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Scientific Articles

Gestión de residuos: el caso del sector manufactura en el Estado de México, México

Waste management: the case of the manufacturing sector in the State of Mexico, Mexico

Gestão de resíduos: o caso do setor manufatureiro no Estado do México, México

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Resumen

La manufactura es un sector que se caracteriza por el uso de máquinas con el objetivo de realizar algún tipo de transformación, por lo que es considerada motor de la economía mundial. Desafortunadamente, no todas las implicaciones que derivan del sector son positivas, ejemplo de ello es la generación de residuos a gran escala, especialmente en zonas altamente pobladas como lo es el Estado de México (Edomex), la entidad federativa con mayor número de habitantes de las 32 que conforman la República Mexicana. Considerando la generación de miles de toneladas de desechos reportados por parte de los 10 municipios con mayor aportación al Producto Interno Bruto en el Edomex, el objetivo de este trabajo es identificar los principales factores asociados al tratamiento y la disposición final de los residuos por parte de industrias manufactureras en dicha zona. Mediante un análisis cuantitativo a partir de datos procedentes de los Censos Económicos 2019 del Instituto Nacional de Estadística y Geografía, y de información del Sistema Integral de Residuos del Estado de México; los resultados muestran que, pese a los altos costos privados que implica el uso de rellenos sanitarios y al escaso número de dichos espacios, las empresas

mayoritariamente seleccionan estos sitios de disposición final para sus residuos. Por otra parte, se muestra que el comportamiento del sector manufactura a nivel Edomex en términos de la gestión de residuos, es el mismo comportamiento que presenta el sector manufactura a nivel nacional. Se concluye que el impacto asociado con la generación de residuos a nivel Edomex es elevado, por lo que es importante propiciar y fortalecer la política pública en materia ambiental y en términos de responsabilidad social.

Palabras clave: desecho, empresas, instrumento legal, manufactura

Abstract

Manufacturing sector is characterized by the use of machines with the objective of carrying out some type of transformation, consequently this industry is considered as an engine of the world economy. Unfortunately, not all the implications that derive from the sector are positive, for example the generation of waste on a large scale, especially in highly populated areas such as the *Estado de Mexico (Edomex)* entity with the largest number of inhabitants in the *Republica Mexicana*. Considering the generation of thousands of tons of waste reported by the 10 municipalities with the highest contribution to the Gross Domestic Product in the Edomex, the objective of this work is to identify the main factors associated with the treatment and final disposal of waste by industries manufacturers in that area. By a quantitative analysis based on data from the *Censos Economicos 2019* of the *Instituto Nacional de Estadística y Geografía*, and information from the *Sistema Integral de Residuos del Estado de Mexico*; results show that, despite of the high private costs involved in the use of sanitary landfills and the low number of those sites, companies mostly select these final disposal sites for their wastes. On the other hand, it is shown that waste management of the manufacturing sector at Edomex is the same as waste management of the manufacturing sector at national level. It is concluded that the impact associated with the generation of waste at the Edomex level is high, so it is important to promote and strengthen public policy in environmental matters and in terms of social responsibility.

Keywords: waste, enterprises, legal instruments, manufacturing.

Resumo

A manufatura é um setor que se caracteriza pela utilização de máquinas com o objetivo de realizar algum tipo de transformação, por isso é considerada o motor da economia mundial. Infelizmente, nem todas as implicações derivadas do setor são positivas, um exemplo disso é a geração de resíduos em grande escala, especialmente em áreas altamente povoadas como o Estado do México (Edomex), a entidade federal com o maior número de habitantes no México dos 32 que compõem a República Mexicana. Considerando a geração de milhares de toneladas de resíduos informada pelos 10 municípios de maior contribuição para o produto interno bruto da Edomex, o objetivo deste texto é identificar os principais fatores associados ao tratamento e destinação final de resíduos pelas indústrias transformadoras no aquela área. Através de uma análise quantitativa baseada em dados dos Censos Econômicos 2019 do Instituto Nacional de Estatística e Geografia e informações do Sistema Integral de Resíduos do Estado do México; Os resultados mostram que, apesar dos elevados custos privados envolvidos na utilização de aterros e do pequeno número desses espaços, as empresas selecionam principalmente estes locais de disposição final para os seus resíduos. Por outro lado, mostra-se que o comportamento do sector transformador a nível Edomex em termos de gestão de resíduos é o mesmo comportamento que o sector transformador apresenta a nível nacional. Conclui-se que o impacto associado à geração de resíduos ao nível do Edomex é elevado, pelo que é importante promover e reforçar as políticas públicas em matéria ambiental e em termos de responsabilidade social.

Palavras-chave: resíduos, empresas, instrumento legal, industria.

