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Case study

Study of waste generation polystyrene based in Misantla, Veracruz from the circular economy

Estudio de generación de residuos de poliestireno basado en Misantla, Veracruz desde la economía circular

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Abstract. - *Recently, the excessive generation of plastic waste and its inadequate management have represented a problem worldwide. Petrochemical plastics, which account for 80% of the world's total plastic use, are the main pollutants. With the growth of the population and its needs, the generation of polystyrene waste increases considerably. Expanded polystyrene (EPS) has a very low recycling rate; it is estimated that, of 125 thousand tons generated annually in Mexico, only 0.1% is recycled. The objective of this project is to obtain a preliminary diagnosis on the generation of EPS waste in the city of Misantla, Ver., which allows its post-consumer use as recycled raw material, under a circular economy approach. The methodological proposal for the development of this research was defined in the following steps: (1) characterization of the participating actors, from the Circular Economy approach; (2) identification of businesses that generate polystyrene as waste; (3) determination of the type of polystyrene generated; (4) estimation of the quantities of waste generated; (5) analysis in comparison with the generation of other types of waste; (6) generation of post-consumer use strategies. According to the 2019 Economic Census, in Misantla the economic sector with the largest number of economic units in the municipality is retail, where it is located, the sale of food in small establishments or street stores, these agents being identified as the main generators of polystyrene waste. A survey was applied to 96 companies, mainly in the food sector. The results of these surveys show that these establishments mainly use disposable products made of expanded polystyrene such as plates and cups, and that, in some cases, the use of disposable polystyrene products such as containers and spoons was identified. With the information collected, it is concluded that the use of disposable products generates approximately 765 kilograms of EPS waste. Unlike plastic waste, misinformation about the recycling of EPS, the lack of strategies for its collection and post-consumer use, as well as the lack of awareness for its recycling, give way to it ending up in final disposal sites, continuing with the trend framed in different investigations that maintain that its final destination is incineration. After the diagnosis, there is a concrete vision of the generation of polystyrene waste and future work is given in the generation and implementation of strategies that allow the use of post-consumer unicel for its return to the value chain.*

Keywords: Polystyrene waste; Circular economy; Post-consumer unicel; Plastic waste; Recycling.

Resumen. - *Recientemente, la generación excesiva de residuos plásticos y su inadecuada gestión han representado un problema a nivel mundial. Los plásticos petroquímicos, que representan el 80% del uso total de plástico en el mundo, son los principales contaminantes. Con el crecimiento de la población y de sus necesidades, la generación de residuos de poliestireno aumenta considerablemente. El poliestireno expandido (EPS), tiene una tasa de reciclaje muy baja; se estima que, de 125 mil toneladas generadas anualmente en México, sólo se recicla el 0.1%. El objetivo de este proyecto es obtener un diagnóstico preliminar sobre la generación de residuos de EPS en la ciudad de Misantla, Ver., que permita su uso posconsumo como materia prima reciclada, bajo un enfoque de economía circular. La propuesta metodológica para el desarrollo de esta investigación se definió en los siguientes pasos: (1) caracterización de los actores participantes, desde el enfoque de la Economía Circular; (2) identificación de comercios que generan poliestireno como residuo; (3) determinación del tipo de poliestireno generado; (4) estimación de las cantidades de residuos generados; (5) análisis en comparación con la generación de otros tipos de residuos; (6) generación de estrategias de uso posconsumo. De acuerdo con el Censo Económico 2019, en Misantla el sector económico con mayor número de unidades económicas del municipio es el comercio minorista, donde se ubica, la venta de alimentos en pequeños establecimientos o tiendas callejeras, siendo estos agentes identificados como los principales generadores de residuos de poliestireno. Se aplicó una encuesta a 96 empresas, principalmente del sector alimentario. Los resultados de dichas encuestas demuestran que, estos establecimientos utilizan principalmente productos desechables hechos de poliestireno expandido como platos y vasos, además de que, en algunos casos, se identificó el uso de productos desechables de poliestireno como recipientes y cucharas. Con la información recopilada, se concluye que el uso de productos desechables genera aproximadamente 765 kilogramos de residuos de EPS. A diferencia de los residuos plásticos, la desinformación sobre el reciclaje del EPS, la falta de estrategias para su recolección y uso posconsumo, así como la falta de conciencia para su reciclaje, dan paso a que este termine en sitios de disposición final, continuando con la tendencia enmarcada en diferentes investigaciones que sostienen que, su destino final es la incineración. Tras el diagnóstico, se tiene una visión concreta de la generación de residuos de poliestireno y se da trabajo futuro en la generación e implementación de estrategias que permitan el uso de unicel posconsumo para su retorno a la cadena de valor.*

Palabras clave: Residuos de poliestireno; Economía circular; Unicel posconsumo; Residuos plásticos; Reciclaje.

