



Extent to Which Tort Liability Rules Address the Damages Caused by Pharmaceutical Residues and Achieve the Goals of Sustainable Environmental Development

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<https://doi.org/10.18280/ijdsdp.200936>

ABSTRACT

Received: 25 August 2025

Revised: 23 September 2025

Accepted: 25 September 2025

Available online: 30 September 2025

Keywords:

pharmaceutical residues, tort liability, sustainable development, environment, pollution

This study examines the legal challenges associated with the management and treatment of pharmaceutical residues, identifies the nature of the damage they cause to the environment and its inhabitants, and assesses the applicability of tort liability rules in protecting affected parties. A doctrinal and policy-analytical approach was employed, relying on previous studies, statutory interpretation of Jordanian legislation, and comparative analysis with international models. The study also evaluates the adequacy of existing legislation governing the treatment of pharmaceutical residues and the mitigation of their effects, positioning its research question within the broader debate on diffuse environmental harm and probabilistic causation. The findings indicate that current legislation on environmental protection and the management of pharmaceutical residues is inadequate, largely due to the diffuse, widespread, and latent nature of harm. Although the harm may originate in a specific location, its impact often extends across broad geographic areas, affecting both environmental elements and public health. The study recommends revisiting and strengthening legislation related to environmental protection and the classification of pharmaceutical residues as hazardous waste. It further calls for establishing a compensation fund and implementing nationwide household take-back programs.

1. INTRODUCTION

This deterioration is referred to as pollution, which can be understood as any unfavorable alteration-whether direct or indirect, to any environmental component, in a manner that exceeds the environmental criteria and standards endorsed by the Ministry. Such alteration may be noticeable or hidden and may result in reduced usability of environmental resources, a decline in their economic, aesthetic, or social worth, their degradation or complete destruction, or may interfere with the natural functioning and life of organisms, ultimately disturbing ecological balance [1].

Environmental damage is the result of harmful actions caused by humans [2] to the environment through failure to comply with the legal obligations governing the treatment and management of pharmaceutical residues. This damage affects various aspects of the environment and its components, such as soil, water, air, and plants, as long as these elements are used by humans, resulting in harm to individuals and to the environment in which they live.

Legislation regulating environmental protection and waste management and treatment encompasses numerous legal branches, including civil law, regarding liability for damages caused by pharmaceutical residues affecting the environment and humans. This type of damage has its own legal nature and

liability, particularly since it affects not just one individual but society as a whole. In other words, it affects the environment itself. It can only be remedied by restoring the environment to its previous state. Therefore, the commitment and continued pursuit of a clean environment is a fundamental right for those affected and all those living within it to achieve the goals of sustainable environmental development. This damage not only represents a reduction in the financial value of the environment, but also constitutes a reduction in the interests and financial value of its beneficiaries [3].

It is worth noting that the regulatory cycle for treating and managing pharmaceutical residues under regulatory legislation remains [4] unable to achieve the desired goal of sustainable environmental development and conservation. This has been confirmed by numerous environmental studies, which have acknowledged the existence of various harms to environmental components that impact the people living within them [5, 6].

Therefore, traditional civil liability rules are often insufficient when harm is diffused, low-dose, and latent, and when causation is probabilistic rather than deterministic. Comparative experiences-including French responsibility sans faute and the EU Environmental Liability Directive (ELD)-suggest doctrinal pathways that relax proof burdens and emphasize prevention and remediation. The European Union's

environmental liability framework, established by Directive 2004/35/EC, introduces a strict liability regime that holds operators responsible for the prevention and remediation of environmental damage resulting from hazardous activities, irrespective of fault or negligence. This approach embodies the “polluter pays” principle and emphasizes the protection of the environment as an independent legal interest. Liability under this directive arises from the inherent risks posed by the activity itself rather than the operator’s conduct or intent [7].

This requires us to seek alternative means to protect those affected and punish those responsible for the damage. We must also develop regulatory measures and proposals aimed at addressing, disposing of, and treating pharmaceutical residues according to approved technical standards.

