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El incumplimiento regulatorio de los sitios de disposición final de residuos sólidos en México y su afectación al ambiente

Regulatory non-compliance of solid waste final disposal sites in México and their impact on the environment

O descumprimento das normas em aterros sanitários no México e seu impacto no meio ambiente

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Resumen

El objetivo del presente estudio es analizar el estado actual del incumplimiento regulatorio de los sitios de disposición final de residuos sólidos urbanos en México, así como las afectaciones ambientales asociadas a dicho incumplimiento. El marco jurídico establece que los sitios de disposición final deben cumplir criterios técnicos y normativos orientados a la tutela del medio ambiente y la protección del derecho a la salud pública. La investigación se plantea las siguientes preguntas: ¿Los sitios de disposición final en México cumplen con el marco regulatorio? ¿Cuáles son las afectaciones al medio ambiente que provoca el incumplimiento regulatorio?

El estudio es de corte descriptivo, documental y comparativo, con un diseño transversal. Se analizaron datos estadísticos, normatividad y legislación, así como información obtenida de fuentes de información gubernamentales. Los resultados evidencian que un gran número de

sitios de disposición final de residuos sólidos reconocidos oficialmente operan sin cumplir el marco jurídico y regulatorio de la materia. Esta situación ha provocado contaminación del agua, del suelo y del aire, lo cual ha sido documentado en estudios previos. En consecuencias se sugiere atender las causas y factores que propician el incumplimiento regulatorio a fin de prevenir afectaciones ambientales.

Palabras clave: sitios de disposición final, residuos sólidos urbanos, incumplimiento regulatorio, contaminación ambiental

Abstract

The aim of this study is to present the current state of regulatory non-compliance in the final disposal sites for municipal solid waste (MSW) in Mexico and the environmental damage caused by non-compliance. The legal framework establishes that these sites must meet certain technical requirements to ensure environmental protection and safeguard the right to public health. This research addresses the following questions: Do the final disposal sites in Mexico comply with the legal and regulatory framework? What are the environmental impacts caused by legal and regulatory non-compliance?

The study follows a descriptive, documentary, and comparative approach with a cross-sectional design. Statistical data, regulations, and legislation were analyzed, along with information from institutional and governmental sources. The results show that a significant number of officially recognized MSW final disposal sites operate without complying with the applicable legal and regulatory framework. This has led to water, soil, and air pollution, as well as biodiversity loss, findings consistent with other studies on regulatory non-compliance in Mexico and other Latin American countries. The study suggests addressing the underlying causes and factors that foster non-compliance to prevent or mitigate environmental impacts.

Keywords: final disposal sites, municipal solid waste, regulatory non-compliance, environmental pollution.

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Resumo

O objetivo deste estudo é analisar o estado atual de descumprimento das normas regulatórias em aterros sanitários de resíduos sólidos urbanos no México, bem como os impactos ambientais associados a esse descumprimento. O marco legal estabelece que os aterros devem atender a critérios técnicos e regulatórios que visam proteger o meio ambiente e o direito à saúde pública. A pesquisa busca responder às seguintes perguntas: Os aterros no México estão em conformidade com o marco regulatório? Quais são os impactos ambientais causados pelo descumprimento das normas regulatórias?

O estudo é descritivo, documental e comparativo, com delineamento transversal. Foram analisados dados estatísticos, regulamentos e legislação, bem como informações obtidas de fontes governamentais. Os resultados mostram que um grande número de aterros sanitários oficialmente reconhecidos opera sem cumprir o marco legal e regulatório pertinente. Essa situação tem levado à poluição da água, do solo e do ar, o que já foi documentado em estudos anteriores. Consequentemente, sugere-se que as causas e os fatores que contribuem para o descumprimento das normas regulatórias sejam abordados a fim de prevenir danos ambientais.

Palavras-chave: aterros sanitários, resíduos sólidos urbanos, descumprimento das normas regulatórias, poluição ambiental.

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Introduction

The purpose of this research is to analyze the regulatory non-compliance of the final disposal sites (hereinafter SDF) of municipal solid waste (hereinafter RSU) in Mexico, as well as the environmental impacts that result from this situation.

In Mexico, the legal framework applicable to the management and final disposal of MSW is made up, in a hierarchical manner, of the Political Constitution of the United Mexican States and the constitutions of the federative entities; general and secondary laws; the corresponding regulations; the official Mexican standards, as well as international treaties on environmental matters.

In this context, the General Law for the Prevention and Comprehensive Management of Waste (hereinafter LGPGIR) constitutes the framework law on the matter, while the Official Mexican Standard NOM-083-SEMARNAT-2003 establishes the mandatory technical criteria for the SDF of RSU.

According to the LGPGIR , in its article 5, section V, the final disposal of MSW is defined as: “the action of depositing or permanently confining waste in sites and facilities whose characteristics allow preventing its release into the environment and the consequent effects on the health of the population and on ecosystems and their elements” (Congress of the Union, 2022, art. 5, fr. V).

Regarding MSW, the provisions of Article Five, Section XXXIII of the LGPGIR are used, defining it as: “Those generated in homes, resulting from the disposal of materials used in domestic activities, products consumed, and their containers, packaging, or wrapping; waste from any other activity within establishments or on public roads that generates waste with household characteristics, and those resulting from the cleaning of roads and public places, provided they are not considered by this Law as waste of another kind; ” (Congress of the Union, 2022, art. 5, fr. XXXIII).

For its part, the Official Mexican Standard NOM-083-SEMARNAT-2003 constitutes the mandatory technical regulation that establishes “the specifications for site selection, design, construction, operation, monitoring, closure and complementary works of a final disposal site for urban solid waste and special handling” (Secretariat of Environment and Natural Resources [SEMARNAT] , 2003).

Once the key concepts that guided this research—waste disposal systems (SDFs) and municipal solid waste (MSW)—and their legal framework have been clarified, it is pertinent to define the consequences of regulatory non-compliance, that is, the environmental impact caused by the improper treatment of MSW in an SDF. This is within the framework established by the General Law of Ecological Balance and Environmental Protection. (Congress of the Union [LGEEPA], 2022, art. 3, frs . VIII, XII and XIV) , three concepts are identified that are related to the environmental damage referred to in this study: environmental contingency , ecological imbalance and environmental impact.