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1. Introduction

Exponential population growth brings with it an increase in consumption needs around the world. This increase in the needs of society leads to an imminent and high generation of municipal solid waste. Particularly in developing countries, this generation represents a latent problem in terms of waste management. Plastic waste, internationally recognized as a problem [1] and considered in recent years as a high-impact pollutant, they represent 3.4% of global greenhouse gas emissions and their consumption totaled 355 million tons from 2000-2019 [2]. This negative impact is mostly generated by single-use plastics, usually disposable products that are often made from polystyrene (PS) [3].

In its expanded form it is thermoplastic obtained from the styrene monomer polymerized with water and an expanding agent and is composed of 98% air with 2% solid matter [4]. Because it has good impact resistance, good insulation properties, as well as being light [5], polystyrene has multiple applications both in the construction sector and in the production of packaging for food and household appliances [6]. Despite being 100% recyclable, the low density of polystyrene hinders and raises transportation costs for recycling [7].

In addition to this, polystyrene waste is generally poorly disposed of and is not used after consumption due to the lack of information on its recycling [8], which consequently keeps it as one of the plastic wastes with recycling rates below 1% in Mexico. An even greater problem is the final destination of this waste that, according to the trend reported in different studies, when it reaches the open dumps it is incinerated to reduce the volume it covers, putting public health at risk because its main component, the styrene monomer is classified as a possible human carcinogen [9]; or on the contrary it remains in the ecosystem and when exposed to sunlight, rain or salt water can decompose and become a polluting agent of the so-called microplastics [10]. In the national context, different laws establish that each state and municipality must be responsible for the waste it generates [11], however, carrying out the correct disposal of solid waste at the municipal level is a complicated task given the deficiencies in terms of infrastructure or scarce resources that most municipalities in Mexico have [12].

In that sense, the reduction of plastic waste is a need that requires high-impact contributions, so a circular economy model based on the recycling of such waste would be a viable alternative [13], [14]. The adoption of circular economy strategies for the environment and industries, as well as the introduction of stricter government regulations is a significant advantage for developing countries [15] that seek to belong to the trend of transformation from a traditional linear economy to a circular economy [16].

To achieve this, information is necessary in a multisectoral sense that together with significant investment [17] enable the processing and reuse of a wide range of plastics, including polystyrene. Moving from a linear to a circular economy in the production of single-use items by reusing and recycling expanded polystyrene products [18] it is the approach that guides the objective of this study.

The objective of this work is to obtain a preliminary study of: 1) the actors, as elements of circular economy, and how they are contributing or the leak of their participation, and 2) the generation of polystyrene waste, at the city of Misantla; given that specific information on the generation of this waste, municipal regulatory policies and quantification are currently unknown, which represents an area of opportunity for the development of research; with the obtaining of the results it would be possible to establish strategies based on the circular economy for the use of post-consumer polystyrene. Since this study adheres to a descriptive research with a quantitative approach, for its realization we proceeded to obtain a significant sample of the population to

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which surveys were applied to later analyze the data obtained.

The following sections have been organized as follows: the section 2 describes works related to the area of study addressed by the work, this section gives the context of the lack of information on the generation of polystyrene waste and addresses works that report the post-consumption use of these wastes. Section 3 presents the methodological proposal for the development of this study and describes the data necessary to carry it out, such as the description of participation of the actors associated with the development of a model of circular economy, the description of the study area, the collection of preliminary information and the obtaining of the population and statistical sample that were occupied in the development. Section 4 below presents the results obtained after applying the surveys to the representative sample, as well as estimates of the total waste of polystyrene and other plastics generated per month in these establishments. Finally, section 5 establishes the conclusions and highlights the relationship of the results obtained with the aspect of the circular economy, considering this study a first step for the generation of strategies for management and post-consumer use of polystyrene waste.

2. Background

In recent years, the production of plastics in the world was estimated at approximately 370 million tons [19], according to the United Nations, Latin America generates 17 thousand tons daily. Plastic waste represents a problem due to its high consumption rates and its poor disposal in landfills that lead to the contamination of terrestrial and aquatic ecosystems [20], as conventionally happens in Mexico and at the municipal level, where most polystyrene waste is disposed of seriously affecting both human health and the environment [21].

Worldwide there is an estimate and data on the generation of polystyrene waste, however, generally in developing countries and mainly in municipalities, this type of waste is not quantified, but is classified within plastic waste [22]. By searching for information on works similar to this research, it is possible to identify that the information is scarce because it is not called null. In Mexico, there are precedents on studies of generation, recycling and final disposal of municipal solid waste [23, 24], or studies on waste generation and management under a circular economy approach [25, 26] including proposals for models to forecast waste generation [27], however, none focus on polystyrene waste, but are studies of residues in general. In the international context, there are reported works on studies of generation and quantification of waste at the domestic level and in cities without a specific quantification for polystyrene waste [28– 31]. It is worth mentioning that the studies on waste generation that had the most boom in the last two years were those related to the generation of hospital waste because of the COVID -19 pandemic [32– 34]. The background on works that, although they are not about studies of polystyrene waste generation, but that do address the use of such waste for different applications under the circular economy approach [35–40], they are the emphasis for future work and represent the area of opportunity for the development of this study, which seeks to contribute to knowledge figures on the generation of polystyrene waste and fill the gap in the literature for this branch of study and support the generation of strategies for post-consumer use of polystyrene waste at municipal scales.