The importance of this research lies in situating the Jordanian legal framework within the broader global debate on diffuse environmental harm and probabilistic causation, and in linking doctrinal analysis to practical reforms that advance sustainable environmental development. Pharmaceutical residues constitute a significant proportion of medical waste. If they are not treated and managed according to established standards, they will inevitably harm the environment and its inhabitants.

Those harmed by pharmaceutical residues need legal protection to guarantee their right to file a liability claim for compensation. However, this is not easy; rather, it is complex, to the point of near-impossibility. Therefore, it is necessary to implement the necessary requirements and measures for the disposal of pharmaceutical residues to find ways to redress the harm caused to those affected, especially since these residues do not decompose over time.

Accordingly, this study examines the legal issues in managing and treating pharmaceutical residues, the nature of resulting harms, and the applicability of tort liability rules to protect affected parties, while proposing doctrinal and policy tools aligned with international benchmarks.

This study also aims to address the legal issues in managing and treating pharmaceutical residues, the damage they cause to the environment and its inhabitants, the application of tort liability rules to protect those affected, the development of various means to mitigate this type of damage, and the achievement of sustainable environmental development goals. The Study Problem is revealed by answering the following questions: Are the legislation regulating environmental protection and waste treatment sufficient to address the damage caused by pharmaceutical residues? Can traditional liability rules be applied to damages resulting from pharmaceutical residues? Are the regulatory foundations and procedures for managing pharmaceutical residues actually applied? Are the facilities designated for treating pharmaceutical residues adequate and in compliance with international standards and requirements?

2. METHOD

This legal study utilizes statutory and conceptual approaches, relying on a descriptive and analytical approach, reviewing previous studies to demonstrate the harms caused by pharmaceutical residues, their treatment according to technical standards and requirements, the adequacy of regulatory legislation, and the achievement of true environmental protection and sustainable development goals.

It also addressed the legal aspects related to pharmaceutical

residues and their relationship to the environmental aspects that can result from the misuse of these residues, which impacts sustainable environmental development. The study addresses these aspects in Jordanian legislation.

It should be noted that this is a legal study aimed at analyzing the relevant legal texts concerning pharmaceutical residues from a technical and doctrinal perspective, and it does not include any empirical data or interviews.

3. LEGAL IMPLICATIONS FOR THE MANAGEMENT AND TREATMENT OF PHARMACEUTICAL RESIDUES

The harm caused by pharmaceutical residues constitutes a form of environmental damage that can combine to produce harmful results affecting various environmental resources. Therefore, treating pharmaceutical residues as hazardous waste requires taking multiple technical measures and procedures to manage, treat, and dispose of them. Failure to do so exposes the responsible party to legal accountability, including civil liability, if a causal relationship between the harmful act and the environmental damage is proven. This is what we will explain as follows:

3.1 Legal issues in the management and disposal of pharmaceutical residues

Medical waste management faces various professional challenges, both in terms of the principles followed for its management and treatment and in terms of the seriousness of the application of legal rules and oversight. This is particularly true since the treatment of medical waste is one of the goals of sustainable environmental development, which requires genuine protection of the environment from pollutants. Therefore, we will first explain the professional and legal implications. We will then present the regulatory frameworks for the management and treatment of residual medicine.

3.1.1 Professional and legal implications of pharmaceutical residues

Pharmaceutical residues are waste that retains the properties of hazardous substances and has no original or alternative uses unless it is treated according to scientific and technical conditions.

Given the serious dangers linked to medical waste, numerous scholars have examined how it is managed in Jordan, with the goal of minimizing its harmful effects on both public health and the environment. Proper management practices are crucial, as mishandling such waste can result in the transmission of infectious diseases, pollution of water resources, and overall harm to the ecosystem. Studies have consistently pointed to serious shortcomings in Jordan's medical waste management system. In 2012, the country was estimated to produce approximately 4,000 tons of hazardous medical waste each year. This includes infectious waste, sharp objects, chemicals, pharmaceutical residues, chemotherapy drugs, pathological waste, and radioactive materials [8].