In this regard, the investigation is justified by the magnitude of the environmental impacts being caused by SDFs in a situation of regulatory non-compliance, which are being recorded internationally.

Given this scenario, the following research questions are posed for the development of this study: Do the SDFs in Mexico comply with the applicable legal and regulatory framework? What are the environmental impacts resulting from regulatory non-compliance at these sites?

Currently, the problem of municipal solid waste transcends national borders and is part of a global environmental crisis. According to the report *What a Waste 2.0: A Global Snapshot of solid According to the World Bank's Waste Management to 2050* report (2018), MSW generation is expected to reach 3.4 billion tons by 2050.

Furthermore, this problem becomes relevant from the nature of MSW, since a significant part of it is composed of materials whose degradation is complex, such as plastics, whose production and final disposal are associated with processes that generate persistent environmental impacts (De Celis, 2007).

In the case of MSW improperly disposed of in SDFs, the main pollutants are related to physical, chemical and biological factors derived from the decomposition of the waste, such as the generation of leachate, biogas emissions and the proliferation of microorganisms, which can affect the soil, water and air, as well as the health of the population.

To contextualize the Mexican case, it is necessary to point out that, according to the *Basic Diagnosis for the comprehensive management of waste,* in the section corresponding to "Urban solid waste" there is a number of 2,203 SDF located in 1,722 municipalities, of which more than 47.8% lack basic infrastructure (Secretariat of Environment and Natural Resources [SEMARNAT], 2020).

From a proportional analysis, this information allows us to identify that a significant proportion of the final disposal sites do not operate under conditions that guarantee the protection of the environment or the safeguarding of public health.

It should be noted that these results do not consider the so-called "dark figure", associated with clandestine or unregistered sites, which are used by the population for the disposal of urban solid waste and which could substantially increase the real magnitude of the problem, as has been documented in previous research.

In the Latin American context, several studies agree that the final disposal of urban solid waste is carried out, in many cases, in open dumps or sanitary landfills that only partially comply with environmental regulations, which generates significant pollution problems (Sáez and Urdaneta G., 2024).

Furthermore, the lack of information or the inadequacy of available information limits the ability to more accurately assess municipal solid waste management processes in Latin America. This situation hinders the formulation of proposals aimed at improving final disposal systems, not only in Mexico but also in other countries in the region.

This problem is closely linked to non-compliance with the legal framework applicable to municipal solid waste management systems (MSWMS), since, according to the study " *Regional Evaluation of Material Flows: Municipal Solid Waste for Latin America and the Caribbean" (EVAL 2023)* , a correlation is observed between the limited availability of statistical information and deficient regulatory compliance in various countries of the region. In this regard, Alarcón Montero (2023) points out that the lack of institutional information is directly related to practices of regulatory non-compliance.

It is important to note that these shortcomings are not a recent phenomenon. As early as 2010, it was already being observed that inadequate practices for the final disposal of municipal solid waste (MSW) prevailed in the Latin American region, generating negative environmental impacts in the countries where they occurred.

According to the *2010 Regional Assessment Report on the Management of Municipal Solid Waste in Latin America and the Caribbean* It was estimated that approximately 2% of the waste was incinerated in the open air, 1.8% was dumped into bodies of water or used to feed animals or for other non-recommended activities, and 27.1% was managed without any control, which evidenced a regional scenario of high environmental vulnerability (Tello Espinoza, 2011) .

Furthermore, the report noted that the public's lack of trust in the authorities involved in urban solid waste management processes, as well as the limited institutional legitimacy to enforce regulations, were additional factors contributing to regulatory non-compliance. According to Tello Espinoza (2011), this lack of legitimacy and enforcement capacity also directly impacts the environment .

Now, returning to the national context, it is pertinent to point out that, according to data from the Ministry of Environment and Natural Resources, approximately 102,895 tons of urban solid waste are generated in Mexico; of this volume, 83.93% is collected, and only 78.54% of the collected waste is disposed of in formally identified final disposal sites (Ministry of Environment and Natural Resources [SEMARNAT], 2017).

From a proportional analysis, these figures reveal that a significant fraction of the waste generated does not receive controlled final disposal, suggesting the existence of

clandestine or unregulated disposal practices. This situation introduces a methodological limitation, as these waste flows are not fully recorded in the available official assessments, preventing a more accurate assessment of the true magnitude of the problem.

The above figures are relevant not only because of the environmental consequences of inadequate MSW management, but also because they demonstrate the fragility of obedience to the law in a state governed by the rule of law.

Although the country has a legal and regulatory framework that governs all stages of MSW management, various SDFs continue to operate in contravention of the provisions of the General Law for the Prevention and Comprehensive Management of Waste and its regulations, as can be seen from the data previously presented.

In this context, it is hypothesized that non-compliance with the legal framework applicable to SDFs (Social Development Funds) generates environmental damage. For its analysis, the study was developed using a descriptive, documentary, and comparative design, based on the examination of legal, statistical, and technical information, which allows for the identification that the omission of regulatory compliance is associated with the generation of environmental damage.

On the other hand, this research is situated not only within the legal field, particularly environmental law, but also within an interdisciplinary approach that incorporates contributions from technical, administrative, and public policy studies. Several previous investigations, even those not developed exclusively from a legal perspective, coincide with the central arguments of this study regarding the relationship between regulatory non-compliance and environmental impact.

This is the case with research conducted in countries such as Peru and Ecuador, which has documented that, even in the presence of consolidated legal frameworks, the lack of adherence to the regulatory framework applicable to final disposal sites generates significant damage to the environment.

Furthermore, the comparative analysis of these investigations reveals that higher levels of regulatory non-compliance correspond to an increase in the magnitude of environmental impacts, which reinforces the hypothesis put forward in this work.

Similarly, it is identified that regulatory non-compliance regarding final disposal sites for urban solid waste is not solely due to legal or technical factors, but is associated with structural elements such as insufficient financial resources, limited effectiveness of oversight efforts, and a weak culture of legality in a broad sense.

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These considerations are based on the analysis of indexed articles, official diagnoses from Mexican institutions such as the Ministry of Environment and Natural Resources, as well as information from the *2022 National Atlas of Urban Solid Waste* .