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Introduction

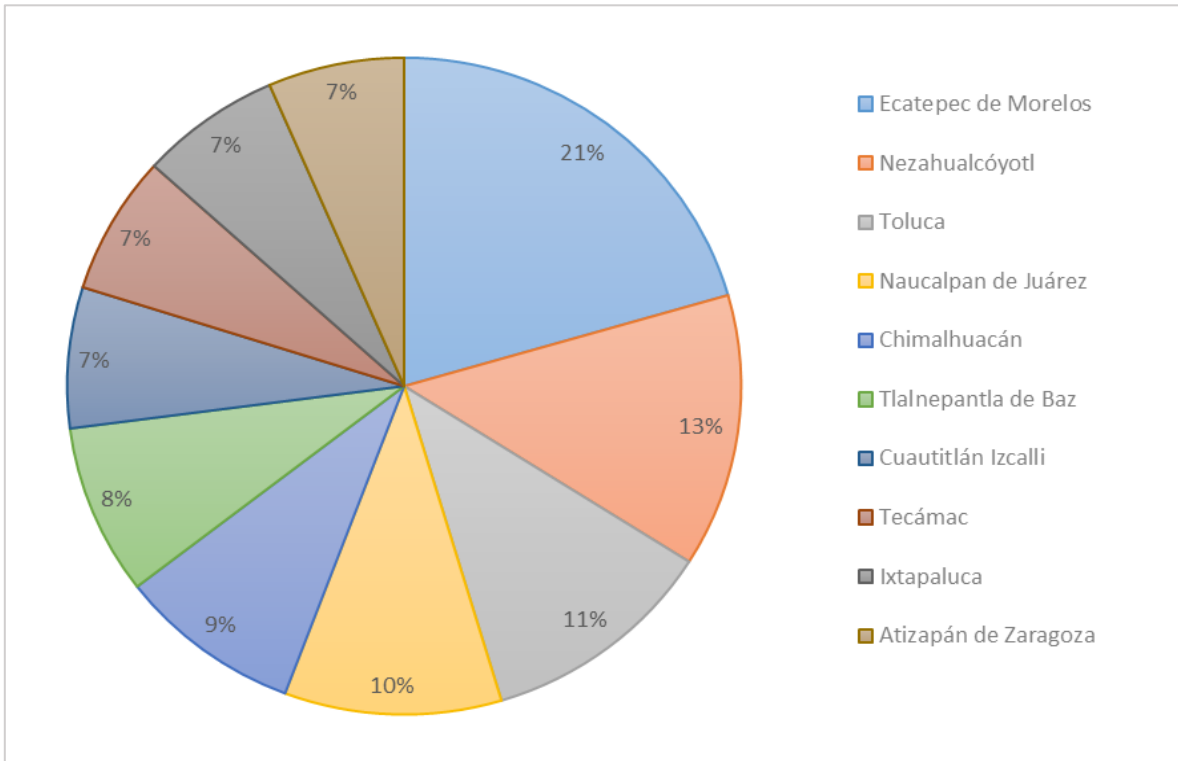
Manufacturing is a sector characterized by the use of machines to carry out some type of transformation (mechanical, physical or chemical), the assembly of parts in series and the manufacturing of prefabricated components, among other activities. By virtue of the above, companies belonging to this sector represent one of the engines of the world economy. Unfortunately, not all the implications derived from manufacturing are positive, an example of this is the waste from this activity since it represents a danger to all forms of life. It is estimated that by 2050 waste will increase by 70% compared to current levels if urgent

measures are not taken, with plastics being one of the main problems since they represent approximately 12% of total solid waste (World Bank [WB], 2024).

Proper waste management involves various aspects: environmental, economic, social, etc. Unfortunately, the areas of opportunity for improvement in developing countries are evident (Toledo and Quintero, 2022; Zohoori and Ghani, 2017). For example, nations such as Turkey record large amounts of household waste (2nd place in Europe and 7th worldwide in plastic production), which has even caused a widespread leakage of plastic into the Mediterranean Sea (Gündogdu and Walker, 2021). In Latin America, the problem is similar, social inequality and tight budgets lead to countless problems, including waste management (García *et al.*, 2023), where one of the main challenges is to raise awareness among citizens regarding their role in reducing the solid waste generated (Sánchez *et al.*, 2022). Contrary to the scenario described, high-income countries such as Norway, Austria, Belgium and Sweden have robust recycling systems that even lead them to import waste from other nations.

In Mexico, the panorama is complex regarding waste. Historically, the issue of “waste management” has represented a challenge marked by urban growth and industrialization, which, due to the lack of adequate infrastructure and awareness about waste management, led to significant problems. The Mexican Republic is made up of 32 federal entities; the State of Mexico (Edomex) is one of them and is the most populated in the nation, housing 16,992,418 million inhabitants (National Institute of Statistics and Geography [INEGI], 2021). Edomex is made up of 125 municipalities; Figure 1 shows the 10 municipalities that have the highest percentages of population registered in said federal entity.

