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ANALYSIS OF MUNICIPAL SOLID WASTE MANAGEMENT IN MUNICIPALITIES WITH LESS THAN 10,000 INHABITANTS. CASE STUDY: TOTONTEPEC VILLA DE MORELOS, OAXACA

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ABSTRACT

This research aimed to analyze the current situation of municipal solid waste management in municipalities with less than 10,000 inhabitants, taking as a case study the Municipality of Totontepec Villa de Morelos, Oaxaca, Mexico. Therefore, 11 performance indicators were selected, and the calculation was carried out through the collection of information, applying a survey to municipal authorities. The results of the indicators showed low values, which reflects inefficiency in human, financial, and material resources management, financial, so it is necessary to propose strategies that allow addressing the problem presented. The lag obtained in the provision of the Public Cleaning Service is common in small municipalities, such as those with less than 10,000 inhabitants.

Keywords: Municipal solid waste; performance indicators; municipalities with less than 10,000 inhabitants.

Introduction

Municipal solid waste management (MSWM) represents a national challenge that local authorities must address, as street sweeping falls under their charge according to article 115 of the Mexican Constitution. Additionally, performance indicators are mainly categorized into general, coverage, efficiency, quality, cost, and employee attitude indicators to determine present-day circumstances in the management of MSW (SEMARNAT, 2001). Within general indicators, it can be emphasized that the production per capita of MSW at a national level generates 2.08 lbs./person/day and 120, 128 tons/ day. Moreover, respecting its composition, there is 46.42% of organic waste, 31.56% of recyclable waste, and 22.03% of other waste. Besides, there is 83.87% of the standard coverage for rubbish collection across the country, (SEMARNAT, 2020). Conversely, values up to 98.2% have been reported in metropolitan areas such as Nuevo León and Guanajuato (Tagle-Zamora et al., 2022), and some others of 97% in Benito Juárez and Quintana Roo councils (Salazar-Rodríguez y Hernández, 2019). Other indicators reveal that MSW management costs \$21.7 dollars per collected ton and \$6.10 dollars per disposed ton (SEMARNAT, 2020). Hence, it is pivotal to mention that those councils with a higher tendency to use controlled landfills typically serve populations of over 100,000 inhabitants (Jiménez, 2015).

Nevertheless, the circumstances of MSWM for small municipalities with a population of fewer than 10,000 inhabitants seem to be more alarming than the other cases. The latter stems from the fact that performance indicators

are lower, which implies a notable lag respecting sanitation service. The importance of this issue is substantial, as only 41.9% (1,038) of the 2,475 municipalities in Mexico have populations of fewer than 10,000 inhabitants (INEGI, 2023). Additionally, due to the low socioeconomic conditions of families, these municipalities generate the highest percentage of organic waste (53.46%), with a smaller proportion being recyclable (27.30%) and other types (19.24%) (SEMARNAT, 2020).

Consequently, this study aims to examine the current state of MSW management in councils with populations under 10,000 inhabitants. As a result, the Municipality of Totontepec Villa de Morelos in the State of Oaxaca, Mexico is used as a case study to identify the strengths and weaknesses of these delegations applying performance indicators.

Totontepec Villa de Morelos is located at coordinates 17°08' to 17°20' north latitude and 95°53' to 96°09' west longitude, at an elevation of 1,840 MASL. It covers an area of 218.08 km², representing 0.28% of the entire Oaxaca region, (INEGI, 2010).

Figure 1. Geographical location of Totontepec Villa de Morelos.

The weather in this Municipality grants a temperate wet climate as well as abundant rainfall. Besides, the region experiences an annual temperature range of 53-78°F, giving rise to the prevalence of luvisol soils (INEGI, 2010). Also, the municipal area is mainly covered by mountain mesophyll forest, which is the predominant vegetation type (CONABIO, 2022). A population of 5,904 inhabitants in Totontepec Villa de Morelos has been reported in a 2020

Census. However, the economically active population (EAP) in the Municipality is 60.6% with an unemployment rate of 1.54%. As of 2020, a significant proportion of the population, 41.9%, lived in extreme poverty, while 49.4% experienced moderate poverty (Gobierno de México, 2023). These figures are compounded by high levels of marginalization and social exclusion (CONAPO, 2020; CONEVAL 2020).

1. Materials and Methods

2.1 Survey to local authorities

First, a survey has been conducted with the person in charge of sanitation services in Totontepec Villa de Morelos, Oaxaca, Mexico to determine the status of MSW management. The above is stipulated based on Appendix A of the Guide for the Preparation of Municipal Programs for the Prevention and Integral Management of Municipal Solid Waste (SEMARNAT, 2006). Correspondingly, the survey included the following sections: general information about the Municipality, sweeping, waste collection, transfer, collection centers, MSW treatment, and final disposal.

