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FACTORS INFLUENTIAL ON THE RETURN OF POST-CONSUMER PESTICIDE PACKAGING THROUGH REVERSE LOGISTICS: A CONTRIBUTION TO THE ESTABLISHMENT OF STRATEGIES

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ABSTRACT

Objective: The objective of this study was to investigate variables that influence the return of pesticide packaging through reverse logistics, listing important factors in four research axes: Product shelf life; Effective compliance with environmental standards; Consumer behavioral issues and Management of the reverse logistics system.

Theoretical Framework: This topic highlights the characteristics of pesticide packaging, possible health risks resulting from improper disposal, as well as factors that influence the return of this waste to the production chain through reverse logistics.

Method: The adopted methodology included a bibliographic survey focusing on the state of the art of the research object, the application of the conceptual model proposed by Marcos *et al.* (2025) and complemented by Ambrozi *et al.* (2020) and Pokriwieski *et al.* (2025), followed by analyses and considerations on the Reverse Logistics System for Pesticide Packaging.

Results and Discussion: From the perspective of the research, the variables that deserve greater attention were consumer behavior and effective compliance with environmental standards.

Research Implications: The practical and theoretical implications of this research encompass a more holistic view of the range of variables that can influence the return of post-consumer products through reverse logistics.

Originality/Value: This study contributes to li by expanding the understanding of variables involved in the reverse logistics of pesticide packaging. The relevance and value of this research are evidenced by listing elements that influence the performance of reverse logistics systems, thus providing inputs for the development of improvement strategies.

Keywords: Reverse Logistics, Pesticide Packaging, Influencing Factors, Campo Limpo System, InpEV.

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FATORES DE INFLUÊNCIA NO RETORNO DE EMBALAGENS DE AGROTÓXICOS PÓS-CONSUMO POR MEIO DA LOGÍSTICA REVERSA: UMA CONTRIBUIÇÃO PARA O ESTABELECIMENTO DE ESTRATÉGIAS

RESUMO

Objetivo: O objetivo deste estudo foi investigar variáveis que influenciam no retorno de embalagens de agrotóxico por meio da logística reversa, elencando fatores importantes em quatro eixos de investigação: Tempo de vida útil do produto; Cumprimento efetivo de normas ambientais; Questões comportamentais dos consumidores e a Gestão do sistema de logística reversa.

Referencial Teórico: Neste tópico, destacam-se as características das embalagens de agrotóxico, possíveis riscos à saúde decorrentes do descarte inadequado, bem como fatores que influenciam no retorno desses resíduos à cadeia produtiva por meio da logística reversa.

Método: A metodologia adotada compreendeu levantamento bibliográfico com foco no estado da arte do objeto de pesquisa, a aplicação do modelo conceitual proposto por Marcos *et al.* (2025) e complementado por Ambrozi *et al.* (2020) e Pokriwieski *et al.* (2025), seguido pelas análises e considerações ao Sistema de Logística Reversa de Embalagens de Agrotóxico.

Resultados e Discussão: Sob o viés da pesquisa, apontou-se como variáveis passíveis de maior atenção, a questão comportamental dos consumidores e o cumprimento efetivo de normas ambientais.

Implicações da Pesquisa: As implicações práticas e teóricas desta pesquisa abarcam um olhar mais holístico sobre a gama de variáveis que podem influenciar o retorno de produtos pós-consumo por meio de logística reversa.

Originalidade/Valor: Este estudo contribui para a literatura ao ampliar o entendimento acerca de variáveis envolvidas na problemática da logística reversa de embalagens de agrotóxico. A relevância e o valor desta pesquisa são evidenciados ao se elencar elementos que influenciam o desempenho de sistemas de logística reversa, assim fornecendo insumos para o desenvolvimento de estratégias de melhoria.

Palavras-chave: Logística Reversa, Embalagens de Agrotóxico, Fatores de Influência, Sistema Campo Limpo, InpEV.

FACTORES QUE INFLUYEN EN EL RETORNO DE ENVASES DE PLAGUICIDAS POST CONSUMO A TRAVÉS DE LA LOGÍSTICA INVERSA: UNA CONTRIBUCIÓN AL ESTABLECIMIENTO DE ESTRATEGIAS

RESUMEN

Objetivo: El objetivo de este estudio fue investigar las variables que influyen en el retorno de envases de plaguicidas a través de la logística inversa, enumerando los factores importantes en cuatro ejes de investigación: Vida útil del producto; Cumplimiento efectivo de las normas ambientales; Cuestiones de comportamiento del consumidor y gestión de sistemas de logística inversa.