Figure 1. Inhabitants in the 10 most populated municipalities of Edomex

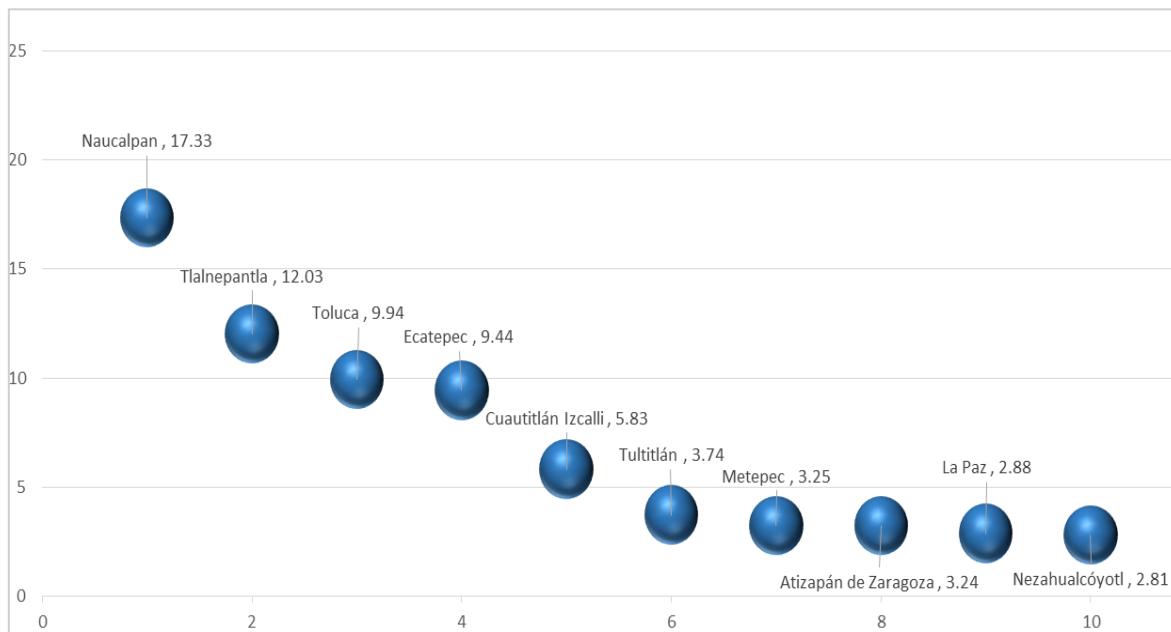


Source: Own elaboration

The municipalities mentioned are densely populated, which implies a high demand for goods and services and imminently high rates in terms of waste generation. For example, Ecatepec de Morelos and Nezahualcóyotl are home to more than 1,000,000 inhabitants and are considered municipalities with important areas of opportunity in terms of environmental management.

According to the Municipal Economic Activity Index (IMAE) of the Institute of Geographic, Statistical and Cadastral Information and Research of the State of Mexico, 10 of the 125 municipalities that make up the Edomex together constitute an important part of the state economy, that is, 70% of the Gross Domestic Product (GDP) (Institute of Geographic, Statistical and Cadastral Information and Research of the State of Mexico [IIIGCEM], 2021). These municipalities are presented below in Figure 2, according to the percentage they contribute to GDP.

Figure 2. Municipal contribution to the GDP of Edomex



Source: Own elaboration

Based on data from the portal of the Comprehensive Waste System of the State of Mexico (*Sistema Integral de Residuos del Estado de México* [SIREM], 2023), Table 1 shows the number of companies registered in the municipalities mentioned above. It is observed that the municipality of Tlalnepantla de Baz has the largest number of companies and that this number is considerably higher than in the other nine municipalities mentioned above.

Table 1. Companies registered in SIREM in municipalities of Edomex

Municipalities	Registered companies
Metepec	32
Nezahualcoyotl	38
Peace	42
Atizapan	95
Tultitlan	98
Ecatepec de Morelos	175
Naucalpan de Juarez	181
Toluca	241
Cuautitlan Izcalli	325
Tlalnepantla de Baz	517

Source: Prepared by the authors with data from SIREM (2023)

Although the companies mentioned above represent an important engine in the economy of Edomex, unfortunately they also promote the generation of various types of waste, a problem that has persisted in Mexico for decades and was characterized, especially, by the unregulated use of landfills. Fortunately, since the 1990s, robust policies have been implemented in the country on this matter. For example, on October 8, 2003, the General Law for the Prevention and Comprehensive Management of Waste [LGPGIR] was enacted in the *Official Gazette of the Federation of Mexico (Secretaría de Gobernación, 2015)* , which establishes three categories for waste materials: Urban Solid Waste (USW); Hazardous Waste (HW) and Special Handling Waste (SWM), whose definitions are presented in Table 2.

Table 2. Definition of the three types of waste established in the LGPGIR

Regulation	Definition
MSW	Generated in homes, they result from the disposal of materials used in domestic activities, products consumed and their containers, packaging or wrapping.
RP	Those that have any of the characteristics of corrosiveness, reactivity, explosiveness, toxicity, flammability, or that contain infectious agents that make them dangerous.
RME	Generated in production processes, which do not meet the characteristics to be considered as hazardous or as urban solid waste, or which are produced by large generators of urban solid waste.

Source: Prepared by the authors based on information from the Ministry of the Interior (2015)

The LGPGIR establishes the differences in terms of management of RP with respect to RSU and RME ; for example, article 15 declares the coordination mechanisms for the prevention of generation, recovery and comprehensive management of waste, at the national level, federal entities and municipalities, while Article 19 provides an extensive list of EMR , since in particular these wastes can be considered MSW unless the quantities generated must receive some type of management and/or may have a value for their use, establishing management plans for efficient and environmentally viable management.

On the other hand, the LGPGIR defines Comprehensive Waste Management as the articulated and interrelated set of normative, operational, financial, planning, administrative, social, educational, monitoring, supervision and evaluation actions, for the management of waste, from its generation to final disposal, in order to achieve environmental benefits, the economic optimization of its management and its social acceptance, responding to the needs and circumstances of each locality or region (Secretaría de Gobernación, 2015). In general, waste management is vital, especially since this process promotes clean cities and even favors a perception of security (Nepal *et al .*, 2022; Jiménez 2017).

The State of Mexico has a General Directorate for Integrated Waste Management , which aims to coordinate actions and activities aimed at preventing and controlling water, soil, and urban solid waste and special management pollution in the state. This agency integrates specific and relevant information on management, for example, it hosts the Consultation Portal of the Integrated Waste System of the State of Mexico (SIREM), where it even describes the categories of MSW (Fig. 3).

Figure 3. Special Handling Waste: Classification



Source: Own elaboration

Based on the large-scale generation of waste by companies in the manufacturing sector in Edomex, the objective of this paper is to identify the main factors associated with the treatment and final disposal of waste from companies belonging to this sector, located in the 10 municipalities with the greatest contribution to the GDP in Edomex.