Despite existing guidelines, enforcement remains weak. Reports from the Ministry of Health and environmental organizations indicate widespread mismanagement—medical waste is frequently mixed with municipal garbage or discharged into public sewage systems [9]. These practices deviate significantly from international standards (e.g., WHO,

1999) and present serious risks to human and environmental health.

In a study at 14 healthcare facilities in Irbid, researchers noted the absence of formal handling procedures, the mixing of domestic and medical waste, and a lack of departmental waste quantification. Waste generation rates in hospitals ranged from 4.02 to 6.10 kg per patient per day, while labs produced between 0.034 and 0.102 kg per test [10].

Infrastructure also remains a major hurdle. While color-coded waste bags and incinerators are in use, most incinerators are outdated, under-capacity, or dangerously close to residential areas. Autoclaving, though safer, is rarely practiced. Improper segregation of hazardous and non-hazardous waste continues to be a persistent issue. The rising costs of fuel and electricity have made waste management more expensive, prompting some facilities to cut corners—further exacerbating the issue [11].

Financial concerns play a key role in this dynamic. Waste disposal costs are often passed down to patients. For example, the treatment of hazardous waste can cost up to JOD 400 per ton, with transport fees reaching JOD 100 per trip and incineration costs ranging from JOD 0.5 to 1 per kg. A 2001 government policy allowed treated hazardous waste to be disposed of in licensed dumpsites, but implementation has been inconsistent.

More recent studies have continued to emphasize the systemic nature of the problem. They stress the need for upgraded infrastructure, effective segregation, and better-trained staff; the COVID-19 pandemic amplified these challenges [12, 13].

Despite Jordan's growing healthcare sector—with the number of accredited health centers rising from 97 in 2017 to 147 in 2022, and computerized centers increasing from 142 to 478 in the same period, waste management has not kept pace. Current practices, such as open burning or landfill dumping, are both unsafe and unsustainable. Jordan now produces an estimated 4.7 tons of medical waste daily, with hospitals averaging 2.69 kg per bed [11].

The studies point to regional disparities, with urban hospitals better equipped than those in southern Jordan. Inadequate funding, poor administrative oversight, and limited resources contribute to inefficient waste collection and disposal. Projections indicate that if improvements are not made, medical waste volumes could double by 2025 [14].

Other researchers have identified critical areas for reform, highlighting regulatory gaps and exposure risks (e.g., at King Abdullah University Hospital), and underscoring the need for staff training, particularly during public-health crises [15]. Researchers also note that the Waste Sector Green Growth National Action Plan (2021-2025) emphasizes high hazardous-waste generation alongside low treatment and recycling rates due to weak frameworks and oversight [16].

Despite the existence of legislation regulating the management of hazardous medical waste, a set of mandatory legal texts has been established to form a legal policy for the treatment of hazardous waste [17].

However, household pharmaceutical residues remain largely unaddressed and are often co-disposed with non-hazardous waste, multiplying environmental risk. The same applies to residues from individual medical clinics: licensing often treats disposal contracts as a formality with limited post-licensing oversight, despite cumulative volumes posing significant risk.

The same applies to medication residues from individual

medical clinics, whose licenses require obtaining a contract from an accredited disposal company as a formality for licensing approval. This formality lacks real oversight after the license is granted, ignoring the extent of the damage this medical waste can cause. This may be due to the small quantities of medical waste produced by each individual medical clinic, but in reality, it is necessary to consider the total number of licensed and unlicensed medical clinics in the country and determine the total waste they produce. Especially since this waste is disposed of with non-hazardous waste, which will ultimately lead to environmental damage over time.

3.1.2 Regulatory frameworks for managing and treating pharmaceutical residues

Jordanian law has established mechanisms and regulatory frameworks for the disposal of waste, including residual medicine, as hazardous waste. This involves reducing waste generation and reusing it whenever possible. It also involves sorting methods to separate components and collecting residual medicine for disposal to ensure it does not accumulate. This stage is difficult and complex due to the diversity of its sources. Some residual medicine can be tracked and collected, such as residual medicine produced by medical facilities, while others are difficult to identify and collect, such as residual medicine from households, due to their mixing with household waste [18].

