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Reverse logistics of medicines in Brazil: environmental and legal impacts

Logística reversa de medicamentos no Brasil: impactos ambientais e legais

Logística inversa de medicamentos en Brasil: impactos ambientales y legales

Indianara Ignacio Milkievicz
Master's Student in Environmental Sciences
Institution: Universidade do Estado de Santa Catarina
Address: Lages – Santa Catarina, Brazil
E-mail: indianara.im@edu.udesc.br

Catiane Rosa Borges
Master's Student in Environmental Sciences
Institution: Universidade do Estado de Santa Catarina
Address: Lages – Santa Catarina, Brazil
E-mail: catiane.arts@hotmail.com

Eduarda Sutil Medeiros Paes
Master's Student in Environmental Sciences
Institution: Universidade do Estado de Santa Catarina
Address: Lages – Santa Catarina, Brazil
E-mail: eduarda.sutil@outlook.com

Alexandre Borges Fagundes
Doctor in Technology
Institution: Universidade Tecnológica Federal do Paraná
Address: São Bento do Sul – Santa Catarina, Brazil
E-mail: alexandre.fagundes@udesc.br

Fernanda Hänsch Beuren
Doctor in Production Engineering
Institution: Universidade Federal de Santa Catarina
Address: São Bento do Sul – Santa Catarina, Brazil
E-mail: fernanda.beuren@udesc.br

Caroline Rodrigues Vaz
Doctor in Production Engineering
Institution: Universidade Federal de Santa Catarina
Address: Florianópolis – Santa Catarina, Brazil
E-mail: caroline.vaz@ufsc.br

ABSTRACT
Pharmaceutical waste management in Brazil faces significant challenges, and reverse logistics is a promising tool to address this situation. One of the main obstacles is the lack of awareness among the population about proper disposal of medicines, which results in inappropriate

practices that compromise both public health and the environment. Incorrect disposal generates alarming environmental impacts, such as contamination of ecosystems and increased resistance of pathogens, which highlights the urgent need for responsible disposal practices. Despite the existence of legislation, such as Law No. 12.305/2010, the effective implementation of these standards is limited, especially in the North and Northeast regions of the country, where the collection infrastructure is insufficient. In this context, education and awareness initiatives are essential for the success of reverse logistics. Programs that establish partnerships between governments and non-governmental organizations have shown positive results. The study proposes improvement strategies, including the expansion of the collection network, intensive educational campaigns, and financial incentives for companies involved in reverse logistics. The findings highlight the need for an integrated approach that combines public awareness, robust public policies and adequate infrastructure to ensure a safer and more sustainable future in pharmaceutical waste management.

Keywords: reverse logistics, pharmaceutical waste, proper disposal, awareness, public health, environment.

RESUMO

A gestão de resíduos farmacêuticos no Brasil enfrenta desafios significativos, sendo a logística reversa uma ferramenta promissora para enfrentar essa situação. Um dos principais obstáculos é a falta de conscientização da população sobre o descarte adequado de medicamentos, que resulta em práticas inadequadas que comprometem tanto a saúde pública quanto o meio ambiente. O descarte incorreto gera impactos ambientais alarmantes, como a contaminação de ecossistemas e o aumento da resistência de patógenos, o que evidencia a urgente necessidade de práticas de descarte responsáveis. Apesar da existência de legislações, como a Lei nº 12.305/2010, a implementação efetiva dessas normas é limitada, especialmente nas regiões Norte e Nordeste do país, onde a infraestrutura de coleta é insuficiente. Neste contexto, iniciativas de educação e conscientização se mostram essenciais para o sucesso da logística reversa. Programas que estabelecem parcerias entre governos e organizações não governamentais têm apresentado resultados positivos. O estudo propõe estratégias de aprimoramento, incluindo a expansão da rede de coleta, campanhas educativas intensivas e incentivos financeiros para empresas envolvidas na logística reversa. As conclusões destacam a necessidade de uma abordagem integrada, que una a conscientização da população, políticas públicas robustas e infraestrutura adequada, visando garantir um futuro mais seguro e sustentável na gestão de resíduos farmacêuticos.

Palavras-chave: logística reversa, resíduos farmacêuticos, descarte adequado, conscientização, saúde pública, meio ambiente.