Materials and methods

This work used data from the 2019 INEGI economic census (INEGI, 2019), which integrate information generated by large economic units in the private and parastatal sectors, corresponding to 2018. Additionally, references from the Comprehensive Waste System of the State of Mexico were used, in order to have robust and reliable statistical information, which was addressed based on the central axis of the work: waste management; considering

technical and legal aspects. Also, the relevance and pertinence of the regulations, as well as the existing guidelines prior to their integration into the research, were evaluated.

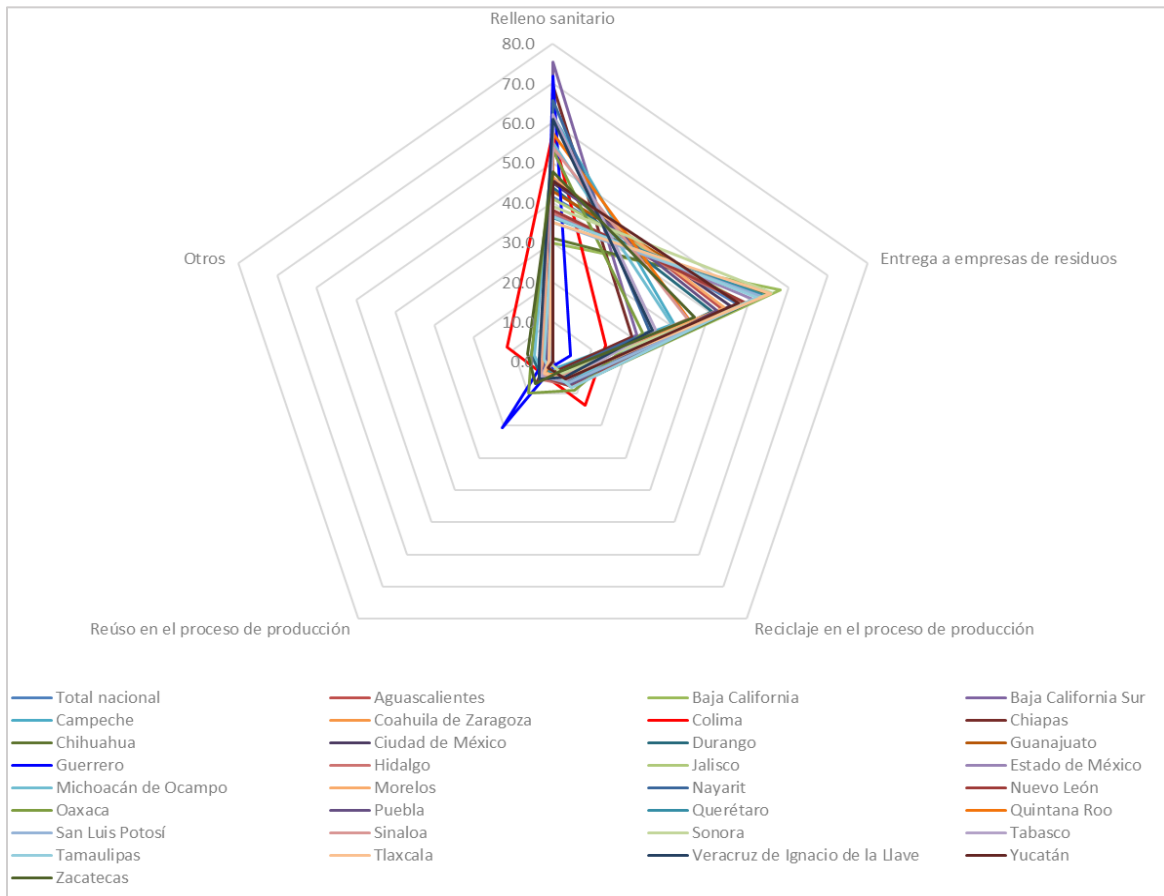
A quantitative analysis was carried out to obtain and analyze central tendency measures in relation to the context of waste generation in the 10 municipalities with the highest contribution to GDP in Edomex. Additionally, this research has an exploratory-descriptive scope because it examines a topic from a new perspective and seeks to specify the properties, characteristics and profiles of a system (portion of space that is delimited to be studied), in addition to measuring the presence, characteristics or distribution of a specific phenomenon in a population (description of the phenomenon).

Results

This section presents the results derived from the analysis of parameters associated with the generation, treatment and final disposal of EWM by companies in the manufacturing sector in the 10 municipalities with the greatest contribution to GDP in Edomex.

In order to generate a context for the analysis of the federal entity of interest, the situation regarding the main destination of the waste generated in Mexico by companies belonging to the manufacturing sector, sector 31-33 in the North American Industrial Classification System (INEGI, 2018), was initially analyzed, which is presented in Figure 4.