Marco Teórico: En este tema se destacan las características de los envases de plaguicidas, los posibles riesgos para la salud derivados de una disposición inadecuada, así como los factores que influyen en el retorno de estos residuos a la cadena productiva a través de la logística inversa.

Método: La metodología adoptada incluyó un levantamiento bibliográfico con foco en el estado del arte del objeto de investigación, la aplicación del modelo conceptual propuesto por Marcos et al. (2025) y complementado por Ambrozi et al. (2020) y Pokriwieski et al. (2025), seguido de análisis y consideraciones sobre el Sistema de Logística Inversa para Envases de Plaguicidas.

Resultados y Discusión: Desde la perspectiva de la investigación, las variables que merecen mayor atención fueron el comportamiento del consumidor y el cumplimiento efectivo de las normas ambientales.

Implicaciones de la investigación: Las implicaciones prácticas y teóricas de esta investigación abarcan una visión más holística de la gama de variables que pueden influir en el retorno de productos postconsumo a través de la logística inversa.

Originalidad/Valor: Este estudio contribuye a la literatura al ampliar la comprensión de las variables involucradas en el problema de la logística inversa del envasado de plaguicidas. Se destaca la relevancia y el valor de esta investigación al enumerar los elementos que influyen en el desempeño de los sistemas de logística inversa, aportando así insumos para el desarrollo de estrategias de mejora.

Palabras clave: Logística Inversa, Envases de Plaguicidas, Factores Influyentes, Sistema Campo Limpo, InpEV.

1 INTRODUCTION

THE agriculture has been practiced by humanity for at least less ten thousand years , and over time , the search for substances to control pests and diseases that harmed crops , led to the development of the agrochemical . This same one had origin when the industry chemical after the wars worldwide , found in the agriculture a new market to be explored (London , 2011).

THE pesticide industry emerged globally , shortly after the First World War, however , the first units that produced pesticides in Brazil , appeared just during mid - 1940s , with the effective park constitution factory of these products , only occurred in mid - 1970s . Since then , the country became one of the main consumers of pesticides in the world (Terra and Pelaez , 2009).

With modernization in the cultivation techniques and frontier expansion agricultural , grew also the use of pesticides . There is a chance of a significant impact environmental , case no there is waste management from there resulting . When the packaging they are discarded in a manner inadequate , they they can contaminate the soils, the waters superficial , such as also you sheets phreatic . The waste also they can come to contaminate people and animals , placing your health in risk (Inpev , 2025).

Despite the pesticide packaging properly said , no to be harmful to health . While accommodate the pesticide , or same after use , when there is no negotiation suitable , they become dangerous sources of contamination . Campos *et al.* (2013) state that when these packaging post-consumption they are discarded in the field, the waste toxic resulting from the arrangement incorrect they are highly harmful to health human and animal, in addition to presenting risks to the quite environment .

Numerous they are you problem reports involving you pesticides , some diseases that develop in resulting from contact with pesticides they can leave serious consequences . Among the dangers involving the use of pesticides , what stands out most is the damage it causes he can cause harm to health , especially to health of those who work directly with the product , whether in the field or industry . Highlighting you dangers of poisoning chronic , in which the contamination happens in a way fractional . The births of children with malformations they can to have relationship with the pesticides , but not necessarily come only from contact directly with the pesticides . The use massive of these substances ends contaminating you food , water and even even the air (London , 2011).

Beyond the dangers occupational and food that come the to present to the beings humans , and can even be same one health issue public , it is known that the introduction of pesticides to the quite environment he can provoke effects undesirable , having as one of his consequences of changes in the functioning of ecosystems affected (Spadotto , 2006).

Like this being , it is exalted to importance of the farmer as the main agent in the logistics chain Reverse of pesticide packaging post-consumption , as it is responsible for cleaning and returning them to the receiving unit (or return point that comes indicated on the sales invoice) ; as the responsibility shared with traders , manufacturers and the Power Public , in order to ensure the correct final destination of these waste , through the Logistics System Reverse (SLR) established at this purpose .

Faced with potential harmfulness of pesticide residues , this search was motivated by seek a greater understanding about the operation of the SLR of pesticide packaging in force in Brazil , as well as the effectiveness of the results of its performance so far , considering as ideal condition the return of all packaging marketed , after your use .

Thus, in addition to the survey bibliographical focusing on the state of the art of the referred object of research , constitutes the main objective of this research , contribute to an intended improvement of the SLR of agrochemical packaging , giving subsidies for possible improvements , through the identification of variables that can interfere in the most wide return of pesticide packaging post- consumer through of this SLR.