RESUMEN

La gestión de residuos farmacéuticos en Brasil enfrenta desafíos importantes, siendo la logística inversa una herramienta prometedora para abordar esta situación. Uno de los principales obstáculos es la falta de concienciación de la población sobre la disposición adecuada de medicamentos, lo que deriva en prácticas inadecuadas que comprometen tanto la salud pública como el medio ambiente. La disposición incorrecta genera impactos ambientales alarmantes, como la contaminación de los ecosistemas y el aumento de la resistencia a los patógenos, lo que pone de relieve la urgente necesidad de prácticas de eliminación responsables. A pesar de la

existencia de legislación, como la Ley nº 12.305/2010, la implementación efectiva de estas normas es limitada, especialmente en las regiones Norte y Nordeste del país, donde la infraestructura de recolección es insuficiente. En este contexto, las iniciativas de educación y concientización son esenciales para el éxito de la logística inversa. Los programas que establecen alianzas entre gobiernos y organizaciones no gubernamentales han mostrado resultados positivos. El estudio propone estrategias de mejora, incluida la ampliación de la red de recolección, campañas educativas intensivas e incentivos financieros para las empresas involucradas en la logística inversa. Los hallazgos resaltan la necesidad de un enfoque integrado que combine la concienciación pública, políticas públicas sólidas e infraestructura adecuada para garantizar un futuro más seguro y sostenible en la gestión de residuos farmacéuticos.

Palabras clave: logística inversa, residuos farmacéuticos, eliminación adecuada, concienciación, salud pública, medio ambiente.

1 INTRODUCTION

The incorrect disposal of medicines on a large scale is a matter of concern at the environmental level, due to the facilitated access and the growing demand for purchase, on the part of the population. Many drugs purchased end up stored in useless homes, resulting in their disposal in ordinary waste, whether due to expiration or destruction. This practice brings pharmaceutical residues to landfills, lakes and rivers, harming aquatic fauna and flora, and consequently, antibiotic-resistant superbacteria appear (Rebehy *et al.*, 2019).

In addition, government agencies have sought to protect environmental conservation and promote public health safety. The Ministry of Health and the Ministry of the Environment have laws and regulations that guide the proper disposal of waste. From the same point of view, the National Health Surveillance Agency (ANVISA) plays a crucial role in the supervision of safe disposal practices of medicines (Brazil, 1999).

Similarly, the National Council for the Environment (Conama), created in 1981 by Law 6,938, which has mechanisms for formulating public policies aimed at environmental preservation (Brazil, 1981). Since its creation, Conama has promoted strategies for the protection and recovery of the environment, including policies for the sustainable use of natural resources. The implementation of effective public policies requires a participatory approach by society. Even so, the population's adherence to these guidelines is often insufficient, causing damage to the environment and public health.

However, in Brazil, the shared responsibility of the product life cycle was adapted instead of extending the responsibility to the producer (Caiado *et al.*, 2017). The Reverse Logistics (LR), for Agrawal *et al.* (2015), is the recovery of the value of goods when no longer used and discarded by a consumer. This logistics is part of Law 12,305 of August 2, 2010, also known as the National Policy on Solid Waste (PNRS), to comply with the principle of shared responsibility (Brazil, 2010). Such action contributes to the reduction of wastes arranged in nature.

In addition, waste management follows the collection step, where products are collected from the consumer. Sorting: in which the material is transported and transshipped, i.e. separated and organized according to its condition and destination. The treatment: end of the environmentally appropriate final process (Brazil, 2010). LR practices aim at reusing the product, repairing and reconstructing damage where necessary so that it is not disposed of (Bouzon *et al.*, 2016; Bouzon *et al.*, 2018). For Zeqiang *et al.* (2006), reuse is to use a functional component of a discontinued assembly. Repair is to get the damaged goods back into operation, and remanufacturing is a transformation of used components that satisfy the same quality as new products.

According to Dat *et al.* (2012) reverse logistics in relation to post-consumption has some problems to be solved in the public or private sectors. Andrade (2013), emphasizes that the main challenges pointed out by the industries are: concentration of recycling companies in the southern and southeastern regions of Brazil, which brings high costs in the transportation of waste from other Brazilian regions; that is, high operating costs involving logistics, recovery and sale of the material; recovered items of low added value in comparison to the high operating costs; little government support for selective collection, among others. Therefore, although there are studies on the correct destination of medicines, there are still many people who discard incorrectly, affecting the soil microbiota and contaminating water sources.

This article presents a survey on the legal means that serve as the basis for the disposal and treatment of solid waste of medicines, emphasizing the importance of educating the population about the correct disposal of this waste. It also discusses how reverse logistics can be effective in mitigating environmental damage caused by incorrect drug disposal.

2 THEORETICAL FRAME

2.1 ENVIRONMENTAL IMPACTS OF INAPPROPRIATE DISPOSAL OF MEDICINAL PRODUCTS

The continued presence of drugs in the environment may contribute to the development of resistance in pathogens, making medical treatments less effective. Exposure to emerging contaminants, such as drugs, can have adverse effects on human health, although the exact mechanisms are still being studied. Intake of contaminated water can lead to acute or chronic effects, depending on the substance and concentration (Ioannidi *et al.*, 2022).