The importance of the development of this study lies mainly in the fact that a study of generation and quantification of urban solid waste provides tools for decision making in municipalities or localities in Mexico [41].

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3. Methodology

3.1 Description of the methodology

The methodological proposal for the development of this research was defined by the following steps: (1) characterization of the participating actors, from the Circular Economy approach, (2) identification of businesses that generate polystyrene as waste; (3) determination of the type of polystyrene generated; (4) estimation of the quantities of waste generated; (5) analysis in comparison with the generation of other types of waste; (6) generation of post-consumer use strategies. These steps are shown below in Figure 1 represented in a flowchart.

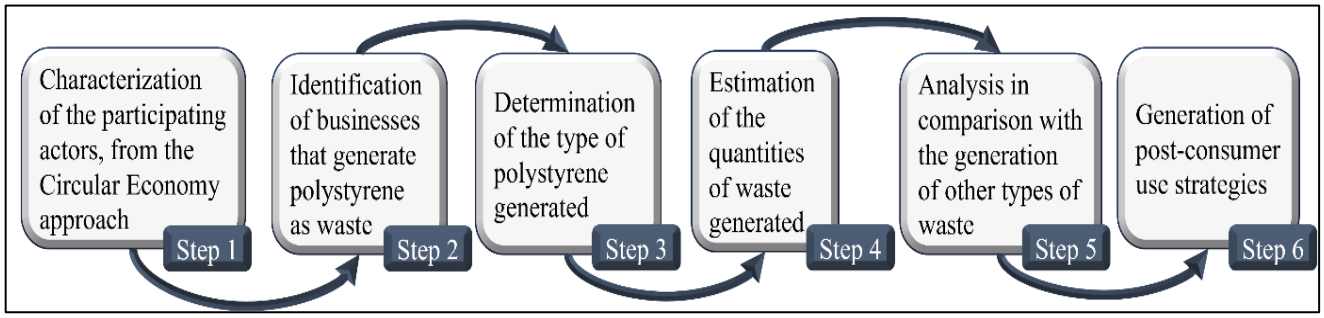

Figure 1. Steps of the methodological process

3.2 Characterization of circular economy actors

Given the urgency to minimize plastic waste pollution worldwide, the emergence of laws, regulations, or policies to achieve this task is currently a persistent global situation and Mexico is no exception. In Mexico, the guidelines on waste are contained within the General Law for the Prevention and Integral Management of Waste (LGPGIR), with a first edition in 2003, this law aims to guarantee the right of every person to an adequate environment and promote sustainable development. through the prevention of generation, recovery and comprehensive management of waste. In relation to single-use plastics, the LGPGIR was recently amended and established a decree in article VII of the same, which establishes the prohibition of Polystyrene (PS) or Expanded Polystyrene (EPS), for the production of single-use products, containers, packaging and packaging for food, except for medical or humanitarian purposes; It also decreed that when this modification comes into force, state governments should issue the corresponding regulations, as well as update local legislation on waste to comply with said decree.

As a result of this, Veracruz promoted the generation of regulations on single-use plastics, being the first state in the Mexican Republic to approve the prohibition of plastic bags and straws in stores. However, within the update of their regulations, polystyrene waste is not contemplated, unlike other entities such as Aguascalientes and Baja California Sur that do include it within their guidelines.

Locally, in Misantla, Veracruz, there are no records of businesses that generate polystyrene waste, there is no record of how much of this waste is generated in the municipality and there are no strategies for its collection and use; This is according to information obtained through personal interviews with those in charge of the area of Ecology and Environment, Public Cleaning and Commerce.

In terms of social participation for the prevention of pollution or poor disposal of plastic waste,

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where polystyrene waste is regularly included. The owners or managers of businesses that generate polystyrene as waste do not implement any action for the separation of these and are unaware of the ability of polystyrene to be recycled; So, they choose to carry out the final disposal of their plastic waste in deposits to be placed in the open dump of the municipality and what is even more alarming, some people resort to incinerating them to minimize the space that this waste covers.

3.3 Description of the study area

The study area includes the town of Misantla, belonging to the municipality of the same name in Veracruz (Figure 2). This municipality is located between parallels 19° 46' and 20° 09' north latitude; meridians 96° 45' and 97° 00' W; Altitude between 10 and 1,900 m. It has a total area of 524.8 km^2 [42]; data on the volume of urban solid waste collected in the municipality of Misantla are estimated at 14.6 thousand tons per year [43].