In order to achieve you objectives established , it was carried out search bibliographical in books , articles scientific and sources specialized on the internet, leading to the realization of the present work scientific through references already published or that discuss the topic of interest and that serve as basis theoretical for the production of new works (Prodanov and Freitas, 2013).

2 THEORETICAL FRAMEWORK

2.1 MANUFACTURE OF PESTICIDE PACKAGING

According to InpEV (2025), there are two large groups of pesticide packaging: washable and non-washable:

Non-washable packaging is that which does not come into direct contact with the product, is flexible, making it impossible to wash, or even involves packaging in which the product does not use water for its application, such as plastic bags, paper bags, metalized bags, mixed bags or bags made with other flexible materials, packaging for seed treatment products, cardboard boxes, cardboard cartridges and fibrous cans ;

Washable packaging is rigid and can be made of plastic or metal (most commonly plastic), and contains the product that must be diluted in water for application. Therefore, around 1% of them are made of steel or other metals, such as HDPE Mono (High-Density Polyethylene), COEX (Multilayer Extrusion) or PP (Polypropylene).

Table 1 presents legal requirements for pesticide packaging.

Table 1

Legal Requirements Packaging.

DECREE Nº 4.074, OF JANUARY 4, 2002, ARTICLE 44. Defines that packaging for pesticides and similar products must meet the following requirements:	
I	They must be designed and manufactured in such a way as to prevent any form of leakage, evaporation or alteration of their contents and to facilitate washing, classification, reuse, recycling and appropriate final disposal operations.
II	They must be immune to the action of their content or likely to form harmful or dangerous combinations with it.
III	They must be resistant in all their parts and adequately satisfy the requirements for their normal conservation.
IV	They must contain a seal or other external device that ensures full visual verification of the packaging's inviolability.
V	Rigid packaging must display, in an indelible and irremovable manner, in an easily visible location, except on the lid, the name of the company holding the registration and a warning not to reuse the packaging.

Source: Adapted from Brazil (2002)

Washable and rigid plastic packaging, which contains pesticides, is made from different resins. The most important ones are: High-Density Polyethylene (HDPE), Polypropylene (PP) and Multilayer Coextrusion (COEX). HDPE resin is the most recycled resin in the world (Inpev , 2025). Used in a wide range of industry segments, its processing includes extrusion, injection and blow molding (Coutinho *et al.* , 2003).

Polyethylene is a thermoplastic material. Thermoplastics are plastics that soften when exposed to heat and can be reused and remanufactured by applying heat and pressure (Fried , 1995). The different types of polyethylene used by the industry are commonly classified and named with acronyms, which incorporate the density of the resin or the molecular weight. HDPE is a material produced by the polymerization of ethylene (Malpass , 2010).

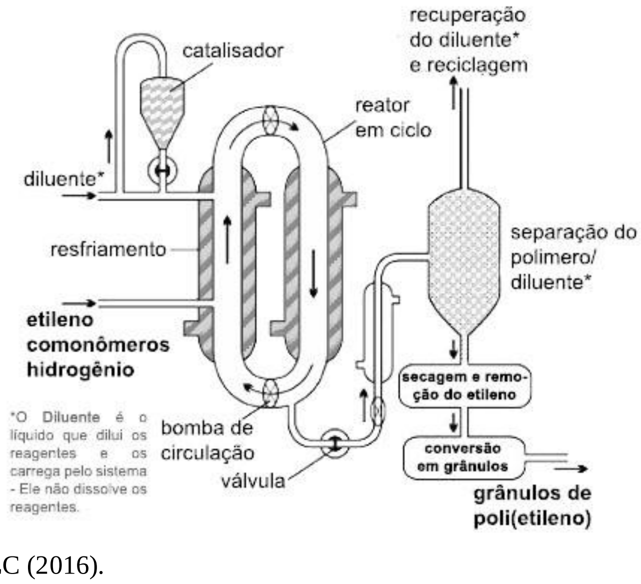
Chemically, a pure polyethylene resin is made up of alkanes with the formula C2nH4n+2, where n is the degree of polymerization, in other words, the number of ethylene monomers polymerized to create the chain. HDPE is the structure that most closely resembles pure polyethylene, being made up mainly of unbranched molecules, with a very low number of gaps that prevent this organization (Peacock , 2000).

Polyethylene is produced through the addition polymerization of ethylene, which can be done by several methods. It is mainly obtained through the cracking of ethylene, propane, naphtha and diesel (Ciec , 2016).