Drugs present in aquatic environments can be bioaccumulated by organisms, leading to higher concentrations in predators and potentially affecting human health through the consumption of fish and other contaminated organisms (Spilsbury *et al.*, 2024). The identified ecological risks may lead to the degradation of aquatic ecosystems, affecting biodiversity and ecosystem services, which are essential for environmental and human health (Rezende; Mounteer, 2023).

The negative impacts of the emerging compounds on model organisms, such as the zebrafish (Danio rerio), highlights that exposure to drug mixtures compromises embryonic development. In addition, these compounds accumulate in sediments and organisms, persisting in the environment and harming the health of species dependent on these habitats, interfere with the endocrine systems of aquatic organisms, causing changes in behavior, reproduction and development, resulting in decreased populations of sensitive species and affecting the food chain (Kumar *et al.*, 2022).

Steroid hormones, such as oestrogens, progestogens, and androgens, are introduced into the environment primarily through human and animal excretion, residues of veterinary drugs, agricultural outlets, and pharmaceuticals. Even in low concentrations (nanograms to micrograms per liter), these hormones can cause significant adverse effects, such as alterations in the sexual characteristics of aquatic organisms and reproductive problems, in addition to potential risks to human health (Almazrouei *et al.*, 2023).

The study by (He *et al.*, 2024) indicates that endocrine disruptors affect CatSper channel function, which is crucial for sperm motility and fertility in both humans and animals, and the

results of the study suggest that exposure to these pollutants may be related to male infertility, and that strict regulation of these substances is necessary to protect reproductive health.

A study carried out in Europe points to the dangers and risks associated with pharmaceutical products in the aquatic environment, synthetic hormones (e.g. ethinylestradiol), which can interfere with the endocrine system of aquatic organisms. The study also identified that some active pharmaceutical ingredients have problematic risk profiles, with predicted environmental concentrations (PEC) exceeding safety limits, indicating a potential to cause harm to the environment (Spilsbury *et al.*, 2024).

Medicines such as antihypertensives, such as losartan, where losartan transformation products may be more toxic than the substance itself, affecting organisms such as Daphnia magna, crustaceans, algae and fish (Ioannidi *et al.*, 2022).

Diclofenac is a compound frequently detected in surface and groundwater, attributed to its low solubility and high sorption capacity, which make it resistant to degradation in wastewater treatment plants. Research has shown that the presence of diclofenac can induce genetic mutations in pathogenic bacteria and cause toxic effects in aquatic organisms such as Daphnia magna, resulting in genotoxicity and reproductive impairment. These impacts threaten biodiversity and the health of aquatic ecosystems. Furthermore, indirect exposure to the human population from the presence of diclofenac in drinking water sources poses a serious risk to public health, especially in regions with inadequate water treatment systems, which facilitate the contamination of water sources (Olasupo *et al.*, 2023; Wee *et al.*, 2024).

Steroid hormones have low biodegradability, which means they can remain in the soil for long periods, leading to continuous contamination. The presence of these compounds can alter the composition and activity of the soil microbiota, affecting essential processes such as decomposition and nutrient cycling. Steroidal hormones can be bioaccumulated in soil organisms such as earthworms and insects, which can impact the health of these organisms and consequently the biodiversity of the ecosystem, as well as affect plant growth and health, interfering with physiological processes and nutrient absorption (Bayode *et al.*, 2024).

2.1.1 Methods of treatment of water contaminated by medicinal products

The pollutants and their metabolites can enter the water bodies through domestic and industrial sewage, highlighting the limitations of the treatment methods currently used (Cravalho *et al.*, 2024). Waste water treatment plants (Wastewater Treatment Plants) are often unable to effectively remove steroid hormones, resulting in these contaminants remaining in effluents and subsequently in bodies of water.

The use of hybrid systems combining physical, chemical and biological methods has demonstrated superior efficacy in hormone removal compared to traditional approaches (Almazrouei *et al.*, 2023). Effective techniques include adsorption mechanisms, which involve physical and chemical interactions, such as hydrogen bonds, π-π interactions and Van der Waals forces, which are fundamental in the capture of antibiotics (Alawa *et al.*, 2024).

The study by Olasupo *et al.* (2023) addresses technologies for the removal of diclofenac, a pharmaceutical contaminant. Polymer Inclusion Membranes (PIMs) use polymers as a mechanical support and are capable of incorporating agents that favor ion exchange and selectivity for contaminants.

Nanotechnology is mentioned as an innovative approach, with the incorporation of silver nanoparticles (AgNPs) into PIMs, which enhance the efficiency in the removal of diclofenac, improving its adsorption and ion exchange properties. In addition, Advanced Oxidation Processes (PAOs) use chemical reactions to degrade organic contaminants into less toxic by-products, while adsorbent materials, such as modified clays and other eco-materials, are being exploited to capture diclofenac from water (Olasupo *et al.*, 2023).