One of the most important means of treating residual medicine is transportation [19]. This means transferring residual medicine to treatment centers, to locations designated by the Ministry, or to a hazardous waste landfill designated for this purpose. Pharmaceutical residues are transported using safe transportation methods designated for this use to avoid any environmental pollution [20].

Pharmaceutical residue treatment includes all practical procedures that allow for the reuse of pharmaceuticals. There are also physical and chemical methods for treating and ultimately disposing of pharmaceutical residues. They allow for the return to the original material with or without conversion. Incineration [21] also involves using heat directly or indirectly to break down organic compounds.

Finally, one of the most commonly used methods, which may not be commensurate with the hazardous nature of pharmaceutical residues due to their non-degradability, is landfilling or sanitary burial. This is a modern scientific method that minimizes the potential side effects of most wastes, but is poorly suited to persistent pharmaceutical residues [22].

This regulation is considered the general framework for waste treatment, including pharmaceutical residues, especially since the legislature has not specified, under the Pharmaceutical and Pharmacy Law and other legislation regulating medical waste management, a mechanism for treating pharmaceutical residues in general and household pharmaceutical residues in particular.

The proper management of medical waste is crucial not only for protecting public health but also for safeguarding Jordan's limited water supplies. This paper takes a closer look at how the current disposal practices affect the environment and water systems. It also examines existing waste management laws and identifies the key agencies responsible for their implementation and enforcement.

According to researchers, the Ministry of Health plays a central role in regulating medical waste disposal, primarily through the Medical Waste Management Instructions No.

1/2001. In addition, the Ministry of Environment, the Ministry of Energy and Mineral Resources, and local municipalities share responsibility for managing and disposing of specific types of waste-such as radioactive, pharmaceutical, chemical, and heavy metal waste. However, without consistent implementation, monitoring, and community engagement, even strong regulations fall short [11].

3.2 Real-world implications of harm caused by pharmaceutical residues

Mismanagement of medical waste disposal causes direct and reversible environmental damage, leading to both environmental degradation and negative impacts on human health [23]. Directly, it can contaminate soil, surface water, and groundwater, creating immediate health hazards [24]. Indirectly, these contaminants can enter the food chain, affecting plants, animals, and ultimately human health [25, 26]. The spread of disease, loss of biodiversity, and disruption of ecosystems are common consequences of such pollution [27].

Medical waste can enter the environment through multiple routes, such as effluents from wastewater treatment facilities, seepage from landfill sites, and leftover substances resulting from inefficient or improperly handled incineration processes [5, 24]. Jordan faces a water scarcity problem, making the protection of its water resources from pollution critically important [28, 29].

Additionally, treated wastewater is commonly reused for irrigation, which raises further concerns about water quality and environmental safety [30]. Conventional primary and secondary wastewater treatment plants are not designed to remove many pharmaceuticals [31-33]. Hospital wastewater also contains hazardous contaminants, including antibiotic-resistant bacteria and persistent viruses [33].

In Jordan, treated water from several wastewater treatment plants has been found to be contaminated with traces of medical waste [34]. These pollutants can also be taken up by plants, leading to further environmental and health concerns [35]. Uncontrolled incineration of medical waste also contributes to environmental pollution by releasing fly ash and harmful pollutants, including heavy metals, acid gases, nitrogen oxides, and sulfur compounds [5].

Accordingly, the harm caused by pharmaceutical residues constitutes the third element of tort liability. However, this harm is not limited to harming a specific individual's interest, but rather affects everyone without exception. The person responsible does not intend to commit a harmful act, but is fully aware that this behavior, related to the failure to properly handle pharmaceutical residues, constitutes unlawful conduct that violates legal permissibility [36].

