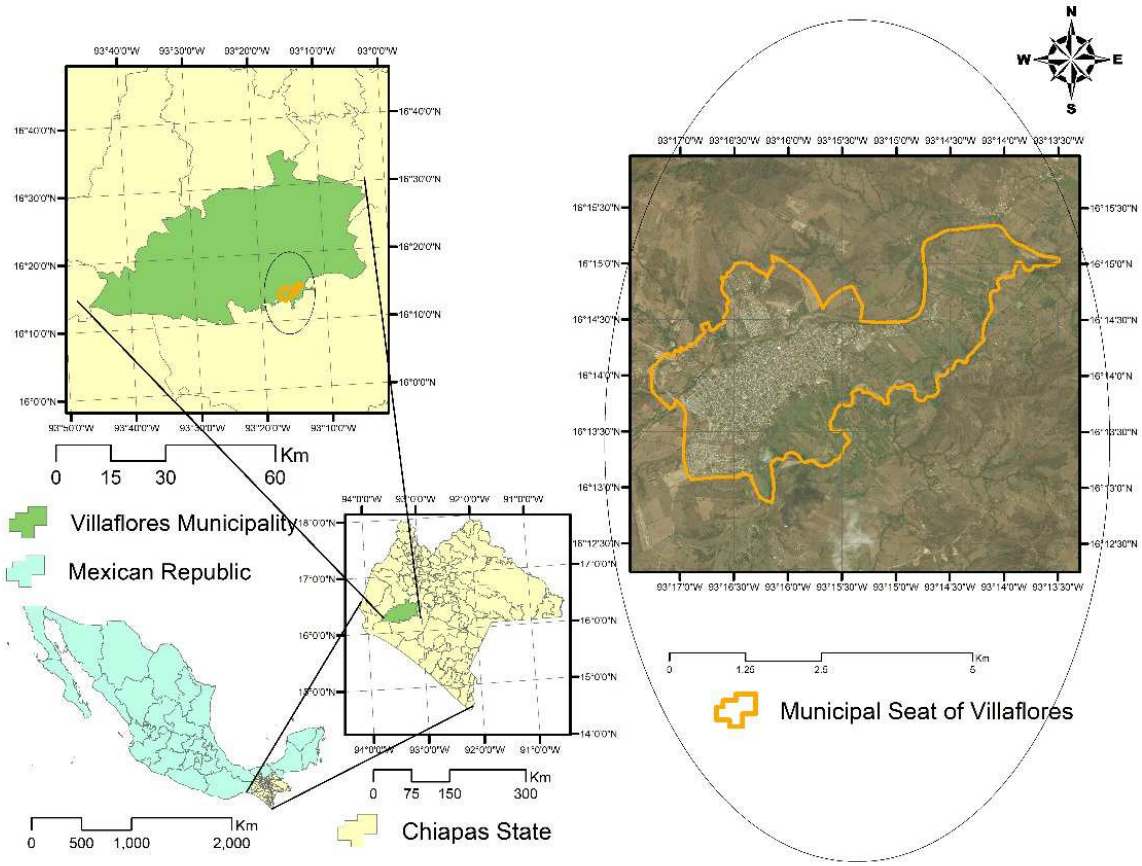


Figure 2. *Study area.*

2.2. Compilation of Information and Study Preparation

For the development of this paper, bibliographic information was examined. The databases of governmental entities, such as SEMARNAT, the Secretary of Environment and Natural History (SEMAHN), the State Committee of Statistical and Geographic Information of Chiapas (CEIEG), the National Institute of Statistics and Geography (INEGI), and municipal council, were reviewed.

Moreover, through field visits and interviews with the employees operating the waste management system, information was obtained on each of the MSW handling stages, and research was conducted to obtain more detailed information.

The research mainly focused on waste characterization and volumetric weight, based on standards NMX-AA-015-1985 [17], NMX-AA-019-1985 [18] and NMX-AA-022-1985 [19], while the Weight-Volume methodology described in Tchobanoglous et al. (1993) [1] was used to obtain the per capita rate of MSW generation.

3. Results

This section presents the information obtained from field work. The results are shown for each stage of municipal solid waste management in the municipal seat of Villaflores, Chiapas.

3.1. Villaflores Waste Management System

The municipal council of Villaflores through the "Department of Public Services" (DPS) is responsible for handling the sweeping, collection, transportation and final disposal of MSW.

