



Reciclacentros: a sustainable municipal solid waste management initiative in a Mexican city

Reciclacentros: iniciativa de gestión sostenible de los residuos sólidos urbanos en una ciudad mexicana

Juana Alvarado-Ibarra ¹, Kelly Cassandra Ochoa-Cabrera ^{2*}, Heidy Burrola-Núñez ³

¹Departamento de Investigación en Polímeros y Materiales, Universidad de Sonora. Bulevar Luis Encinas y Rosales S/N, Col. Centro, C.P. 83000. Hermosillo, México.

²Departamento de Ingeniería Industrial, Universidad de Sonora. Bulevar Luis Encinas y Rosales S/N, Col. Centro. C. P. 83000. Hermosillo, México.

³Programa de Ecología, Universidad Estatal de Sonora. Avenida Ley Federal del Trabajo S/N, colonia Apolo, C. P. 83100. Hermosillo, México.

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ABSTRACT: Due to the increase in the generation of municipal solid waste and its impact on the environment and health, governments have been overburdened by its impact. Therefore, they have developed initiatives for waste disposal options in which citizens are involved. For that reason, this article aims to identify the population sector that participates in the separation of municipal solid waste and goes to the collection centers, as well as to characterize waste in three points known as *Reciclacentros* in the city of Hermosillo, Sonora. For this purpose, surveys were applied, selecting the respondents in a non-probabilistic way. In the characterization, the amount of waste received at each point was weighed. The data obtained were analyzed through a non-parametric Kruskal - Wallis test with 95% confidence ($p < 0.05$). It was found that the people going to the *Reciclacentros* have an average monthly income of more than 30 thousand Mexican pesos, mostly young adult women between 25 and 44 years old, with the highest participation. In addition, the collection center identified as R3 presented a significantly higher difference in waste received with respect to the other collection centers in the period evaluated (23 t). Cardboard and paper, plastic, and glass are the most recovered waste in the city.

RESUMEN: Como consecuencia del aumento en la generación de residuos sólidos urbanos y su impacto en el medio ambiente y la salud, los gobiernos se han visto rebasados por sus impactos; por lo que han desarrollado iniciativas para el aprovechamiento de residuos en la que se involucra a la ciudadanía. Por lo tanto, este trabajo de investigación se plantea el identificar al sector poblacional que participa en la separación y entrega de residuos sólidos urbanos; así como caracterizar éstos en tres puntos denominados reciclacentros de la ciudad de Hermosillo, Sonora. Para ello, se aplicaron encuestas, seleccionando de forma no probabilística a los encuestados. En la caracterización, se pesó la cantidad de residuos recibidos en cada punto. Las cantidades obtenidas se analizaron a través de la prueba no paramétrica Kruskal - Wallis con una confianza del 95% ($p < 0.05$). Se encontró que las personas que acuden a los reciclacentros tienen un promedio de ingresos mensual superior a los 30 mil pesos mexicanos, siendo en su mayoría mujeres adultas jóvenes de entre 25 a 44 años las de mayor participación. Además, el reciclacentro identificado como R3 presentó una diferencia significativa superior de residuos recibidos con respecto a los otros reciclacentros en el periodo evaluado (23 t); el cartón y papel, plástico y vidrio son los residuos más recuperados en la ciudad.

1. Introduction

In Mexico, the General Law for the Prevention and Integral Management of Waste (LGPGIR by its acronym in

* Corresponding author: Kelly Cassandra Ochoa-Cabrera

E-mail: a221130078@unison.mx

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Spanish) stipulates that it is the responsibility of municipal governments to perform the functions of municipal solid waste (MSW) management; however, as in many other developing countries, municipal governments often find difficulties to carry out the tasks of collection, transfer, treatment and final disposal of these wastes [1, 2]. These difficulties have been potentiated as a result of population expansion, and increasing urbanization and industrialization, which have drastically increased the amount of MSW generated, making them one of the major environmental and health problems that cities and governments have to face [3, 4].

According to estimations, Mexico generates 120,128 t of MSW daily, from which 46% is organic waste, 32% is waste that can be recycled, and the remaining 22% is classified as other waste [5]. Specifically, in the city of Hermosillo, located in the state of Sonora in Mexico, about 580 t of MSW/day are generated; their composition is presented in Figure 1, with organic waste, followed by paper and cardboard being the predominant ones [6].