Figure 4. Main destination of waste generated in the manufacturing sector

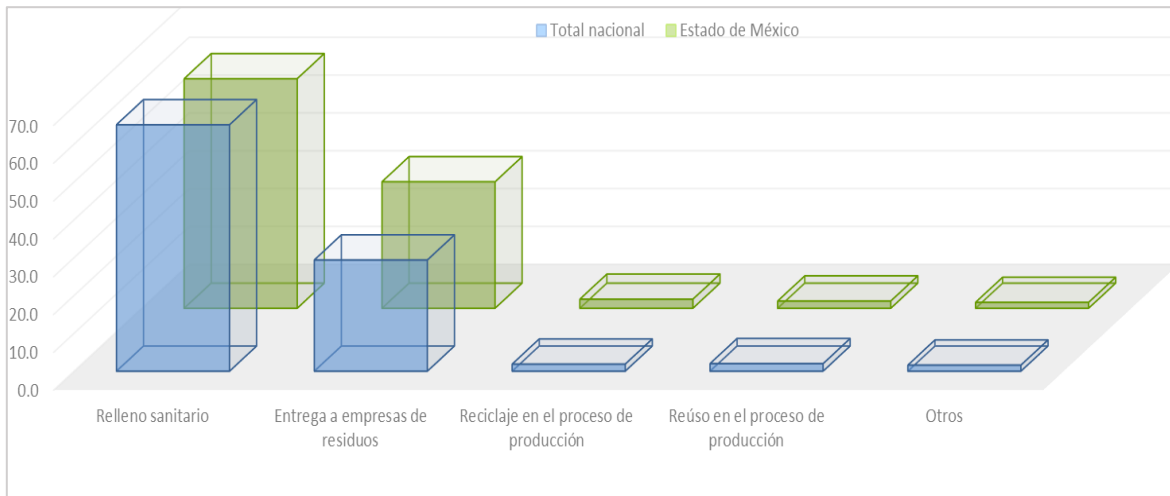


Source: Own elaboration

In the figure above, a general trend can be observed regarding the destination of waste from the manufacturing sector in Mexico, since most economic units in the 32 federal entities select sanitary landfills as the main destination for their waste. It is important to consider that in Mexico only 10% of final disposal sites meet the basic infrastructure and operation requirements (García *et al.* , 2023).

Figure 5 shows a comparison of the main destination of waste materials or residues generated both at the national level and those generated in Edomex. It can be observed that the trend between both cases is consistent, so it can be inferred that the destination of the residues generated in the industrial sectors present in the state follows the same trend as the industrial sectors at the national level.

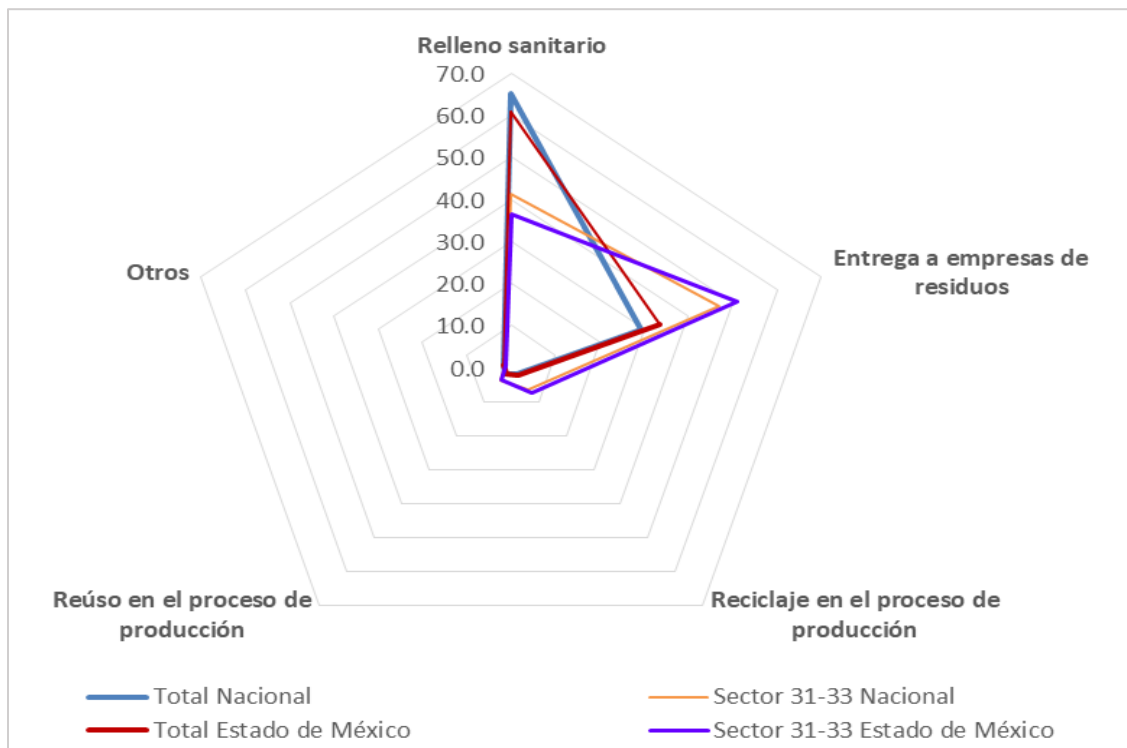
Figure 5. Main destination of waste: Mexican Republic – Edomex



Source: Own elaboration

In relation to the specific case of sector 31-33 (manufacturing), in Edomex the main destination of the waste generated by this industry corresponds to the scenario at the national level: they are delivered to service companies and waste management and transportation companies, as shown below in figure 6.