Regarding the above, information was also gathered from the *National Program for the Prevention and Comprehensive Management of Waste 2022–2024* of the Ministry of Environment and Natural Resources [SEMARNAT] (2022) [PNPGR], which notes that, in the section corresponding to the "current state" of the problem derived from MSW, the federal government recognizes the complex nature of the phenomenon, which not only concerns the unrestricted adherence to the law in this matter, but does establish legal adaptation as one of its goals.

In Mexico it is clear that, in the chain of responsibilities, the first ring corresponds to the municipal authorities, who, according to article 115, section III of the federal Constitution, are responsible for the public service of collection, treatment and final disposal of solid waste.

However, as stated in the aforementioned national program on the matter (PNPGR, 2022), budgetary limitations commonly impact the projection of public works related to the final disposal of MSW, hence the facilities where the waste is finally deposited do not fully comply with the regulatory framework (PNPGR, 2022).

This situation is attributed to the lack of resources and adequate or insufficient facilities, which leads the population to choose to incinerate their waste in the open air instead of disposing of it correctly, which undoubtedly contributes to generating gases into the atmosphere.

Therefore, it can be inferred that, of the more than two thousand sites counted in Mexico according to the latest diagnosis (SEMARNAT, 2020), the vast majority are in that scenario and that, in about eighteen hundred municipalities where they are located, the lack of capacity for the sites where MSW is confined to comply with the regulatory framework means that waste generators opt for harmful practices such as clandestine dumps.

Methodology

This descriptive research falls within the field of legal sciences, with a legal-environmental focus, particularly on environmental law and the analysis of regulatory compliance of municipal solid waste management systems (MSWMS). Its design is cross-sectional and examines information generated between 2020 and 2024. Data collection was carried out using documentary research techniques, based on a review of official sources, legislation, and scientific articles related to MSWMS in Mexico.

To determine the selection criteria for information sources, their relevance and methodological validity were considered. In this regard, only sources from agencies and institutions that, within their areas of competence and function, generate official, up-to-date, and verifiable information, as well as studies prepared by specialists in the field, were included. These criteria ensured that the information analyzed was relevant, reliable, and appropriate for achieving the research objectives.

Regarding the exclusion criteria, journalistic documents that presented moral, political or religious biases were discarded, as well as those from personal analyses or that lacked institutional or academic support.

Likewise, priority was given to the analysis of scientific articles indexed in recognized databases such as Scopus , Web of Science and SciELO, because they are repositories that guarantee peer review processes and academic quality standards.

Given the time frame, studies published between 2010 and 2024 were included to ensure an analysis based on recent information. These included research conducted in comparable contexts, such as El Oro and Juliaca in Peru and Morona in Ecuador, which were used as comparative background to contextualize the phenomenon of regulatory non-compliance at municipal solid waste disposal sites.

For the creation of the figures and graphs, based on data obtained from the previously mentioned sources, the ChatGPT artificial intelligence tool (GPT-5.2 model), developed by OpenAI , was used as technical support for generating graphical representations. It is important to clarify that the use of this tool was limited exclusively to supporting data visualization, without intervening in the processes of analysis, interpretation, or methodological decision-making, which were carried out entirely by the authors.

Although the title of the study alludes to "environmental impacts", one of the main limitations of the research lies in the scarce availability of statistics and previous research that allow for the direct and quantifiable identification of the ecological damage attributable

to the deficient management of urban solid waste disposal sites due to a lack of regulatory compliance.

In this sense, the analysis of these impacts is approached from a descriptive and general scope, in accordance with the documentary nature of the study, which highlights the need for future research that delves deeper, through empirical and quantitative approaches, into the specific measurement of the environmental impacts associated with these sites.

Results

According to data reported by Tello Espinoza (2011), 27.1% of urban solid waste generated in Latin America and the Caribbean is managed without any type of control, including highly polluting practices such as open burning and dumping into bodies of water.

This result highlights the magnitude of the regional problem associated with the final disposal of waste and allows us to contextualize the situation of countries with high volumes of MSW generation, such as Mexico.

Based on the data presented, it is possible to suggest, as an analytical inference, that in contexts where there is a high generation of urban solid waste, there tend to be higher levels of non-compliance with the legal framework applicable to final disposal sites.

In this sense, regulatory non-compliance—whether through total omission of the obligations established in environmental legislation or through partial compliance with regulatory instruments, such as the General Law for the Prevention and Comprehensive Management of Waste and the Official Mexican Standard NOM-083-SEMARNAT-2003—is associated with the persistence of practices that generate damage to the environment.

In the Mexican legal system there is a broad regulatory framework that governs the management and final disposal of MSW, comprised of secondary legislation derived from the constitutional text and international commitments assumed by the Mexican State in matters of environmental protection and human rights.

However, the results analyzed show that the existence of this legal framework, both national and international, does not translate into its effective implementation in the field of final disposal sites, since there is a persistent lack of compliance with the required technical and environmental standards.

This noncompliance with the General Law for the Prevention and Comprehensive Management of Waste and the Official Mexican Standard NOM-083-SEMARNAT-2003 is related, among other factors, to the lack of adequate conditions in the facilities of the SDF,

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which prevents them from fully complying with the technical criteria established in terms of infrastructure, operation, monitoring and closure.

In this regard, according to the Basic Diagnosis for the comprehensive management of waste, a significant proportion of final disposal sites do not have the minimum conditions to comply with current regulations, which limits the correct application of the legislation on the matter (SEMARNAT, 2020).

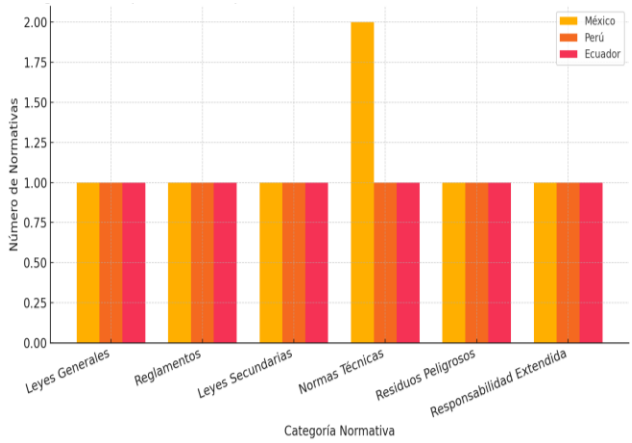
The above is consistent with the information contained in the National Program for the Prevention and Comprehensive Management of Waste 2022–2024, which recognizes that structural limitations persist in the management of urban solid waste, such as regulatory deficiencies, lack of infrastructure, limited financial resources and inadequate final disposal practices, which generate negative impacts on the environment (PNPGR, 2022).