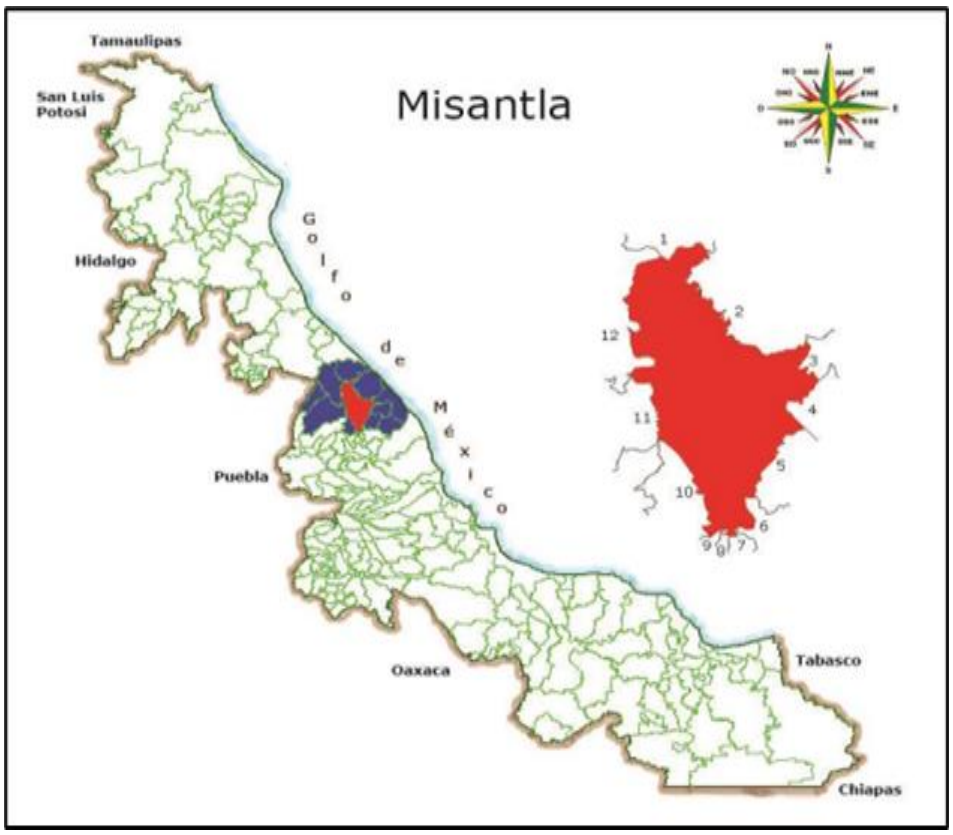

Figure 2. Geographical location of the Municipality of Misantla, Veracruz [42].

3.4 Collection of prior information

To know the current status regarding the information registered on the generation of polystyrene waste in the municipal capital of Misantla, documentary information obtained from the municipal trade office and the direction of Forestry Development, Ecology, Environment, Science and Technology was acquired (FFEMACYT acronyms in Spanish) of the town hall. In the office of commerce, the register of food businesses, whether fixed or

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itinerant, that could use disposable polystyrene products, was requested and in the direction of FFEMACYT information was requested on the records and classification of waste to know if the amount of polystyrene waste generated in the municipality is registered.

3.5 Data collection tools and techniques

According to the information reported in the literature, the survey is the most used technique for the collection of information in study with quantitative and qualitative approach [44], this, accompanied by a properly structured questionnaire is the tool that was used in the development of the research. The survey used consists of 40 closed questions in which the main objective is to know: the turn of the establishment and accordingly, the type of disposable product used or the amount of polystyrene waste it generates.

3.6 Population and sample

To define the population, retail trade establishments were considered, since according to the 2019 Economic Census this sector was the one that counted the largest number of economic units in the municipality. Within this sector it is very likely to find different applications of polystyrene products, such as the use of expanded polystyrene for packaging products that the final consumer acquires for personal use, in addition to the use of disposable products made of polystyrene used for the sale of food products, for the study educational establishments were also considered since within them food that is delivered in products are distributed. disposable and finally the establishments selling products that generate polystyrene waste such as furniture stores or commercial chains were contemplated.

In the database of the National Statistical Directory of Economic Units (DENUE acronym in Spanish) of the National Institute of Statistics and Geography (INEGI), the following criteria were established to define the population: the Economic Activity (a) where the food and beverage preparation establishments were considered, the Size of the Establishment (b) considering all sizes and the Geographical Area (c) considering only the municipal seat, as shown below in Figure 3.

Figure 3. Criteria established for the identification of the population.

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With these criteria it was possible to identify 233 economic units that meet the characteristics of establishment that could generate polystyrene as waste. This number of economic units is considered as the total population utilized to perform statistical analysis in this study. Next, in figure 4, the defined geographical area of the municipal seat and the establishments identified by points are shown.

