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From Policy to Practice: Comparing EU and Mexican Regulations for Landfill Remediation through the Cases of the Netherlands and San Luis Potosí State

by

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I, the undersigned, **María de Lourdes Ángeles Topete**, candidate for the MA degree in Environmental Sciences and Policy declare herewith that the present thesis titled "**From Policy to Practice: Comparing EU and Mexican Regulations for Landfill Remediation through the Cases of the Netherlands and San Luis Potosí State**" is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright.

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Vienna, 26 June 2025

María de Lourdes Ángeles Topete

Acknowledgments

This journey has been such an exciting adventure! Coming back to study after working for a while has opened my eyes to just how different this experience can be. I've loved diving into my studies and exploring the topics that really ignite my passion. Honestly, I couldn't have made it this far without the amazing support and companionship of many wonderful people along the way.

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Abstract

This thesis presents a comparative analysis of landfill remediation policies between the European Union and Mexico, emphasizing the interrelationship among legal frameworks, institutional arrangements, stakeholder dynamics, and environmental outcomes. Given that closed and unremediated landfills pose ongoing threats to soil, water, and public health, this research aims to illuminate the governance mechanisms that govern remediation initiatives, which are essential for effective policy development and implementation. The study focuses on two case studies: the Volgermeer polder in the Netherlands and the La Pedrera site in San Luis Potosí, assessing differences in regulatory approaches, funding mechanisms, and levels of citizen participation.

Employing qualitative research methods—including policy document analysis, reviews of articles on landfill remediation, and case study documentation—this paper underscores the similarities and differences between the two systems. The findings indicate that while both nations adhere to the "polluter pays" principle, the Dutch model prioritizes long-term risk management and territorial integration, whereas the Mexican framework emphasizes immediate problem-solving. This research advocates for more proactive, participatory, and context-specific remediation strategies in various regions of Mexico, drawing lessons from the Netherlands to guide future policy initiatives. Ultimately, it contributes to a broader discussion on the need to update legislation, establish dedicated waste management agencies, and, most importantly, develop policies that yield better long-term outcomes.

Key words: landfill, remediation, closure landfills, regulations.

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List of Abbreviations

CH4- Methane
CIESAS- Center for Research and Advanced Studies in Social Anthropology of the Gulf of Mexico.
CONABIO- National Commission for the Knowledge and Use of Biodiversity
CO2-Carbon dioxide
CONAHCYT-National Council of Humanities, Sciences, and Technologies (CONAHCYT)
COTERIN-Technical Confinement of Industrial Waste S.A
DG-ENV- Directorate-General for Environment
DGGIMAR- General Directorate of Comprehensive Management of Materials and Risky Activities.
DWMA-Dutch Waste Management Association
EEA- European Environmental Agency
EU-European Union
GHG´s- Greenhouse gases
INE-National Institute of Ecology
INECC- National Institute of Ecology and Climate Change
INEGI- National Institute of Statistics and Geography
INSC-National Inventory of Contaminated Sites
LGEEPA- General Law of Ecological Balance and Environmental Protection
LGPGIR- General Law for the Prevention and Integral Management of Waste
MSW- Municipal Solid Wastes
N2O- Nitrous oxide
NAFTA-North American Free Trade Agreement
NAVOS- Aftercare former-landfills' program
NGOs-Non-governmental organizations
NOM-Official Mexican Standards
PROFEPA- Federal Prosecutor's Office for Environmental Protection
SECIHTI- Ministry of Science, Humanities, Technology, and Innovation
SEDESOL- Secretary of social development
SEGAM- The Secretariat of Ecology and Environmental Management
SLP-San Luis Potosí State
SEMARNAP- Ministry of Environmental and Natural Resources and Fisheries
SEMARNAT- Ministry of Environmental and Natural Resources
USW-Urban Solid Waste
VOS- Exploratory research landfills program
VROM-Ministry of Housing and Spatial Planning

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Introduction

Landfills have emerged as a pressing issue for environmental specialists, sparking significant concern due to their ecological impact, particularly in regions burdened by legacy contamination. As a result, numerous contemporary agreements are being crafted with the primary goal of minimizing waste disposal in these sites. However, the challenges associated with landfills do not merely end with their operation; they also involve the crucial phase of site closure and post-closure management. These sites are responsible for generating a substantial amount of methane emissions, making landfills the third-largest man-made source of this potent greenhouse gas (Sustainable Solid Waste Systems n.d.). In fact, they account for approximately 11% of the global total methane emissions, according to data from C40 Cities report in 2016. Without effective regulatory oversight, abandoned landfills continue to emit harmful greenhouse gases, further exacerbating climate change concerns. Research conducted by Scharff, Van Zomeren, and Van Der Sloot in 2011 underscores the ongoing risks posed by these unregulated sites, highlighting the urgent need for remediation efforts to mitigate their disastrous environmental legacy.

Over the years, there has been an increasing awareness of the environmental and health risks associated with waste repositories, leading many countries to adopt rigorous regulations aimed at rehabilitating contaminated sites (Rangel 2011). As societies strive towards sustainable waste management, the remediation of neglected or poorly managed landfills has emerged as a pivotal issue in environmental governance, risk reduction, and land-use planning (Agamuthu 2013).

This thesis delves into the regulatory, technical, and institutional frameworks that underpin landfill remediation in two distinct contexts: the Netherlands and San Luis Potosí, Mexico.

Through a comparative case study methodology, the research evaluates how policy design, implementation strategies, and stakeholder engagement impact environmental and health outcomes within these jurisdictions. Moreover, it investigates how the insights gained from this analysis can support the realization of Sustainable Development Goal 11 (SDG 11), which seeks to foster inclusive, safe, resilient, and sustainable urban environments.

The Netherlands serves as a paradigm for progressive environmental policies and a holistic approach to land use and waste management. The country's approach to landfill remediation has developed within a robust legislative framework, shaped by various institutions dedicated to environmental wellbeing, particularly landfill issues. This approach is intricately linked to spatial planning policies and risk-based assessments, with objectives centered on public health, ecological preservation, and sustainable land use (S. Lieten and Dijcker 2018). Conversely, landfill remediation efforts in Mexico have largely been guided by federal legislation (López-Gasca et al. 2024). The situation in San Luis Potosí, particularly in Guadalcázar, highlights the challenges and often reactive nature of the country's remediation initiatives. While national regulations, including NOM-083 (2003) and NOM-147 (2004), were established to govern landfill operations and soil restoration, issues such as institutional fragmentation and external factors—including influences from international treaties like NAFTA—have significantly impacted local implementation processes (Schmidt, Flores Serrano, and Ruiz Saucedo 2013). The role of federal agencies underscores the necessity for multi-level governance in addressing intricate contamination challenges.

By comparing these two case studies, this thesis aims to elucidate how varying legal histories, institutional capabilities, and environmental emphases shape the remediation of contaminated landfill sites. Special focus is directed towards policy goals, funding frameworks, and the involvement of stakeholders. Ultimately, this study aspires to extract key lessons and policy recommendations that could lead to more efficient and just landfill remediation strategies applicable to middle-income countries, such as Mexico.

Chapter 1

1 Literature review

In this section, I gather various articles, policies, and pertinent information related to waste management and landfill remediation in the EU and Mexico. This topic is crucial to explore, as it highlights the primary challenges associated with landfills and their impacts on the environment. To clarify my research questions, I focus on the differing contexts between both places, examining the environmental frameworks, regulations, and organizations involved in this subject.

1.1 Landfills

Landfills continue to pose a significant environmental challenge globally, often exacerbated by insufficient regulations governing their construction, monitoring, and rehabilitation. While many countries are working to improve their standards to minimize waste disposal in landfills, numerous developing nations still depend on landfills due to their lower costs compared to alternatives like incineration or recycling (Agamuthu 2013) . Nevertheless, landfilling is still necessary for managing waste that cannot be recycled or treated through other means (Osazee 2021), emphasizing the vast amounts of waste generated each year that lead to the closure of numerous landfills. This scenario creates considerable challenges for waste management. Consequently, I have decided to revisit the traditional linear waste management system to propose solutions for the ongoing issues associated with landfills like climate change or greenhouse gases, aiming to address these challenges before they escalate further.

In a linear waste management system, several crucial steps take place: generation, storage, collection, separation, and finally, disposal. This document will explore the complex issue of disposal sites, focusing specifically on closed landfills that have not yet been remediated. These

decommissioned sites take significant environmental risks, casting a long shadow over local ecosystems and threatening the health and well-being of surrounding communities. The challenges presented by closed landfills are closely tied to the impending threat of climate change and its associated environmental issues. The impacts of climate change are evident in the form of Natural disasters that are becoming increasingly severe, such as rising sea levels that lead to more frequent storms and heavy rainfall. These extreme weather events disrupt fragile ecosystems and urban areas, where persistent flooding endangers the safety and livelihoods of residents.

Moreover, human activities are driving climate change by releasing vast amounts of greenhouse gases (GHGs) into the atmosphere, including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) (Osazee 2021). Among these sources, landfills are particularly notable (Figure 1), being the third-largest man-made contributor to methane emissions, accounting for approximately 11% of the global total. This staggering amount is equivalent to nearly 800 million metric tons of CO2, underscoring the urgent need for more sustainable waste management practices (Sustainable Solid Waste Systems n.d.).

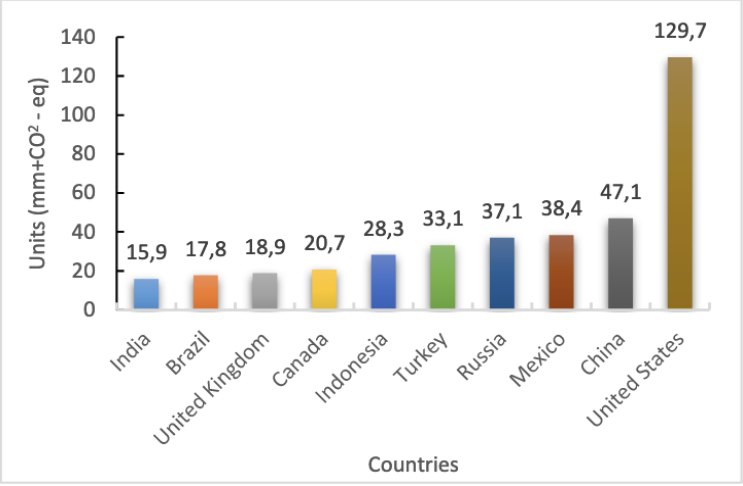


Figure 1. Methane Emissions from Landfills in ten countries. Source: Osazee 2021

Landfills can have a profoundly negative impact on the surrounding environment, adversely affecting the soil, water, and air quality in nearby communities, while also posing significant health risks to residents (Osazee 2021). These detrimental effects often stem from poorly designed and executed practices during both the construction and operation of landfills. In many cases, the

safety measures and technologies intended for effective waste management do not function as expected. This issue is especially pronounced in closed landfills, which frequently lack any form of post-closure remediation. Without proper oversight, these abandoned sites continue to emit harmful GHGs, as mentioned above, into the atmosphere (Scharff, Van Zomeren, and Van Der Sloot 2011). These gases can permeate through the soil and contaminate groundwater, leading to the pollution of local water supplies with toxic substances. The cumulative impact of unchecked landfill emissions results in deteriorating air quality, exacerbating respiratory issues among residents, and threatening the health of the local ecosystem. Therefore, without proactive management and remediation strategies, the legacy of inadequately managed landfills continues to pose serious risks to both environmental and public health.

To fully appreciate the core concept of this research, it is crucial to understand the historical context of landfill closures in both the European Union and Mexico, as well as to analyze the political strategies employed to tackle these issues. This full approach potentials to provide valuable perceptions into the interconnectedness of these challenges and their implications for sustainable development in both areas. To gain a clearer understanding of the study, it is crucial to familiarize oneself with the terminology related to landfills. This terminology will serve as a general framework for examining waste and environmental issues. However, the main focus of this discussion will be on two distinct case studies: The Netherlands and San Luis Potosí, México. It is important to highlight the differences in terminology specific to each location. In The Netherlands, there are two primary classifications of landfills. All landfills operating after September 1, 1996, are subject to strict aftercare regulations and are known as Sanitary Wm-landfills (S. Lieten and Dijcker 2018). As the authors mentioned, these landfills are meticulously

constructed with an impermeable layer—or an equivalent measure—to safeguard the underlying soil and groundwater. The second classification consists of Former landfills, which include sites that ceased to accept new waste after September 1, 1996 (*ibid).* Many of these former landfills are non-sanitary, although some were built under sanitary conditions *(ibid).* This category also encompasses illegal dumpsites as well as sites authorized by municipalities, which may include mono-landfills or landfills designated for household waste and construction debris *(ibid).*

In the context of San Luis Potosí, standardized categories are established throughout the country, which include former landfills, open dump sites, and sanitary landfills. Former landfills are designated areas for the final disposal of municipal solid waste that undergo a degree of inspection and surveillance, along with the implementation of necessary measures to ensure compliance with established regulations (PAOT, n.d.). Open dump sites are locations where various types of municipal solid waste are indiscriminately dumped and mixed without any control or environmental protections in place (ibid). Finally, Sanitary landfills, on the other hand, are engineered facilities specifically designed and operated to minimize impacts on public health and the environment during the disposal of municipal solid waste *(ibid).*

1.2 Political Environmental Framework in the European Union (EU) and Mexico

The environmental policy document states that the EU is founded on four key principles; the first is the precaution principle, which asserts that if an action or regulation could potentially harm people or the environment, it must be stopped until more information is available. The second principle is prevention, which emphasizes the importance of anticipating and averting potential environmental damage (European Parliament 2024). The third principle focuses on rectifying pollution at its source; this applies when environmental harm has already occurred, and it mandates that those responsible for the pollution address the issue *(ibid)*. Finally, the fourth principle is "the

polluter pays," which holds that polluters are responsible for remedying the situation and covering the associated costs (European Parliament 2024). This principle is incorporated into the Environmental Liability Directive, which aims to prevent and address environmental harm to protected species, natural habitats, water, and soil *(ibid)*.

The political structure (Figure 2) focused on the environment is led by the European Commission, which is in charge of the Directorate-General for Environment (DG-ENV) and is responsible to lead in drafting EU waste legislation and policies, monitoring member states' compliance with directives, and initiating infringement procedures if laws are not implemented (European Commission 2025).

For the next level of the structure, we identify three key components. Firstly, the European Parliament plays a significant role in shaping EU environmental law. During its eighth term (2014-2019), it addressed legislation stemming from the circular economy action plan, which includes topics such as waste management, batteries, end-of-life vehicles, and landfilling (Parliament 2025). Additionally, it tackled climate change issues, including the ratification of the Paris Agreement, efforts towards sharing responsibilities, accounting for land use, land-use change, and forestry in the EU's climate commitments, and reforms to the Emissions Trading System, among other areas. (European Commission 2024). Next, the Council of the European Union, commonly referred to as 'the Council,' serves as a crucial decision-making body within the EU (European Council 2025). It convenes the ministers from the 27 member countries to negotiate and adopt EU legislation and coordinate various policies. Additionally, the Council is responsible for adopting the EU budget, concluding international agreements on behalf of the EU, and shaping the EU's foreign and security policy. The Council operates at three distinct levels: Ministers, Permanent Representatives, and working parties/committees (European Council 2025). The third key for the

political structure is the European Environmental Agency (EEA), which actively supports Europe's environmental and climate policies.