This legal violation results in future harm to the environment and its inhabitants. Therefore, tort-law doctrines may need adaptation where proof of but-for causation is impracticable; courts in toxic-tort and asbestos cases have used concepts like material contribution to risk to bridge evidentiary gaps.

4. LIMITS OF CIVIL LIABILITY FOR HARM CAUSED BY PHARMACEUTICAL RESIDUES

Tort liability in the field of civil law is stipulated in Article 256, which states: "Any harm caused to a third party obligates

the perpetrator, even if he or she is not discerning, to compensate for the damage." The key question is whether this provision, as applied, can adequately address diffuse and latent environmental harms where multiple sources and long latency complicate attribution. This will be explained as follows:

4.1 The legal framework for the treatment and management of pharmaceutical residues

The Jordanian legislator and regulatory authorities have devoted numerous legal texts in the Environmental Law and the regulations and instructions issued pursuant thereto that address hazardous and non-hazardous medical waste. Pharmaceutical residues are considered hazardous medical waste, and the principles, procedures, requirements, and material and legal implications applicable to hazardous waste also apply to pharmaceutical residues.

4.1.1 Regulatory legislation for the management of pharmaceutical residues

Residual medicine constitutes hazardous medical waste [37]. Referring to the Pharmaceutical and Pharmacy Law, we find that the Jordanian legislator has regulated the means, methods, and protections for private practice in the manufacture and distribution of medicines. However, the legislator did not address in this law the importance of disposing of residual medicine resulting from medical practice by public and private medical institutions and private households. Rather, the issue of its treatment was left to the Environmental Law, which considers it a type of hazardous waste whose disposal requires specific scientific and technical conditions. This is done in coordination with the relevant authorities, including the Ministry of Environment, by establishing the principles for the classification, collection, storage, transportation, destruction, and disposal of hazardous materials [38].

Thus, the legislator has obligated relevant authorities to adhere to technical and environmental requirements when establishing and operating medical waste landfills to avoid direct and irreversible environmental damage. These instructions recognize that medical waste may be hazardous or non-hazardous. This requires relevant authorities to designate a landfill for each type of medical waste. Medicine residues are considered hazardous medical waste which must be disposed of according to a professional and technical mechanism due to their non-degradability. This presupposes that failure to dispose of them will inflict environmental damage, particularly pollution of surface and groundwater, soil, and air. This impacts human health from burying waste throughout the lifecycle of the landfill [39].

It should be noted that Appendix No. (1) of the aforementioned instructions classifies household waste as non-hazardous and suitable for non-hazardous landfills as biodegradable, yet this ignores household pharmaceutical residues-a hazardous, non-biodegradable stream-thereby creating a structural gap with direct environmental repercussions [39].

The landfill classification criteria specified are internationally recognized standards. Therefore, relevant authorities must take into account the nature of the landfill, soil type, and soil strata when selecting sites for sanitary waste landfills. The aforementioned studies indicate that landfills for medical waste and pharmaceutical residues, in particular, lack many of the standards required by Annex No. (2) of the

Technical and Environmental Requirements Instructions of 2021 [40]. The lack of these standards leads directly and indirectly to environmental damage, negatively impacting the lives of living organisms, including plants and animals, especially humans.

Because pharmaceutical residues are considered an integral part of hazardous waste, the legislature has issued specific instructions for their management, including waste disposal, identifying their producer, means of transport, receipt, delivery, treatment, and storage at designated sites until treatment and disposal. These instructions are the Hazardous Waste Management and Handling Instructions of 2019. They also require hazardous waste producers to adhere to general conditions related to hazardous waste in general and pharmaceutical residues as a form of hazardous medical waste in particular. These instructions require waste producers to determine the quantity and type of waste, replace hazardous pharmaceutical residues with less hazardous ones, and establish treatment units for medical waste at the source, subject to approval from the Ministry of Environment and any relevant authorities. If treatment and disposal are not possible, producers of medical waste and pharmaceutical residues must transport them to a landfill approved by the Ministry. The instructions also include the requirements for collecting and storing hazardous waste, the requirements prior to transporting it, and the obligations on landfill operators [41].