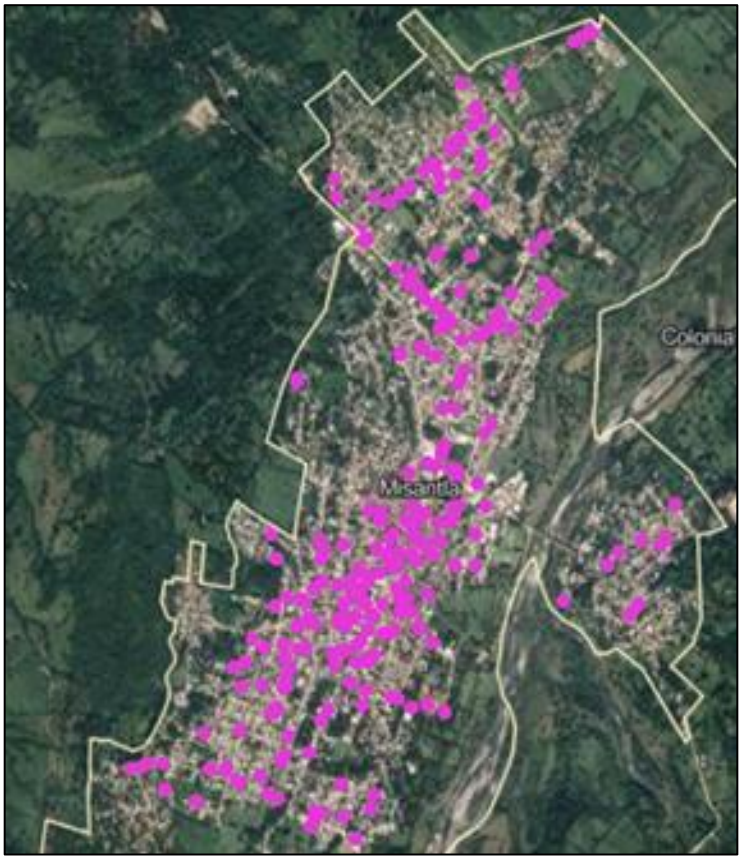

Figure 4. Geographical area of the municipal seat of Misantla and identification of the population.

The sample to which the surveys were applied was determined by the probabilistic sampling formula for finite populations and known number [45], shown below in equation 1.

$$N = \frac{(Z^2 * N_p * p(1-p))}{\left((N_p - 1) * e^2 + Z^2 * p(1-p)\right)} \qquad (1)$$

For the development of the formula, the number of previously identified population (**Np = 233**) was considered, a degree of confidence of 80% (**Z = 1.28**), an error of (**0.05**), at the end a sample of 96 economic units was obtained to survey (**N = 96**).

4. Results and discussions

Although at national level there are studies on the quantification of waste and its classification; one of the wastes for which there are few records is polystyrene and these records are even scarcer at the state or local level. With the personal interviews carried out in the municipal offices of Ecology and Environment, Public Cleaning and Commerce of the city of Misantla, it is possible to identify the lack of information on the generation of plastic waste and the non-existent

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participation of government actors in the proper management of polystyrene waste.

According to information provided by the trade office, in the municipal seat of Misantla there is only a record of approximately 450 establishments in different sectors, without classification by the line of business to which they are dedicated, nor regulations that control the generation of their waste. This register includes food and retail establishments that are identified as generators of polystyrene waste according to the activities they carry out.

Currently in the municipality of Misantla by the Office of Ecology and Environment there are no regulations for single-use plastics, nor strategies for the proper management of plastic waste; In addition to the fact that the Municipal Public Cleaning Department does not control the way in which this waste is disposed of, which is only dumped in the municipality's open-air landfill, in addition to the above, there are no records of quantification of its generation.

Finally, it should be mentioned that the owners of establishments do not know a way to recycle polystyrene waste, so there is no participation in the recovery of plastic waste or proper disposal of it. All the above generates an area of opportunity for the approach of a circular economy model that seeks to recover polystyrene waste for post-consumer use.

To propose this model, we proceed to characterize the polystyrene waste discarded within the municipal seat of Misantla through a generation study that takes as a representative sample economic unit of the food service sector, since they are identified as the main consumers of disposable products.

With the documentary information obtained from the trade office of the municipality of Misantla shows a lack of follow-up in terms of the economic units that are registered in the DENUE database of the INEGI, given that the establishments that are in the municipal register are without classification by economic activity and only the count of the establishments that are registered with the same office is available. On the other hand, it is important to mention that the City Council by the direction of FFEMACYT does not have a record of the amount of polystyrene waste generated in the municipality, since a classification of this waste is not established as such, but it is quantified within plastic waste, of which there is no record in quantities since there is no diagnosis of waste generation.

Of the population surveyed, 56.3% represent fixed businesses and the rest represent street businesses, as shown below in figure 5.

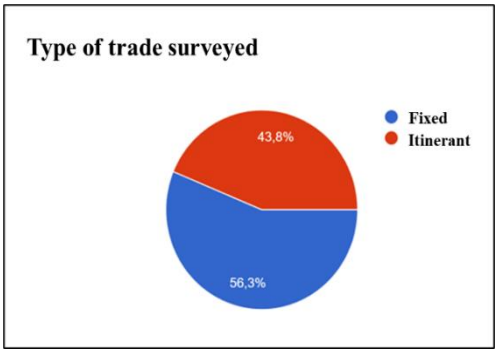

Figure 5. Type of trade surveyed (fixed).

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The total of the establishments surveyed is constituted by 84.4% of food stores, 8.3% of sales stores and 7.3% of establishments of the educational line as shown below in figure 6.