“Among its main functions are:

1. Close cooperation with a multitude of organizations at European, regional, and global levels.
2. Collect and validate data from reliable sources to analyze trends and produce policy-relevant analyses on environment and climate topics.
3. Explore emerging issues and tools within our areas of expertise.
4. Make sure to solely rely on trustworthy sources source for data collection and knowledge.” (European Environment Agency 2025b)

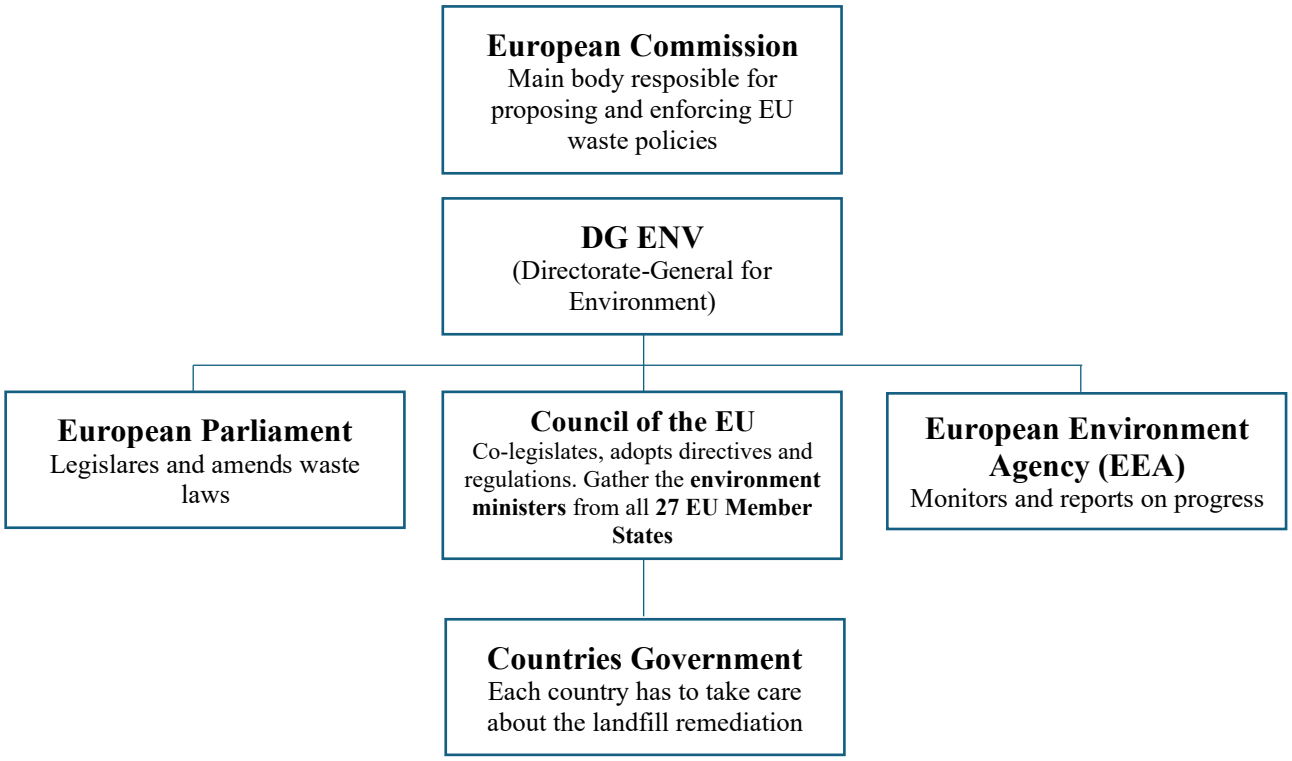


Figure 2. Own design, environmental political structure organigram in the EU

When discussing directives relevant to landfill remediation, it is essential to highlight five key directives and strategies. The first is the Waste Framework Directive, which asserts that landfilling should be the last resort for waste disposal (European Commission 2025b). As the Waste Framework Directive mention, it establishes principles such as the waste hierarchy and promotes the remediation of illegal or non-compliant landfills. Additionally, it emphasizes the importance of monitoring hazardous waste that has already been disposed of (European Commission 2025b). The second directive is the Landfill Directive, which outlines the requirements for the closure and aftercare of landfills, including necessary pollution control measures (Landfill Directive 2025). The third is the Environmental Liability Directive, which holds operators financially accountable for environmental damage affecting soil and water (European Commission 2007). The fourth directive, the Water Framework Directive, specifies the requirements for the protection and remediation of water bodies impacted by landfill leachate (European Commission 2000). Finally, the Soil Strategy focuses on the myriad benefits that healthy soils provide, which are crucial for human well-being, sustainable food production, biodiversity, and climate resilience (European Commission 2025a). The Commission is still working on this strategy to ensure to turn it into a directive to make it equivalent to the water protection law (European Council 2025). Moreover, it is the responsibility of each member state's government to identify contaminated or illegal landfill sites, enforce closure and remediation requirements, apply the polluter pays principle where applicable, and develop national remediation plans or brownfield strategies (Council Directive 1999). Additionally, an important aspect of the EU's support for environmental regulations is the Cohesion Policy, which helps achieve many EU policy objectives. The European Green Deal is among the projects financed in regions and cities

that contribute to the priorities of the Commission priorities (EU 2025.). A summary of the Directives and strategies are enlisted in the Figure 3.

Directive	Role of landfill remediation
Waste Framework Directive (1975-1991-2006-2008)	Sets principles like waste hierarchy and promotes remediation of illegal or non-compliant landfills
Landfill Directive (1999-2020)	Requires closure and aftercare of landfills, including pollution control
Environmental Liability Directive (2004-2009)	Makes operators financially liable for environmental damage (soil, water)
Water Framework Directive (2000-2009-2015)	Requires protection and remediation of water bodies affected by landfill leachate
Soil Strategy / EU Soil Monitoring Law (2021-…)	Addresses contamination risks, and promotes soil health (not yet a binding directive)

Figure 3. Own abstract from the different directives and strategies related to landfill, water, and soil remediation. Source: Waste Framework Directive, Landfill Directive, Environmental Liability Directive, Water Framework Directive, Soil Strategy, 2025

Mexico's environmental framework (Figure 4) is governed by three key federal institutions. The primary agencies involved are the Ministry of Environmental and Natural Resources (SEMARNAT), the Federal Prosecutor's Office for Environmental Protection (PROFEPA), and the National Institute of Ecology and Climate Change (INECC), which was established more recently.

SEMARNAT is a government entity dedicated to the protection and sustainable management of the nation's natural resources and environment. Founded in 1992, SEMARNAT plays a crucial role in developing and implementing policies related to environmental conservation, biodiversity, and natural resource management. Its objectives are aligned with both national and international environmental commitments, ensuring that Mexico meets its sustainable development goals (Sauceda and Sánchez 2020). In contrast, PROFEPA is responsible for monitoring and evaluating compliance with legal provisions that pertain to the restoration, preservation, and protection of natural resources (PROFEPA 2025). This agency conducts

inspections, addresses public complaints, and promotes civic engagement in environmental protection efforts *(ibid)*. Lastly, INECC serves as a research organization within the Mexican State, generating and integrating technical and scientific research on ecology and climate change to inform decision-making processes (Federal Government 2025). The Institute was established concurrently with the enactment of the General Law on Climate Change (Federal Government 2025).

For the local decisions, states are required to follow the policies set by these three key organizations; however, the laws and regulations often tend to be quite general. When it comes to landfill remediation and reuse, each state has the autonomy to address waste management issues based on its unique circumstances. States are aware of the challenges they face and have the flexibility to create regulations tailored to their specific needs. As a result, some states have developed more effective waste management regulations than others. This situation highlights the importance of analyzing specific case studies within states to enable meaningful comparisons of regulatory practices.

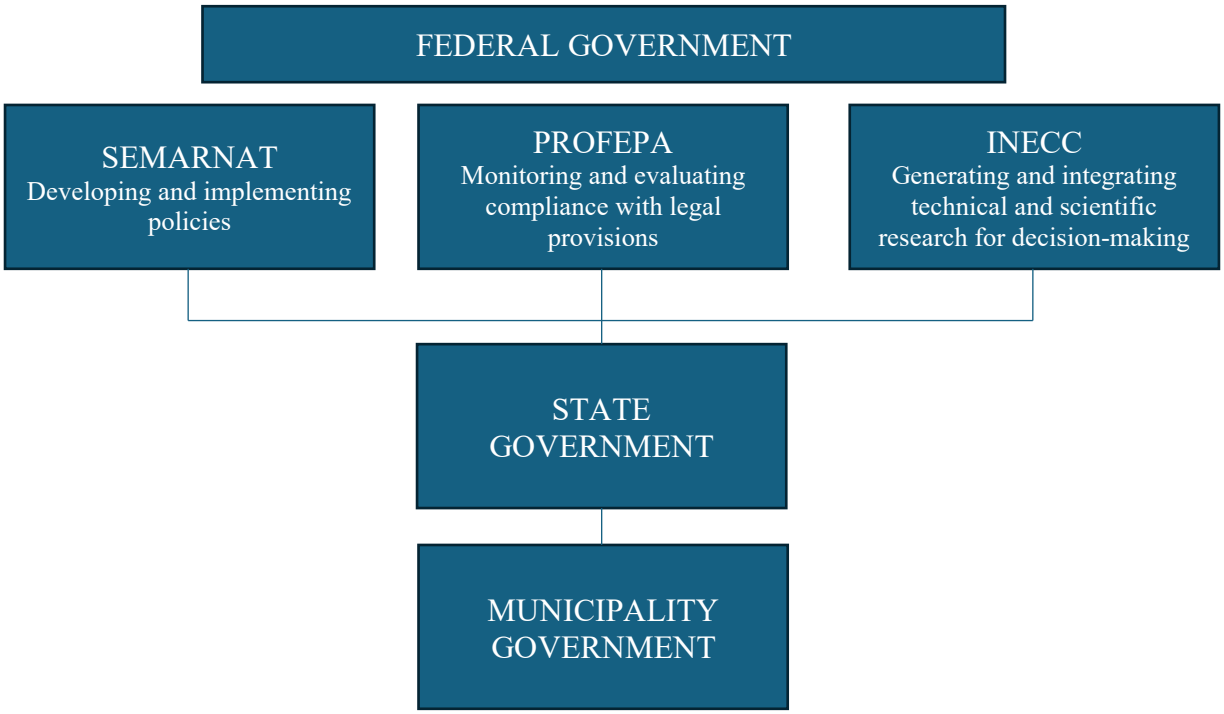


Figure 4. Own design, environmental political structure organigram in Mexico, 2025

In Mexico, various regulations are in place to address the remediation of contaminated sites; however, there are no specific standards dedicated to landfills. The pertinent regulation identified as NOM-083 governs these sites and outlines the necessary procedures for closure, particularly detailing the monitoring period required before a site can undergo remediation. Unfortunately, it does not sufficiently address potential solutions for repurposing the site post-remediation. For this reason, I needed to explore regulations focused on soil and water remediation to understand how these standards might relate to those for landfills.

1.3 Waste Framework

In this section, I will present an overview of waste generation in the EU and Mexico, highlighting the number of operational landfills and the sites that have undergone remediation. This information will enhance our understanding of the current situation in these regions and allow us to form an objective perspective on how this issue is being addressed in each area.

1.3.1 European Union (EU) Framework

In 2022, the total waste generated in the EU by all economic activities and households amounted to 2,233 million tonnes or 4,991 kg per capita (Eurostat 2024). The Figure 5 shows the waste generation per capita in 2022 for each country that are part of the EU. For this reason, the EU Directive on waste landfills has introduced specific goals for reducing the volume of disposed waste and very strict requirements for landfilling and landfilling sites (European Parliament, 1386/2013/EU 2013) which encourage member countries to work towards a gradual reduction of Municipal Solid Wastes (MSW) to 75% of the 1995 disposal level by 2010 and 35% reduction by 2020 (Osazee 2021). Regardless of this directive, the situation in Europe is not homogeneous. For

example, Switzerland, Germany, the Netherlands, Sweden, Austria, Denmark, and Belgium report landfilling below 5% of waste produced (Vaverková 2019). However, it is estimated to have between 150,000 and 500,000 landfill sites, with approximately 90% classified as "non-sanitary" landfills, having been established before the EU Landfill Directive of 1999 (Council Directive 1999). This situation presents a significant challenge, especially considering that these sites will eventually need or already have been closed.

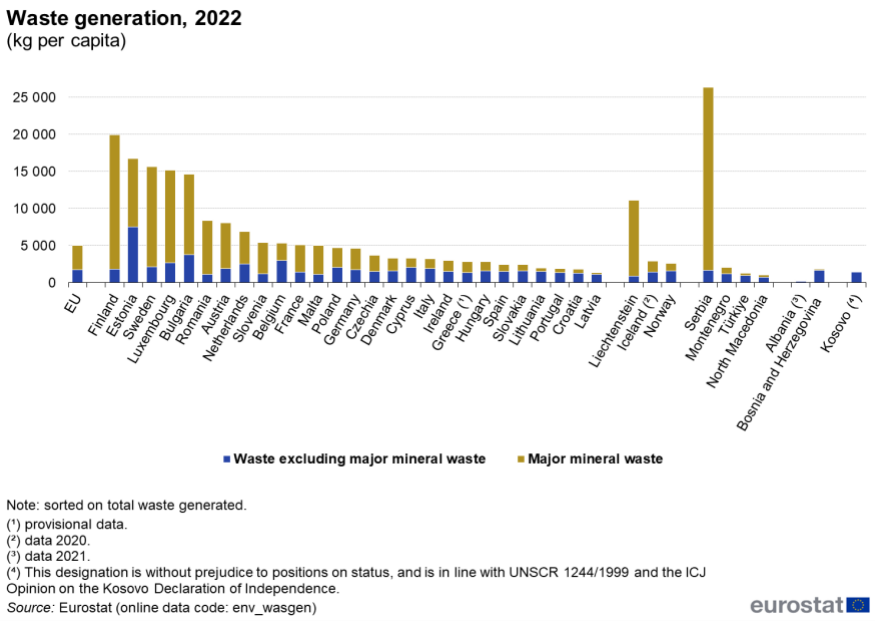


Figure 5. Waste generation in EU in 2022 (kg per capita). Source: (Eurostat 2024)

Their strategy of reducing waste (Figure 6) is related to the structure of how the decisions and proposals are done for all the countries that are part of the EU. One of the requirements outlined in the Landfill Directive of 1999 is that, shortly, landfilling will be limited to inert materials that are neither biodegradable nor combustible (Council Directive 1999). The primary goal of this regulatory change is to substantially mitigate the emissions of methane gas which is produced

principally from organic waste decomposes in anaerobic conditions. Nevertheless, it may take more time to be applied especially in the new nations joining the EU (Themelis and Ulloa 2007).