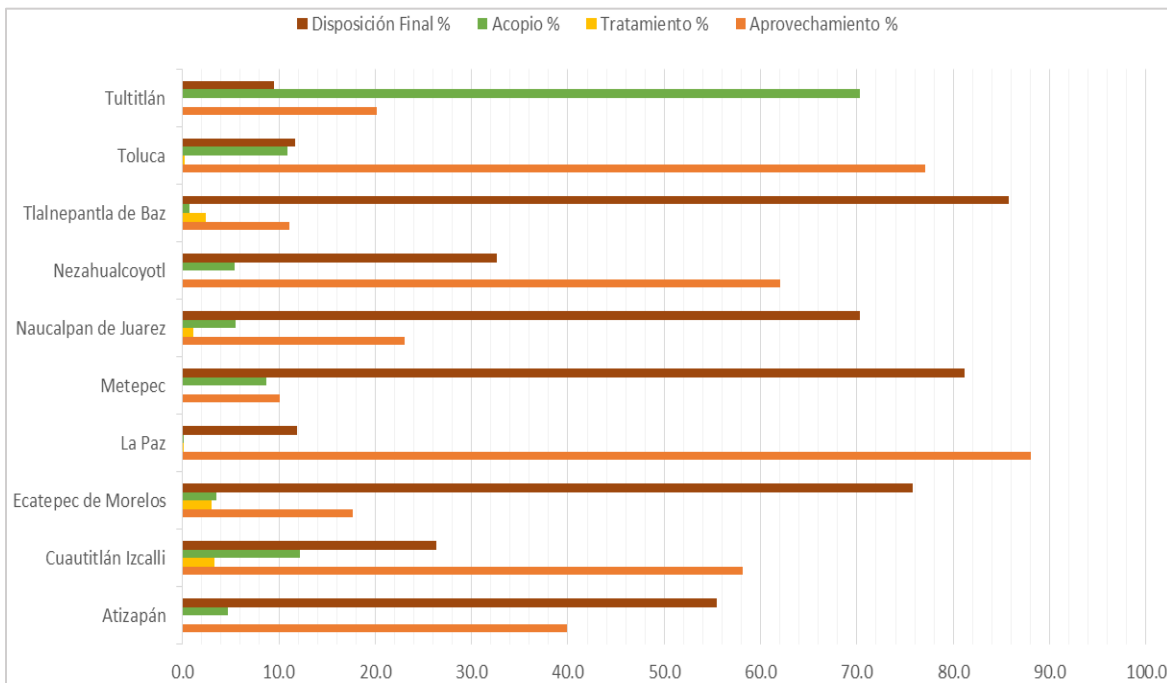
Figure 6. Main destination of waste: National Manufacturing Sector - Edomex



Source: Own elaboration

The destination of the waste generated in the State of Mexico at the municipal level is shown in Figure 7, where several singularities can be distinguished. The first is that the municipalities of La Paz and Toluca report the highest percentage of waste utilization at the state level, greater than 70% in both cases. On the other hand, Tlalnepantla de Baz, Metepec, Ecatepec de Morelos and Naucalpan de Juárez mostly send their waste to a final disposal site (they record percentages of 86%, 81%, 76% and 70% in this category). On the other hand, regarding the collection of waste, in all municipalities the percentage is low (average of 6% and zero in the case of La Paz), except for the municipality of Tultitlan where it is recorded that 70% of the waste is managed through a collection process. Unfortunately, regarding waste treatment, six of the 10 municipalities report that the waste generated does not undergo any type of treatment, while the average in this area considering the 10 municipalities is 1%.

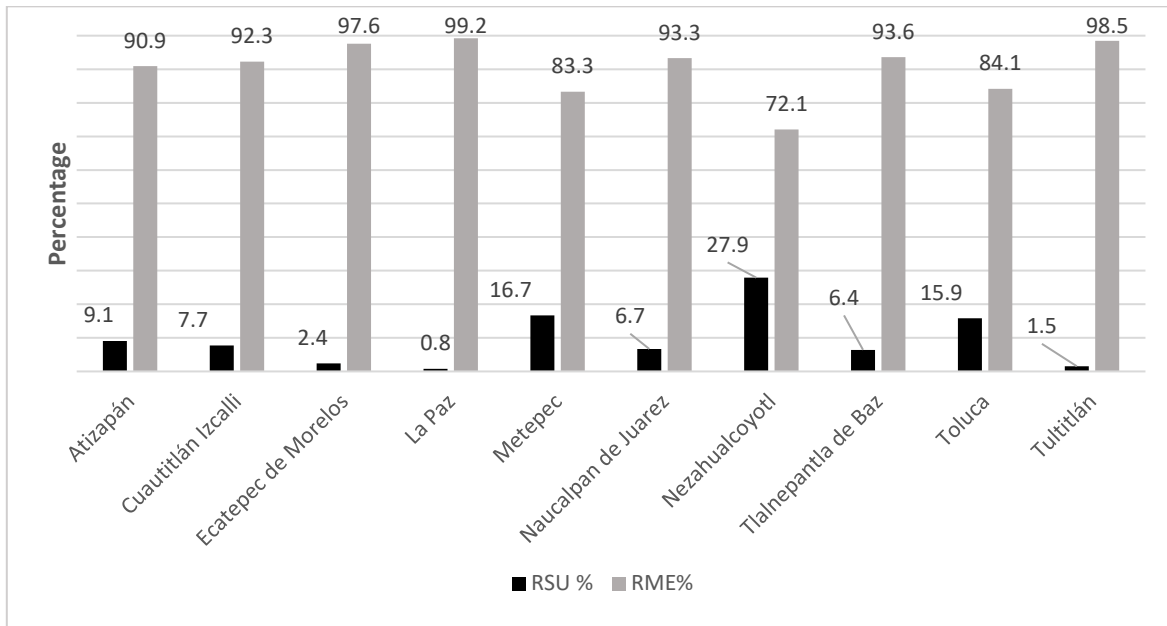
Figure 7. Waste management in municipalities of Edomex. Main destinations



Source: Own elaboration

Based on the three categories of waste contemplated in the LGPGIR (RP, MSW and MSW), Figure 8 shows the incidence of two categories: MSW and MSW, especially considering the quantities generated monthly. It can be observed that in all cases the %MSW is considerably higher than the %MSW in all municipalities. Even in the municipality of La Paz, MSW represents practically all of the waste. Finally, the municipality of Nezahualcóyotl reports the highest %MSW, equivalent to 28%.