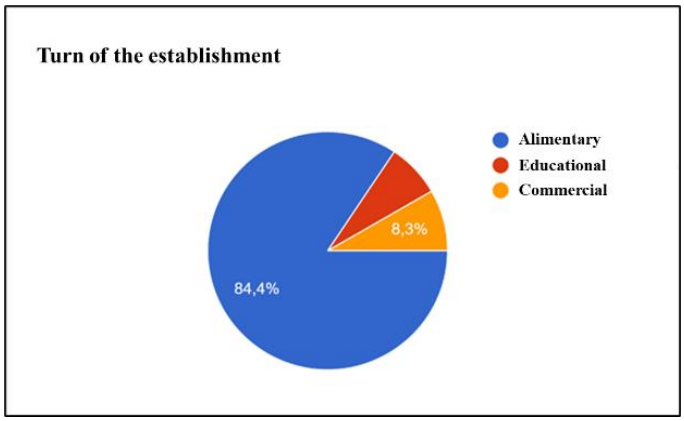

Figure 6. Turnover of the establishments

At this point it is necessary to mention that the surveyed cooperatives of educational institutions reported that they have policies to reduce single-use plastics generated as a result of the Clean School program of the Government of Mexico, which seeks to promote responsible consumption in educational communities, the proper management of solid waste and not use single-use plastics.

Unfortunately, most cooperatives do not comply with these regulations, since there is no record in awareness campaigns for the use of reusable utensils, so the use of disposables is more economically profitable.

In the case of food establishments, as well as for cooperative areas in educational institutions, the use of disposable products is vital to be able to offer their services. Among the disposable products most frequently identified among the establishments surveyed are: plastic and unicel cups; unicel dishes; cup lids; spoons or forks; and with a lower proportion of use of plastic and unicel containers; All these products made mostly of polystyrene as shown below in Figure 7.

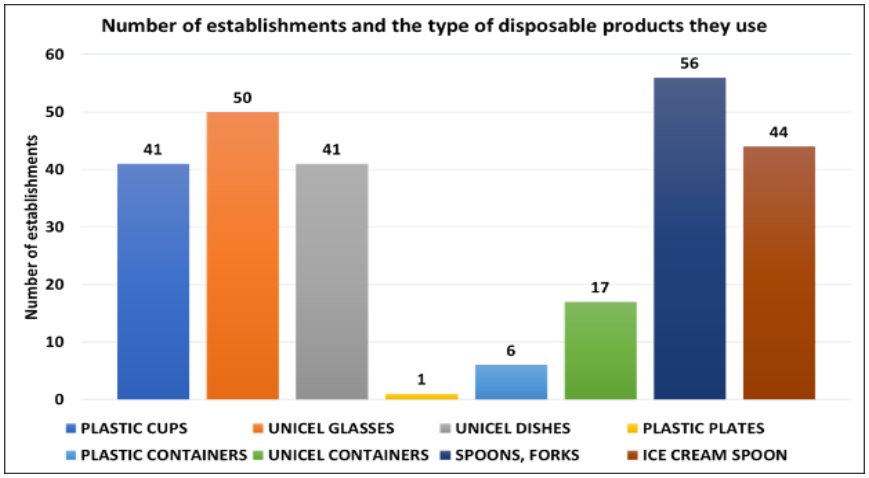

Figure 7. Number of establishments and the type of disposable products they use

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By counting the number of packages per month used by the surveyed businesses, the results shown below in figure 8 are obtained, where it is possible to appreciate the type of disposable product and the number of packages of this used per month.

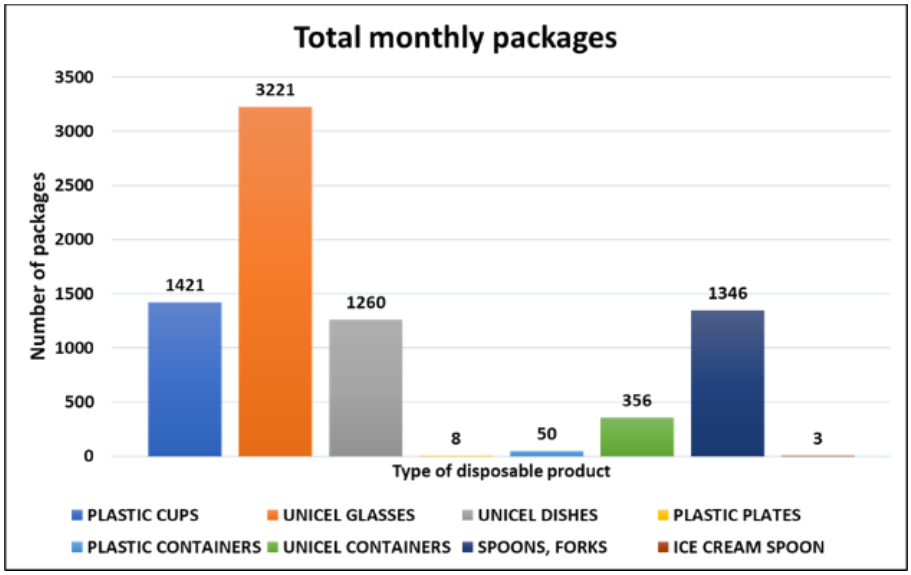

Figure 8. Total packages used per month.