Country	1995	2016	2017	Waste Treatment—Landfill, 2016 (Share of Landfill Disposal)
Austria	480	552	570	3%
Belgium	446	414	409	1%
Bulgaria	531	404	416	64%
Cyprus	595	592	637	81%
Czech Republic	312	339	344	50%
Denmark	521	777	781	1%
Estonia	370	327	390	12%
Finland	437	504	510	3%
France	476	510	513	22%
Germany	623	625	633	1%
Greece	331	498	-	82%
Hungary	377	380	385	51%
Ireland *	430	615	-	22%
Italy	468	436	489	28%
Latvia	184	367	438	72%
Lithuania	542	422	455	31%
Luxemburg	587	614	607	17%
Malta	387	584	604	92%
Netherlands	509	518	513	1%
Poland	284	307	315	37%
Portugal *	351	483	487	49%
Romania	254	228	272	80%
Slovakia	294	344	378	66%
Slovenia **	469	434	471	24%
Spain	365	443	462	57%
Sweden	386	442	452	1%
United Kingdom *	501	476	-	28%

* Data from 2014; ** Data from 2015.

Figure 6. Municipal solid waste generated in 1995 and 2016 in the EU (kg/capita), Source: Vaverková 2019

According to this database, the Netherlands stands out as the most efficient country in waste management regulations. It not only focuses on minimizing the volume of waste sent to landfills but also actively remediates those that have already been closed. For this reason, I have chosen to explore a case study in this area (S. Lieten and Dijcker 2018) . I aim to draw a comparison between the regulations and norms in place in Mexico and the European Union to enhance Mexican policy. Therefore, it makes sense to investigate one of the leading examples of remediation for this study.

1.3.2 Mexican Framework

According to the "Basic Diagnosis for Waste Management" published by the Ministry of the Environment and Natural Resources (SEMARNAT) in 2020, the calculated per capita waste generation stands at 0.944 kg per inhabitant per day, with the total waste generation in the country estimated at 120,128 tons per day (INEGI 2023). Mexico has been implementing various initiatives to raise awareness about the importance of minimizing unnecessary purchases and properly

separating waste for recycling. One notable effort is the waste management program launched by the National Council of Humanities, Sciences, and Technologies (CONAHCYT), now referred to as the Ministry of Science, Humanities, Technology, and Innovation (SECIHTI). This program was developed in collaboration with the Center for Research and Advanced Studies in Social Anthropology (CIESAS) of the Gulf of Mexico. The cities selected for this initiative—Acapulco, Cuetzalan, Tlaxcala, Ensenada, Coatzacoalcos, and Papantla—were chosen based on a study assessing recycling generation, separation practices, and resource availability. This initiative aims to gather successful local waste management practices and replicate them on a larger scale (CONAHCYT 2022.). However, despite these efforts, the challenge of reducing waste remains significant, with substantial amounts still being deposited in landfills and open dump sites.

The country has more than two thousand disposal sites for urban solid waste (USW) generated in the country (Figure 7). According to the National Institute of Statistics and Geography (INEGI) 87% are open dump sites and just 13% correspond to landfills between former and sanitary (INEGI 2019) and from this, only few comply with sanitary and safety measures required by the NOM-083 (Federal Government 2003). According to the latest report from SEMARNAT, a total of 337 closed disposal sites have been remediated (Figure 8) between 2001 and 2024 (SEMARNAT 2024), all of them need to achieve the standards named in the NOM-147, related with contaminated sites and remediation (Federal Government 2004). However, the majority of these sites were only addressed after they had escalated into environmental crises. Nevertheless, when such deposits are not officially registered, organizations lack a comprehensive understanding of the situation, which impedes closure efforts and, ultimately, the potential for remediation. This

issue primarily stems from inadequate policies regarding the interval between site closure and remediation monitoring.

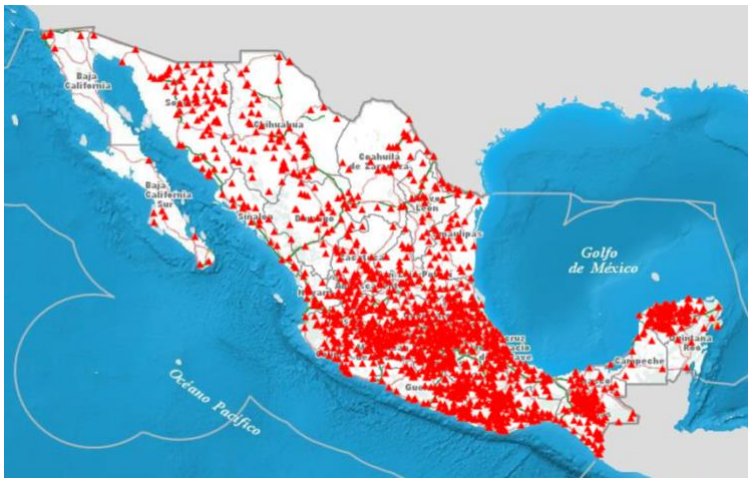


Figure 7. Disposal sites in Mexico, more than two thousand sites distributed in the country, considering open dumps, former lanfills and sanitary landfills. Source: INEGI, 2024

Figure 8. Mapping of the closed and remediated disposal sites in Mexico, period between 2001-2024. Source: Own design with SEMARNAT, 2024

In the realm of site remediation, San Luis Potosí stands out as a prominent example in Mexico, having established a series of regulations and remediation plans in response to its mining history. The primary focus of these regulations is land remediation resulting from extensive mining excavation (*INEGI* 2002). Over time, these standards have expanded to encompass soil remediation and, subsequently, landfill management. Therefore, my case study is situated in this state to examine and compare the most effective regulations that Mexico has implemented in such contexts. The aim is to explore opportunities for enhancing solutions and regulations, ultimately to develop a model that other states can adopt for improving their environmental frameworks regarding landfill remediation.

1.4 Environmental Legislative Landfill Framework in The Netherlands and San Luis Potosí

The Netherlands legislative environmental framework started with the former law-Nuisance Act- stablished in the 1875 (S. Lieten and Dijcker 2018). This law described the rules for businesses/activities that could cause risk, damage or 'nuisance' to the environment (S. Lieten and Dijcker 2018). After, the national remediation policy was stablished in 1980, which focuses on stringent waste treatment standards; landfills bans in place of materials that can be treated/recycled with best available techniques (S. Lieten and Dijcker 2018).

In response to incidents involving former landfills, such as the Volgermeerpolder, and growing concerns about the environmental and societal impacts of hazardous waste management, the Netherlands initiated the Exploratory Research Landfills (VOS) project (S. Lieten and Dijcker 2018). The primary goal of this initiative was to collect information on existing landfills, beginning with their locations and later assessing the financial implications of non-sanitary landfills (*ibid)*. To better understand the risks associated with these former landfills, the "Aftercare Former Landfills" (NAVOS) program was established in the 1990s according to the Netherlands Landfill Management report of 2018. At the same time, the National Waste Stakeholders Council was created, and the Dutch government began addressing contaminated sites resulting from human activities *(ibid).* The council's main objective was to unite all stakeholders in the waste management system, including national and local authorities, as well as waste management agencies *(ibid)*. This collaboration aimed to discuss and approve potential legislative measures before they were submitted to the Dutch parliament *(ibid)*. This approach has been a fundamental aspect of the long-standing tradition of consultation in the Netherlands, promoting cooperation among government entities, citizens, and civil society organizations *(ibid)*.

According to the Landfill Management document of the Netherlands, on March 1, 1993, the Environmental Management Act was enacted, superseding the former Nuisance Act, Wastes Act, and Chemical Waste Act (S. Lieten and Dijcker 2018). This new legislation introduced a more integrated approach to environmental management within the country and established a comprehensive legal framework delineating the roles of national, regional, and municipal governments (*ibid)*. In addition to maintaining oversight of operational landfills, the national government delegated the management of former landfill sites to regional authorities (S. Lieten and Dijcker 2018). As a result, this decentralization permits provinces to act as the competent authority, granting them jurisdiction over landfill management, which facilitated the monitoring these sites and make sure to carry out the necessary actions to rehabilitate the spaces *(ibid)*. The primary concern with this regulation is that only sanitary landfills operational after September 1, 1996, are governed by the Environmental Act. As a result, former landfills that were active prior to that date do not align with the EU Directive 1999/31/EC (S. Lieten and Dijcker 2018).

Another significant decree in the history of landfills in the Netherlands is the Landfill and Soil Protection, enacted in January 1993 *(ibid)*. According to the report, this decree sets forth the essential measures required during the construction of a landfill and applies to all landfills that commenced operations after September 1, 1996. On the other hand, in terms of important organizations for the environmental legislation and landfills field is the Dutch Waste Management Association which represents about two-third of the Dutch waste market and negotiates on their behalf with the government and other organizations (Dutch Waste Management Association (DWMA) n.d.). This body helped to create in 1999 the Dutch Sustainable Landfill Foundation which represents all the Dutch landfill operators with the aim to ensure that new landfill sites stance no risks for environment or people (Sustainable Landfill Foundation 2025).

The Netherlands enforces specific regulations regarding aftercare following the closure of sanitary landfills, as delineated in the Environmental Management Act. According to this Act, prior to closing a landfill, the owner must submit an 'Aftercare Plan' to the province, which has the authority to approve or reject the plan, either in whole or in part. This plan must encompass both technical and financial components. Once the plan and the landfill's closure are approved, the province assumes administrative, financial, and organizational responsibility for the site's aftercare (Ministry of Housing, Spatial Planning and the Environment 2004).

To facilitate project financing, an Aftercare Fund has been established, into which provincial charges from landfill owners are deposited (S. Lieten and Dijcker 2018). The province, acting as the competent authority, is responsible for a range of tasks, including the approval of aftercare plans, the final top cover, estimating aftercare costs, managing the Aftercare Fund, issuing a closure statement, and overseeing aftercare activities *(ibid).* Under Dutch legislation, once a landfill is closed, the responsibility for administration, finances, and environmental management is transferred from the site owner to the regional authority or province. However, in accordance with the EU Landfill Directive, the site owner remains liable for costs for a minimum period of 30 years. Figure 9 clearly represents the various conditions for funding and managing the sites during operations and after their use.

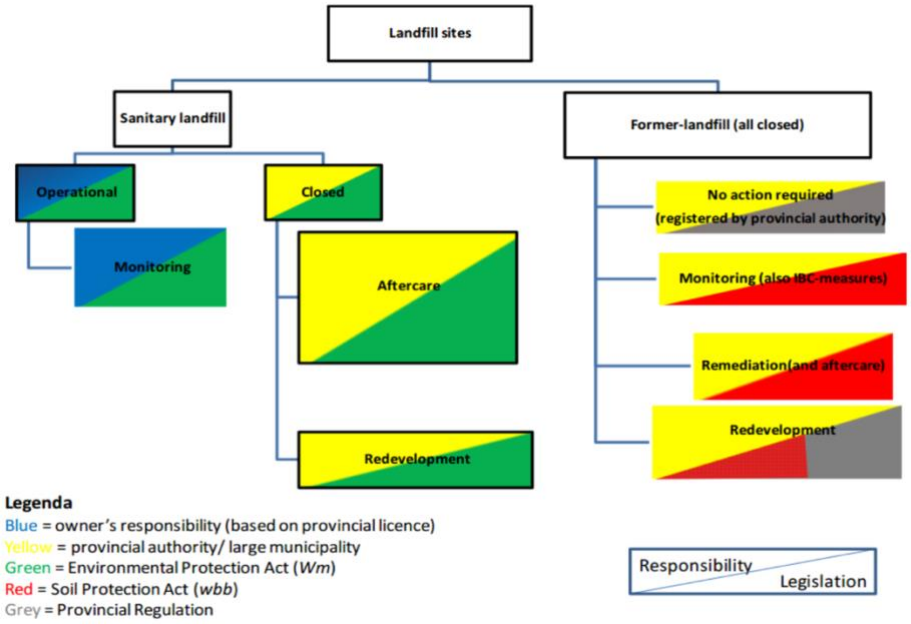


Figure 9. Responsible actor, competent authority and relevant legislation specified for landfills in the Netherlands. Source, (S. H. Lieten, Dijcker, and Dijcker 2018)

As it stands, San Luis Potosí lacks comprehensive regulations specifically designed for the management and operation of landfills. The regulatory framework governing landfills in the region primarily stems from national legislation, particularly the LGPGIR (Federal Government 2015). Additionally, two key legislative instruments, the NOM-083 (Federal Government 2003) and NOM-147 (Federal Government 2004), contribute to shaping the regulatory landscape . At the state level, the Environmental Law of San Luis Potosí (San Luis Potosí Government 1999), enacted in 1999, establishes the foundation for environmental governance; however, it does not specifically address operational standards for landfills. The most recent legislation concerning environmental issues is the Climate Change Law (2020) (San Luis Potosí Government 2020), yet it also falls short by failing to provide detailed guidelines on the lifecycle management of landfills, including aspects such as design, operation, and closure procedures. Overall, the information available regarding landfill management in San Luis Potosí remains basic, lacking both depth and specificity.

Moreover, there are no designated funds for landfill remediation initiatives, highlighting a significant gap in environmental investment and support. This financial shortfall contributes to an absence of data on both past and present landfill remediation efforts, leaving stakeholders with limited understanding of the methodologies and effectiveness of such projects. Furthermore, the lack of detailed regulations and protocols for addressing landfill-related issues complicates the ability to effectively tackle environmental challenges within this sector.

With this detailed information in hand, I can now explore the methodology more comprehensively, examining the complex connections between the case studies like the existing regulations, and the diverse actors involved in the management of landfills remediation. This detailed analysis will allow me to determine how these studies have positively influenced legal frameworks within their respective jurisdictions. Through this effort, I aim to identify best practices and innovative strategies that will enhance environmental sustainability and public health in the region.

Chapter 2

2 Methodology

To embark on this project, I employed a qualitative comparison approach; by examining lobbying practices within both the EU and Mexico, I aim to reveal overarching similarities and differences. My literature review highlights the importance of considering specific cases to facilitate a more comprehensive comparison of local policies. Consequently, I have selected two distinct case studies of remediated closed landfills—one in the Netherlands and the other in San Luis Potosí. These cases were chosen based on the effectiveness of their remediation policies, the type of disposal site (hazardous waste), the end-reuse of the land, and the availability of information regarding the sites before and after remediation. My objective is to explore the processes involved, the stakeholders engaged in decision-making and actions, and the policies that were implemented. Through this analysis, I seek to draw comparisons concerning the outcomes in each region and identify potential areas for methodological enhancements in the implementation of policies in Mexico. I will primarily utilize resources such as the European Commission database, The Netherlands government as well as data from the Mexican and San Luis Potosí government and scholarly articles.