Currently, the DSP employs 67 workers distributed in different service areas, as shown in Table 1. With this infrastructure, practically the whole municipal seat is covered, but coverage is low in remote settlements, such as Jesús María Garza, Benito Juárez, Joaquín Miguel Gutierrez, Palenque Los Pinos, Francisco Villa, and Guadalupe Victoria, among others.

Table 1. *Personnel and infrastructure of the DPS.*

Personnel activities	Number of employees	Description
Administrative	3	One DSP director and two assistants
Waste collectors	5	One driver per truck (three 20-yd^3 waste compacting trucks and two dump trucks 6 and 7 m^3)
Assistants	20	Four assistants per compacting truck
Sweepers	13	13 sweeper with sweeping trolleys
Caretakers	23	Gangs of caretakers are assigned to the various areas of intense flow of people
Controlled Site personnel	2	They are responsible for allowing access to collection and private vehicles
Machinery Operator	1	Excavator operator

In the above mentioned remote places, collection and final disposal is provided every 7 or 15 days, and thus people burn the wastes or throw them in ravines and vacant lots.

3.2. Generation and Composition of Waste

Knowing the quantity and composition of MSW is fundamental for any entity in charge of waste management, because this knowledge allows them to estimate the equipment necessary for the task, as well as to design engineering works such as landfills or storage cells, separation plants and others.

Table 2 shows the domestic and non-domestic solid waste generated at the municipal seat of Villaflores, Chiapas. Currently, 59 tons/day of MSW are generated, i.e., 0.707 kg/per capita-day.

The above mentioned quantity is lower than the figure reported by INECC (2012) [14] of 0.75 kg/per capita-day for towns having a populations between 50,000 and 100,000 inhabitants.

Table 2. *Generation of waste by source.*

Source of waste Generation	kg/per capita-day	Tons/day
Domestic	0.495	41.30
Non-domestic	0.212	17.70
Total	0.707	59.00

A projection of the MSW generation rate and population growth in the areas currently having waste collection services (see Figure 3) shows that within 10 years, 0.782 kg/per capita-day will be generated, i.e., 80.62 tons/day. It will thus be necessary to reformulate current MSW management strategies, and include modifications to local regulations, emphasizing waste separation at home.

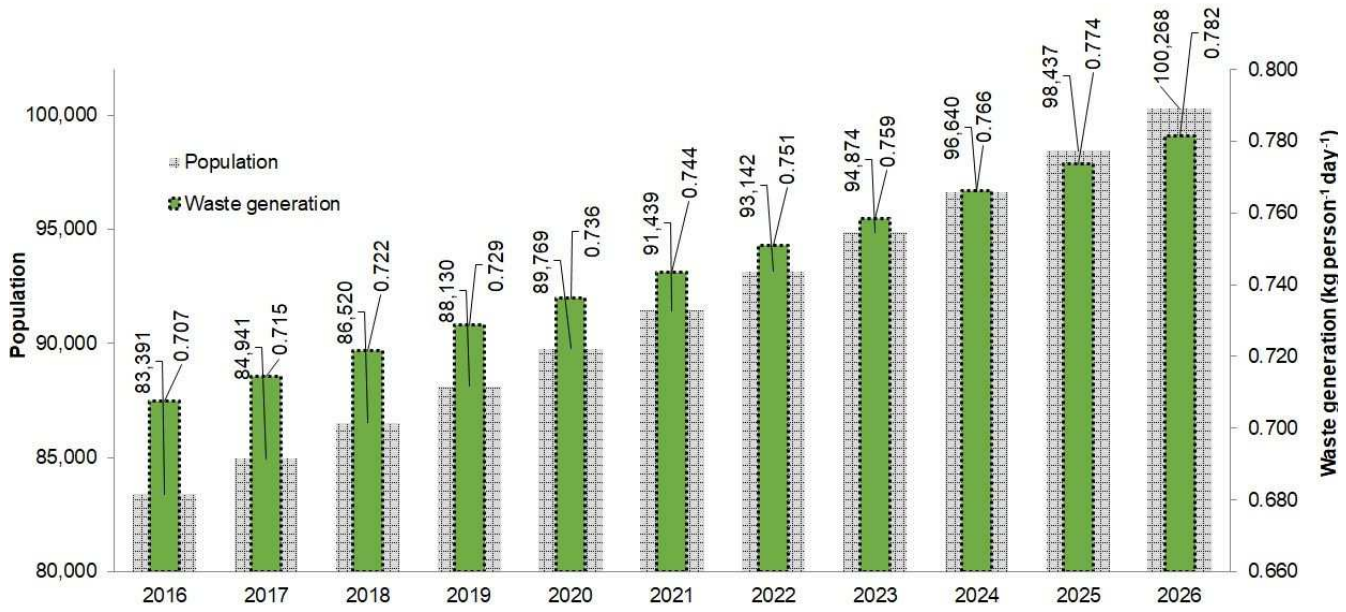


Figure 3. *Population and per capita generation of MSW.*

Source: Population and waste projections were elaborated using the geometric method, considering 1.86% annual population growth and 1% per capita waste generation increase.