Despite the seriousness of the aforementioned legal texts, the Ministry of Environment, in its 2023 report, indicated numerous environmental violations, without clarifying the share attributable to medical facilities or the specific breaches tied to pharmaceutical-waste handling—an opacity that undermines enforcement and accountability.

4.1.2 Legal difficulties in addressing harm resulting from pharmaceutical residues

Pharmaceutical residues that lack proper treatment and disposal according to technical standards, especially when oversight over hazardous waste landfills is weak, can alter environmental properties, diminish value, or cause partial/total loss-harming living organisms, particularly humans.

It is worth noting that, after examining the Environmental Protection Law, the legislator has largely left civil liability for environmental harm to general tort rules, while Article 256 of the Civil Code stipulates liability for any harm [42].

In practice, diffuse and latent harm with multiple contributors renders strict but-for proof unrealistic; presumptions upon regulatory breach and calibrated objective/strict liability offer more workable avenues for compensation and deterrence. Although the Framework Law on Waste Management (2020) introduces “financial liability,” its scope (penalties vs. compensation) remains vague and warrants clarification. On the criminal side [43, 44], environmental crimes are defined broadly and penalties exist (Articles 17-29), but criminalization alone cannot substitute for a robust civil-remedy architecture capable of handling diffuse harm.

Civil liability plays an important role in environmental protection from hazardous pharmaceutical residues. Effective protection requires a liability system that both deters and compensates, supported by proactive state oversight and modern enforcement tools (insurance/financial guarantees, mandatory reporting, and audits). Many landfills were established prior to Environmental Impact Assessment; applying EIA rigorously across the landfill lifecycle is

essential [3].

Therefore, proving criminal violations, sanctioning offenders, and documenting regulatory failures can serve as evidence of harm. Yet, given cumulative and probabilistic causation, courts may justifiably consider relaxed causation doctrines (e.g., material contribution to risk), as seen in asbestos and toxic-tort jurisprudence.

We believe that establishing civil liability against a single perpetrator is often impracticable for pharmaceutical-residue harm, which is typically cumulative and multi-source. This supports developing liability rules tailored to diffuse harm, including objective liability for designated high-risk activities and sectoral compensation mechanisms.

Therefore, proving a causal relationship between the harmful activity and environmental damage is difficult and raises numerous legal issues due to the multiple causes to which the damage can be attributed. Environmental damage caused by pharmaceutical residues is diffuse in nature. It may occur in a specific area, but its effects extend over long distances and across a wide geographical area due to air and water currents that carry the pollutant to distant regions [45].

The concept of presumed fault [46] can be a legal basis for establishing civil liability, relieving the injured party of the burden of proof, which is the major obstacle in environmental disputes. However, it is insufficient to establish liability, as the responsible party can deny responsibility by proving an external cause. Therefore, we believe that objective liability is the most appropriate modern means of protecting those harmed by environmental pollution. It bases its concept on the harm resulting from the contamination, which causes environmental damage whose effects go beyond personal fault, without the need to prove the fault of the responsible party or the presumed fault. This achieves the desired development in economic, industrial, and medical conditions.

Thus, the special nature of damages resulting from pharmaceutical residues creates legal difficulties in proving many damages immediately upon their occurrence or determining them in terms of time and place. This leads us to argue that the rules of tort liability may not accommodate this type of damage, which necessitates calling for the development of liability rules to be compatible with the nature of these damages or the development of legal and practical means to redress the damages resulting from pharmaceutical residues [45].

4.2 Framework relationship between reducing pharmaceutical residues and sustainable environmental development in light of legal protection

Legislation regulating the management of pharmaceutical residues and the responsibility of those handling them—regulators, waste managers, and producers—constitutes the legal basis for achieving sustainable environmental development goals. Every human being has the right to live in an environment free of pollutants. Any harm to the environment or to humans must be eliminated, efforts must be made to prevent it, and those affected must be compensated.