2.1. Theoretical framework

In social sciences, there are four fundamental control processes: experimental, statistical, comparative, and historical. Among these, the comparative method is the most accessible for public policy analysis; it serves as a bridge between abstract concepts and tangible realities. This process enhances the ability to evaluate policy experiences across various geographic levels—regional, national, and subnational—as well as through different historical periods. Additionally,

incorporating historical, political, economic, and social elements allows for a deeper understanding of the evolution of public policy and the varying roles organizations and public servants play in different contexts (Bulcourf and Cardozo 2008). For effective public policy comparison, it is essential to first establish a solid classification of elements that can be compared, moreover across different countries. According to Borsotti, the process of construction should be linked to a problematic situation that is considered unacceptable from a normative perspective. This relevance is crucial for contributing empirical knowledge to explain these issues (Borsotti 2007). From this understanding, my research questions are:

Research Question:

What are the challenges and elements of adapting EU waste management regulations in the Mexican context to remediate and reuse closed landfills?

Sub Question:

What are the contributions of EU policies for landfill remediation in comparison with Mexican policies?

This will help me to explore the feasibility of generating regulations that can foster innovative and improved solutions in this field for Mexico, from this explanation I created a diagram for my theoretical framework with all the elements to take in account for the research (Figure 10).

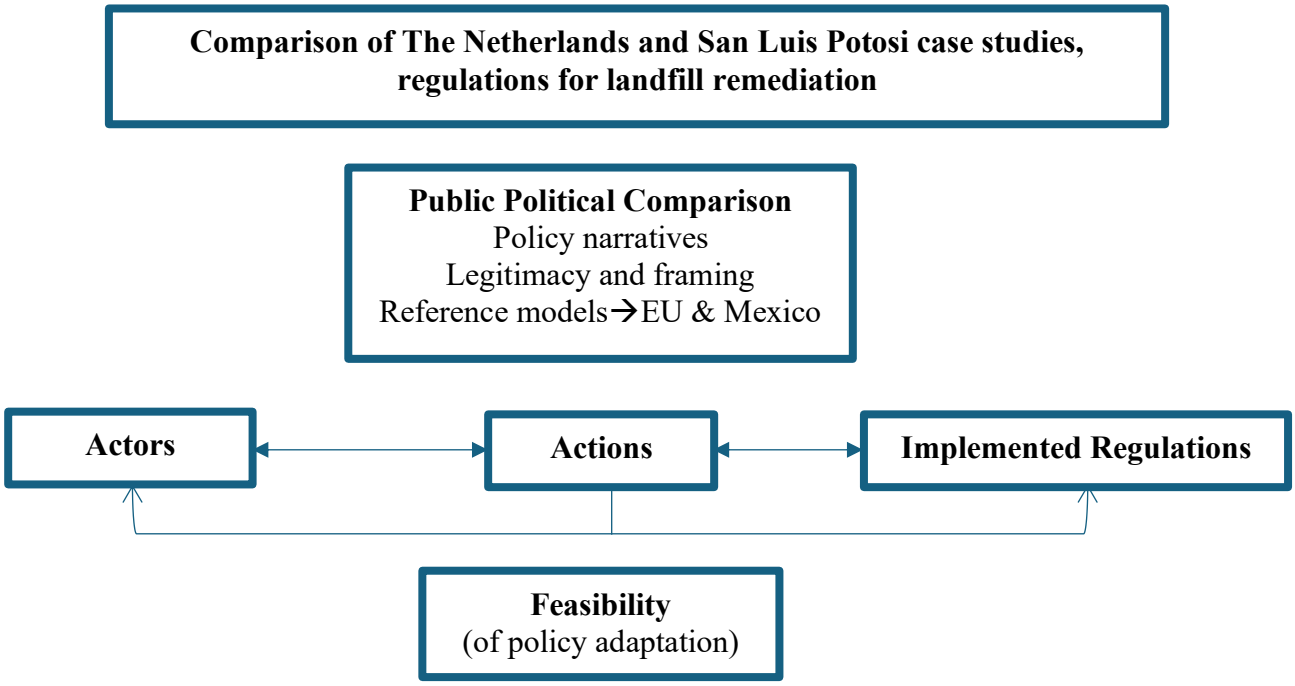


Figure 10. Adaptation of the Public Political Comparison for the study cases.

2.2. Database

This study includes a comprehensive database that includes the following information:

• A literature review of the specific case studies examined

• Reports detailing the remediation processes implemented in each case

• A compilation of environmental policies in the EU and Mexico

The selected study periods are connected to the duration required for the complete remediation of the sites. For the Netherlands, the timeframe spans from 1990 to 2011, while for San Luis Potosí, it covers 1993 to 2009. This timeframe also facilitates an understanding of the evolution of environmental regulations in both regions and how various stakeholders have interacted to provide solutions for remediation.

2.3. Research procedure

In order to conduct a comprehensive and insightful comparison of the policies in these two cases, I examined the relevant regulations and pinpointed the key stakeholders involved in each scenario. My objective was to uncover the intricate interconnections between these elements, highlighting both the distinct differences and the underlying similarities in the remediation processes. I developed a detailed timeline that documents the various regulations enacted throughout these remediation efforts. This timeline acts as a visual representation, illustrating the evolving relationships between the regulations and the stakeholders over time. By employing this approach, I will be able to provide a nuanced and updated overview of each factor once the comparison and analysis are finalized (see Figure 11).

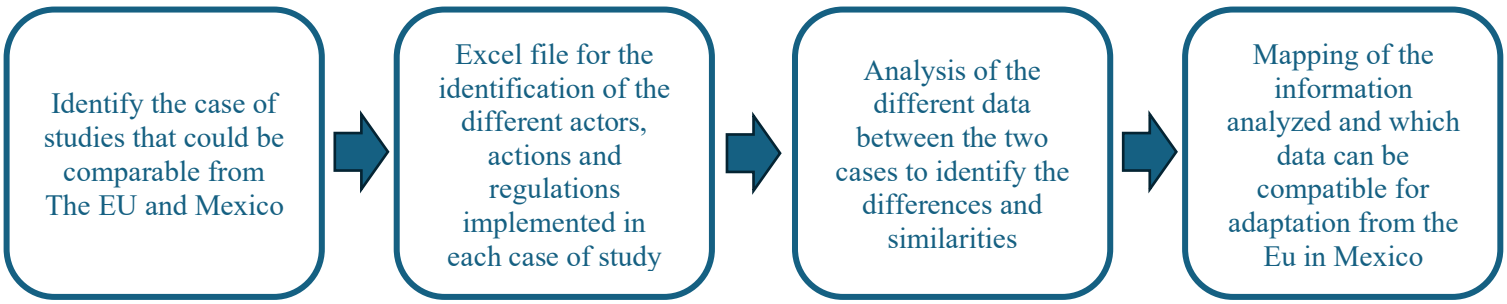


Figure 11. Steps for the research procedure. Own design.

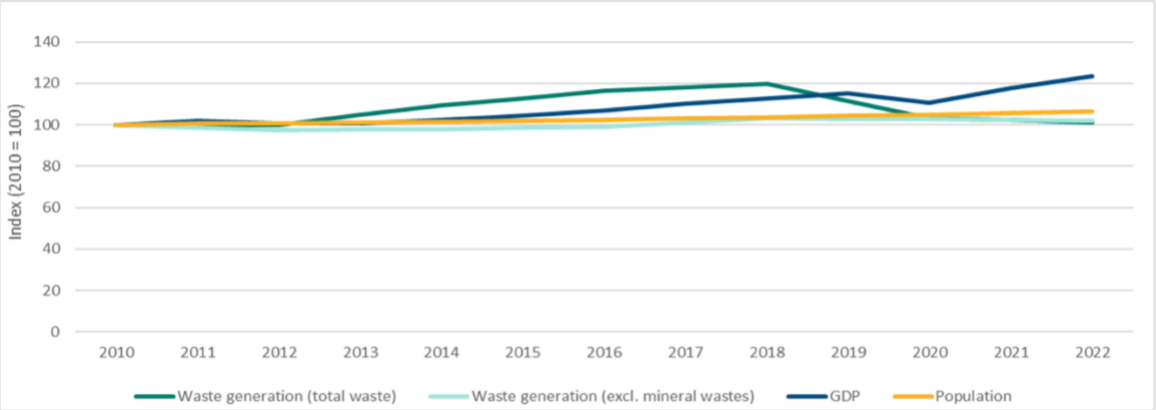
Limitations of the study

The lack of comprehensive information regarding remediated sites in Mexico is quite striking. Although a list of these sites exists, my thorough investigation revealed that detailed insights are remarkably limited. This deficiency in in-depth information was a primary factor in selecting "La Pedrera" as the focus of my case study. As I navigated through various sources, I encountered challenges in obtaining a complete dataset; nevertheless, I managed to uncover pertinent information that enriched my analysis for this particular study. Additionally, the nature

of the available information presented certain limitations, especially given that my research was conducted abroad my methodology didn't include interviews and all I needed to focus on the information directly from online resources, including government websites, academic articles, and accessible legislative documents. Furthermore, it's important to recognize that the case studies I compared were rehabilitated quite some time ago. However, I was able to draw comparisons between the regulations and organizations involved in these studies and how they have evolved over time under current conditions in various regions.

2.4. Case Study in The Netherlands

In 2023, Municipal Waste Generated in the Netherlands was 451 kg/cap of municipal waste, which means a generation of 9.3 million tons approximately (Netherlands 2024). In the Netherlands, waste management is organized at the national level, primarily through central environmental legislation and the Dutch law on packaging waste (Rijkswaterstaat 2024). According to the national government of The Netherlands, both the Dutch National Waste Prevention Plan and the National Waste Management Plan have been updated to align with the Waste Framework Directive, which was amended in 2018. The Figure 12 shows the generation of waste from the 2010-2022 and how this has been changing during these years.



Source: Eurostat (2024a, 2024b, 2024f)

Note: Waste generation data for odd years are interpolated.

Figure 12. Generation of waste (total and excluding major mineral wastes), population and economic development, 2010-2022 in The Netherlands. Source: Waste Management Country Profile, 2025

Additionally, there is an action plan in place aimed at implementing a circular economy by 2050 (European Environment Agency 2025). The Netherlands also emphasizes waste prevention measures through the National Waste Prevention Program, which originates from the circular economy initiative "Netherlands Circular in 2050" *(ibid)*. All these efforts are intended to comply with the regulations established by the EU Commission.

Nowadays the Netherlands is known as one of the most important countries in the EU with the best technologies, initiatives, and policies for landfill remediation, also, this country relies on incineration for the disposal of mixed municipal waste *(ibid)*. The Dutch disposal tax is equal for landfilling and incineration and is adjusted annually (European Environment Agency 2025), this is

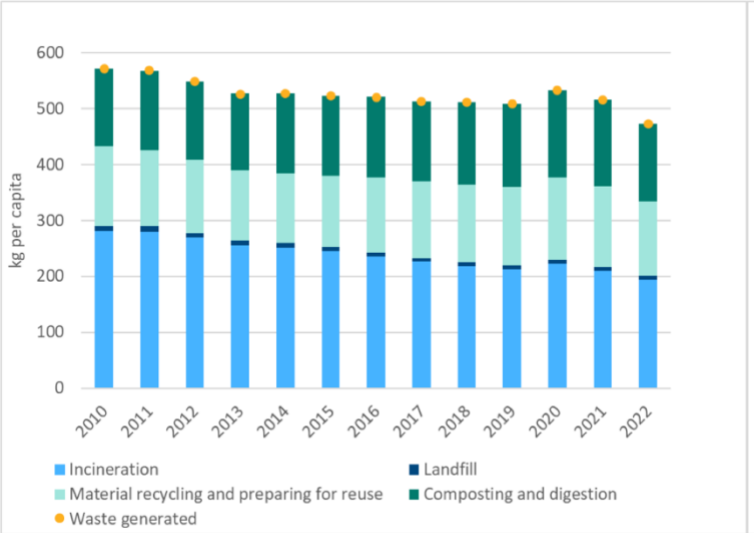


Figure 13. Waste disposal in The Netherlands from 2010-2022. Source: Waste Management Country Profile, 2025

one of the biggest regulations that helped the country to stop disposing waste in landfills. In the 1970s there were over 1600 operational landfills, this number dropped to approximately 200 in the 1980s and to 80 in 1992, currently, only 19 landfills are operational (S. Lieten and Dijcker 2018). Many regulatory interventions have led to this decrease *(ibid).* For this study, I am going to focus on the project of remediation in Amsterdam on the case study of The Volgermeerpolder (Figure 14,15). It is an area of approximately 105 ha, located 5 km north of the city of Amsterdam in a marshy polder with shallow groundwater, open water, and peaty soils (EcoShape 2025). Which nowadays is a nature reserve.