Ziegler-Natta catalysis (Figure 1) is one of the methods used to obtain HDPE commercially. The method is quite flexible and is used in a wide variety of catalytic systems. This type of polymerization uses relatively low pressure and heat conditions, well below those used in free radical polymerization, but overlaps with the average temperature and pressure required for the catalysis of the metal oxide (Peacock , 2000).

Figure 1

Polyethylene Production using Slurry Process in a Reactor in Cycle .



Source: Adapted from CIEC (2016).

The chemical industry is seeking a new approach to prevent, eliminate or reduce process waste. When it is not possible to eliminate production, the reuse of waste should be sought. However, it is still preferable to avoid it.

In agrochemical packaging, production by blow molding process stands out, where in large containers it is necessary to have resistance to falling, stacking and chemical products, or in smaller containers that require high resistance under tension, without presenting ruptures or cracks (Coutinho *et al.* , 2003).

HDPE resins have good resistance to visible light. However, when stored outdoors, they can be damaged by the combined effects of ultraviolet radiation and atmospheric oxygen. This can result in a decrease in durability and tensile strength (Molgroup , 2018).

It is worth highlighting as potential risks arising from the inadequate disposal of post-consumer pesticide packaging, the fact that they can take hundreds of years to degrade in nature, in addition to the risk of contamination of soil, water and air, which can cause impacts on human health and the environment (Sinir , 2025a).

2.2 THE REVERSE LOGISTICS SYSTEM FOR AGROCHEMICAL PACKAGING IN BRAZIL

The main objective of reverse logistics is to manage the flow of discarded material efficiently, in order to make it possible to return the goods and materials to the beginning of the production chain, or even to properly dispose of the product. The product does not necessarily need to return to its origin, nor be returned exactly to the point where it was manufactured, but rather to return to the company in some way. In practice, it is a means of reducing environmental pollution and avoiding waste, as well as enabling the recycling and reuse of waste. This process adds economic, ecological and legal value to the company (Wille and Born, 2013).

Some reverse logistics channels are structured naturally, simply by market laws, such as when the recovery of a product guarantees a financial return. In other cases, environmental legislation may be implemented, which aims to reduce the impact on the environment. The most recent legislation seeks to hold the manufacturer responsible for any impact that its products may cause (Leite, 1999).

The SLR for 'Pesticides, their residues and packaging' has as its managing entity the National Institute for Processing Empty Packaging (InpEV), which relies on the Campo Limpo System to provide environmentally appropriate disposal for these packages, and is governed by the following regulations, in chronological order (Sinir , 2025a).

Law No. 7,802/1989 , which provides for research, experimentation, production, packaging and labeling, transportation, storage, marketing, commercial advertising, use, import, export, final destination of waste and packaging, registration, classification, control, inspection and supervision of pesticides, their components and the like, and provides other measures;

Law No. 9,974/2000 , which amends Law 7,802/1989;

Decree No. 4,074/2002 , which regulates Law No. 7,802/1989;

Conama Resolution No. 465/2014 , which provides definitions, in accordance with federal legislation, that each participant in the reverse logistics system for pesticide packaging has a well-defined role within the shared responsibilities;

ANTT Resolution No. 5,947/2021 , which updates the Regulation for the Road Transportation of Dangerous Products and approves its Supplementary Instructions and provides other measures.

It should be noted that the aforementioned Reverse Logistics System was implemented prior to Law No. 12,305/2010, which established the National Solid Waste Policy.

In the reverse logistics system for agrochemical packaging implemented in Brazil, the responsibility of those who produce it goes from "cradle to grave", with the manufacturer being responsible for the disposal of its products, as well as its waste (Cometti , 2009).

Table 2 presents the responsible actors and their respective responsibilities in the reverse logistics of pesticide packaging.

Table 2

Responsibilities and Responsible Parties.

LAW Nº 9974, OF JUNE 6, 2000. Defines the following responsibilities and responsible parties:	
Responsible is	Responsibilities
Manufacturer	The fractionation and repackaging of pesticides and similar products for the purpose of commercialization may only be carried out by the producing company, or by a duly accredited establishment, under the responsibility of the producing company, in places and under conditions previously authorized by the competent bodies.
Manufacturer **Traders**	Companies that produce and sell pesticides, their components and similar products are responsible for the correct disposal of empty packaging of products they manufacture and sell. This includes packaging received through returns from users, as well as the correct disposal of products seized by inspections and products that are unfit for use or no longer in use. They seek to reuse, recycle or even render the packaging useless, in compliance with the rules and instructions of the competent regulatory and health-environmental agencies.
Users	Rigid packaging containing water-miscible or water-dispersible formulations must be subjected by the user to a triple wash operation, or equivalent technology, in accordance with the technical standards of the competent bodies and guidelines contained on their labels and leaflets.
	Users of pesticides, their components and similar products must return empty product packaging to the commercial establishments where they were purchased, in accordance with the instructions on the leaflets, within one year from the date of purchase, or a