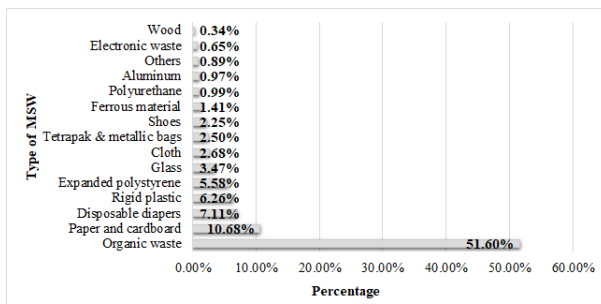


Figure 1 Composition of MSW of Hermosillo, Sonora [6]

To collect MSW that can be recycled, there are government-operated collection centers that receive various recyclable materials; nevertheless, these are very few and do not receive, on average, even the 1% of the waste that can be recycled in Mexico. Also, it should be noted that they do not include the collection of organic waste [5, 7].

According to [7], as of 2017, the state of Sonora had none of the 1,060 existing collection centers in the country. In turn, recycling and composting indicators of the city of Hermosillo indicate that 0% of waste is composted, and only between 1% and 2% is recycled [8]. Therefore, according to [9], MSW management in Hermosillo focuses on the collection, not the treatment.

In this sense, there is a need to minimize the amount of confined waste and take advantage of the MSW generated, through sustainable management [10], in which priority is given to health protection, environmental quality, and the

promotion of sustainable development [11–13]. Likewise, it is essential to promote the separation of MSW from the source of origin, since this makes it possible to increase the quality and quantity of waste that can be recycled [14].

Therefore, several authors point out that MSW management not only concerns governments, but involves diverse actors, among which society, as a generator of waste, plays a crucial role given that with its cooperation, it is possible to improve MSW management [15–18]. In this context, the General Direction of Municipal Public Services (DGSPM), the agency responsible for MSW management in the city of Hermosillo, Sonora, launched an initiative to bring MSW management toward sustainability. In 2018, the municipal government initiated the collection centers to reduce the amount of waste that is taken to the landfill; nowadays, these centers are still active and are part of the program called *Reciclacentros*, which are collection centers for recyclable waste managed by the municipality of Hermosillo [19].

To contribute to the MSW management in Hermosillo, Sonora, this research aims to identify the population sector that participates in the separation and delivery of MSW at the collection centers, in addition to showing that the initiative *Reciclacentros* is an alternative for the improvement of MSW management. The aforementioned, through the characterization in type and quantity of the MSW, recovered in the *Reciclacentros*.

2. Methodology

2.1 Place of study

The study was conducted in the city of Hermosillo, Sonora, located in the northwestern part of Mexico (N 29° 6'9.36", W 110° 58'38.55"). The city is the state capital and has a land area of 15,724.3 km²; it is the most populated municipality in the state, with 936,263 inhabitants, representing 31.8% of the state population. The climate in the city is classified as semi-warm to dry, so temperatures tend to be hot most of the year [20].

Specifically, this study was developed in the collection centers of Hermosillo, Sonora, better known as *Reciclacentros*. Those are located in different parts of the city (see Figure 2) and were defined as Reciclacentro Permanente (R1), Reciclacentro Pulso (R2), and Reciclacentro Bachoco (R3). The study was conducted from January to May 2022.

2.2 Population and sample

To define the socio-demographic characteristics of the population involved in the separation and recovery of

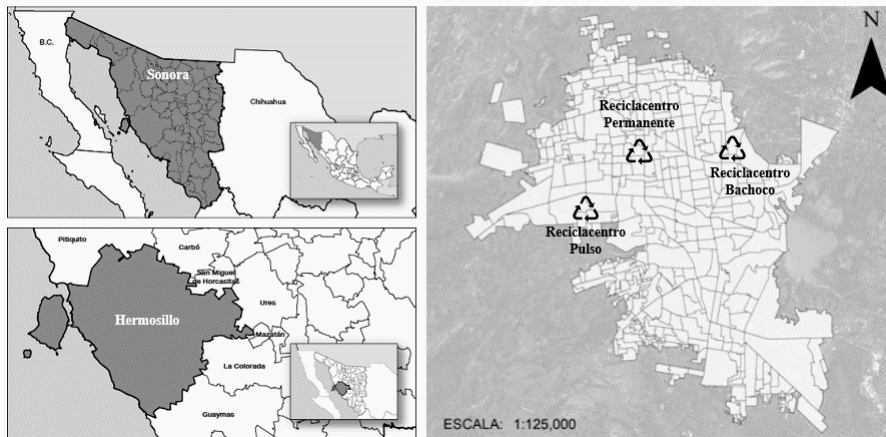


Figure 2 Geographical location of the area of study

MSW in the collection centers, the survey “Study of characterization of the municipal solid waste recovered in the *Reciclacentros* of Hermosillo, Sonora”, was applied from February to April 2022, and it was elaborated based on the book Encuestas. Elementos para su diseño y análisis [21].