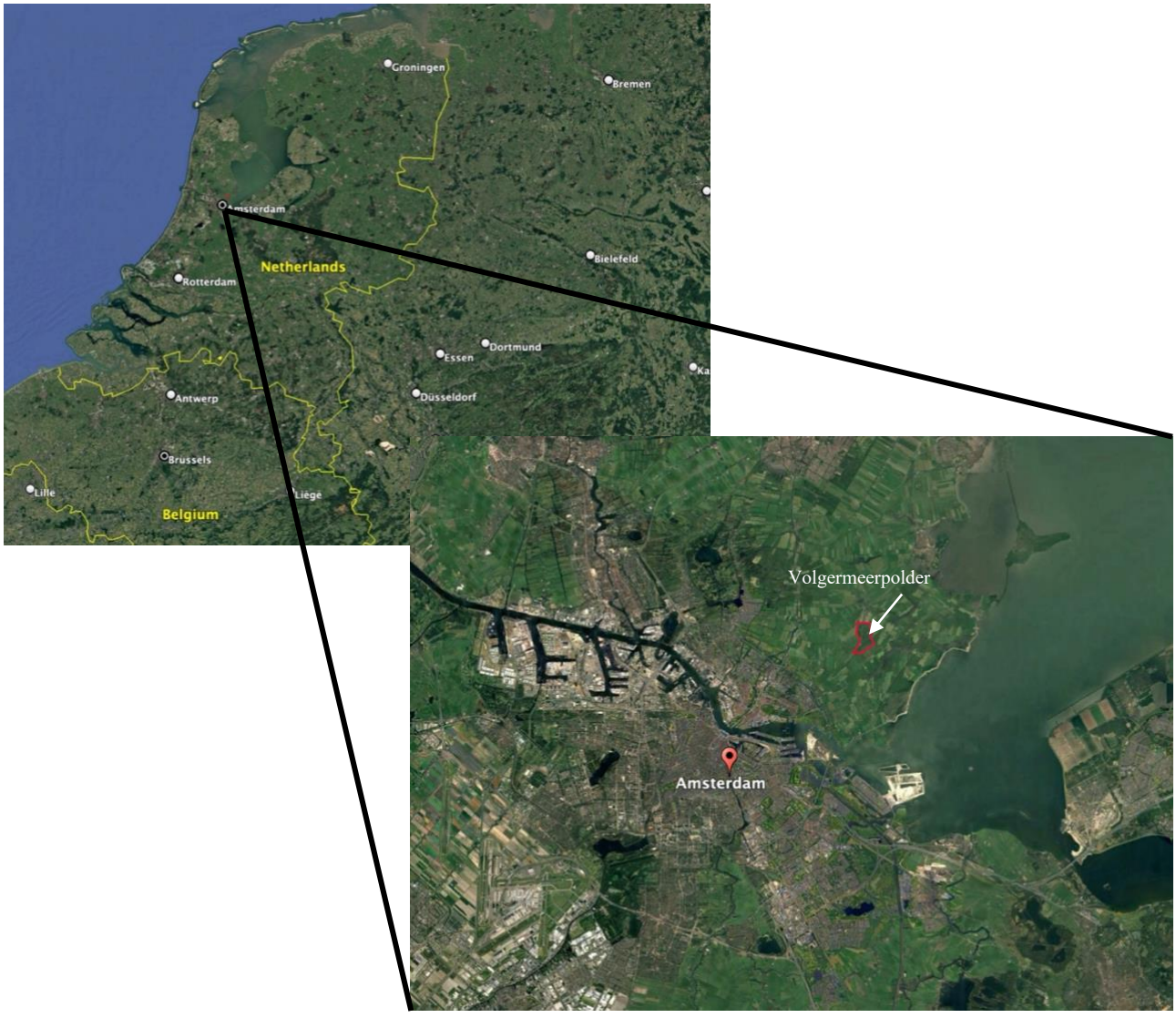


Figure 14. Localization of the Case Study in Volgermeerpolder, Amsterdam. Source: Google Earth Pro, 2025

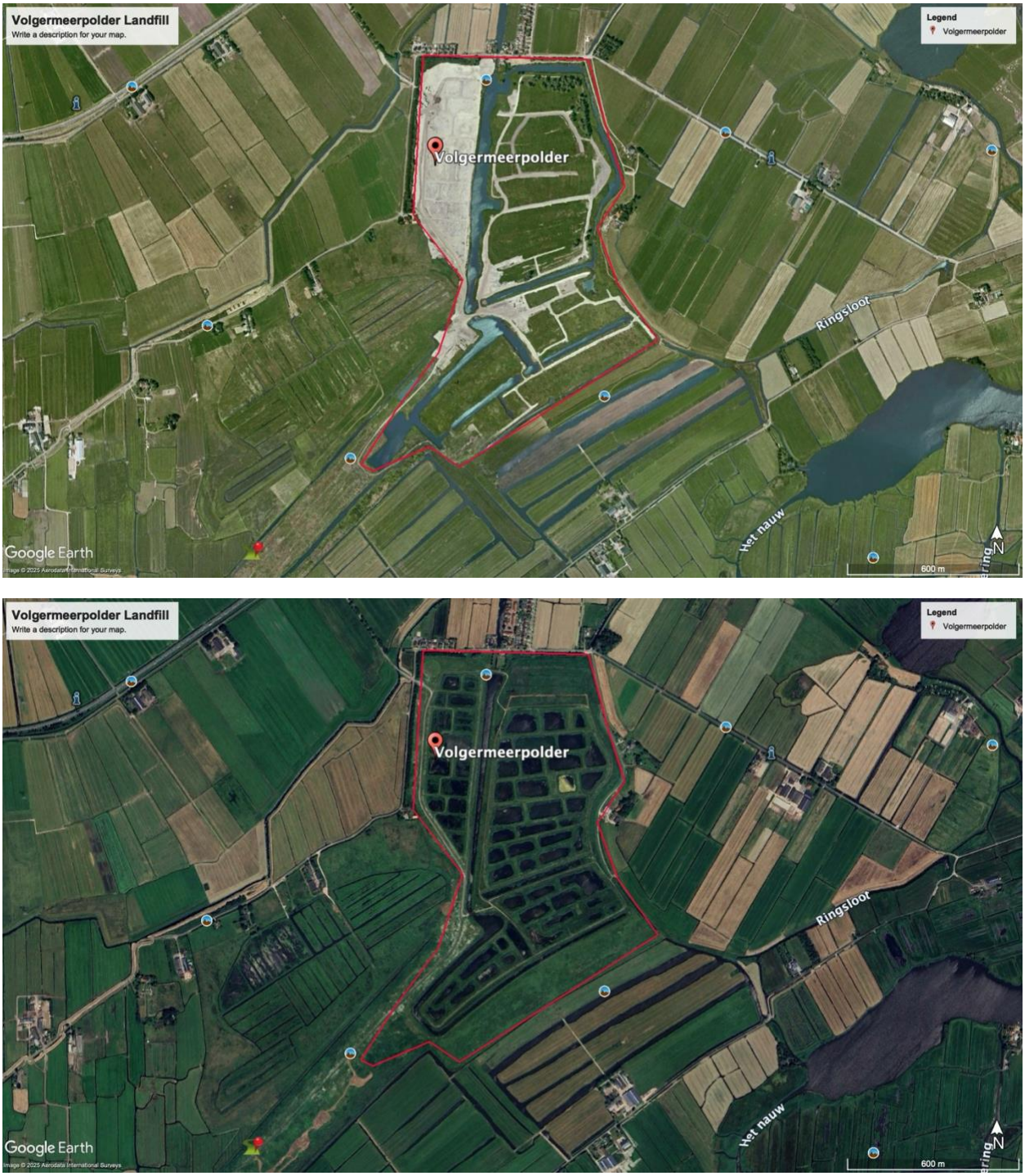


Figure 15. Volgermeerpolder site. First image shows the place in 2005 and the second image is the most resent in 2022. Source: Google Earth Pro, 2025

The Volgermeer, a site historically associated with peat mining from 1920 to 1955, has undergone significant environmental scrutiny due to its transformation into a hazardous waste area (EcoShape 2025). The initial extraction activities resulted in the formation of waterways that later became repositories for municipal and industrial refuse, including chemical waste during the 1950s and 1960s (Amsterdam Municipality n.d.). This led to the emergence of one of the most significant toxic waste regions in the Netherlands, a situation that was publicly acknowledged in 1980 *(ibid)*. According to the reports of the municipality of Amsterdam, in 1989, the responsibility for the remediation of this hazardous waste site became a matter for legal deliberation, particularly regarding whether the incumbent government or the waste-disposal company, Duphar, should bear the costs. Ultimately, the court ruled that the government must undertake the remediation efforts, with Duphar contending that it should not be solely accountable for waste disposal in the landfill (Amsterdam Municipality n.d.). A comprehensive risk assessment was subsequently conducted to evaluate potential remediation strategies *(ibid).* After careful examination of the environmental site conditions and associated health risks, the authorities opted for an innovative open dynamic barrier system as part of the final remediation approach (Amsterdam Municipality n.d.). Reports from the Volgermeerpolder indicate that initial remediation efforts commenced in 1989, with experts assessing that a thorough cleanup would require at least a decade, consequently leading to a considerable increase in budget requirements. Throughout this timeframe, the responsibility for remediation fluctuated among various governmental levels, initially with the municipality of Amsterdam before shifting to the province of North Holland. A collective decision was ultimately reached, wherein multiple levels of government—including the Ministry of Housing, Spatial Planning, and the Environment (VROM), the provincial authority, and the municipality—decided to share the financial burdens associated with the cleanup efforts.

Further studies conducted in 2001 indicated that the remediation could be expedited, suggesting a timeframe of not more than five years. After a decade of inactivity concerning site remediation, the municipality of Amsterdam, in partnership with the central government, finally proceeded with the site's remediation. The construction of the cap began in 2005, involving the covering of the landfill with multiple layers of surface sealing made of soil and HDPE (high-density polyethylene) foil, and was completed in 2010 (Amsterdam Municipality n.d.). The implemented system is designed to manage and redirect groundwater flow effectively, thus preventing the movement of contaminants from the site. This technology aims to safeguard local ecosystems and communities by ensuring the safety and quality of groundwater resources in the area (*ibid)*. To provide a clearer understanding of the timeline of the case study refer to Figure 16.

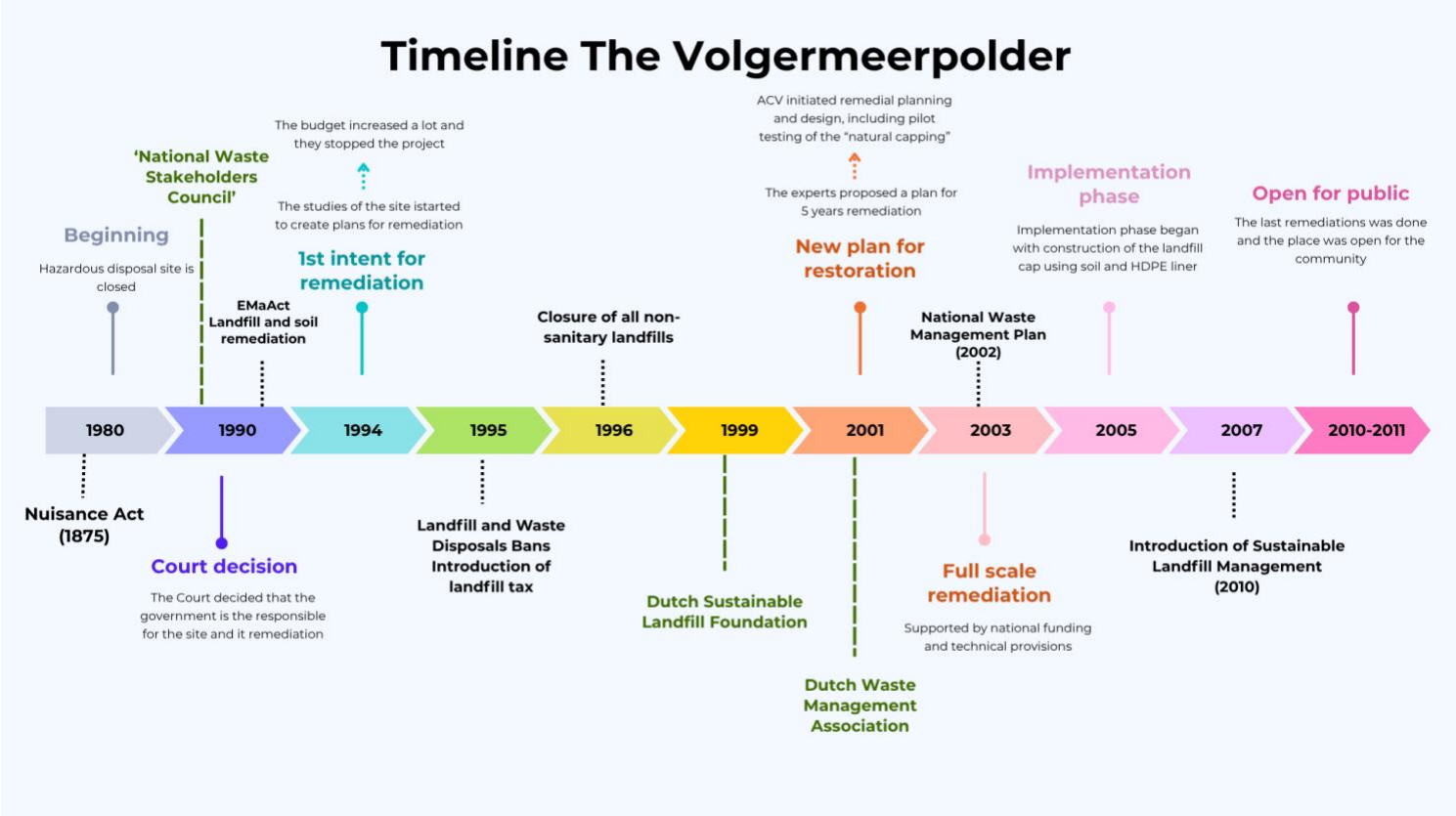


Figure 16. Timeline about the history of the remediation site in The Netherlands and how the actors and regulations were taking part of the role consideringt their creation. Own design from literature review.

2.5. Case Study in San Luis Potosí (SLP)

San Luis Potosí is one of the 32 states located in Mexico (Figure 15). It has a big biodiversity, and it's full of different ecosystems, between forests, mountains, desert areas, and more. This state is situated in the central-eastern region of Mexico. Its geographic coordinates range from 24° 29' north latitude to 21° 10' south latitude, and from 98° 20' east longitude to 102° 18' west longitude. It shares its northern borders with Zacatecas, Nuevo León, and Tamaulipas; the eastern borders with Tamaulipas and Veracruz-Llave; the southern borders with Hidalgo, Querétaro de Arteaga, and Guanajuato; and finally, the western border with Zacatecas. San Luis is important in the national production of fluorite, zinc, silver, lead, gold, copper, and iron, among other minerals, as well as ornamental rocks; its mining tradition dates back to the 17th century (INEGI 2002).

Figure 17. Localization of San Luis Potosí State. Source: Own design with data from INEGI, 2024

In the waste management sector, approximately 737,538 tons of waste were generated in 2020, according to INEGI (INEGI 2020) resulting in a per capita waste generation rate of about 0.716 kg, which is slightly below the national average (0.944kg). Currently, there are 121 registered final disposal sites within the system, including landfills, open dump sites, sanitary landfills, and waste transport stations. In contrast to the data collected on remediated sites from 2001 to 2024 (SEMARNAT 2024), only seven sites have experienced remediation in the municipalities of Guadalcázar, Zaragoza, Matehuala, Villa de Arriaga, San Luis Potosí, Charcas, and Villa de Reyes. For this study, I will focus on the landfill remediation project at "La Pedrera," located in the municipality of Guadalcázar (Figure 16).