Organic wastes represent the greatest fraction, the highest percentage corresponding to food waste (33.19%), followed by garden waste (16.97%) (See Figure 4 and Table 3).

Because of current consumption trends, specifically "Use and throw" culture, other products, such as plastics (13.21%) continue to increase, particularly PET (1.01%), HDPE (1.90%) and LDPE (6.92%).

Table 3. *Composition of MSW generated in Villaflores, Chiapas.*

Fraction	Components	%
Organic	Food waste	33.19%
	Garden waste	16.97%
Paper and paperboard	Wood	0.41%
	Paperboard	4.15%
	Waxed carton / Tetrapak	0.53%
	Waxed paper / magazine	0.19%
	Printing paper	1.03%
	Newspaper	1.96%
Plastic products	HDPE (High Density PolyEthylene)	1.90%
	LDPE (Low Density PolyEthylene)	6.92%
	PET (PolyEthylene Terephthalate)	1.01%
	Other plastics	3.02%
	PS (PolyStyrene)	0.36%
Glass	Color glass	0.20%
	Transparent glass	3.88%
Metals	Aluminum (cans)	0.24%
	Cans of other metals	1.14%
	Ferrous material	0.11%
Hazardous waste	(Syringes, batteries, medicines)	1.42%
Technological waste	Equipment or technological parts	0.52%
Non usable fraction	Diaper /sanitary towels	8.11%
	Toilet paper	7.60%
	Leather / shoes	0.98%
	Rag (natural and synthetic)	1.42%
	Earthenware and ceramics	1.15%
	Rubber	0.28%
	Construction waste	0.90%
	Fine residues	0.38%

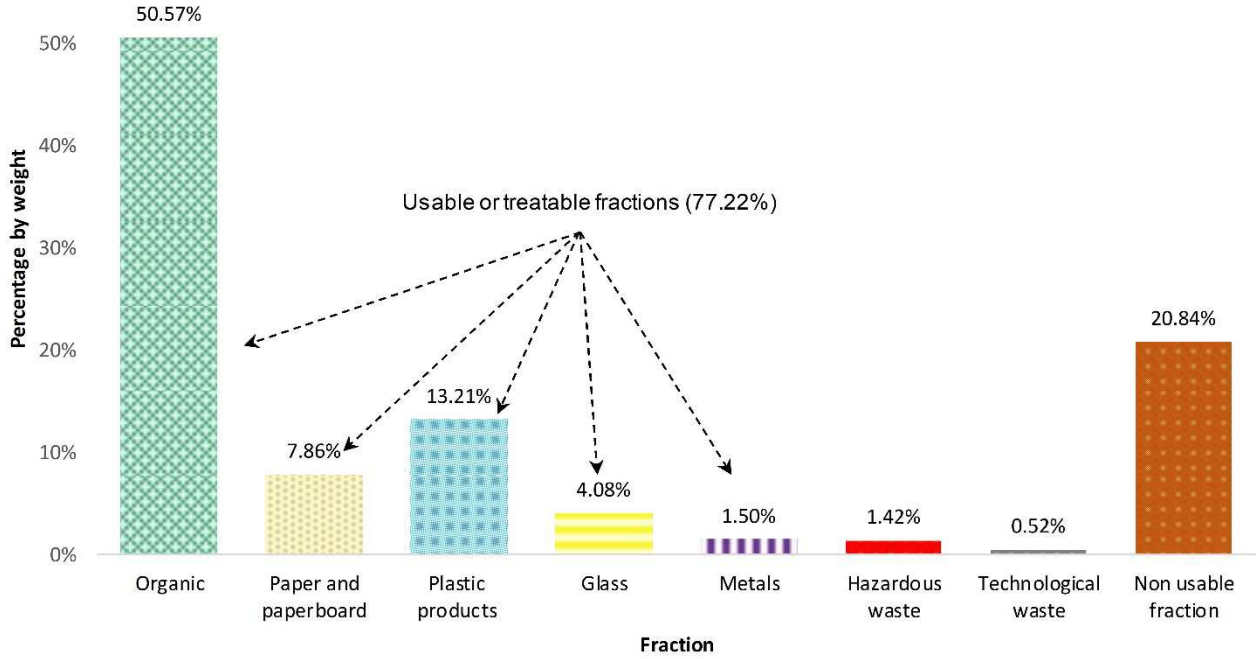


Figure 4. *MSW main fractions.*

It is important to emphasize that over 77% of the wastes could be considered treatable or recyclable and used in some way instead of being directly sent to final disposal, extending thus FDS useful life.