Functionalized biochar has demonstrated a considerable antibiotic adsorption capacity, overcoming untreated biochar, as functionalization improves its surface properties, increasing surface area and the presence of functional groups that favor interaction with antibiotics. Various types of biomass, such as sugarcane residues, rice husks and coffee grounds, can be used in the production of biochar, each having characteristics that influence its effectiveness in removing antibiotics (Alawa *et al.*, 2024).

According (Ioannidi *et al.*, 2022) to the detection of losartan in effluents, this contaminant is not completely degraded by conventional biological treatment methods, resulting in concentrations that can negatively impact the environment.

A study on the ecological risk assessment of endocrine disrupting drugs and compounds in Brazilian surface waters showed that these compounds were the most frequently detected, with diclofenac and triclosan being the most prevalent drugs. Diclofenac has been identified as the one with the highest potential for ecological risk, with research predicting acute ecological risk in two thirds of the water bodies analyzed and chronic risk in one third. The presence of estrogen hormones was determinant for chronic risk, while diclofenac and triclosan were critical for acute risk (Rezende; Mounteer, 2023).

In addition, electrochemical techniques such as electrochemical oxidation and electrocoagulation have shown high efficacy in the degradation of pharmaceutical contaminants that are often difficult to biodegrade. These techniques can significantly reduce the concentration of drugs in wastewater, with countries such as China, India, Spain and the USA being leaders in research in this area, evidencing a growing international interest and collaboration (Nabgan *et al.*, 2022).

Bayode *et al.* (2024) highlight that the use of biosolvents and carbonaceous materials can achieve removal efficiency of up to 90%, outperforming the effectiveness of membrane filtration systems (~75%) and biological treatments that require more time. Advanced oxidation processes, such as photocatalysis and catalytic ozonation, have shown greater efficiency in removing steroid hormones at shorter periods, resulting in less toxic mineralized products. Despite the promising effectiveness of these advanced techniques, there is an urgent need for further research, especially in the photocatalytic degradation of steroid hormones (Bayode *et al.*, 2024).

2.2 LEGISLATION AND CHALLENGES FOR IMPLEMENTING REVERSE LOGISTICS IN PRACTICE

There are many laws in the area of medicine disposal, however, not all of them are followed by the population, either through ignorance of the subject, through lack of access, among other factors, which harm and jeopardize biodiversity and future generations. In Brazil, Law No. 12,305/ 2010, instituted the National Policy on solid waste (PNRS), the system of reverse logistics of home medicines expired or in disuse (Brazil, 2010). Furthermore, the Ministry of the Environment also has a role assured in this context, guaranteeing the preservation of the environment and water resources, with a focus on guaranteeing the security of biodiversity.

Likewise, the actions of the Ministry of Health regarding the disposal of medical waste are done by the National Agency for Sanitary Surveillance (ANVISA), which monitors and focuses on good practices to be followed in industries. Then, the professional responsible for the company with active registration should, together with the advice of his class, organize a Health Services Waste Management Plan (PGRSS). According to the technical regulations of ANVISA and CONAMA, Health Service Waste (HSR) produced in health establishments, whether human or animal, require rules to perform the correct disposal of solid waste and thus avoid health and environmental risks (Brazil, 2010). In short, Solid Residue (RS), is any discarded material that results from human activities in society (Brazil, 2010). The RS can be of home origin, commercial, fairs, health services, among others (Brazil, 2006).

As already mentioned, the irrational use of medicines by a good part of the population, is alarming, whether ingested or discarded in an incorrect manner, the drug ends up coming into contact with the environment. Undoubtedly, the lack of fractional sales contributes to the accumulation of useless medicines in households and, finally, they end up being discarded wrongly, as in common garbage (Alencar *et al.*, 2014; Bueno; Weber; Oliveira, 2009). The lack of existence of a program of collection of medicines overdue at home, is worrying (Souza; Falqueto, 2015), since as quoted by Pinto *et al.* (2014), wrongly disposing of medicinal products by society makes it possible for waste pickers to consume or abandon such waste in order to sell the packaging.

Second, Ramos *et al.* (2017), many Brazilian municipalities still use open-air landfills, an example of this is the capital Brasilia, in the Federal District, which has the largest landfill in Latin America. It is extremely worrying, as waste can contaminate soil, water, rivers, lakes, oceans, groundwater and groundwater (Pinto *et al.*, 2014; Bila; Dezotti, 2003; Zaparroli *et al.*, 2011). For Borges *et al.* (2016), the presence of drugs in waters at water treatment plants is challenging as it is difficult to remove.

The implementation of the reverse logistics laws faces a number of challenges. Amongst them, the lack of awareness of the population about the suitable places for discarding medicines that have expired or are in disuse stands out. Studies indicate that a large part of the population still discards these products in common garbage or in sanitary vessels, which aggravates soil and water contamination (Pinto *et al.*, 2014; Bila; Dezotti, 2003).