2.2 Performance indicators

For the selection of the performance indicators, the characteristics of the Municipality, the availability of information, as well as the infrastructure available for MSW management were taken as references. Nonetheless, due to the absence of street sweeping by the City Council, the lack of transfer sites, and the unavailability of waste treatment facilities, the following indicators were selected (SEMARNAT, 2001):

- Collection coverage in relation to generated waste.

$$Cr = \left(\frac{T_{tr}}{T_{tg}} \right) * 100\%$$

Where:

Cr = Waste collection coverage (%).

T_{tr} = Total collected tons.

T_{tg} = Total generated tons.

- Collection coverage in relation to the population served.

$$Cr = \left(\frac{Ha}{Th} \right) * 100\%$$

Where:

Cr = Waste collection coverage (%).

Ha = Number of served inhabitants.

Th = Total population in the area.

- Final disposal coverage in relation to waste collection.

$$Ct = \left(\frac{T_{td}}{T_{tr}} \right) * 100\%$$

Where:

Ct = Final disposal coverage (%).

T_{td} = Total disposed tons on site (t).

T_{tr} = Total collected tons (t).

- Final disposal coverage in relation to generation.

$$Cdf = \left(\frac{T_{td}}{T_{tg}} \right) * 100\%$$

Where:

Cdf = Final disposal coverage (%).

T_{td} = Total disposed tons on site (t).

T_{tg} = Total of generated tons (%).

- Sanitation service efficiency regarding population served.

$$Esr = \left(\frac{Ter}{Ha} \right) * 100\%$$

Where:

Esr = Sanitation service efficiency.

Ter = Total number of employees in waste collection.

Ha = Number of served inhabitants.

- $$E_{pr} = \frac{Trv}{Tev}$$

Where:
 E_{pr} = Efficiency of waste collection personnel expressed in t/employee.
 Trv = Total collected tons per vehicle (t).
 Tev = Total number of employees per vehicle.
- $$E_{uur} = \left(\frac{Ttr}{Cv} \right) * 100\%$$

Where:
 E_{uur} = Collection equipment efficiency (unit) (%).
 Ttr = Total tons of collected waste per unit (t).
 Cv = Collection vehicle capacity.
- Maintenance and collection equipment efficiency.

$$E_{mer} = \left(\frac{Eor}{Eor + Err + Emr} \right) * 100\%$$

Where:
 E_{mer} = Maintenance equipment efficiency.
 Eor = Number of equipment (vehicles) in activity.
 Err = Number of backup equipment.
 Emr = Amount of equipment under maintenance.
- Complaint frequency regarding sanitation service.

$$F_{qr} = \left(\frac{Q}{U} \right) * 100\%$$

Where:
 F_{qr} = Complaint frequency regarding sanitation service (%).
 Q = Number of complaints.
 U = Total number of service users.

- Collection cost.

$$C_r = \frac{Crd}{Trd}$$

Where:

C_r = Cost per collected ton (\$/t).

Crd = Waste collection cost per day (\$).

Trd = Total collected tons per day.

- Employee turnover.

$$R_p = \left(\frac{Eem}{Et} \right) * 100\%$$

Where:

R_p = Personnel turnover by service (%).

Eem = Number of employees discharged from service per month.

Et = Total employees.

3 Results and Discussion

3.1 Survey results

The City Council is in charge of the Public Cleaning Service in Totontepec Villa de Morelos, however, it is only provided to certain areas of the Municipality. The person in charge of Public Cleaning does not have prior knowledge of MSW. As a result, personnel are mainly constituted by a group of 6 people, which operates a 5-hour shift per day, once a week. Therefore, a 2015 tipper truck with a 10-ton capacity and a standby unit, follows 3 waste collection routes (central area and 2 neighborhoods) within the Municipality. This council does not have transfer stations, and no treatment is achieved on MSW, so the waste is not recovered. The collected waste is taken to an open-air dump at the end of each route, located on the outskirts of the community.

3.2 Indicators results

The outcomes of the 11 performance indicators applied in the Municipality of Totontepec Villa de Morelos, Oaxaca, Mexico are presented in Table 1.

Table 1. Performance indicators results.

3.3 Indicators analysis

- Collection coverage in relation to generated waste

The collection coverage rate in relation to generated waste in Totontepec Villa de Morelos is 55.74%, which is notably close to the 59.05% reported by SEMARNAT for municipalities with fewer than 10,000 inhabitants (SEMARNAT, 2020). Nevertheless, it exceeds the established coverage for rural communities in Latin America and Caribbean (LAC) (World Bank, 2018).