	longer period if authorized by the regulatory body. The return may be arranged by collection points or centers, provided that they are authorized and inspected by the competent body.
Importer	When the product is not manufactured in the country, the responsibility for the return is transferred to the individual or legal entity that was responsible for the import and, in the case of an imported product subjected to industrial processing or new packaging, it will be up to the regulatory body to define it.

Source: Adapted from Brazil (2000)

To leverage the system and meet its legal obligations, InpEV established shared responsibilities for each link in the chain. It is everyone's responsibility to raise awareness and inform producers about the importance of properly carrying out technical procedures and participating in reverse logistics (Inpev , 2025).

Therefore, farmers are responsible for washing, disposing of and storing the packaging. Farmers are also responsible for returning the packaging to an authorized location, in addition to keeping proof of return for at least one year.

Distribution channels and cooperatives were tasked with recording on the invoice the location for returning empty packaging to farmers. After receiving the packaging, they must store the empty packaging appropriately and issue proof of return to farmers.

Furthermore, it is up to INPEV, representing the manufacturing industry, to remove the packaging collected at the receiving units and dispose of the material correctly, whether incineration or recycling.

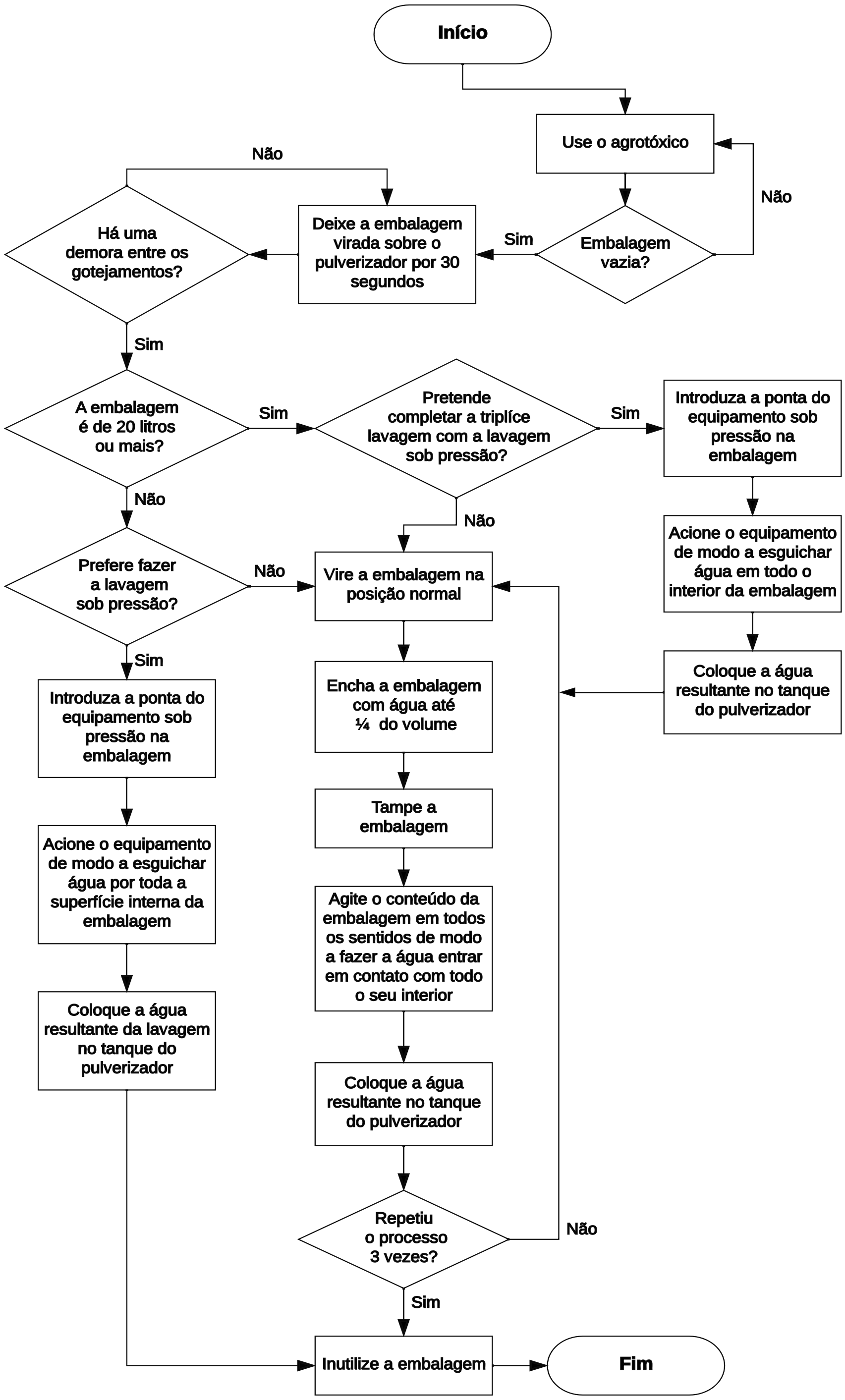
Finally, the public authorities are responsible for monitoring compliance with legal attributions at all levels of the chain, as well as licensing receiving units.