To support the results presented above, two investigations developed in Latin American contexts were analyzed which, although not specifically within the field of environmental law or other legal disciplines, empirically address regulatory non-compliance at final disposal sites and their environmental impacts.

In this regard, studies conducted in countries such as Ecuador and Peru show that, despite having an established legal framework for waste management, the lack of regulatory compliance at urban solid waste disposal sites generates negative impacts on the environment, a situation that is comparable to the Mexican context.

See Figure 1 below for details.

Figure 1. Comparison of the legal and regulatory instruments applicable to the management and final disposal of municipal solid waste (MSW) in Mexico, Peru and Ecuador



Source: Prepared by the authors based on a comparative analysis of environmental legislation, technical standards, and official programs regarding the management and final disposal of municipal solid waste in Mexico, Peru, and Ecuador.

As can be seen in Figure 1, the legal and regulatory frameworks of Mexico, Peru and Ecuador present a similar normative structure in matters of management and final disposal of urban solid waste, by integrating legal and technical instruments that establish obligations, control mechanisms and, where appropriate, the imposition of sanctions.

However, this regulatory similarity does not necessarily translate into effective compliance, since, despite the existence of provisions that delimit the co-responsibility of the obligated subjects, final disposal practices persist that contravene the established standards, particularly in the final disposal sites of MSW.

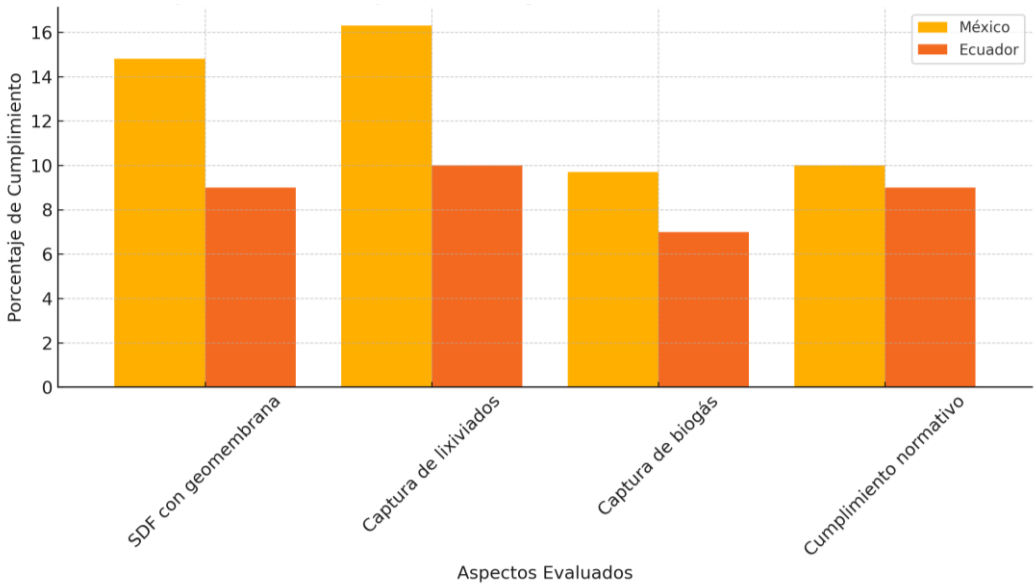
Several studies conducted in Latin American countries help to contextualize the results obtained in this comparative analysis, showing that non-compliance with environmental regulations regarding final disposal sites for urban solid waste is associated with environmental damage.

Such is the case of Ecuador, where the research developed by Ramones Ruiz (2022), entitled *Analysis of the environmental legal compliance of the location of the final disposal sites for solid waste in the province of Morona Santiago* , addresses the management of waste from a regulatory and environmental approach.

Although that study presents methodological differences with respect to the present investigation, it agrees in pointing out that non-compliance with the legal framework applicable to final disposal sites generates negative environmental impacts.

In the case of Morona, 91% of the sample analyzed by Ramones Ruiz (2022) corresponds to SDFs that do not comply with the legal requirements stipulated by the current regulations of their country. His study shows that only between 3% and 11% of the province has suitable soils for SDF locations, indicating low compliance with technical and regulatory criteria that are causing environmental damage. See Figure 2 below.

Figure 2. Comparison of regulatory compliance of municipal solid waste disposal sites between Mexico and the province of Morona Santiago, Ecuador, in relation to the aspects evaluated