4.2.1 Forward-looking perspective on reducing harm

Under Article 10/C of the Framework Law for Waste Management, the Ministry of Health leads waste management and oversight in affiliated facilities and may engage accredited private-sector firms. Beyond legislation, continuous public awareness, targeted training, and transparent monitoring are

indispensable to deliver outcomes on the ground.

The Ministry of Health's fulfillment of its duties in accordance with legislative procedures and measures is a necessary requirement for achieving the Sustainable Development Goals advocated by the international community through the United Nations. Achieving the Sustainable Development Goals depends on promoting prosperity while taking into account protecting the planet from the harm caused by pharmaceutical residues. Therefore, legislation regulating the management of hazardous medical waste alone is not sufficient to achieve environmental protection. The role of relevant authorities must expand in educating and raising awareness among society and educating them on a positive environmental culture, particularly regarding pharmaceutical residues, clarifying their dangers to soil, plants, animals, and humans, and identifying the nature of the harms that may befall individuals.

To achieve this, the media must be directed and supported to serve this goal. The media, through its various means, plays a crucial role in communicating information, educating people, and expanding the circle of knowledge, especially with the diversity of social media and the rapid transmission of information [47].

Especially in the absence of any legislation regulating the work of environmental awareness programs, it is only possible to support various environmental initiatives. Thus, any entity wishing to manage an environmental awareness program can apply for funding from the Jordan Environment Fund at the Ministry of Environment. This fund is used to cover waste recovery and disposal costs [48]. Household pharmaceutical residues remain a persistent challenge. A nationwide pharmacy-anchored take-back program, with incentives for the public, can curb improper disposal; research suggests substantial willingness to participate [49].

It is worth noting that the failure to manage household medication residues is one of the most significant causes of environmental pollution, given their potential hazards and inability to decompose. The presence of this type of waste and its disposal through the traditional household waste collection system poses health risks to living organisms in general and humans in particular. Furthermore, the legislation regulating the management of hazardous medical waste does not address household medication residues, as if these residues were an integral part of non-hazardous household waste. The relevant authorities should have worked diligently to establish a pharmaceutical residue recovery program for the manufacturer or distributor in exchange for various benefits that the consumer of the medicines receives from this action, such as a partial discount on the price previously paid. This effort requires the cooperation of all parties, including pharmaceutical companies, pharmaceutical stores, pharmacies, and medical institutions.

Relevant authorities can support this by providing specialized drop-off points and safe collection devices in public spaces. Legislative backing and use of the Environmental Protection Fund can finance recovery and safe disposal.

4.2.2 Practical and legal means for official authorities to intervene in the protection of pharmaceutical residues to preserve sustainable environmental development

The damage caused by pharmaceutical residues is often non-obvious and delayed, complicating proof of interest, harm, and causation. To bridge these gaps, the state should

clarify access to remedies and establish a dedicated Pharmaceutical Residues Compensation Fund-financed by regulatory fines, sectoral levies, and targeted support to compensate victims and fund remediation [50].

Given the nature of the commitment to environmental protection and the profound legal framework, although some of its provisions are characterized by complexity, ambiguity, and deficiencies, they are nevertheless somewhat sufficient to address environmental threats. This leads us to conclude that environmental protection and the state's role do not stop at issuing regulatory legislation, granting licenses, managing waste, and preparing and operating landfills. Rather, they focus on monitoring the implementation and fulfillment of these requirements and measures. They also focus on monitoring medical facilities and households that generate hazardous medical waste as a result of their operations, and ensuring its collection and disposal in accordance with approved technical procedures. In the event of harm to a person, the state must be held responsible for compensation for its failure to protect the environment, as it has breached a fundamental obligation incumbent upon it.