According to the Brazilian Regulatory Standard NBR 13968:1997 (Abnt , 1997), it is essential for farmers to wash post-consumer packaging, as this drastically reduces the amount of residue contained therein to a negligible amount. This practice is absolutely essential for the proper and safe final disposal of packaging. Recognized by countries belonging to the European Community, which agreed that packaging that has residue remaining in the water from the last wash of less than 0.01% can be considered common and non-hazardous waste.

Figure 2 shows a flowchart of the empty packaging washing procedure, based on the ABNT standard. NBR 13968:1997.

Figure 2

Packaging Rigid Empty : washing procedures .



Source: Adapted from ABNT (1997).

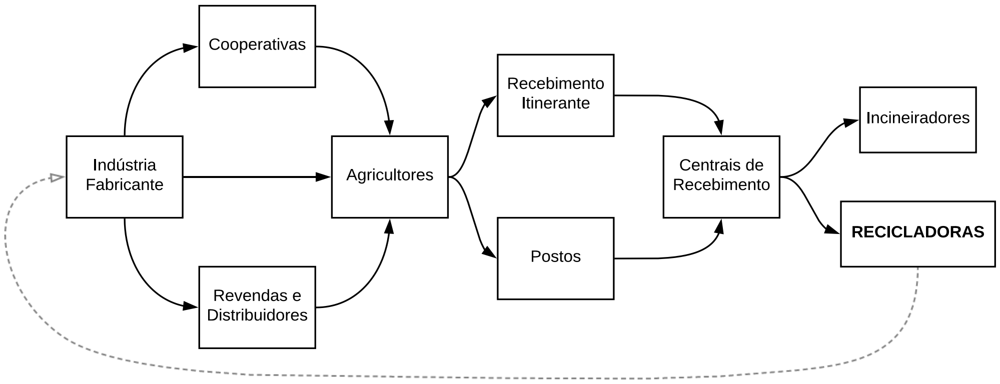
After the washing process, the packaging must be kept empty, with its respective lids and labels, stored in a suitable place and separated by type. They must be returned to the receiving unit indicated on the invoice, within one year after the date of purchase. Packaging that still contains the product must be returned within six months after the expiration date. The return can be scheduled electronically (Inpev , 2025).

Being a complex procedure, the correct final destination requires the collaboration of all agents involved in the chain of production, commercialization, use, licensing and inspection of activities. Supervision during the processes of movement, storage and processing of packaging is also necessary (Abnt , 2001).

Figure 3 shows the reverse flow of pesticide packaging through the Campo Limpo System.

Figure 3

Flow of Agrochemical Packaging by the Campo Limpo System .



Source: Adapted from INPEV (2025).