From the quantities of packages used per month that were obtained, we proceeded to estimate the weight in kilograms of waste generated, as can be seen below in figure 9. According to the results obtained, it is estimated that on a monthly basis the 96 establishments surveyed generate an average of 765.05 kg of unicel waste (polystyrene) and 407,282 kg of plastic waste (polyethylene), which significantly represents the behavior of the total population.

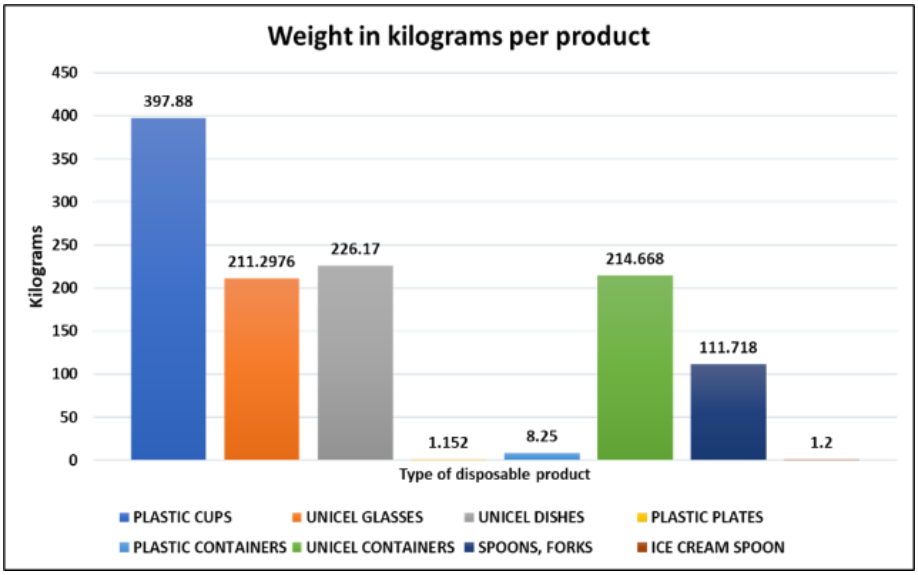

Figure 9. Weight in kilograms of disposable products generated per month as waste.

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Of the establishments surveyed, eight belonged to the commercial line and the type of products they offer are between white goods, kitchen and appliances, motorcycles and mobility, among others. According to the information obtained from these establishments, they generate the following waste (Figure 10).

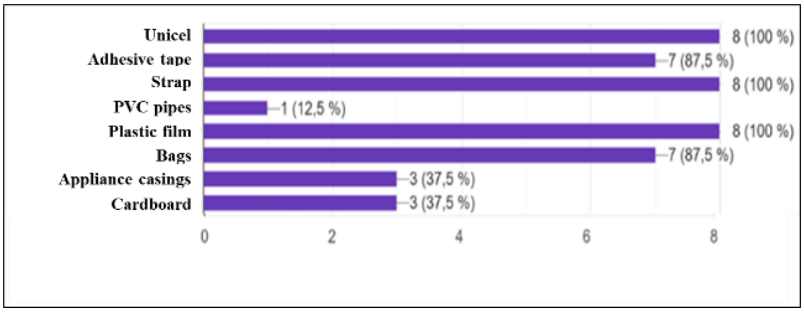

Figure 10. Type of waste generated by commercial establishments.

The study shows that the surveyed establishments that are part of a commercial chain have established recycling programs, as well as accreditations that guarantee their compliance as responsible companies with the environment. So, some of these companies take care of their waste with recycling strategies planned by the supply matrix of their products, which collect the waste generated to avoid its poor disposal. Otherwise, there are commercial establishments in the municipality that do not take care of their waste and conventionally send it to the final waste disposal site of the municipality.

In terms of quantities, most of these establishments do not quantify their waste, only some sporadic records in which the generation of 5 kilos per month of unicel is reported; and a particular case in which 12 kg of unicel waste is generated per month, as well as 20 kg per month of clothes hooks, which are mostly made of polystyrene.

From the surveys carried out, information is obtained on the waste management that each establishment gives to its waste. As can be seen in figure 11, 92.7% of establishments deposit their waste where the garbage passes, so its final destination will be the municipal landfill; Of the total respondents, only 5.2% recycle their waste and as can be seen that, although minimal, there is a percentage of establishments that incinerate their waste.

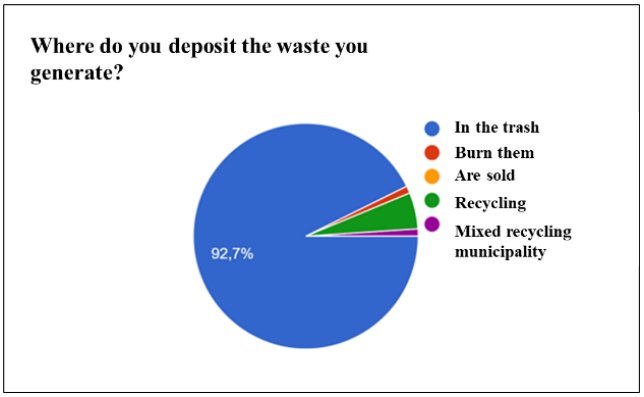

Figure 11. Final disposal of plastic waste generated by surveyed establishments.