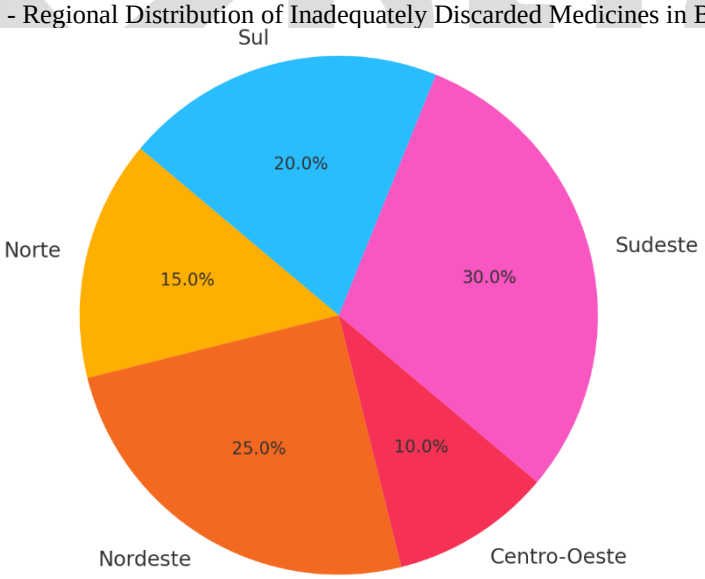
2.2.1 Implementation Challenges in Brazil

In Brazil, the challenges to implement the reverse logistics of drugs reflect a combination of structural and cultural factors. Despite the existence of legislation such as Law 12,305/2010, only a small fraction of the population has access to collection points and clear information on proper disposal. The concentration of recyclers in the South and Southeast aggravates the inequality in access to reverse logistics infrastructure (Andrade, 2013).

The absence of accessible collection points in smaller municipalities and the lack of educational campaigns amplify the problem. Furthermore, a study conducted in São Paulo revealed that only 4% of the interviewees use adequate collection points, while 62% dispose of medicines in common garbage and 19% in running water (Sincofarma, 2024).

Figure 1, shows the proportion of Medicines Discarded in Common Garbage by Region: It shows the estimated percentages of medicines discarded inadequately in different regions of Brazil. This data shows regional disparities, with the Southeast registering the highest proportion (Silva, 2023).

Figure 1 - Regional Distribution of Inadequately Discarded Medicines in Brazil.



Source: Adaptado de Silva (2023).

The analysis of these data suggests the need for decentralized policies adapted to regional specificities.

2.2.2 International Comparison

The implementation of drug reverse logistics systems in countries such as Germany, Japan and Canada offers examples of success that can serve as a reference for Brazil:

Germany: The country adopts a largely decentralized system, with pharmacies serving as collection points for expired drugs. Collection is integrated with a logistics chain that ensures proper disposal in advanced treatment facilities (Ojemaye; Petrik, 2019);

Japan: With a strong focus on environmental education, Japan promotes annual campaigns involving schools, communities and businesses. In addition, the use of advanced technologies, such as thermal oxidation processes, is common in the treatment of pharmaceutical waste (Toan *et al.*, 2019);

Canada: The Canadian reverse logistics program combines tax incentives for manufacturers and distributors with public awareness campaigns. This has resulted in a significant *reduction of pharmaceutical waste discarded in ordinary waste (Calderón-Moreno et al.*, 2019).

2.3 EFFECTIVE STUDY CASES AND PRACTICES: EDUCATION AND AWARENESS

Successful initiatives have shown that education and awareness are key to the effectiveness of reverse logistics. Programs involving partnerships between local governments and nongovernmental organizations have shown positive results in the collection and proper destination of medicines. For example, educational campaigns in schools and communities have contributed to increasing knowledge about the risks of inappropriate disposal and the correct methods of disposition (Ramos *et al.*, 2017). In addition, experiments such as the "Green Pharmacy" program, which offers collection points in pharmacies for expired drugs, have been shown to be effective in minimizing environmental impacts (Borges *et al.*, 2016).

In order to improve the effectiveness of the reverse logistics of medicines and the management of pharmaceutical waste in Brazil, it is essential to implement a series of recommendations. First, it is necessary to review existing legislation to include all cities, regardless of population size, ensuring that everyone has access to adequate disposal services (Souza; Falqueto, 2015). In addition, continuous environmental education campaigns should be

promoted to raise awareness of the risks associated with inappropriate disposal and inform about the correct locations for this practice (Pinto *et al.*, 2014). Finally, encouraging public-private partnerships can facilitate the implementation of innovative and sustainable solutions in pharmaceutical waste management (Zaparroli *et al.*, 2011).