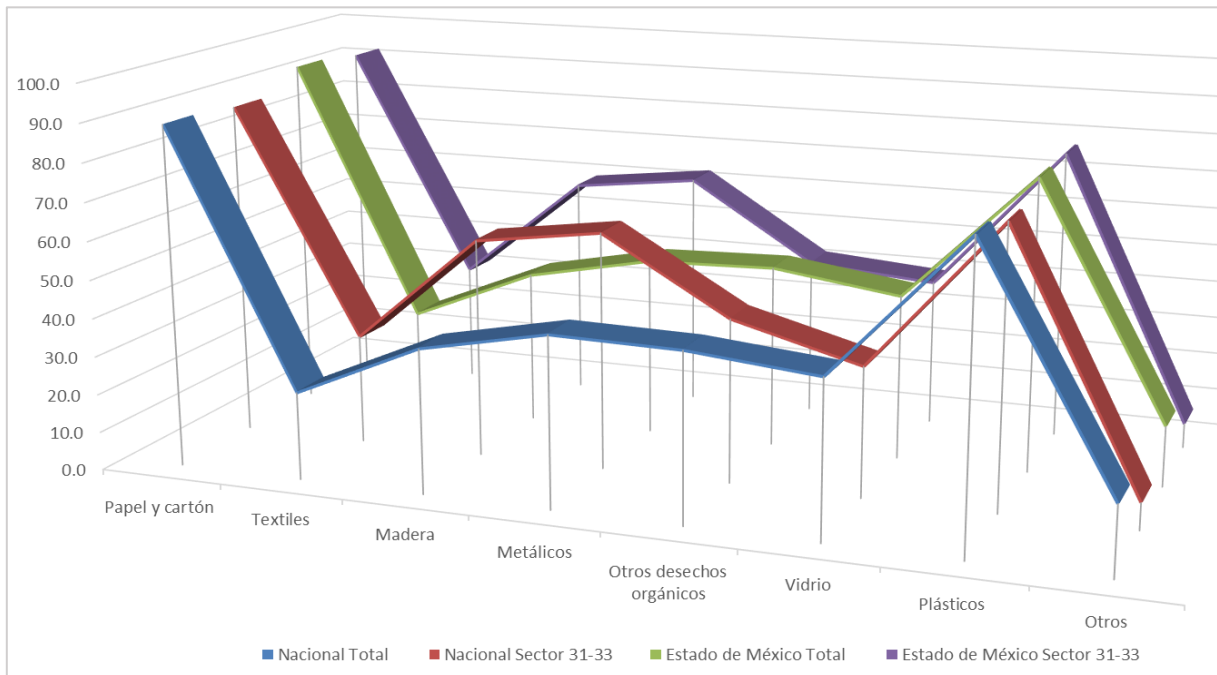
Figure 8. Generation of MSW and RME by companies in Edomex



Source: Own elaboration

In addition to the problems arising from the high rates of waste generation, as well as the limited number of final disposal destinations, there are also low rates of use of EMR and MSW. Figure 9 shows the percentage of use of recycled material in large economic units in the manufacturing sector that had activities in 2018, both nationally and in Edomex (INEGI, 2019).

Figure 9. Use of recycled material in the manufacturing industry

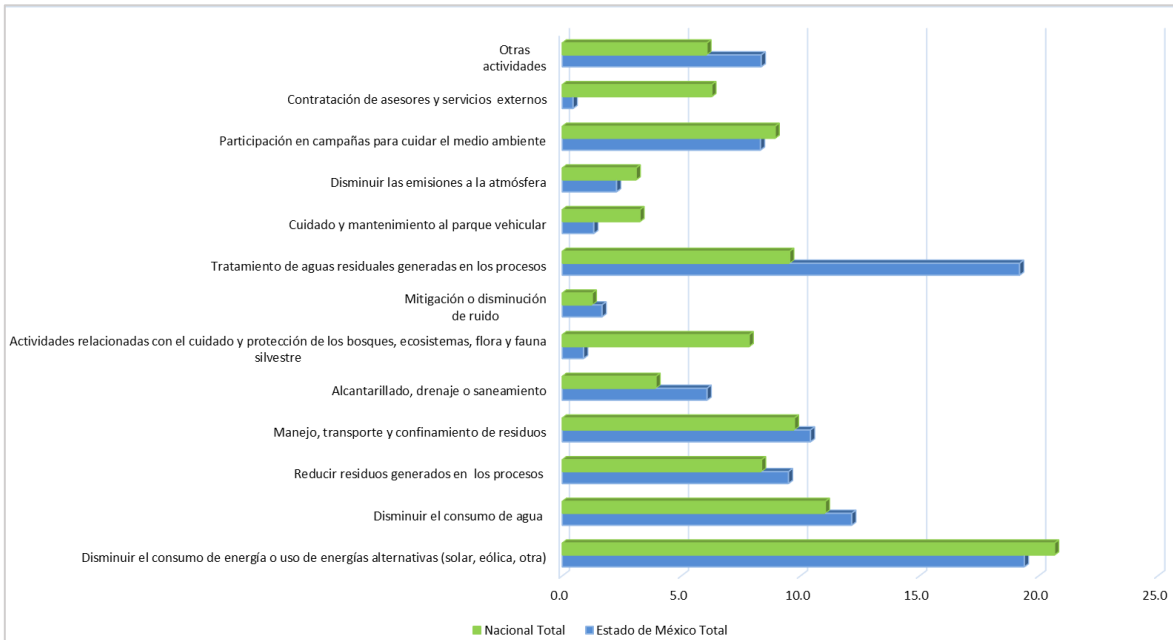


Source: Own elaboration

Figure 9 shows two trends. The first corresponds to the scenario that integrates all industrial sectors, while the second trend corresponds to the situation that occurs only in Sector 31-33, manufacturing. However, in both cases, the material that is recycled the most in the manufacturing industry is paper and cardboard, while plastics are in second place. The opposite occurs with textiles and other types of materials, since they have considerably low reuse percentages.