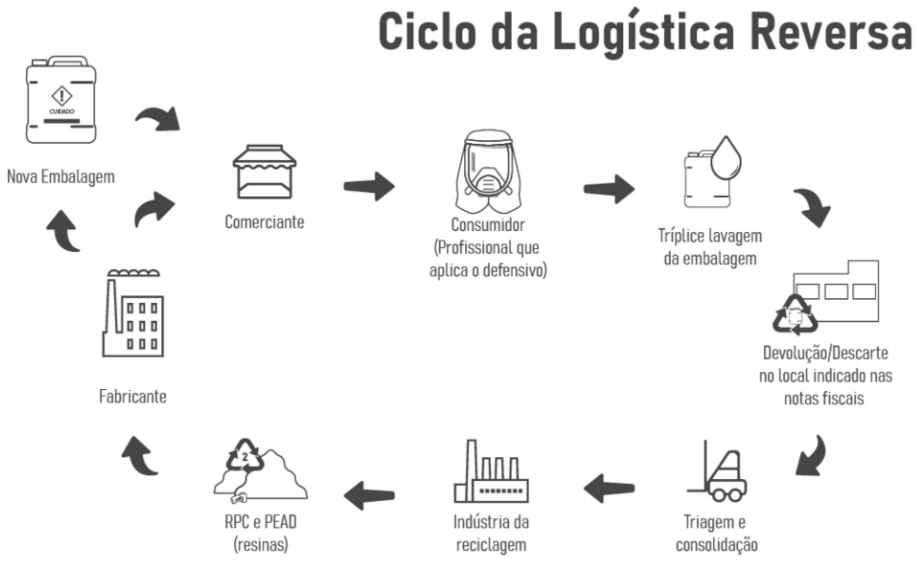
The NBR – Brazilian Standard, regulates the methods for the proper final disposal of agrochemical packaging. The user is responsible for meeting the washing and transportation criteria for returning the packaging, in addition to documenting its delivery and ensuring its washing. If a contaminated package is found, the owner of the package is held responsible for the false declaration and may be subject to penalties provided for by law (Abnt , 2001).

In economic terms, in order to be maintained effectively, the system must cover the costs used to maintain the storage space and to sort the packaging, as well as the equipment used, labor and transportation costs. Its main foundation is the search for recovering the investment with the return of post-consumer packaging (Lambert *et al.* , 2012).

Figure 4 shows the reverse logistics cycle for post-consumer pesticide packaging.

Figure 4

Logistics Cycle Reverse of Pesticide Packaging Post-Consumer .



Source: SINIR (2025a).

Therefore, this cycle works as follows. The disposal of empty packaging and leftover pesticides must always follow the technical recommendations presented in the package insert or supplementary leaflet acquired when purchasing the product (Sinir , 2025a). After using the product, before returning it, the farmer is responsible for washing the packaging in the field, storing it temporarily for delivery to the receiving unit.

Commercial establishments, receiving points and collection centers for empty packaging must have adequate facilities for receiving and storing empty packaging returned by users until the manufacturing company collects these items. In addition, merchants are required to provide proof of receipt of these packages. When the manufacturer is not from the country, the importer, whether an individual or legal entity, is responsible for reusing, recycling or rendering useless, and is responsible for the disposal (Sinir , 2025a).

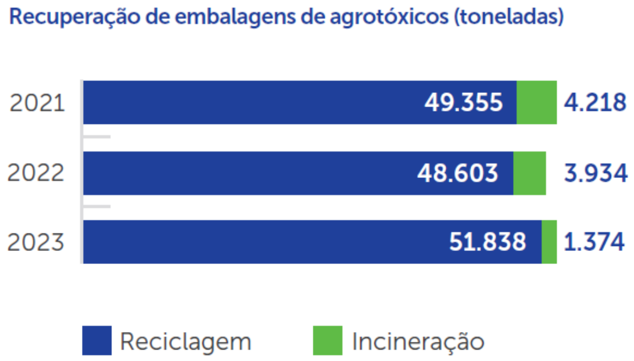
2.3 RESULTS OF THE IMPLEMENTATION OF THE REVERSE LOGISTICS SYSTEM FOR AGROCHEMICAL PACKAGING IN BRAZIL

The Campo Limpo System, operated by the National Institute for Processing Empty Packaging (InpEV), has seen positive progress in its processing, regarding the amounts received and destinations assigned to the Reverse Logistics System for Agrochemicals, their waste and packaging: it went from 53,573 tons processed in 2021 to 53,212 tons in 2023, of which 97% were sent for recycling and 3% for incineration. The resins resulting from the recycling process of these materials are used to manufacture other products, such as pipes for construction effluents, signaling posts for the transportation sector, and crossbars for power poles (Abrema , 2024; Inpev , 2025).

Figure 5 shows the amounts of post-consumer packaging disposal from 2021 to 2023.

Figure 5

Packaging intended by the Campo Limpo System (in tons).



Source: ABREMA (2024).

2.4 FACTORS INFLUENTIATING THE RETURN OF POST-CONSUMER PRODUCTS THROUGH REVERSE LOGISTICS

Traditionally, companies were primarily concerned with improving their supply chain. Nowadays, with increased competitiveness in environmental terms, companies have begun to focus more time and efforts on finding ways to improve their environmental performance. The main focus is on the return of post-consumer products through reverse logistics (Kumar and Chatterjee , 2011).