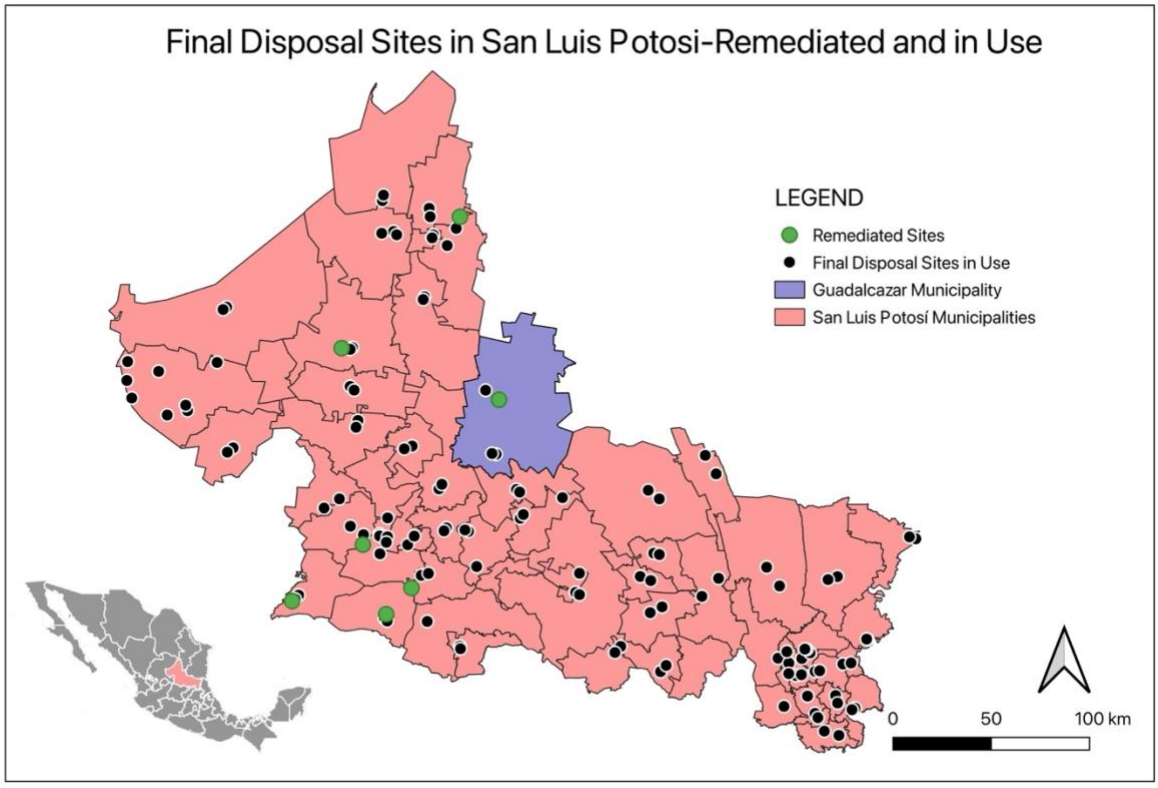


Figure 18. Final Disposal Sites in San Luis Potosí and remediated sites. Source:Own design from data of INEGI, 2024

From 1982 until 1989, the Technical Confinement of Industrial Waste S.A. (Coterin), a Mexican company, utilized this site for illegal hazardous waste disposal. Initially, the company drilled holes in the land intending to provide potable water for ranches and agricultural applications (Milán 2002). However, over time, it began to dump significant quantities of hazardous waste on the site. It is relevant to note that at that time, the General Law on Ecological Balance and Environmental Protection (LGEEPA) had only been enacted for two years, and no specific standards were available (Milán 2002). In 1993, San Luis Potosí established the General Coordination of Ecology and Environmental Management, reporting directly to the state mayor, to address environmental concerns. The situation intensified when Coterin expanded its operations to accept not only its hazardous waste but also that of other companies. The site is situated near a canal, leading to the dispersal of toxic waste into the water following heavy storms, which contaminated adjacent urban areas (Milán 2002). The community of El Huizache relied on a dam for water supply, further complicating the issue. Residents raised concerns regarding the illegal dumping and the perceived inadequate response from local authorities (Rangel 2011).

The government issued a temporary permit for a "Transfer Station" for 120 days, without the environmental impact assessment mandated by LGEEPA. After this period ended the site was closed. However, in 1993, the sire was reopened with the operation of a hazardous waste containment facility without documentation of compliance or established waste disposal methods (Milán 2002). During this period, a U.S. company, MetalCald, expressed interest in the Mexican hazardous waste management sector during NAFTA negotiations. MetalCald proposed to introduce advanced waste management technologies to Mexico, including a new hazardous waste incinerator, which ultimately did not proceed. Despite this situation, MetalCald maintained its interest in participating in hazardous waste management efforts in Mexico. The company was

drawn to the La Pedrera site due to its existing permits, despite the irregular operation of the site. Eventually, MetalCald acquired the land from Coterin from one member of the Secretariat of Urban Development and Ecology (SEDUE) (Milán 2002), which became the Secretariat of Social Development (SEDESOL) in 1992 (Sauceda and Sánchez 2020).

Efforts to resolve the controversy through negotiation ultimately proved unsuccessful. Since September 27, 1997, major Unzueta issued a decree establishing an ecological preserve known as the "Protected Natural Area State Reserve, Real de Guadalcázar" (San Luis Potosí Government 1997). This action led to the cessation of Metalclad's operations at La Pedrera, and the landfill never opened for business. The establishment of a protected natural area to conserve the diverse cacti species in Guadalcázar has been a demand voiced for two years by representatives from ejidos and communities SEMARNAP by Greenpeace, 35 environmental and social organizations from San Luis Potosí and across the country, as well as environmental organizations in the United States, including the National Wildlife Federation (Milán 2002).

The total land area is 11.52 hectares, that are divided into five zones (Figure 18): the two first ones are cells, permanent constructions, paths, and accesses, which represent 2.13 hectares, and the other three areas that represent 9.39 hectares where are concentrated the ecological restoration

Figure 19. View of the hazardous waste confinement cell on the La Pedrera property, SLP. Source: Tavarez, 2009

Foto: Carlos Tavarez durante levantamiento topográfico 27/04/2009.

works (Tavarez 2009). In 2009, the National Commission for the Knowledge and Use of Biodiversity (CONABIO) proposed a remediation plan for the 2.13 hectares left of the total area, occupied by confinement cells and other permanent structures on the property. According to their findings, the remainder of the area was covered with abundant vegetation, along with sections where the soil had been removed or compacted for the construction of permanent facilities (Tavarez 2009). Much of this vegetation was considered secondary and invasive. This commission planned to allocate financial resources for the ecological restoration of the confinement area, employing rehabilitation, containment, revegetation, conservation, and soil improvement techniques. The proposal was developed following a site visit conducted on September 12 and includes recommendations from an external academic evaluation (Tavarez 2009). To provide a clearer understanding of the timeline of the case study refer to Figure 21.

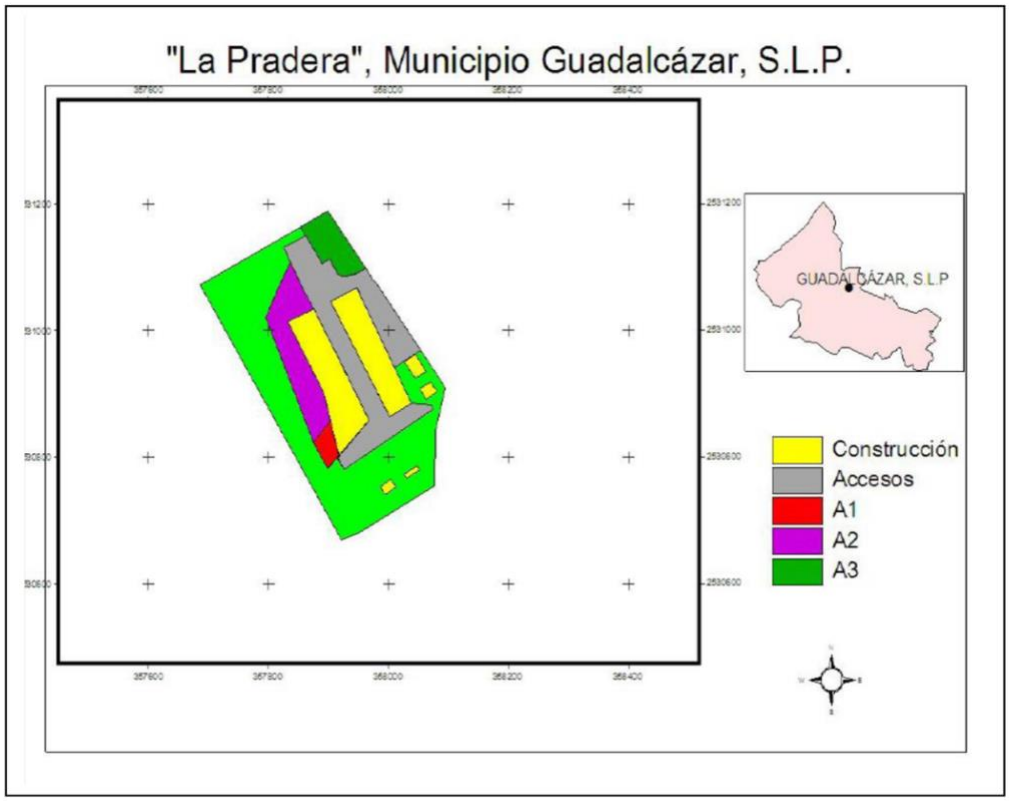


Figure 20. Sketch of the location of the restoration work areas. Construction & accesse (2.13ha)s, A1, A2, A3(first restauration areas, 9.39ha). Source: Tavarez, 2019

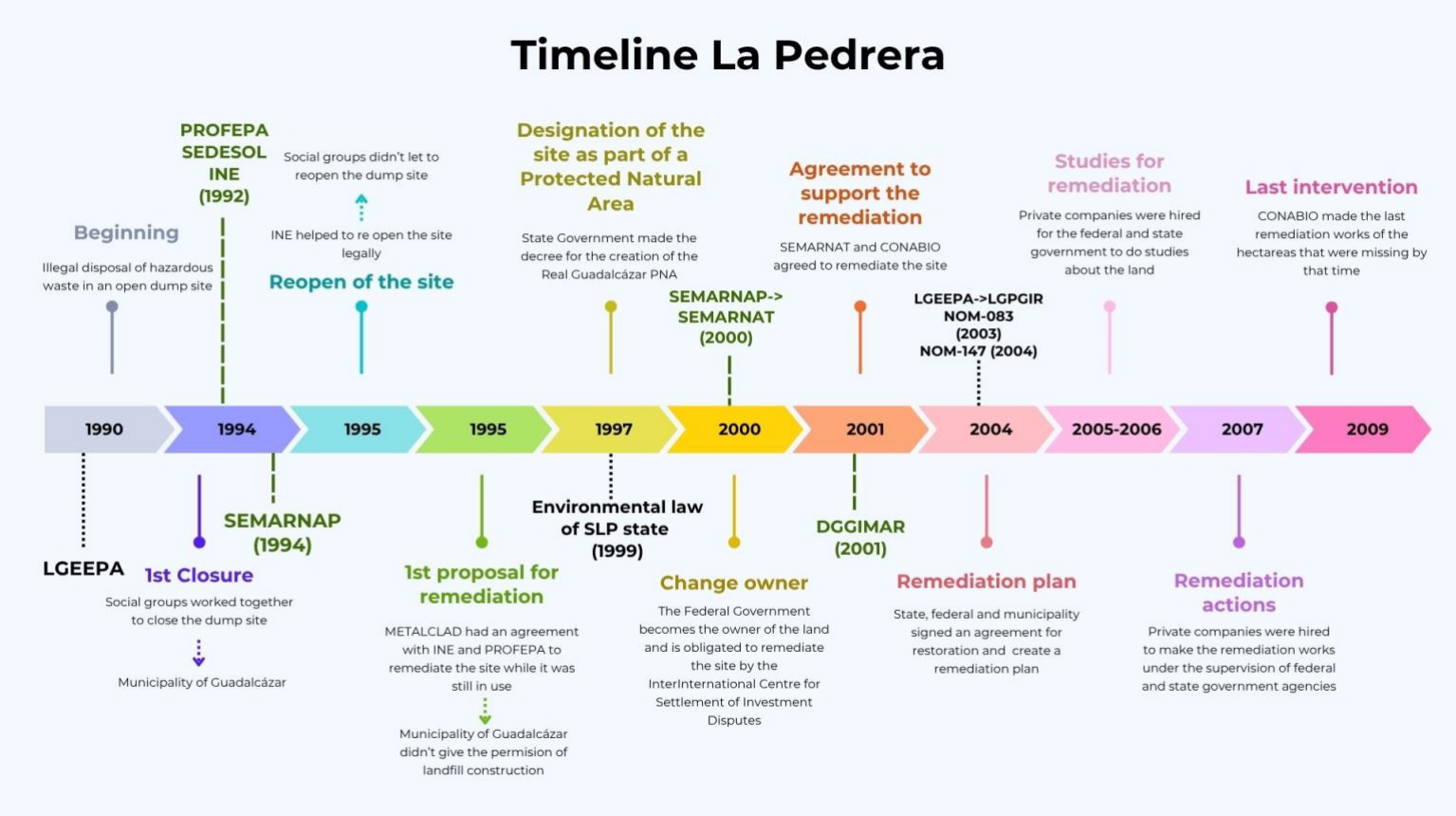


Figure 21. Timeline about the history of the remediation site in SLP and how the actors and regulations were taking part of the role consideringt their creation. Own design from literature review.

Chapter 3

3 Results

This section presents a detailed comparative analysis of two distinct sites, shining a spotlight on their unique characteristics and essential information. The chapter is thoughtfully structured into three distinct subheadings: 1) Policy Objectives and Framework, 2) Funding Mechanisms and Cost Recovery, and 3) Public Participation and Stakeholder Engagement. This organized approach facilitates a comprehensive comparison of each case study within these vital areas, exploring the relevant regulations that have developed over time and been implemented in these analyses. To deepen the understanding of the intricate relationships between the regulatory frameworks and key stakeholders involved in the two case studies, please consult Figures 21 and 22 at the conclusion of this chapter. These visual aids will further illuminate the connections and dynamics at play, enriching the overall examination of the subject matter.

3.1 Policy objectives and framework

This section outlines the comparative findings regarding the legal and institutional frameworks governing landfill remediation in two case studies: San Luis Potosí, Mexico, and the Netherlands. The analysis highlights significant differences in regulatory development, implementation strategies, and policy objectives, which ultimately influence the scope, timing, and effectiveness of remediation efforts.

Dutch policy distinctly differentiates between historical contamination (pre-1987) and contemporary pollution, establishing remediation obligations when contamination poses a significant risk to human health or ecosystems. The framework advocates for the reuse of remediated land, conditional on the management of residual risks, and aligns remediation strategies with goals inherent to land-use planning. Furthermore, the Waste Management Directive

and the Landfill Directive established by the EU Commission regulate this sector in a general perspective and this provides a framework for the country. However, the ability the national local/province governments to develop their own regulations tailored to their specific circumstances allows for a more effective pursuit of the objectives set by the Commission. This integration reflects a national ambition toward sustainable land use, characterized by a commitment to public transparency, decentralized governance, and standardized technical protocols. The framework for landfill remediation in the Netherlands is meticulously constructed, attached in a comprehensive set of integrated environmental legislations prioritizing risk management and innovative spatial planning. At its core lies the Soil Protection Act, established in 1987, which defines crucial concepts such as "serious contamination" and "urgent remediation." This landmark legislation imposes a legal imperative on stakeholders to address contamination issues that threaten both human health and the surrounding ecosystem. Subsequently, additional legislation, including the Environmental Management Act of 1993 and the recently instituted Environment and Planning Act of 2024, has further strengthened the legal framework for environmental protection. These laws operate simultaneously to implant remediation efforts within wider land-use planning and spatial development strategies, promoting decentralized governance by assigning regulatory responsibilities to provincial and local authorities. This strategy not only enhances the efficiency of oversight mechanisms but also allows for customized responses that address regional and site-specific conditions. The Netherlands employs a sophisticated risk-based model that allows for adaptability in remediation strategies, placing paramount importance on public and ecological health while also being mindful of cost-effectiveness.