2.3.1 Proposals for Improvement

Based on the examples already mentioned, the following strategies can be adopted in Brazil:

Expansion of the Collection Network: Expand the network of collection points for pharmacies and health centers in small and medium sized municipalities. Studies indicate that a broader geographical coverage could increase the collection of pharmaceutical residues by up to 30% (Sincofarma, 2024);

Intensive Environmental Education: Implement large-scale educational campaigns, such as those conducted in Japan, highlighting the impacts of inappropriate disposal and promoting the correct use of collection points. Research shows that awareness can increase adherence to responsible disposal by 40% (Toan *et al.*, 2019);

Financial Incentives: Offer subsidies to companies involved in reverse logistics and tax rebates to manufacturers who invest in treatment technologies;

Monitoring and Transparency: Creating digital platforms for tracking and disseminating information on pharmaceutical waste, in addition to establishing well-visible sites for proper disposal, is key to attracting attention in pharmacies that carry out collection.

Figure 2 presents an example of a collection point for pharmaceutical residues.

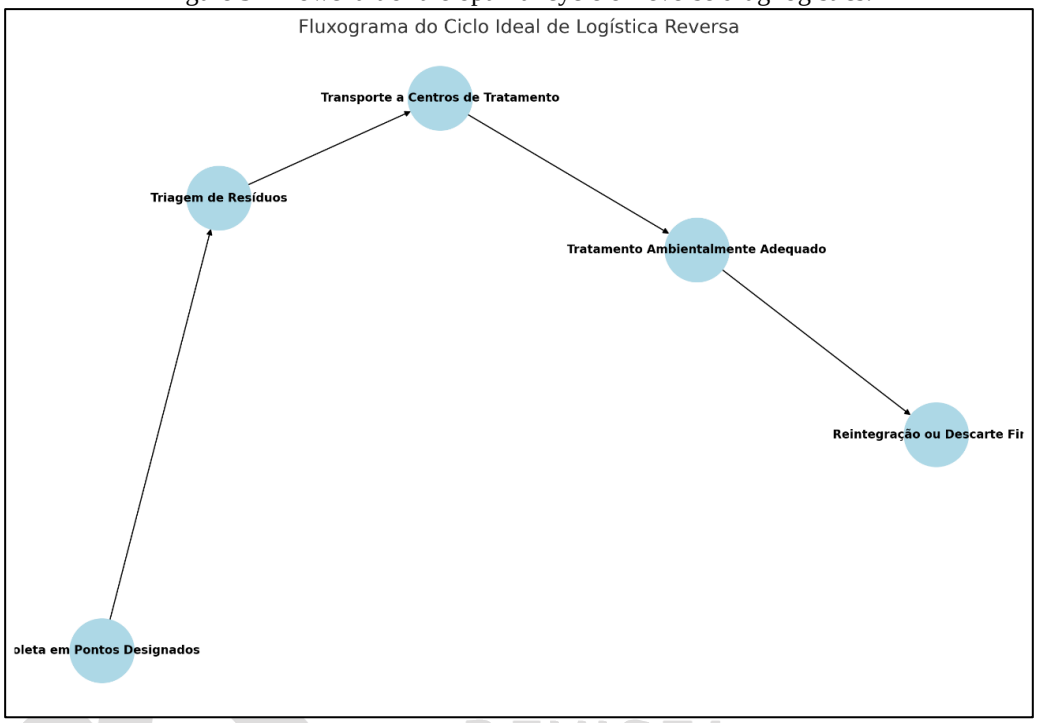
Figure 2 - Pharmaceutical waste collection point.

Source: Sincofarma (2024).

To do so, the ideal cycle of reverse logistics for medicines includes steps such as collection at designated points, waste sorting, transportation to treatment centers, environmentally appropriate treatment, and reintegration or final disposal. This process is critical to the design of effective waste management systems, ensuring that expired or disused drugs are disposed of in a safe and environmentally responsible manner (Da Silva Brito, 2019).

Figure 3 illustrates a flow chart of the optimal cycle of reverse drug logistics.

Figure 3 - Flowchart of the optimal cycle of reverse drug logistics.



Source: Prepared by the authors, based on Da Silva Brito (2019).