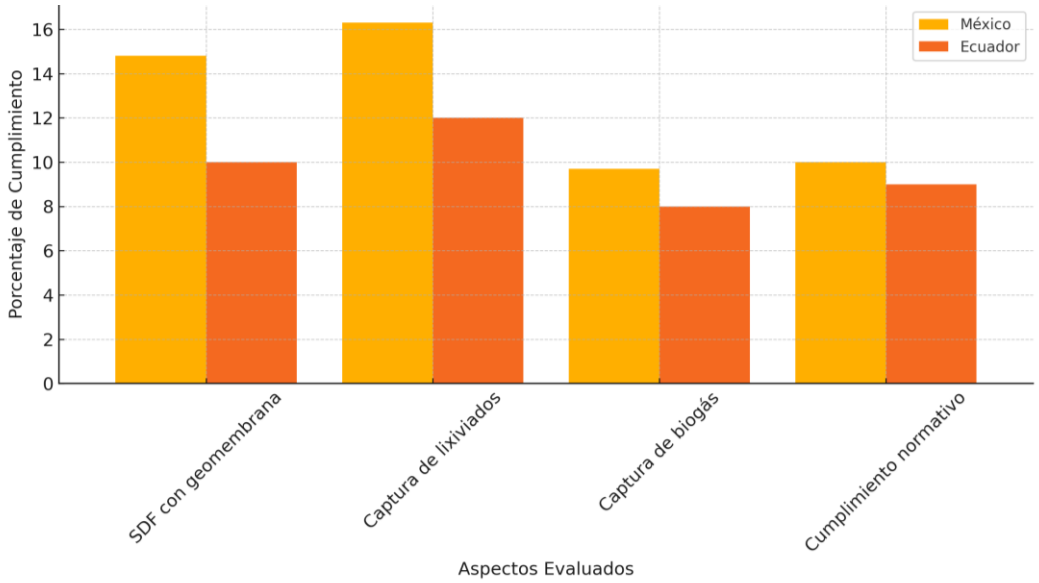


Source: Prepared by the author based on data from the study by Ramones Ruiz (2022) for Morona Santiago and Romero (2022) for El Oro, in comparison with information from the *National Atlas of Urban Solid Waste 2022* , the *National Program for the Prevention and Comprehensive Management of Waste 2022–2024* and the *Basic Diagnosis for the comprehensive management of waste* (SEMARNAT, 2020, 2022).

Another precedent that we can find in previous studies on waste management is the study carried out in the town of El Oro, Ecuador, by Romero (2022), whose results identify problems comparable to the Mexican case, noting that the final disposal sites have inadequate locations that affect water sources and generate environmental pollution processes.

This regulatory non-compliance applicable to the location of final disposal sites is related to the hypothesis put forward in this study, as shown in Figure 3.

Figure 3. Comparison of SDF regulatory compliance between Mexico and El Oro, Ecuador, in relation to the aspects evaluated

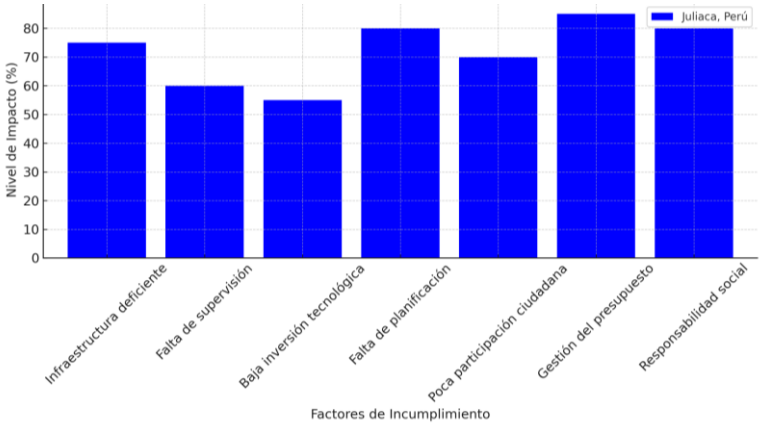


Source: Prepared by the author using data obtained from the study on regulatory compliance of SDF in the town of El Oro, Ecuador (Romero, 2022), compared with data obtained from the documents *National Atlas of Urban Solid Waste 2022* (Secretariat of Environment and Natural Resources [SEMARNAT], 2022), *National Program for the Prevention and Comprehensive Management of Waste 2022–2024* [PNPGR] (SEMARNAT, 2022) and *Basic Diagnosis for the Comprehensive Management of Waste* (SEMARNAT, 2020)

Furthermore , as can be seen in Figure 3, as in Mexico, in Ecuador, although regulations exist for its control, the level of compliance with the law is weak, which increases the dispersion of waste in unauthorized areas, resulting in environmental damage.

On the other hand, in the case study carried out by Tino Betancur (Madona Tito Betancur, 2021)et al., on the main factors associated with regulatory non-compliance in the management of municipal waste in Juliaca, Peru, the following are highlighted in Figure 4:

Figure 4. Factors associated with regulatory non-compliance in solid waste management, identified from analytical categories, in Juliaca, Peru



Source: Prepared by the author based on data from the study *Factors associated with regulatory non-compliance in the management of municipal waste in Juliaca, Peru* (Tito Betancur, 2021)

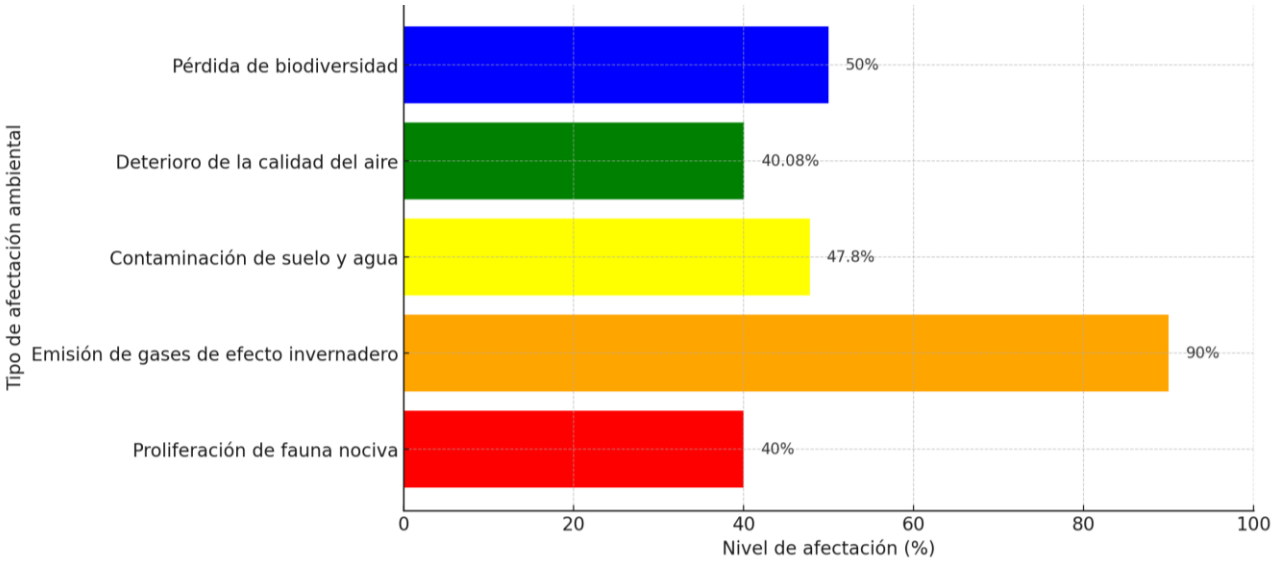
In addition to the factors shown in Figure 4 associated with the lack of regulatory compliance in final disposal activities in Mexico, the results demonstrate that, within the stages that comprise MSW management, the disposal stage is the most prone to disregard for the law, as Bernache (2012) expresses it: "they are a weak link, which suffers from many problems in its daily operation."