Hazardous and technological wastes currently represent small percentages (together 1.94%), but this could change in the future, and therefore new control or treatment mechanisms may be required.

Volumetric weight was 209.37 kg/m^3, which is very high compared to the national average of 153.12 kg/m^3 reported by INECC (2012) [14]. This is because the samples used in the study were taken directly from the Villaflores FDS after having been pre-compacted inside the collection trucks, and not from homes.

3.3 Sweeping of Streets and Public Spaces

The sweeping of streets and public spaces can be performed manually or mechanically. However, mechanical sweeping can only be implement in places where paved roads and infrastructure (sweepers and water dispatchers) permit it [20].

Because Villaflores does not have such an infrastructure, only manual sweeping is performed. The DSP employs 13 sweepers with the necessary equipment (sweeping trolleys, shovels and brooms), who are assigned to the main roads and places with greater flow of people, such as parks, gardens and sports centers. Sweeping is usually done individually, on a fixed route, during a single shift, from 05:00 a.m. to 1:00 p.m., except for the central park, where sweeping is usually organized in 2 shifts (05:00 a.m. to 1:00 p.m. and 2:00 p.m. to 8:00 p.m.), with only 6 sweepers. Sweeping equipment and infrastructure can be seen in Figure 5.

Figure 5. *Tools used for manual sweeping equipment.*

During field work, it was observed that the DSP does not have a sweeping route schedule, which makes it difficult to calculate the length of the routes. However, they were estimated at around 2 km, with a collection of approximately 250 kg of waste, mainly plastics, especially PET and PS.

In addition to sweeping the city, 23 workers were in charge of pruning trees and taking care of parks and gardens, piling up the residues found in these areas, and then transporting them to the FDS in the collection trucks.

3.4. Waste Collection

MSW collection and transportation is one of the most important activities in terms of costs and infrastructure, as well as relevance as regards the prevention of waste dispersion in the environment [14].

Figure 6. *Waste collection equipment (6 m^3 dump truck).*

To implement this activity, the DSP has a fleet of 5 waste collection trucks (Figure 6), (three 20-yd^3 waste compacting trucks and two dump trucks (6 and 7 m^3). Waste collection is performed along 5 routes within the municipal seat and 5 routes in the nearest localities. Collection coverage is estimated at 78% at municipal level.

Collection frequency varies depending on the zone: it is performed daily in the central area, and three times per week in the suburbs where collection days are Monday, Wednesday and Friday or Tuesday, Thursday and Saturday. Outside the municipal seat, the service is provided once a week, usually on Sundays.

Collection gangs are made up of 5 people (1 driver and 4 assistants) who collect the wastes according to the fixed stop method. Working hours are from 5:00 am to 4:00 pm, depending on the route. The route usually starts at the truck storage site

The greatest quantity of MSW is collected on Monday (Figure 7), reaching up to 100 tons/day. This is because on Sundays waste collection is almost nil, doubling thus the waste quantity to be collected on the next day.