The survey consisted of 16 questions and was applied in a non-probabilistic way; it was determined by the accessibility and availability of people participating in the research [22], at the locations and times indicated in Table 1. Since the population attending the *Reciclacentros* was unknown, a statistically representative sample of 100 units was chosen [23].

2.3 Experimental design and statistical analysis of Municipal Solid Waste

The experimental design is a completely randomized, one-factorial design. The factor to be studied is the location of the *Reciclacentros*. Therefore, weekly samples were taken for 16 weeks between January and May 2022. The data obtained were analyzed in the statistical package IBM SPSS Statistics version 2.1, through a non-parametric Kruskal – Wallis test with 95% confidence ($p < 0.05$); and the mean comparison test was performed by the Games – Howell post-hoc test.

The response variables included the kilograms of waste recovered: polyethylene terephthalate (PET), plastic bags (polyethylene, PE), cardboard and paper (C & P), polystyrene (PS), glass, Tetrapak, egg carton, and metal. In addition, the number of vehicles observed at each collection center during the sampling was considered.

3. Results and Discussion

3.1 Socio-demographic information

Table 2 shows the number of surveys conducted in each *Reciclacentro*. It was found that the families that separate their waste are made up of a range of 3 to 5 people, which coincides with the average number of occupants per household in the city [20]. In turn, the population involved in waste separation is primarily female, represented by 53.5%, while the male gender is represented by 46.5%. This result agrees with a report by [24] in Spain, in which women represent the demographic group with the greatest concern for waste separation.

Regarding age, 41% of the participants are young adults between ages 25 and 44, which, according to [20], corresponds to the average age of the city’s inhabitants. The low participation of the young population stands out, as only 6% of the respondents are people under 24 years of age. The population that actively participates in the *Reciclacentros* is characterized by having a monthly income of more than 30 thousand Mexican pesos. It is worth mentioning that in the R3 collection center, there was no participant with an income of less than 9 thousand Mexican pesos; on the contrary, 10% of those surveyed at this collection center stated that they had an income higher than 100 thousand Mexican pesos per month.

From the total number of people surveyed, 67% stated that they separated their waste before the collection center initiative began; the waste was delivered to the collection truck, where it was either sent to the landfill for confinement or taken by the cleanup system’s workers. On the other hand, 33% of the respondents confirmed that they did not separate their waste before the collection centers. Furthermore, 28% of those surveyed said that in their household, they generate some type of waste that they would be willing to separate; that waste includes vegetable oil, textiles (used clothes or fabrics), and

Table 1 Modality and operation hours of the *ReciclaCentros* in the city of Hermosillo, Sonora

ReciclaCentro	Location	Modality	Operation Hours
R1	Periférico Norte s/n Colonia Zona, C.P 83, Hermosillo Sonora.	Permanent (Monday - Saturday)	8:00-15:00 hrs
R2	Blvd. Quiroga esquina con Blvd. Navarrete Colonia Real de Quiroga, C.P 83220, Hermosillo, Sonora.	Semi Permanent (Only Saturday)	8:00-13:00 hrs
R3	Blvd. Morelos casi esquina con Blvd. López Portillo Colonia Sacramento, C.P 83144, Hermosillo, Sonora	Semi Permanent (Only Saturday)	8:00-13:00 hrs

Table 2 Modality and operation hours of the *ReciclaCentros* in the city of Hermosillo, Sonora

ReciclaCentro	Number of surveys conducted
R1	28
R2	53
R3	48
Total	129

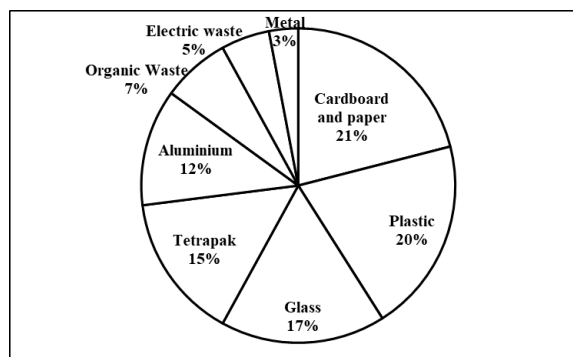


Figure 3 Types of MSW separated for recovery

metallic wrappers.