3 METHODOLOGY

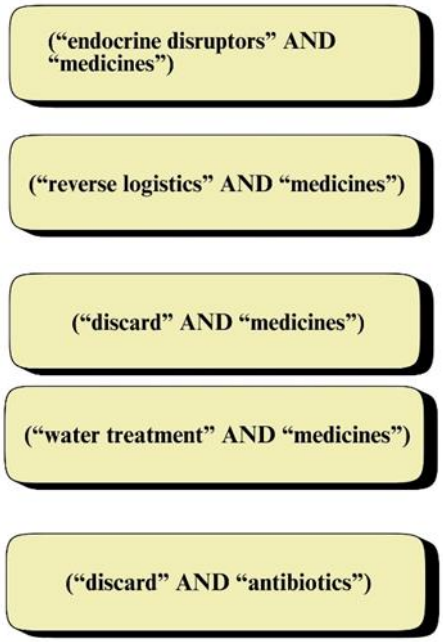
The objectives of this research were defined in order to address the gaps in pharmaceutical waste management and promote awareness about reverse logistics. Such objectives include: identifying the main challenges faced in implementing the reverse logistics of medicines, assessing the effectiveness of education and awareness-raising initiatives in promoting the proper disposal of medicines, and proposing recommendations for improving the infrastructure and public policies related to the disposal of pharmaceutical waste.

The bibliographic review was carried out following the PRISMA methodology, as proposed by Page *et al.* (2021). The authors describe this methodology as a set of guidelines that aims to improve the transparency and quality of systematic reviews. Thus, this method makes it possible to classify the articles with greater scientific relevance.

Initially, the keyword combinations set out in Figure 4 were used with the objective of contemplating the largest quantity of articles that interlinked the themes reverse logistics, medicines, environmental impacts and human health. The Science Direct database was used to

carry out the bibliographic survey. The period selected for the survey was from 2019 to 2024, covering the last six years of research on the subject.

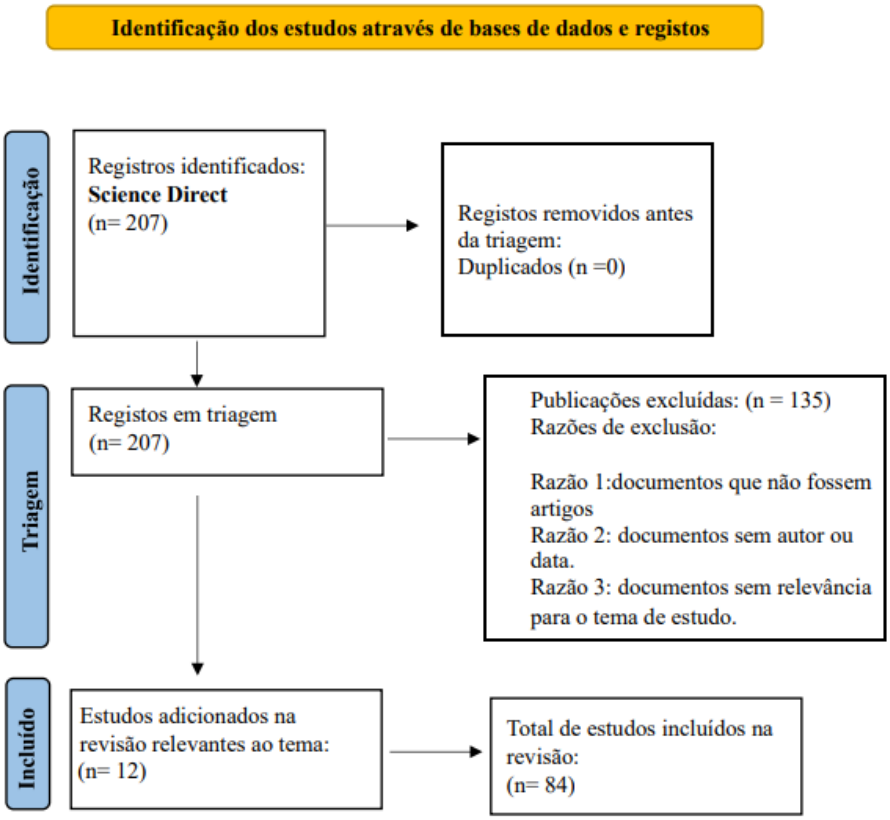
Figure 4 - Combination of keywords used in the database search.



Source: Prepared by the authors.

The initial search generated a total of 207 articles. These articles were submitted to a filtering process, which resulted in the deletion of: a) duplicates; b) documents that were not articles; c) documents without author, date or relevance to the topic in question. Thus, after the application of the ranking defined by the method, a bibliographic portfolio with 72 articles was obtained. In addition to these, 12 articles were added that were considered relevant to the theme, totaling a portfolio of 84 articles. This process can be seen in Figure 5.

Figure 5 - Steps carried out according *to the Prism Method* for the construction of the bibliographic portfolio.