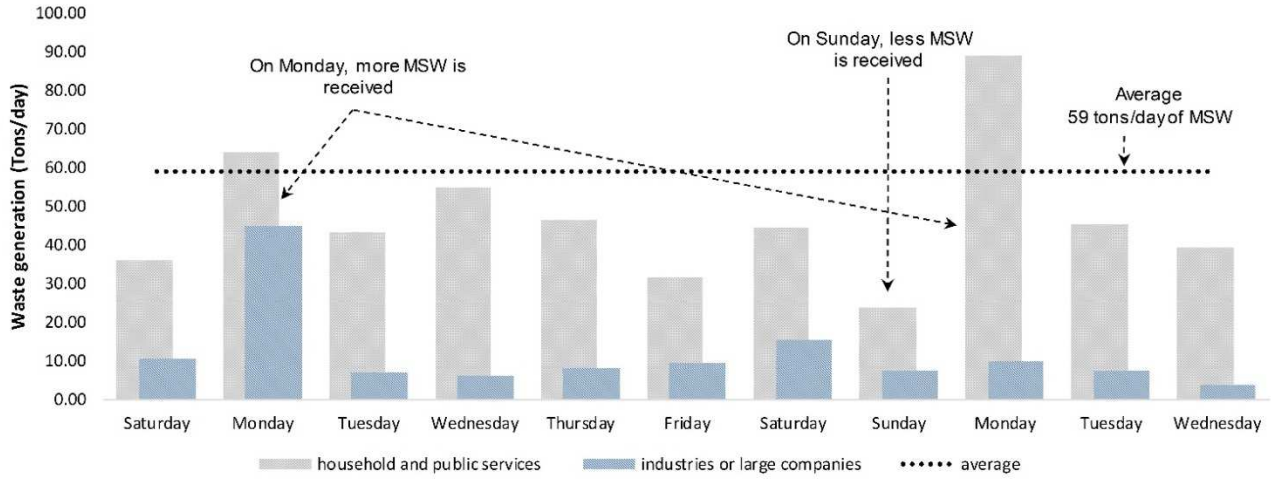


Figure 7. *Generation of MSW in Villaflores, Chiapas.*

It is important to mention that municipal council's vehicles collect only household, street and public space wastes. FDS also receives large amounts of industrial wastes.

3.5. Transfer and Transportation

Transfer Stations are facilities where MSW are transferred from conventional collection trucks to other vehicles with greater carrying capacity, to transport wastes to their final disposal or treatment sites [21, 22]. These facilities are habitually used when the FDS are located more than 20 or 30 km away from the waste generation areas, or when the roads are too steep for conventional trucks.

In the state of Chiapas transfer stations are not very common. "Tuxtla Gutiérrez" and "San Cristóbal de las Casas" are the only municipalities having this type of infrastructure [15].

In the municipal Seat of Villaflores, wastes are transported directly to the FDS at the end of the collection stage with conventional collection trucks. Usually, trucks make 2 or 3 trips per day; however this depends on the collection time and the amount of waste generated.

The trip to the FDS takes around 12 to 15 min, at an average speed of 20 to 25 km/h with loaded vehicle.

3.6. Treatment and Final Disposal

DSP uses a Controlled Site (CS) for waste final disposal. The SC surface is 11.21 hectares, fenced with perimeter trellis. The SC has been operating for approximately 9 years as of today and is expected to continue operating for 10 additional years.

The SC is located approximately 5.0 km southwest of the Municipal Seat, at coordinates X = 466,680.54 m, Y = 1,794,107.29 m, of Datum UTM WGS84 of zone 15N. Two (2) people work on this site, registering the arrivals of collection vehicles and directing them to the appropriate cell.

At the SC, a Caterpillar 320D hydraulic excavator (see Figure 8) distributes and covers MSW.

Figure 8. *Waste final disposal at Villaflores, Chiapas.*

Because of inappropriate operating practices at the CS, the infrastructure presents shortcomings (Figure. 9) such as ruptures in the geotextile liner of the storage cells, clogging of rainwater drain channels, neglected leachate evaporation pond, and fauna, especially birds. The situation is beginning to affect the surrounding area and leachate seepage can be observed downstream.

Figure 9. *Affectation of FDS infrastructure -Neglected evaporation ponds-.*

Inside the FDS, three (3) families (7 people), working from Monday to Saturday without personal protective equipment, segregate about 200 kg a week of valuable materials, such as plastics, cardboard and metals which they sell to private companies (Figure 10).

Figure 10. *Separation of valuable waste, weighing of valuable recovered materials.*

4. Conclusions

MSW management diagnostics provide basic tools that can be used by the authorities for making decisions as regards infrastructure design, plans, programs, or equipment acquisition.

Derived from the diagnostic study conducted at Villaflores, Chiapas, specifically its Municipal Seat and nearby towns, it was found that they currently generate 0.707 kg/per capita-day, equivalent to 59 ton/day of MSW, which are managed with limited equipment and personnel, which leads to difficulties in some stages of MSW management such as final disposal.

An aspect to be highlighted in the data reported above is the percentage of wastes or sub-products that can be used or treated, such as plastics, paper, cardboard, organic matter and metals, which account for about 77% of the waste generated in the municipality.

Despite the limited number and poor characteristics of the existing collection vehicles, waste collection is moderately effective with a 78% coverage.

To improve the efficiency of MSW management in the municipality of Villaflores, the DSP, together with the competent areas of the Municipal Council, should promote strategies to develop awareness and waste separation at the source. Likewise, it would be convenient to establish links with external factors, such as entrepreneurs, academia and civil society organizations, in order to design waste management strategies.

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