Regarding *ReciclaCentros*, 50% of the participants indicated that they would go to another collection center if the municipality decided to end the initiative, 27% said they would continue separating their waste without taking it to another collection center, and the remaining 23% said they would stop separating their waste. It is relevant to mention that the respondents comment that if the *ReciclaCentros* close, they would pressure and demand the municipal authorities to continue with the initiative. This demand, according to [15, 16], shows that the population accepts its responsibility in the generation of MSW and presents a commitment to cooperate and participate in improving MSW management.

Finally, according to the results, 24% of the respondents consider that taking their waste to the collection centers is the best way to reduce pollution in the city, while 19% intend to take responsibility for the waste generated. Other factors mentioned include educating children and encouraging them to take care of the environment.

3.2 Municipal solid waste characterization

As shown in Figure 3, cardboard and paper (21%) are the most separated MSW because, according to the respondents, it is easy to identify and simple to separate. To continue, MSW recovered at the *ReciclaCentros* in the city of Hermosillo consists of cardboard and paper, PET, plastic bags, Tetrapak, egg cartons, metal, and polystyrene. For its part, organic waste is also received at R2 and R3; however, the quantity of organic waste received at the collection centers varies from 100 g to 20 kg, contrary to what is stated in the literature [8]; organic

waste is being composted in the city.

As a result of the quantification, 49,681.4 kg were received at the *ReciclaCentros* in the evaluation period; it is estimated that this represents 0.08% of the total MSW generated in the city of Hermosillo. Although this is not a higher percentage than that reported in the city's recycling indicators (between 1% and 2%) [8], according to Hermosillo authorities, more and more citizens are joining the initiative, which has increased the amount of MSW recovered in the city [25, 26].

Additionally, 4,762 vehicles were accounted for at the three collection centers. In both cases, the volume of MSW recovered, and the vehicles accounted for; R3 was the collection center with the largest quantities (see Tables 3 and 4). It is attributed that the difference between the collection centers is due to the location since R3 is located in a residential area with high affluence; in this sense, [27] demonstrates that a shorter distance between the container or collection center increases the number of citizens who recycle. To know the differences between various groups of observed measures of a categorical variable, the optimal test to utilize was a non-parametric test.

Table 4 shows the medians and ranges obtained for each type of waste in the non-parametric Kruskal – Wallis test, also known as the H test. It is equivalent to a one-way ANOVA test. The significant differences between each recycling center were found by the Games-Howell test.

Table 3 Total quantification of MSW recovered, and number of vehicles accounted for by *Reciclacentro*

Reciclacentro	Total of MSW recovered (kg)	Number of Vehicles
R1	8,721.2	321
R2	17,527.2	1773
R3	23,365	2,648
Total	49,681.4	4,762

Table 4 Comparison of the amount of waste collected in each recycling center using the Kruskal Wallis test (H test). Significant differences among *Reciclacentros*, using the Games-Howell test ($P < 0.05$).

Waste	R1 Mdn (Rank)	R2 Mdn (Rank)	R3 Mdn (Rank)	H	P
PET	40 (60) ^a	140 (80) ^b	200 (240) ^c	37.8	<.001
C & P	120 (180) ^a	300 (360) ^b	360 (570) ^b	33.0	<.001
PE	25 (25) ^a	50 (25) ^b	50 (75) ^b	25.5	<.001
PS	15 (22) ^a	20 (18) ^b	28 (15) ^b	13.6	<.001
Glass	300 (270) ^a	400 (500) ^b	600 (900) ^c	30.0	<.001
Tetra pak	24 (24) ^a	44 (48) ^b	66 (60) ^c	33.3	<.001

As we can see, in most cases, there were significant differences in the recycling of the three *Reciclacentros* compared, R1 being the one that received less waste. Likewise, significantly, R3 was the one that received the greatest amount of material. This might be because the location is a part of the city where people with a higher income live and where the culture of caring for the environment is more present. Besides, egg cartons, cardboard and paper, and polystyrene, the amount received by R2 and R3 was similar, with no significant difference. This is likely, because the reciclacentro R2 is surrounded by many commercial food businesses. Figure 4 shows that glass, cardboard, paper, and PET reported the highest percentage in weight among the waste recovered in the *Reciclacentros*; this is similar to the composition of MSW received in the collection centers at the national level [7]. For glass, the waste with the highest volume in kilograms (21,840 kg) received, there was a significant difference in the amount recovered at each *Reciclacentro*; the largest volume, 10,020 kg, was received at R3. Similarly, the volume of PET received showed a difference between the collection centers, being again R3 the one that statistically received a significantly higher volume (3,256 kg). In the case of cardboard and paper, the comparison of means showed no significant difference between R2 and R3, with 5,208 kg and 6,372 kg received, respectively (see Figure 5).