The proactive involvement of provincial governments in supervising remediation plans, coupled with the establishment of aftercare funds, illustrates a meticulously structured approach to long-term risk management. By ensuring ongoing oversight even after remediation is completed, this model fosters sustainability and efficient land use, facilitating the reintegration of previously contaminated areas into vibrant and productive spaces.

A key component of the Dutch remediation approach is its risk-based methodology, which enables shade, site-specific decision-making by considering critical factors such as intended land use, the nature of contaminants, and associated exposure risks. After successful remediation, rehabilitated land is frequently repurposed for diverse activities, although under strict conditions. To ensure ongoing management and safeguard the integrity of remediated sites, aftercare funds are typically established, frequently financed by the landfill operators. Furthermore, the legal framework governing landfill remediation is complemented by clearly defined technical protocols that standardize remediation practices, thereby guaranteeing both consistency and efficacy. This framework fosters transparency and encourages active stakeholder participation, including input from local communities and environmental organizations, thereby promoting a collaborative approach to managing environmental risks and enhancing public confidence in the remediation process. Furthermore, the Netherlands is structured in a way that all the provinces and the national government are interconnected and can act simultaneously in the decisions for landfill remediation.

In Mexico, the remediation of landfills is fundamentally governed by the General Law for the Prevention and Integral Management of Waste (LGPGIR), implemented in 2003. This pivotal legislation establishes a comprehensive national framework for waste management, emphasizing the "polluter pays" principle, which holds responsible parties accountable for the financial

management of pollution. Furthermore, the law mandates federal authorization for any remediation actions on contaminated sites, ensuring a regulated and systematic approach to addressing environmental hazards. The LGPGIR represents a significant evolution from the preceding General Law of Ecological Balance and Environmental Protection (LGEEPA), established in 1988, which encompassed a broader focus on sustainable development and environmental protection without delineating specific standards for contaminated land remediation. The LGPGIR aimed to rectify this gap by providing precise regulations. Under the LGPGIR, there are clear definitions and protocols for managing various waste types, such as hazardous waste, urban waste, and special-handling waste. To support these regulations, the LGPGIR is augmented by a series of Normas Oficiales Mexicanas (NOMs). Specifically, NOM-083 governs the design, operation, and management practices of sanitary landfills, while NOM-147 outlines specific threshold values for soil contamination and technical criteria for effective remediation strategies. These regulations create a legal framework for assessing contamination levels on sites and determining appropriate remediation methods.

Federal agencies, particularly the Ministry of Environment and Natural Resources (SEMARNAT) and the Federal Attorney for Environmental Protection (PROFEPA), are tasked with the authorization and oversight of remediation activities. These bodies play a crucial role in ensuring compliance with established laws and standards throughout the remediation process. Moreover, international agreements such as the North American Free Trade Agreement (NAFTA) have influenced Mexico's environmental policy landscape. Case studies, like the La Pedrera landfill case, exemplify how international trade obligations can prompt federal intervention and enforcement actions, thus illustrating the interconnectedness of domestic law and international agreements in addressing environmental challenges.

At the state level, the Environmental Law of San Luis Potosí, amended in 2015, aligns its provisions with federal regulations to create a cohesive strategy for managing non-hazardous waste and enhancing local oversight, this by the creation of the Secretariat of Ecology and Environmental Management. Remediation efforts are typically triggered by various factors, including environmental inspections, legal disputes, or public complaints regarding contaminants. Within this legal structure, both the original polluter and the current property owner may face joint liability for contamination, underscoring the importance of accountability in environmental management.

While both jurisdictions adhere to the overarching "polluter pays" principle, the Dutch legislative framework places a priority on preventive planning, risk-based interventions, and the integration of remediation within land-use policies. Conversely, the approach in San Luis Potosí is predominantly characterized by regulatory enforcement, established contaminant thresholds, and legal accountability. These differing methodologies significantly influence the way each jurisdiction conducts site remediation, thereby affecting the timing, scope, and coordination of remediation activities in practice.

3.2 Funding mechanism and cost recovery

The remediation strategies for landfill sites in the Netherlands and San Luis Potosí demonstrate distinct approaches shaped by their respective institutional frameworks and regulatory environments.

In the Netherlands, various levels of contributions exist for environmental projects. At the outset, the EU Commission initiates projects, such as the European Green Deal, which tackles environmental issues in member countries and provides funding for specific initiatives addressing these challenges. At the national level, there is a financial aid structure that mandates landfill

operators to contribute to provincial aftercare funds. These funds are specifically designated for long-term remediation and monitoring after a landfill has closed. Establishing a dedicated fund for aftercare enables projects aimed at rehabilitating sites to be effectively pursued. This requirement facilitates a structured funding mechanism that emphasizes financial planning, ensuring that adequate resources are available for ongoing environmental management. Once a landfill site is closed, responsibility for aftercare shifts to the provincial authority, which utilizes funds acquired from technical assessments of future risks and long-term monitoring needs. This proactive approach not only strengthens financial sustainability but also addresses potential issues with non-owner sites, where no responsible party exists to manage environmental liabilities. Additionally, public co-financing through national programs or EU subsidies can be leveraged to support remediation efforts, particularly for historically contaminated sites. Furthermore, establishing foundations for the landfill's structure contributes to a supportive network for specific cases, ensuring that all stakeholders are informed and can collaboratively develop remediation plans.

The remediation funding mechanisms in San Luis Potosí are predominantly influenced by the "polluter pays" principle established in Mexico's federal General Law LGPGIR. Under this framework, both the polluter and the site owner bear joint liability for remediation costs. The enforcement of these responsibilities is overseen by PROFEPA and SEMARNAT. San Luis Potosí lacks a dedicated aftercare fund; instead, remediation costs are typically recovered through legal penalties or cleanup agreements. Furthermore, the state of San Luis Potosí does not possess an independent funding mechanism for the long-term management of remediation efforts. However, the introduction of environmental taxes, such as those targeting greenhouse gas emissions, presents a potential avenue for financing broader sustainability initiatives. Nevertheless, the absence of

earmarked funds for landfill remediation underscores the variability in financial resources available for such projects, often contingent upon the capacity and willingness of private parties to comply with federal mandates.

3.3 Public participation and stakeholders' engagement

Public participation in the Netherlands is formally embedded in planning processes. According to the Environment Act (Omgevingswet), stakeholders must be consulted during permitting and remediation planning, with all actions disclosed through digital platforms. In contrast, public participation in San Luis Potosí is less structured. Although some transparency measures, such as a public registry of contaminated sites, are in place, formal consultation processes are not consistently applied in landfill remediation projects.

In both case studies, the collaboration of various social groups was crucial for site remediation. In Mexico, for example, these groups worked together to advocate for the closure of a former landfill on multiple occasions. Health concerns emerged as a significant challenge to address in both cases, and the involvement of various NGOs and private organizations played a vital role in raising awareness about the issues affecting the sites and the people impacted by the lingering toxic materials. Moreover, the participation of different government bodies varied between the two situations. In the Netherlands, the government engaged with the problem proactively, recognizing the importance of addressing soil toxicity to prevent health issues and to comply with directives set forth by the European Commission at that time.

In the Netherlands, public participation is formally embedded within environmental decision-making processes. Under the Environment and Planning Act (Omgevingswet)—which

consolidated earlier planning and environmental laws and came into effect in 2024—stakeholder engagement is a mandatory part of the permitting and remediation cycle. During the preparation of remediation plans, local governments are required to consult affected residents, businesses, and environmental groups. Notification and feedback mechanisms are facilitated through the Environment Counter (Omgevingsloket), a national digital portal that allows the public to view, comment on, and track remediation projects. Public consultation is typically conducted early in the process, often during spatial planning, and may involve information sessions, public hearings, and formal objection procedures. These requirements are enforced by provincial or municipal authorities, who have significant autonomy over implementation.

In contrast, San Luis Potosí does not have a standardized framework for public participation in landfill remediation, although general principles of transparency and community involvement are present in federal environmental legislation. The General Law for the Prevention and Integral Management of Waste (LGPGIR, 2003) and the State Environmental Law (amended in 2015) include provisions for environmental transparency and access to information. However, public engagement during remediation planning is not systematically required, and when it does occur, it is usually limited to information dissemination rather than participatory decision-making. Public access to contaminated site information is available through the National Inventory of Contaminated Sites (INSC) managed by SEMARNAT, but this registry does not consistently provide updates on remediation progress or outcomes. Local participation is typically limited to specific projects where civil society organizations or communities initiate advocacy or legal action.

Overall, the Dutch system emphasizes institutionalized, proactive stakeholder engagement as a core component of remediation governance. In contrast, San Luis Potosí exhibits

more reactive and discretionary participation, with limited institutional mechanisms to ensure consistent community involvement in remediation planning or oversight.

Category	The Netherlands	San Luis Potosí (Mexico)
Legal Framework	Waste Management Directive Soil Protection Act (1987) Environmental Management Act (1993) Environment and Planning Act (2024)	LGEEPA (1990)→LGPIR (2003) Environmental law of SLP state (1999)
Policy Objectives	Risk. Based remediation, long-term aftercare, integration with land-use planning	Environmental Health protection, legal liability for contamination
Legal Structure	Decentralized	Centralized
Remediation Cause	Exceeding regulatory limits (risk-based criteria)	Contamination above NOM limits, federal inspection or site transfer
Enforcement agencies	Provincial and municipal governments	SEMARNAT (federal), PROFEPA and state authorities
Funding Mechanism	Operator-paid aftercare funds (mandatory); public-private arrangements possible	"Polluter pays" principles; no dedicated aftercare fund
Public Participation	Legally required under the Environment and Planning act (Omgevingswet); digital disclosure portals	Informal or project-specific consultation, no standard procedure
Post-remediation land use	Often reused for recreation, nature or light development	Reuse depends on developer interest and compliance
Monitoring and Outcomes	Long-term monitoring required; outcome publicly reported	Some federal oversight; limited data on outcomes or long-term site performance

Figure 22. Summary of the main criteria for the comparison

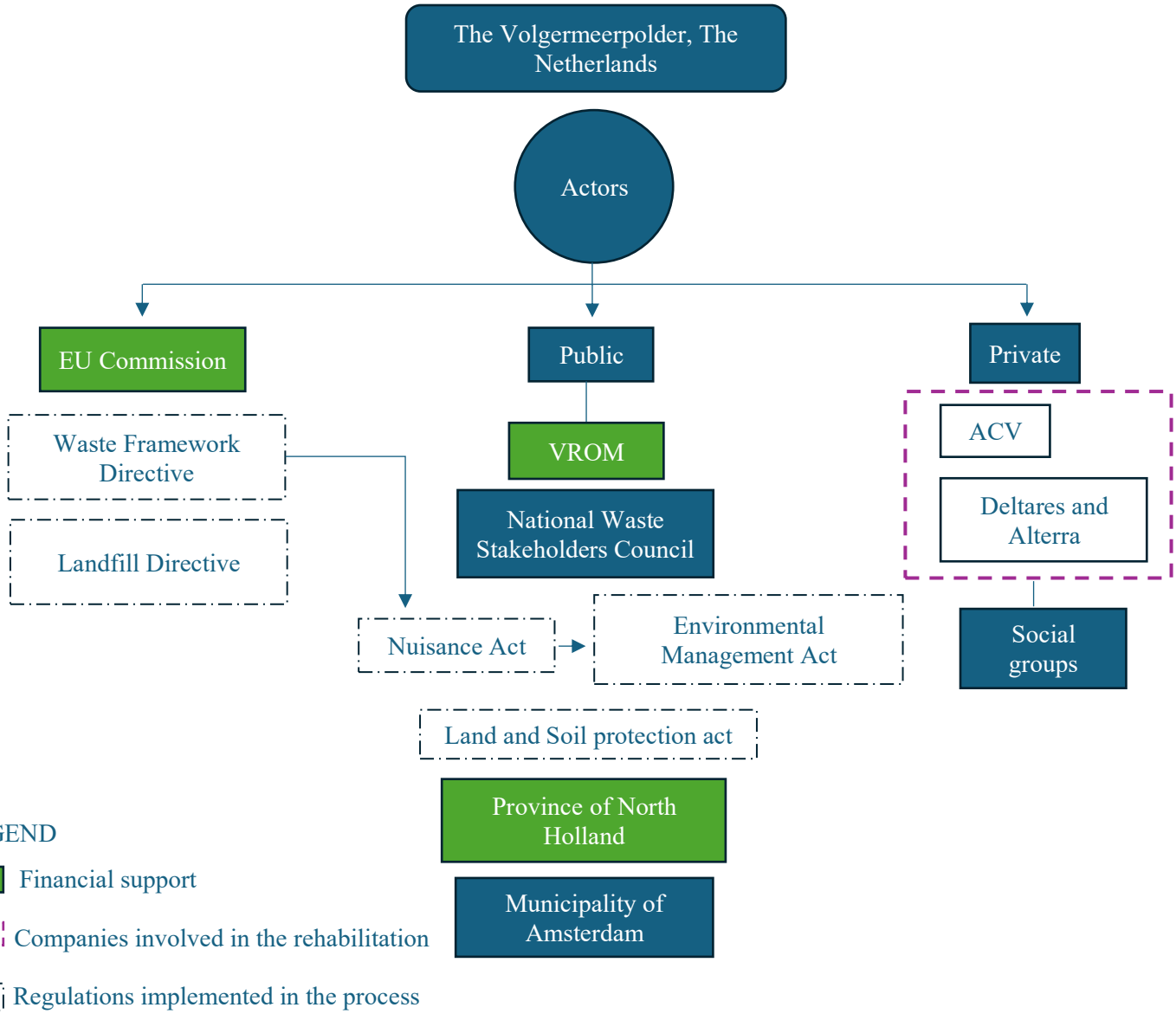


Figure 23. Mapping of the environmental framework for the remediation of The Volgermeerpolder, The Netherlands. The chart shows the interrelation between all the actors and regulations implemented in the rehabilitation. Source, Literature Review