- Collection coverage in relation to the population served.

The outcome of the collection coverage in relation to the population served is 61.66%. Consequently, this value was lower than the 88.2% reported internationally for Latin America and the Caribbean for populations under 15,000 inhabitants (Tello et al., 2010), as well as the 92.92% value (Alcocer et al., 2020).

- Final disposal coverage in relation to waste collection

A meticulous 100% is the value for final disposal coverage in relation to waste collection. This value reflects the lack of byproduct recovery, meaning that the waste is not being valorized. It is worth noting that the national average reported by SEMARNAT is 78.54% (SEMARNAT, 2017), due to the recovery of recyclable waste during the collection process.

- Final disposal coverage in relation to generation

Final disposal coverage in relation to generation according to Totontepec Municipality is 55.74%, which was equal to the collection coverage indicator in relation to generated waste. This confirms that there is no waste recovery, as all waste is disposed at the final disposal site (FDS).

- Sanitation service efficiency regarding population served

Sanitation service efficiency was 0.56% relative to the number of populations served. The minimum and maximum values for this indicator, as recommended by the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS), are 0.025% and 0.033%, respectively. In this way, the result suggests that there is an excess of personnel in the collection service (Paraguassú&Rojas, 2002).

- Collection personnel efficiency

Collection personnel efficiency was 0.6 ton/employee, which is below the minimum and maximum range values of 2 ton/employee, and 5 ton/employee, respectively, reported by the World Health Organization (WHO) for Latin America and the Caribbean (SEMARNAT, 2001). However, an alternative to increase the indicator value to the established range would be to reduce the number of employees involved in the collection process.

- Collection equipment efficiency

Collection equipment efficiency is 35.7%, which is lower than the minimum of 80%. This result is due to the common use of

tipper trucks in rural municipalities, which have a capacity of 10 tons and 247.20 ft³ but lack compaction systems, making them inefficient for this task.

- Maintenance and collection equipment efficiency.

Maintenance and collection equipment efficiency is 50%, which is considered acceptable since the Municipality owns a backup truck available. The truck would be used in case the person in operative experiences any issues.

- Complaint frequency regarding sanitation service.

Complaint frequency regarding the collection service for Totontepec under study is 1.42%. This value indicates that user complaints are significantly low, thus suggesting that locals are satisfied with the service. However, the result may also reveal that there are insufficient communication paths between users and sanitation service employees.

- MSW collection cost.

MSW collection cost in the Municipality is \$18.2 dollars per ton. Moreover, at a national level there is a value of \$21.7 per ton (SEMARNAT, 2020). This value is lower than the standards, likely because it does not account for the recovery of the cost of the collection truck.

- Employee turnover

The employee turnover rate is 0%, which is considered acceptable as it indicates there is no attrition or job abandonment. Álvarez (2020) reported that, generally, companies in Mexico reported a personnel turnover rate below 5%.



Figure 1. Geographical location of Totontepec Villa de Morelos.

Source: Data elaboration using Esri ArcMap version 10.4 (2015).

Conclusions

This study has established that municipalities with populations under 10,000 inhabitants exhibit delays in waste management, as indicated by the analyzed results. Consequently, this leads to lower efficiency, particularly when compared to larger populations. Besides, it may also be due to a lack of planning and the deficiencies that small municipalities face in terms of human, financial, and material resources, revealing the inefficient use of these resources.

Since the waste is neither valorized nor utilized, it is recommended that local authorities implement strategies for home composting of the organic fraction of waste and the recovery of recyclable materials such as cardboard, paper, glass, plastic, and metals. In the case of final disposal sites, it is necessary to verify whether it complies with the specifications established in environmental regulations, so that if it

does not, the appropriate actions can be taken.

For this reason, it is imperative to address the issue, considering that the circumstances of this study are commonly to be found, given that there are over 1,000 municipalities in the country with similar characteristics.

Table 1. Performance indicators results.

No.	Indicator	Result
1	Collection coverage in relation to generated waste.	55.74%
2	Collection coverage in relation to the population served.	61.66%
3	Final disposal coverage in relation to waste collection.	100%
4	Final disposal coverage in relation to generation.	55.74%
5	Sanitation service efficiency	0.57%
6	Collection personnel efficiency	0.60 t/emp
7	Collection equipment efficiency (unit).	35.7%
8	Maintenance and collection equipment efficiency.	50%
9	Complaint frequency regarding sanitation service.	1.42%
10	Collection cost	\$364.14/t
11	Employee turnover	0%

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