This vulnerability not only affects the process of optimal MSW management *per se* , but, as observed in the studies analyzed above, in Mexico, Peru and Ecuador, the environmental consequence is devastating in the short, medium and long term, both in the environment and public health.

However, despite the fact that the consulted literature does not contain more precise or specific data to know the dimension at the national level, given this lack of information that prevails in many investigations, which is a valuable and strategic resource since without it it is not possible to monitor, evaluate, much less identify areas of opportunity, according to Alarcón Montero (2023).

Furthermore, regarding the impact or degree of harm to the environment, according to data obtained from the *2022 National Atlas of Urban Solid Waste* (Secretariat of Environment and Natural Resources [SEMARNAT] and National Institute of Ecology and Climate Change [INECC], 2022), the main environmental damages associated with it are shown in Figure 5, which is presented below:

Figure 5. Main environmental impacts caused by regulatory non-compliance of SDFs

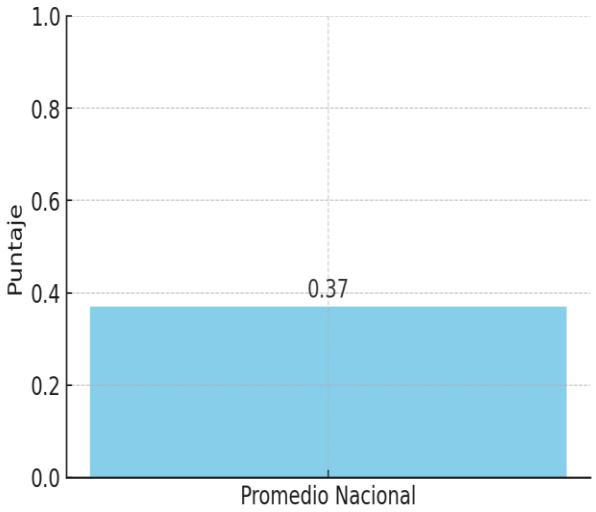


Source: Prepared by the author using information extracted from the *National Atlas of Urban Solid Waste 2022* (Secretariat of Environment and Natural Resources [SEMARNAT] & National Institute of Ecology and Climate Change [INECC], 2022)

Finally, one of the findings that correlates with the reference problem is the association that exists between the regulatory non-compliance of the SDF of RSU in our country and the weakness of its rule of law.

Since this non-compliance is only one manifestation of the vulnerability reported in the assessment carried out in the *Rule of Law Index in Mexico* (World Justice Project [WJP], 2024), which, among other factors, evaluates "regulatory compliance," assessing the extent to which regulations and norms issued by government authorities are effectively applied. In the Mexican case, the result is shown in Figure 6 below:

Figure 6. National average of regulatory compliance in Mexico



Source: Prepared by the author using information obtained from the "Rule of Law Index in Mexico 2023-2024", (World Justice Project, 2024) .

The aforementioned results certainly include a lack of compliance with the law regarding municipal solid waste disposal systems (MSWDS), as it considers how regulations and standards are being applied and whether or not they are effective. This evaluation takes into account the environmental context within which MSWDS regulations are framed.

This weakness noted in the reference report is indicative of the low level of compliance with regulations in the country, and is directly correlated with the problem analyzed in the area of SDF.

Discussion

The analysis developed in this paper on environmental regulatory compliance regarding municipal solid waste disposal (MSW) identifies a structural problem that transcends the technical sphere and is embedded in a broader context of institutional weakness. This situation is consistent with the results of the Rule of Law Index, which reveal persistent deficiencies in compliance with and application of environmental regulations (World Justice Project [WJP], 2024).

In this context, when an environmental regulation is not met, as is the case with municipal solid waste disposal sites in Mexico, this situation can be linked to structural factors related to the State's institutional capacity. Specifically, when the responsible authorities—primarily at the municipal level—do not guarantee effective compliance with

the regulations, this condition is associated with the weakness or strength of the rule of law, as described by Bellamy (2024).

In this sense, in order to articulate a general proposal aimed at improving respect for the regulatory norms applicable to the SDF of RSU in Mexico and preventing damage to the environment and health resulting from non-compliance, it is necessary to strengthen the rule of law in the country.

In addition to the above, the weakness of the rule of law is associated with two structural problems: limited institutional capacity and a weak culture of legality. The stronger the culture of legality, the greater the observance of the rules, which directly impacts the effective enforcement of the legal framework.

Hence, the results of this research coincide with the arguments presented in the previous sections, in the sense that the weakness of the rule of law and disobedience of the law, associated with regulatory non-compliance of MSW systems in Mexico, constitute phenomena that are also observed in other regions of Latin America and the Caribbean.

This situation is supported by the evidence documented in the case studies analyzed for Peru and Ecuador, in which similar patterns of regulatory non-compliance, deficiencies in the application of current legal frameworks and environmental impacts derived from the inadequate operation of the SDF are identified.

The above demonstrates that, despite the existence of legal and regulatory frameworks regarding final disposal sites for municipal solid waste —even when these are integrated, harmonized and aligned with international instruments—, their effective compliance remains limited.

Furthermore, it is observed that the negative environmental consequences resulting from regulatory disobedience do not depend on the legal system to which a State belongs, but on the actual degree of compliance and application of the legal and technical provisions that regulate the management and final disposal of urban solid waste.

Following this line of reasoning, it becomes clear that another facet of the central problem of the deficient management of municipal solid waste disposal systems (MSWDS) lies not solely in the absence of regulations, but rather in the gap in effective compliance with existing regulations. This explains why, despite the existence of a legal framework and technical standards, there has been no substantial improvement in the environmental conditions associated with the final disposal of MSW.

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Furthermore, the results show that the environmental impacts resulting from regulatory non-compliance have been addressed predominantly from a descriptive perspective, which limits the possibility of prioritizing the damages, identifying the most critical impacts, and strategically guiding intervention actions.