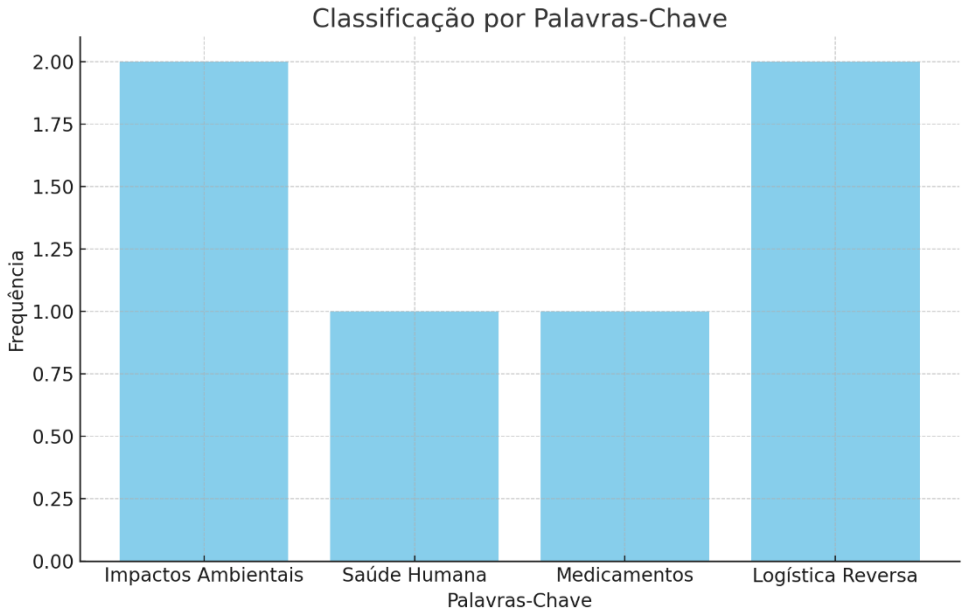


Source: Prepared by the authors.

3.1 TIME DISTRIBUTION OF PUBLICATIONS

Figure 6 shows the distribution of the articles analyzed over the period from 2019 to 2024. The data indicates that the theme has gained constant prominence in terms of publications during these years. This reflects a growing interest in the reverse logistics of drugs and their environmental and health impacts, with a regular contribution from relevant studies.

Figure 6 - Classification of articles according to key words used.



Source: Prepared by the authors.

4 ANALYZES AND DISCUSSIONS

The implementation of reverse logistics in Brazil faces significant challenges, both in structural and cultural terms. The lack of awareness of the population about the appropriate places for discarding medicines that are overdue or in disuse is one of the main obstacles. Research indicates that many individuals still dispose of these products inappropriately, contributing to soil and water contamination.

Environmental impacts resulting from inappropriate drug disposal include ecosystem contamination and potential pathogen resistance. The presence of pharmaceutical waste in the environment can compromise public health and biodiversity, underlining the urgency of responsible disposal practices.

Education and awareness initiatives are essential for the effectiveness of reverse logistics. Programs that promote partnerships between governments and non-governmental organizations have shown positive results in the collection and adequate destination of medicines. Promoting educational campaigns in schools and communities is crucial to increasing knowledge about the risks of inappropriate disposal and correct methods of disposal.

Although legislation exists, such as Law No. 12,305/2010, the effective implementation of these standards is still limited. The concentration of collection points in the South and Southeast regions of Brazil aggravates inequality in access to reverse logistics infrastructure, evidencing the need for decentralized policies that meet regional specificities.

Based on the analyzes, there are proposals for improvement, such as the expansion of the collection network, the implementation of intensive educational campaigns, and the offering of financial incentives to companies involved in reverse logistics. These strategies aim to increase adherence to responsible disposal and improve pharmaceutical waste management in Brazil.

5 FINAL CONSIDERATIONS

The main challenges faced in implementing disposal policies are the lack of awareness of the population and inequality in access to collection points. These factors have contributed to inadequate drug disposal, resulting in serious risks to public health and environmental contamination.

Knowing that there is ignorance and negligence in the disposal of medicines, on the part of society, it is interesting that in the package leaflets of the medicines, they dispose about the correct disposal of the product after it is no longer used by the buyer, in order to avoid contamination of the environment. This situation calls not only for a review of the legal rules, but also for a strong environmental education campaign to raise awareness of the risks associated with inappropriate disposal.

In addition, information campaigns are crucial to increase the population's adherence to responsible disposal. The promotion of clear information on suitable disposal sites and the risks associated with inadequate disposal can lead to significant improvements in pharmaceutical waste management practices.

The proposed improvements, which include expanding the collection network, implementing intensive educational campaigns and offering financial incentives to companies involved in reverse logistics, aim not only to increase the effectiveness of waste management, but also to foster a culture of environmental responsibility.

In short, this study contributes to the understanding of the challenges and opportunities in the management of pharmaceutical waste, serving as a call to action for the implementation of

sustainable and effective solutions. Public awareness and education, coupled with robust public policies, are essential to ensure a safer and healthier future, minimizing the negative impacts of inappropriate drug disposal on the environment and public health. The relevance of this research stands out in the search for a balance between human health and environmental preservation, promoting practices that benefit both society and the ecosystem.

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