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5. Conclusions

In general, it can be concluded that Misantla, Ver. is a municipality with a high generation of plastic waste. And what is even more aggravating is that most of the waste generated ends up in the municipal landfill, so it is very likely that, when it reaches the final disposal site, this waste will continue with the trend described in different studies of the literature, which support, that its final destination is incineration, generating an important problem or on the other hand its permanence in nature as a polluting agent.

In order to generate strategies for the collection and post-consumer use of polystyrene waste generated in the municipality of Misantla, and subsequently implement a circular economy model, it was essential to characterize the participating actors. This characterization shows that their degree of participation is deficient, given that government actors have no knowledge about the quantities of polystyrene waste generated in the municipality and have no control over its final disposal. In addition, the social actor is unaware of the damage that this waste causes to the environment and does not know how it can be reused after consumption, but, above all, it lacks the necessary conditions to achieve this.

This study provides evidence on this situation and the information on the importance of paying attention to the generation of polystyrene waste, since it has been shown that even more of this is generated than other plastic waste. It is now necessary to characterize the properties of polystyrene waste generated by food establishments and different businesses that were evidenced in this study, to identify the way in which the different actors (governmental and social) related to its generation and management should participate and jointly achieve the implementation of a circular economy model for the collection and post-consumer use of such waste.

The results of this study show that 87% more polystyrene waste is generated in the surveyed establishments compared to polypropylene or other plastic waste. If you consider that these results represent the amounts of waste generated by the total study population, the problem is even greater. Despite this situation, in Mexico, the General Law for the Prevention and Integral Management of Waste (LGPGIR), which promotes sustainable development through the prevention of the generation, recovery and integral management of hazardous waste, municipal solid waste and special handling; It is not applied regularly. In addition, it was until 2021, when this law was reformed on the issue of single-use plastics, these reforms were aimed at strengthening the prevention of the generation, minimization, separation, collection, use, recovery, collection and integral management of plastic waste; this reflects the non-existence of control and management of plastic waste in Mexico from 2021 backwards, leading to environmental problems due to the polluting characteristics of these residues that remain for decades in ecosystems.

The LGPGIR foresees by 2025 the total elimination of single-use plastics, except those that cannot be replaced by other materials; It also proposes to prohibit its use, consumption, commercialization, distribution or entry into protected or insular natural areas; A fact that in most of the states of the Mexican Republic was supported by the restriction of the use of single-use plastics, as well as modifying state legislation to prohibit or regulate the use of plastic bags, straws or unicel items. As in the case of Veracruz, which since 2018 approved a law reform to reduce the use of plastics and straws in favor of environmentally friendly alternatives.

Despite the modifications to the laws and generation of new regulations, such as those mentioned above; The reality in their application

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is very distant from the objective for which they are generated. The lack of awareness in society about the problem generated by waste, the lack of sanctions by the government bodies in charge of these laws to their violators, in addition to the lack of strategies with circularity approaches from the generators of plastic products; They prevent meeting the objective of reducing plastic waste.

As for government strategies for the management of plastic waste, the development of recycling campaigns does not include materials such as unicel, as it is considered a difficult material to recycle, even though numerous studies show otherwise and the large quantities of this waste that are discarded. This gap generates the opportunity to create channels for the recovery of this waste to later analyze strategies for its post-consumption use. These channels and strategies should be based on the inclusion of actors involved in the value chain of these products; the public agent in charge of regulating this type of waste, the private agent that produces these products (the single-use plastics industry), and the social agent who, as the final consumer of these products, should take a responsible consumption stance.

With the results of this study, the need for actions for the separation and integral management of polystyrene waste is based and creates an area of opportunity to study its post-consumer use based on the circularity of plastics, following circular economy models such as those that have been developed in Europe in recent years.

Now that there is a specific panorama on the generation of polystyrene waste in the municipality of Misantla, Ver. And since it was a previous study to know the current situation on the generation of polystyrene waste, it is advisable to carry out a study on the generation per capita in accordance with the provisions of the regulations of the current issue of waste to begin with the generation of strategies for the valorization of said waste and to be able to estimate viability situations on the use of these wastes, with possible applications in the development of composite materials, lacquers and varnishes, materials with improved properties or their reincorporation into the value chain.

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Romeo García Cruz: Research; Original draft writing; Methodology. *David Reyes González*: Conceptualization; Analysis of data; Methodology. *Yodaira Borroto Pentón*: Data analysis; Validation of results. *Neira Sánchez Zárate*: Conceptualization; Investigation; Formal analysis. *Yensy Fernández Pentón*: Methodology; Data collection; Data curation. *Cleotilde Anahí Álvarez Contreras*: Formal analysis; Validation of results.

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