This situation reinforces the need to link regulatory compliance not only with formal adherence to the law, but also with the strengthening of comprehensive MSW management plans and programs, so that regulation translates into operational instruments capable of effectively mitigating environmental impacts.

On the other hand, a comprehensive strategy to improve the rule of law with a focus on adherence to the regulatory framework of the MSW systems must also integrate actions that strengthen the oversight of the systems, to promote due compliance with the regulations and, where appropriate, reinforce the system of responsibilities (administrative, criminal, civil, patrimonial and international) of the subjects involved in the MSW management process.

Above all, it is pertinent to review the design of the legal and regulatory framework applicable to municipal solid waste disposal sites, not necessarily because it is nonexistent, but because of the structural conditions that hinder its effective compliance. In this regard, Laveaga Rendón (2004) identifies five factors that directly influence non-compliance with the law—ambiguity, profusion, complexity, inequity, and obscurity—which suggest that an excessively complex, dispersed, or unclear regulatory framework can weaken compliance, even when it is formally in force.

On the other hand, the results of the study highlight the financial and budgetary dimension as a structural factor that significantly affects regulatory non-compliance at urban solid waste disposal sites in Mexico.

At the municipal level —the first level of government responsible for the management, collection and final disposal of MSW—, budgetary limitations are identified as one of the main causes that prevent compliance with the technical criteria established in current regulations.

Both the *National Atlas of Urban Solid Waste* (SEMARNAT & INECC, 2022) and the *Basic Diagnosis for the Integrated Management of Waste* (SEMARNAT, 2020) agree that a considerable proportion of the SDF lacks adequate infrastructure due to persistent financial constraints.

This budget shortfall, widely recognized in official reports from the Ministry of Environment and Natural Resources and in specialized government diagnoses, is most pronounced at the municipal level, where the provision of the public service of comprehensive management of MSW falls.

At this level of government, the limited availability of resources affects not only the operation and suitability of final disposal sites, but even basic stages of the system, such as the regular collection of waste, which generates a cumulative effect of regulatory non-compliance and fosters inadequate disposal practices with adverse environmental consequences.

Based on the above, it is recommended that a national financial diagnosis be carried out to identify the budget allocation of municipalities with the highest levels of regulatory non-compliance regarding final disposal sites for urban solid waste.

An exercise of this nature would contribute to planning and budget reallocation with a preventive and corrective approach, aimed at strengthening the financial capacity of municipal governments to reverse structural conditions of non-compliance and, indirectly, generate better conditions for environmental protection.

According to the 2023 National Census of Municipal Governments and Territorial Demarcations of Mexico City, when municipal services for the collection of urban solid waste are deficient, inadequate disposal practices are recorded by the population, including the burning of garbage (National Institute of Statistics and Geography [INEGI], 2024).

This practice, as documented in the specialized literature, contributes to the emission of polluting gases with adverse effects on air quality and climate, particularly in contexts where there are no formal alternatives for waste management.

In this context, when municipal governments—as primary authorities—are unable to adequately guarantee both the collection and final disposal of municipal solid waste, the need to review the system of shared powers and responsibilities among the different levels of government becomes evident. This review is relevant so that the state and federal levels can contribute technical, financial, and administrative resources to mitigate the environmental problems arising from non-compliance with the regulatory framework applicable to municipal solid waste.

From this perspective, the analysis of the burden of competence and the scheme of concurrence acquires special relevance to address the environmental effects associated with poor compliance with regulations, particularly if the structural limitations —technical,

operational and budgetary— that municipalities face in fully complying with the public service of management and final disposal of MSW are recognized.

Under this scenario, this paper proposes to discuss the adequacy of the current constitutional framework, particularly Article 115 of the Political Constitution of the United Mexican States, given a context in which the volume of waste generated in cities and municipalities has, in many cases, exceeded the institutional capacity of municipal governments to ensure environmentally sound final disposal. Therefore, it questions whether the current model for the distribution of powers effectively addresses the magnitude and complexity of the problem.

Likewise, a possible redefinition of the competence scheme would have direct implications for regulatory and programmatic planning in the area of MSW, by affecting both national instruments and the equivalent plans of the federative entities, as well as the set of legislative provisions that regulate the comprehensive management of waste and its disposal in authorized sites.

In this regard, the discussion on the concurrence of powers finds a point of connection with the principle of environmental co-responsibility already established in secondary legislation. The General Law on Climate Change establishes shared obligations between the Federation and the federative entities to guarantee the right to a healthy environment, which opens the possibility of analyzing the sufficiency and articulation of the intergovernmental coordination mechanisms provided for in said legislation in the face of the challenges posed by the management of municipal solid waste and the operation of waste management systems (Congress of the Union, 2025).

Similarly, it should also have a regulatory impact on the General Law for the Prevention and Comprehensive Management of Waste (Congress of the Union, 2024), legislation that establishes that municipalities are responsible for the comprehensive management of MSW.

In this context, the need to strengthen the levels of compliance with the rule of law and to ensure that the operation of urban solid waste disposal sites complies with current regulations is evident, in order to reduce the persistence of practices such as the burning of waste or the operation of open dumps —in many cases clandestine—, which are associated with negative impacts on ecosystems and with risks to public health, particularly due to their impact on aquatic fauna and the transmission of diseases (Fuentes, 2024).

The above consequences to the environment have been ratified in the *2024 World Waste*

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Management Outlook Report of the United Nations Environment Programme [UNEP], which warns that "the transport, processing and disposal of waste generate CO_2 and other greenhouse gases, contributing to climate change" (UNEP, 2024).

Thus, based on the results obtained, a vicious cycle can be observed in the management of municipal solid waste in Mexico, in which the high volume of MSW generated nationwide faces structural deficiencies at various stages of the integrated management process, particularly in collection and final disposal. These deficiencies manifest themselves in inadequate waste treatment by the responsible authorities and operators, who fail to effectively comply with the applicable legal framework and official standards.

This lack of regulatory compliance not only reflects weaknesses in the rule of law and the culture of legality, but is also associated with material and structural limitations, such as insufficient financial and human resources, as well as a lack of adequate facilities at final disposal sites. These conditions compromise the institutional capacity to guarantee proper waste management at its final stage.