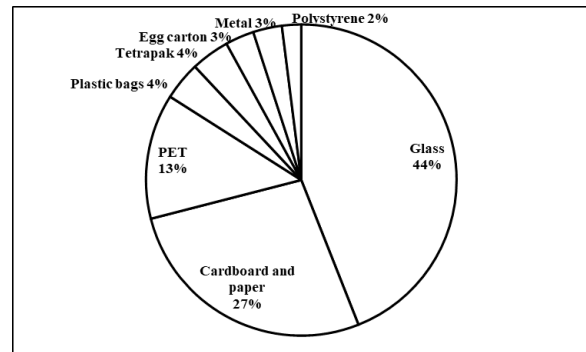


Figure 4 Total percentages of MSW recovered in the *Reciclacentros*

4. Conclusions

It is concluded that women are likely to be more involved in MSW separation, aged 25 to 44 years old. It is emphasized that the collection centers in the city of Hermosillo are directed to a population with a monthly income of more than 30 thousand Mexican pesos.

Cardboard and paper are the most separated waste for recycling, since, according to the participants, they are easy to identify and separate. Meanwhile, glass constituted the highest percentage of the total waste collected in the collection centers. It should be noted that, although the percentage of organic waste received at the *Reciclacentros* is not known, it is being considered for recovery and is already being composted in the city of Hermosillo.

On the other hand, 33% of the participants began to separate their waste as a result of the *Reciclacentros* initiative, which reflects the interest and commitment of citizens to participate in initiatives that improve MSW management. In addition, the amount of MSW received at the collection centers shows statistically significant differences, with R3 having 47% of the total MSW received, being the most successful collection center. This success is related to the location of the collection center and the monthly income level of the population in that sector.

Finally, according to the respondents, the *Reciclacentros* help reduce the contamination in the city; therefore, it is demonstrated that the *Reciclacentros* are an MSW management initiative that helps reduce the environmental and health impacts associated with waste. They also encourage the efficient use of resources and promote the sustainable development of the city, in addition to promoting environmental awareness among citizens. In this sense, it is shown that the municipal government of Hermosillo, Sonora no longer only focuses its attention on the collection of MSW, but also

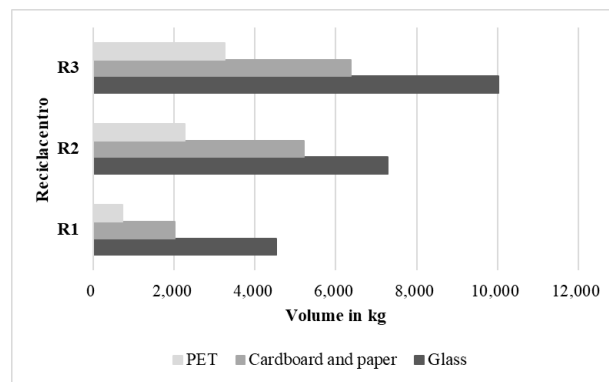


Figure 5 Comparison of the volume in kilograms of the most recovered MSW in the *Reciclacentros*

contemplates the recovery and treatment of MSW, through initiatives that have an impact on MSW management.

5. Declaration of competing interest

We declare that we have no significant competing interests including financial or non-financial, professional, or personal interest, interfering with the full and objective presentation of the work described in this manuscript.

6. Acknowledgements

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8. Author contributions

Alvarado-Ibarra, J. designed the study and collaborated in the collection, analysis, and interpretation of data. Ochoa-Cabrera, K.C collected data and assisted in data analysis and interpretation; she wrote a part of the manuscript. Burrola-Nuñez, H. provided statistical data analysis tools, supported the interpretation of results, wrote a part of the manuscript.

9. Data Availability Statement

The data associated with this manuscript is available and without access restrictions by request to the email kellycochoa@gmail.com or juana.alvarado@unison.mx.

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