It is worth noting that in order for the state to fulfill its commitment to compensating and protecting those truly harmed [51], there must be foundations and regulations governing recourse to the state. This must be done by clarifying the nature of the damage caused by pharmaceutical residues and the amount of compensation it is committed to. To address this, a fund must be established within the Ministry of Health for those harmed by pharmaceutical residues. This fund should be modeled after the Environmental Protection Fund [48]. Its financial resources should be financed by fines imposed on violators of regulatory legislation [52, 53] fees imposed on pharmaceutical companies and warehouses, and local and international financial support. It should have an independent financial and administrative entity and operate in accordance with the requirements of its internal regulations.

To ensure the effectiveness of this fund and to advance sustainable development, a unified National Environmental Observatory should monitor compliance, publish data on pharmaceutical residues, and coordinate inspections across ministries-thereby ensuring the practical implementation of regulations and strengthening both environmental protection and public health.

Finally, the weakness and fragmentation of civil liability rules for environmental damages leads us to seek different means to adapt these rules. Among these means has emerged the idea of insurance against environmental damages in general, and pharmaceutical residues in particular, as they are considered hazardous medical waste. Liability insurance has evolved significantly, encompassing many risks previously unknown in the insurance field. However, environmental damage insurance has a specific characteristic that raises questions regarding its legal and technical suitability and insurability.

This leads us to conclude that the concept of insurance against pharmaceutical residues is difficult to achieve. While the legal requirements are met, the technical requirements are difficult to meet for this type of risk, especially since one of the technical requirements is that the risk should not be dependent on the will of either party. The risk of pollution resulting from pharmaceutical residues does not fall under this description. Furthermore, this type of pollution does not occur suddenly, but rather gradually and is not detected until a period of time has passed.

Therefore, it is necessary to adapt the provisions of insurance in Jordanian law to enable it to be used as a financial resource to compensate those affected by damages resulting from pharmaceutical residues. In some countries, special insurance systems for environmental damages have emerged, such as the Clarkson system and the Carbol system, which is a special insurance system for nuclear pollution [54, 55]. Accordingly, pharmaceutical residues can be inventoried, collected, and disposed of Allouzi et al. [56]. Therefore, creating a special insurance system for this type of damage is not difficult for specialists in the fields of insurance, quantity calculations, and actuarial studies, provided it is prepared in parallel with the legislation necessary to manage the aforementioned pharmaceutical residues. Insurance instruments and financial guarantees can thus serve as complementary tools to the public mechanisms described above, provided that the existing legal provisions are adapted to effectively address the gradual and cumulative nature of pollution risks posed by pharmaceutical residues.

5. CONCLUSION

Although Jordan has enacted several laws aimed at environmental protection and waste management, specialized studies reveal that medical residues continue to cause significant harm to the environment, pointing to clear gaps in both the legislation itself and its enforcement. Current regulations do not specifically address medical waste within the environmental framework, and regulatory bodies have often failed to properly distinguish or manage household medical waste, treating it as ordinary non-hazardous trash. The environmental damage caused by these residues is widespread and dispersed, making it difficult to trace to a single source, and traditional tort law struggles to handle such slow and diffuse harm. This underscores the need to refine liability rules (presumptions upon breach; objective liability for specified high-risk activities) and to create complementary compensation mechanisms.

From a technical standpoint, the study highlights the urgent necessity to enhance Jordan's medical waste management systems, ensure stricter enforcement of relevant laws, and implement extensive training programs for all personnel involved in waste handling. Developing a unified national framework is vital to safeguard both public health and the environment. Although types, amounts, and treatment methods of medical waste vary across healthcare facilities, most practices remain inadequate. Despite notable progress in modernizing the healthcare system, waste management still faces major challenges such as outdated infrastructure, weak regulatory oversight, limited resources, and low public awareness. Accordingly, we recommend legislative amendments to clarify "financial liability" (penalties vs. compensation), explicit civil-liability provisions for environmental harm, establishment of a National Environmental Observatory, and creation of a Pharmaceutical Residues Compensation Fund to support remediation and victim compensation. Upgrading wastewater treatment to address pharmaceuticals-aligned with WHO (2019) and OECD (2020)-and rolling out a nationwide household take-back program are essential to reduce diffuse inputs at source and advance sustainable environmental development.

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