In order to know the investment to reduce the waste generated in the processes, both at the national level and in Edomex, Figure 10 shows the expenditure on environmental protection by economic units in the manufacturing sector in 2019. In general, it is observed that said investment generally has the purpose of reducing energy consumption or the use of alternative energies, while the second incentive is the treatment of wastewater generated in the processes.

Figure 10. Investment in environmental protection



Source: Own elaboration

Finally, the State of Mexico has various guidelines in terms of waste regulation, which are presented below in Table 3. Although the guidelines cited seek to optimize the comprehensive management of waste, there are still areas of opportunity, especially in terms of coordination between agents, the exploration of new treatment alternatives and the incorporation of environmental technologies that promote the mitigation of the problem described.

Table 3. Main regulatory instruments in terms of waste, applicable in Edomex

Legal instrument	Description
NTEA-023- SeMAGEM-RS-2021	State environmental technical standard, which establishes the specifications for the provision of the collection and transfer service of urban solid waste and special handling, for the State of Mexico (Executive Power of the State of Mexico, 2022).
General Law for the Prevention and Comprehensive Management of Waste	Its purpose is to guarantee the right of every person to a healthy environment and to promote sustainable development through the prevention of the generation, valorization and integral management of hazardous waste, urban solid waste and special handling; to prevent the contamination of sites with this waste and to carry out its remediation (Secretariat of the Interior, 2015).
Mexican Official Standard NOM-161- SEMARNAT-2011	It establishes the criteria for classifying Special Management Waste and determining which are subject to a Management Plan; the list of the same, the procedure for inclusion or exclusion from said list; as well as the elements and procedures for the formulation of management plans (Secretariat of the Interior, 2013).



Legal instrument	Description
Code for the Biodiversity of the State of Mexico	Legal instrument to promote the conservation, preservation, rehabilitation, remediation, improvement and maintenance of ecosystems, the recovery and restoration of ecological balance, the prevention of damage to health and deterioration of biodiversity and the elements that compose it as a whole, the management and promotion of environmental protection and environmental planning, the use and sustainable use of natural elements and resources and environmental assets, the internalization and fair distribution of the benefits and costs derived based on providing certainty to the markets within the framework of the policies established for sustainable development in the State (Executive Power of the State of Mexico , 2006).

Source: Prepared by the author based on regulatory instruments

Discussion

Despite the scarcity of landfills in Edomex, the 10 municipalities with the highest contribution to the GDP in said federal entity regularly use them as a final disposal destination. However, it is important to consider that landfills have a short useful life, that there are limitations to their use (such as geographic location), that there are basic infrastructure requirements and operating conditions that are difficult to meet, etc., which is why what was established by García *et al* . (2023) is reaffirmed, who propose a set of conditions that frame a series of disadvantages regarding the use of landfills.

Another issue that deserves to be addressed is in line with what was established by Nepal *et al* . (2022), in terms of perception of security since in the 10 municipalities with the highest contribution to GDP in Edomex, these indicators must be addressed. The scope of this text does not allow inferences or correlations to be made, but it does show the low levels of recycling and reuse in the production process by companies in the aforementioned areas, which does not favor the development of clean cities.



It is important to consider that although investment to reduce the waste generated in processes (both at the national level and in Edomex) generally aims to reduce energy consumption or the use of alternative energies, it is unfortunate that investment is extremely low in terms of participation in campaigns to protect the environment. However, this problem could be addressed if the disorganization and distancing between public administration and society raised by García *et al.* (2023) are addressed.

Finally, it is evident that there are important areas of opportunity in terms of appropriate waste management, which is consistent with what was stated by Toledo and Quintero (2022) and Zohoori and Ghani (2017), who indicate that this situation prevails in most of the less developed countries.

Conclusion

The economic impact associated with waste in Edomex is high, it involves costs of collection, treatment, etc. Therefore, the proper management of such waste is of vital importance and is even a matter of social responsibility.

Although public policy establishes environmental protection criteria by establishing barriers (quotas), this is still in its infancy. The collection of taxes associated with the generation and treatment of waste is not sufficient; elements in terms of environmental, technological, social, etc. efficiency need to be analyzed and incorporated in order to address the various situations described in this research, such as the almost exclusive use of sanitary landfills as final disposal sites for waste, as well as the low rate of waste utilization.

Finally, it is vital to have coordination between the agents involved in the problem described. The participation of waste generators (companies, society, etc.) is required, as well as the participation of the three levels of government to design robust solutions. Otherwise, the records associated with the problem described will present the alarming behavior that they have maintained until now (or even more complex).

Future lines of research

In addition to this work, it is considered important to carry out analyses related to the generation of zero waste. To this end, it is proposed to address the circular economy (CE) as a central axis in the face of the massive generation of waste. The use of computer applications as inputs to move to a CE model could be explored through businesses for repairing and extending the life of waste, for example.

On the other hand, it would be important to analyse mechanisms that promote coordination between the agents that influence waste (generation, treatment, financing, etc.) and, for example, explore the interaction between government, companies and society.

Finally, it would be interesting to analyze information from the survey: Perception of public safety, carried out by INEGI in Mexico, in order to understand its relationship with the generation and management of waste in various cultural and economic environments.

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