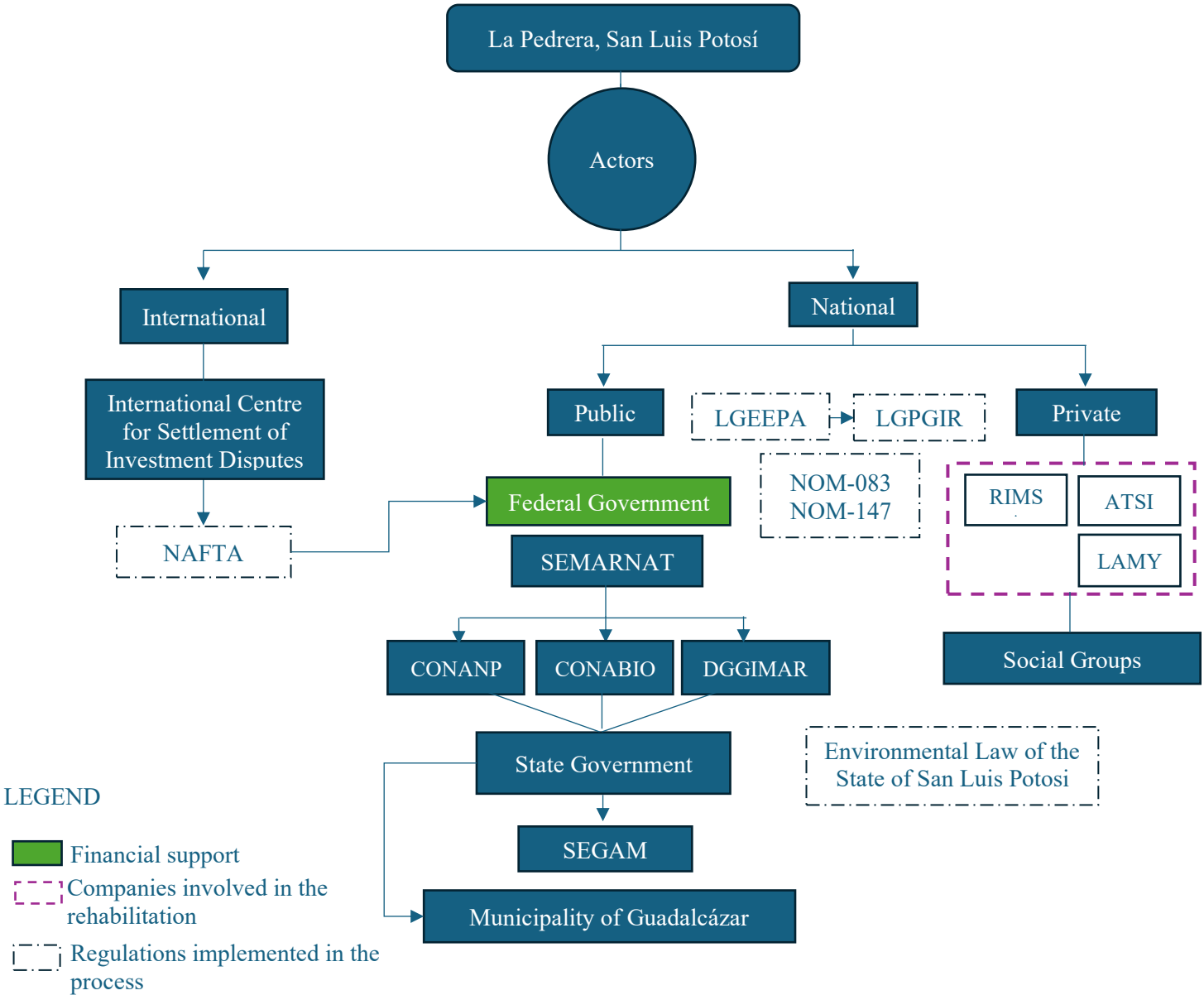


Figure 24. Mapping of the environmental framework for the remediation of La Pedrera, SLP. The chart shows the interrelation between all the actors and regulations implemented in the rehabilitation. Source, Literature review

Chapter 4

4 Discussion

In my discussion, I examine the various levels of implementation observed in the case studies, starting with the involvement of the European Commission in the EU and the Federal Government in Mexico. This initial level is crucial, as the laws enacted for remediation significantly facilitated the necessary actions. Additionally, in the context of Mexico, there is an international component at this level due to its connection with NAFTA, which proved instrumental in prompting decision-makers to address land issues and encouraging the government to allocate financial support for remediation efforts in La Pedrera site. At this stage, governance is somewhat similar; a specific body creates the laws that regulate the general categories and highlight the issues that require attention. However, a notable difference at this level is that regulations in Mexico tend to lack consistent updates over time. Once a law is established, there are often no follow-up revisions to assess improvements based on international agreements or recent research data on a particular issue. Typically, it is only when a significant problem arises that decision-makers recognize the need to address it.

In observing the next level of governance, I can clearly see a significant difference. The Netherlands is well-organized, adhering to the legislation established by the EU Commission. They not only have entities dedicated to addressing environmental issues but also specific departments that focus on these concerns (S. Lieten and Dijcker 2018). They meticulously track all collected data and share this information with the community (European Environment Agency 2025a), also the improvement that is use nowadays about involving the stakeholders in the decisions of landfill remediation from this specific event (Sustainable Landfill Foundation 2025).

In contrast, San Luis Potosí's organizational structure appears less defined. While they have a secretariat responsible for environmental issues, there are not clear distinctions in how they manage these problems, particularly regarding waste and landfills. This secretariat tends to prioritize habitat preservation over other critical environmental matters, such as the rehabilitation of contaminated sites. I believe it would be beneficial for them to categorize each department to focus on specific issues like air, soil, and waste. Despite recognizing the importance of engaging the public and informing them about decisions being made, there has been a notable lack of specific initiatives aimed at effectively communicating this information to the community. Additionally, efforts to involve community members in the decision-making processes that impact their areas have been insufficient. This situation presents an opportunity for improvement. By following the example set by The Netherlands in stakeholder participation at remediation sites—such as establishing dedicated portals and forming more social groups for information dissemination—we can enhance social participation in these critical matters.

The significance of this study lies in its ability to highlight the substantial differences in the environmental frameworks of the two locations, which can inform strategies to enhance the Mexican approach to landfill remediation. One potential avenue is to establish governmental entities focused on consultation and collaboration among government agencies, citizens, and civil society organizations, similar to the model employed in the Netherlands (S. Lieten and Dijcker 2018). A key challenge regarding existing laws is the inadequate communication among the various stakeholders involved in decisions concerning final disposal sites and their remediation (Sustainable Landfill Foundation 2025). Creating an organization dedicated to fostering dialogue and building consensus among these parties could streamline the implementation of necessary

changes and rehabilitation efforts across different sites in Mexico. Furthermore, it is crucial to recognize that it is not only necessary to enact more laws but also to periodically update the information required for regulations and laws based on the ongoing analysis and monitoring of waste management practices.

Another difference is that the legislative framework surrounding waste management in the Netherlands has a well-documented history that stands in stark contrast to that of Mexico. The Dutch regulations pertaining to landfills are founded on extensive and systematically updated strategic directives. Central to the Dutch approach is a strong emphasis on waste prevention, recycling, and the strategic removal of materials to diminish waste generation (European Environment Agency 2025). This proactive stance is reinforced by significant taxes on landfill disposal, which incentivizes businesses to pursue incineration methods rather than landfilling waste. Conversely, challenges arise when attempting to implement a similar waste management model in developing nations like Mexico, because of all the investment that is needed to increase the different disposal sites like building incinerators, which is one of the reasons why this study is relevant, because is still relevant to focus on ways to improve the disposal sites and have a backup solution after closure.

One specific relevant topic is the information regarding waste management and landfill operations is relatively straightforward in The Netherlands. The transparency of this information lends itself to a better understanding of operational practices and their resultant outcomes. Furthermore, the provincial governments have established distinct regulations and plans concerning landfills, thus providing detailed information on both active and decommissioned sites.

The organizational structure around this data promotes effective research and facilitates data collection concerning waste management practices. In Mexico, however, there exists a significant deficit in the attention paid to waste management. The existing local laws lack relevance and specificity concerning the challenges posed by landfills (Federal Government 2015) . Notably, even the climate change legislation does not delineate concrete actions aimed at mitigating greenhouse gas emissions from landfills, focusing instead on broader waste management improvements. This indicates a continuing oversight, as significant progress concerning former landfills has not been achieved over time despite the ongoing issues. The lack of attention to this matter complicates the search for information, as there is insufficient follow-up regarding the management of these sites. Consequently, this neglect contributes to the proliferation of more open dump sites throughout the country.

A significant issue in Mexico is the lack of a dedicated agency focused specifically on waste management. While there are environmental entities that have implemented laws, they do not possess the structured framework needed to effectively address waste management concerns. As a result, there is a substantial gap in accountability surrounding this critical issue. The absence of specialized departments or secretariats devoted solely to waste management leaves numerous problems unaddressed. Among the various aspects of environmental protection in Mexico, waste management is one of the least prioritized areas, highlighting the urgent need for a more focused and coordinated effort to tackle the complexities associated with waste and landfill management. Additionally, the funding mechanisms for this issue are inadequate; there are no aftercare funds designated for rehabilitating sites as in The Netherlands (S. Lieten and Dijcker 2018), leading to a lack of oversight once the sites are no longer in use. A collaborative approach between private and

public entities is essential to develop a comprehensive aftercare plan. Companies responsible for creating these sites should be held accountable for their condition post-use. Furthermore, authorities must be involved in this process, as aftercare must align with sustainable solutions that comply with existing laws, such as the climate change law and the General Law for the Prevention and Comprehensive Management of Waste (LGPGIR). This reactive approach can lead to challenges, particularly when responsible parties are unable to fulfill their obligations due to financial constraints or when legacy contamination remains unaddressed. In summary, while the Dutch system prioritizes comprehensive financial planning and a collective responsibility framework through provincially managed aftercare funds, the approach in San Luis Potosí is characterized by reactive enforcement and legal liability, resulting in a more precarious funding landscape for long-term remediation efforts, particularly concerning legacy pollutants and financially insolvent polluters.

The landfill remediation policy frameworks in the Netherlands and San Luis Potosí demonstrate distinct regulatory histories, environmental priorities, and institutional capacities. Both jurisdictions acknowledge the necessity of controlling contamination resulting from legacy waste disposal practices; however, their objectives and legal instruments exhibit considerable differences in emphasis and structural organization. In the Netherlands, the principal policy objectives surrounding landfill remediation focus on the protection of human health, the preservation of soil and groundwater quality, and the integration of environmental recovery into spatial development strategies. These objectives are underpinned by a robust and evolving legal framework, with the Soil Protection Act (European Council 2025) serving as foundational legislation. This act introduced critical concepts such as “serious contamination” and “urgent

remediation," and it operationalizes the principle of a duty of care for soil polluters. Successively, the Environmental Management Act (Wet milieubeheer) has been implemented, culminating in the consolidation of these elements under the Environment and Planning Act (Omgevingswet) effective in 2024. This legislation aligns soil policy within the broader paradigms of spatial planning and environmental stewardship, emphasizing a risk-based approach alongside principles of long-term management.

Nevertheless, the path of remediation policy implementation in Mexico often feels more reactive than proactive, characterized by a response to acute contamination crises or mounting legal pressures. This reactive nature leads to unnecessary delays in addressing persistent environmental hazards. Additionally, the weight of international trade agreements, particularly NAFTA, imposes external pressures that prompt the government into action. While Mexico's legal framework has certainly made strides towards improvement, its effectiveness is vulnerable by a persistent lack of interconnected planning and preventive measures.

Learnings:

- The issue extends beyond merely closing landfills; it encompasses the monitoring processes conducted prior to their opening. When a landfill is compelled to close due to adverse conditions from the outset, it often complicates and increases the costs related to site remediation for future reuse.
- To truly grasp the landfill remediation process, it is crucial to assess both soil and water remediation practices. Current landfill and waste management policies predominantly focus on preventing waste disposal at these sites, rather than prioritizing effective remediation strategies.

- There are various techniques for remediating contaminated sites, along with numerous reuse initiatives that can be implemented, especially during the extended period required for comprehensive remediation.
- Additionally, community involvement is essential for the successful management of landfills and waste. Integrating the perspectives and participation of local groups and neighboring urban communities is vital.
- Successful examples of landfill remediation have provided valuable frameworks for policy improvement in various regions, establishing benchmarks for effective land remediation practices that can be adapted to local contexts. However, there is still significant room for improvement in Mexico. These successful examples of landfill remediation have provided valuable models for policy enhancement in different regions, establishing benchmarks for effective land remediation practices applicable to their respective areas, however, there is still a lot to improve in Mexico.

Conclusions

The primary aim of this study was to examine the challenges and factors associated with adapting EU waste management regulations to the context of Mexico, particularly concerning the remediation and reuse of closed landfills. Additionally, the study investigated how EU policies regarding landfill remediation could inform and enhance Mexican policies.

The analysis and discussions highlighted that several elements of the Netherlands' environmental framework could be applicable in Mexico. However, adaptations cannot be implemented in the same way as in the Netherlands due to specific challenges, particularly financial constraints. A key focus for the Netherlands has been to prevent the generation and disposal of waste in landfills, thereby avoiding the establishment of new landfill sites. This approach is not feasible in Mexico, given the substantial investments required. Nonetheless, there are potential regulatory actions that could be pursued in Mexico. For instance, developing websites to inform the public about remediated sites could prove beneficial. These platforms should provide not only a list of remediated locations but also detailed information about the technologies employed and the ongoing monitoring of these sites. This initiative could help mitigate open dumping and lead to more effective regulation of former landfill areas.

Future research and recommendations:

In Mexico, it is essential to conduct a thorough investigation into methods and propose regulations aimed at reducing waste generation and disposal in landfills. Additionally, strategies and standards must be developed to remediate former landfills and open dump sites. A differentiation similar to The Netherlands should be established for landfills constructed prior to

the implementation of regulations governing landfill management and regulate its use and, if necessary, close it down, but for this, it is also relevant that site remediation regulations be more specific about the methods and strict in their implementation. This approach would help to improve the database, management, and oversight of these sites. My research underscores a significant issue: challenges in landfill remediation do not solely arise at the end of a landfill's operational life; rather, they start at the construction phase and persist throughout the entire lifecycle of these facilities. Frequently, decision-makers and companies overlook regulatory compliance from the outset, setting a concerning precedent for future operations. This lack of foresight can lead to considerable environmental repercussions. Moreover, a breakdown in collaboration between government agencies and the private sector can have detrimental effects, exacerbating issues related to waste management and environmental protection. On the other hand, fostering effective collaboration and communication throughout the entire remediation process can lead to significantly positive outcomes. By aligning objectives and sharing expertise, both sectors can work together to develop innovative solutions that not only address existing challenges but also cover the way for sustainable practices in landfill management. This cooperative approach is essential for minimizing the adverse impacts of landfills on the environment and local communities.

Another important point to highlight is to advise the Mexican government to take action to refresh the information on remediated sites. Rather than just supplying a list, it would be advantageous to offer thorough documentation that outlines the remediation methods, especially concerning the regulations enacted. Although I managed to gather details about the technologies employed in many of the sites listed, there was insufficient information on how the regulations influenced the processes.

As noted in chapter 2, the legislation pertinent to these case studies was enacted several years ago and has been repealed and replaced by new policies. I recommend that future researchers utilize this study as a key reference and compare current regulations with those in effect at the time the sites were remediated to assess whether significant changes have taken place in the legal landscape.

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