In this context, the lack of sufficient resources limits the possibility of creating and maintaining the technical conditions required by the Official Mexican Standards, resulting in the operation of final disposal sites outside the legal framework, such as open dumps or uncontrolled facilities. These practices are carried out outside the operational processes established in current regulations and generate negative impacts on the environment, affecting the soil, water, flora, fauna, and , in general, biodiversity.

Finally, the findings of this research allow us to conclude that strengthening the rule of law and a culture of legality is central to improving compliance with environmental regulations regarding municipal solid waste. Without effective enforcement of the legal and regulatory framework, efforts aimed at environmental protection and mitigating the impacts associated with the final disposal of MSW are limited, reinforcing the need to comprehensively address the legal, institutional, and structural factors that influence this problem.

Conclusions

The results of this research allow us to conclude that a significant proportion of municipal solid waste disposal systems (MSWDS) in Mexico operate without effectively complying with the applicable regulatory framework. This lack of compliance is associated with environmental impacts, particularly in terms of soil, water, and air pollution. Furthermore, the identified non-compliance stems from a set of structural, institutional, and regulatory factors that add complexity to the problem analyzed.

Furthermore, the lack of adherence to regulations regarding municipal solid waste disposal sites reflects the weakness of the rule of law in the national context. This situation is associated with a limited culture of legality and significant environmental degradation resulting from the disposal of waste in sites that do not meet the technical and regulatory requirements for its proper management.

Consequently, if the majority of the final disposal sites for municipal solid waste identified in the *National Atlas of Municipal Solid Waste and in the Basic Diagnosis for the Comprehensive Management of Waste* effectively complied with the provisions established in the applicable legal and regulatory framework, particularly with the technical criteria provided for in the Official Mexican Standard NOM-083-SEMARNAT-2003, the environmental impacts currently documented in these instruments would be significantly reduced.

Regarding the adverse environmental consequences of inadequate MSW management in waste disposal sites, impacts such as water, soil, and air pollution; increased greenhouse gas emissions; biodiversity loss; and the proliferation of harmful fauna have been identified. However, these impacts are not fully quantified in national government or academic research, which has limited the ability to quantitatively assess the specific degree of environmental impact associated with these sites.

It is pertinent to explore, in addition to the environmental impacts, the implications for public health and the right to health, particularly in relation to the impacts that may be generated in people living in areas near urban solid waste disposal sites that do not comply with applicable regulations .

Likewise, to strengthen regulatory compliance of municipal solid waste disposal sites in Mexico, it is necessary to structurally improve the indicators related to the rule of law and the culture of legality, insofar as these factors are closely associated with respect for and effective observance of the law in general.

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Furthermore, it is relevant to review the current capacity of municipalities with low levels of regulatory compliance regarding municipal solid waste, in order to identify their financial resources and the budget allocations earmarked for guaranteeing the public service of collection, transport, and final disposal of MSW. This analysis would allow for an assessment of the extent to which budgetary constraints affect non-compliance with the legal framework, considering that, by constitutional mandate, these functions fall primarily under the municipal level.

If the results documented in reports, diagnoses, programs, and plans prepared by federal authorities demonstrate that the operational responsibility of municipalities is insufficient to guarantee adequate management of municipal solid waste and its containment in accordance with current regulations at final disposal sites—which present structural deficiencies that not only violate the law but also generate damage to biodiversity—then it is legally pertinent to review the scope of municipal powers recognized in the Political Constitution of the United Mexican States, in order to assess possible regulatory adjustments that allow for a more effective distribution of responsibilities among the different levels of government.

In this context, the results obtained allow us to analyze the relevance of rethinking the current model of public service provision for the management of urban solid waste at the municipal level, insofar as this level of government faces structural limitations to guarantee adequate conditions for collection and final disposal in accordance with current regulations.

From this perspective, it becomes important to assess intergovernmental coordination mechanisms and, where necessary, adjustments to the overlapping of responsibilities, so that addressing the environmental impacts associated with improper waste disposal can be handled by levels of government with greater technical, operational, and financial capacity. This would allow for a more effective contribution to reducing environmental damage resulting from poor municipal solid waste management practices.

Future lines of research

Based on the findings obtained, several lines of research are identified that, if developed, could contribute to the formulation of comprehensive solutions to the problem analyzed in this study, which are presented below.

First, it is a priority to develop studies aimed at analyzing the impacts on public health and the right to health of populations living in areas near urban solid waste disposal sites that do not comply with current regulations, given that direct exposure to polluting agents—such as leachate, gas emissions, polluting particles and biological agents—as well as to the waste itself, places them in a condition of special vulnerability.

Secondly, it is pertinent to analyze the scope of the Mexican State's responsibility arising from its failure to fulfill its functions of monitoring, supervising, and enforcing compliance with environmental regulations applicable to municipal solid waste disposal sites. This analysis could be approached from the various forms of liability recognized in the Mexican legal system—civil, administrative, criminal, and political—as well as from the perspective of the State's international responsibility in matters of environmental protection and human rights.

Third, it is pertinent to analyze the distribution of powers and responsibilities among the federal, state, and municipal levels of government in relation to the management of urban solid waste, with the objective of determining whether, in the current scheme, the municipalities have sufficient budgetary capacity to effectively fulfill the constitutional mandate to provide the public service of collection, transfer, and final disposal of waste.
Should structural limitations be identified in this area, the feasibility of mechanisms for reassigning or strengthening competencies could be examined, in favor of higher levels of government, which have greater technical, operational and financial resources to reduce the high levels of non-compliance with the environmental regulations applicable to final disposal sites.

Finally, it is pertinent to analyze the regulatory standards applicable to the management and final disposal of urban solid waste, as well as to evaluate whether the oversight and control entities have sufficient institutional mechanisms to guarantee their effective compliance by the municipal governments that currently fail to comply with environmental regulations.

This analysis could be developed in light of Lorenzetti's arguments on the effectiveness of environmental law, particularly in relation to preventive compliance mechanisms, normative deterrence and institutional responsibility, in order to determine to what extent the normative design and the instruments of control favor —or inhibit— the actual observance of environmental regulations regarding final disposal sites.

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