The return of pesticide packaging, or the lack thereof, can have numerous reasons, which may be directly linked to the consumer, as well as to the product and system that manages its reverse logistics. The factors that influence the return of pesticide packaging that are intrinsically linked to the consumer can be described in parallel with the factors that influence consumption. The opposite can also be said, since the profile of pesticide consumers can influence the return.

Understanding consumer behavior is important to know how the processes involved occur as individuals select, purchase, and discard. It is important to know that different people will have different responses to these processes. Decisions about how to dispose of the product are as important as the decision about how to buy it (Solomon , 2017). Among the factors that influence consumer behavior, according to Kotler and Keller (2012), are: cultural, social, and personal factors. Cultural factors are of greater importance because they have greater influence.

Among the cultural factors, each culture is composed of other subcultures, which identify their members more specifically. Within these, their members have similar, although not identical, behaviors (Kotler and Keller, 2012). Culture consists of elements of thoughts, perceptions, and values that act in groups that have shared a period, history, location, and even language (Wänke , 2009).

Communication must be articulated in a specific way to reach the target audience. Social factors present social groups that end up influencing the behavior of another individual. These groups can aspire both positively and negatively, where values and behaviors are rejected (Kotler and Keller, 2012).

From this perspective, researchers have been mobilizing studies, aiming at the full performance of Reverse Logistics Systems, as shown in Table 3.

Table 3

Authors active in the subject.

Marcos *et al.* (2025)	They propose a conceptual model listing factors that influence the return of post-consumer products through reverse logistics, considering three dimensions: Product useful life (planned obsolescence; warranty provided by the manufacturer; weather conditions; equipment maintenance; availability of spare parts; new technologies), Environmental responsibility (compliance with current regulations), Consumer behavioral issues (environmental awareness; incentives; cost x benefits of maintenance; consumer style; access to information; accidents/breakages/misuse);
Pokriwieski *et al.* (2025)	They present four groups of factors that influence the return/disposal of post-consumer products through reverse logistics (Compliance with environmental standards; Product lifespan; Consumer behavioral issues and the management of the reverse logistics system itself); which, in turn, are subdivided into more specialized topics, focusing on their object of study (cell phones);
Radzinski *et al.* (2025)	They propose a generic model of performance indicators for Reverse Logistics Systems, investigating four research topics: Quantities of products produced; Estimates of product lifespan; Predilections for disposal/destination of these residues by consumers; and Quantities of residues returned by Reverse Logistics Systems *versus* Environmental requirements of the products;
Schwarzer *et al.* (2025)	They present an analysis of nine Reverse Logistics Systems - with national scope - established in Brazil, classifying them - through the development of an AHP tool - according to the best fulfillment of pre-established performance requirements, taking into account four analysis topics: Reverse Flow, Objectives and Goals, Number of Collection Points and Quantities of waste to be returned;
Goeldner *et al.* (2020a)	Provides a discussion on the impacts arising from the Sectoral Agreement for the Reverse Logistics System for Packaging in General, providing an overview of the sector's actions towards promoting sustainability in the environmental, economic and social spheres;

Ambrozi *et al.* (2020)	They list four groups of factors that influence the return/disposal of post-consumer products through reverse logistics (Shelf life; Effective compliance with environmental standards; Consumer behavioral issues; Management of the reverse logistics system) which, in turn, are subdivided into more specialized topics, focusing on their object of study (batteries);
Goeldner *et al.* (2020b)	They promote an analytical comparison between Reverse Logistics Systems, highlighting six topics of interest (Reverse flow, Objectives and goals, Systems Management, Number of collection points, Counterpart of participating companies and Quantities of waste returned) in order to bring contributions to the area;
Couto and Lange (2017)	They propose performance indicators considering challenges involving three groups: Political and legal aspects, Operational aspects and Social aspects;
Rebelatto *et al.* (2016)	They point out the following as factors that hinder Reverse Logistics: Access of Systems to consumers; Capacity of dissemination and coverage of Systems in the national territory; Control of the quantities of products inserted in the market; Environmental demands related to the life cycle of products; Innovation and obsolescence of products; Shared responsibility and Systems still in the process of implementation.

It is therefore evident, as Couto and Lange (2017) proclaim, that in the context of Reverse Logistics Systems, performance indicators should not be limited to measuring material return rates.

2.5 POSSIBLE FACTORS INFLUENCE THE RETURN OF POST-CONSUMER AGROCHEMICAL PACKAGING THROUGH ITS REVERSE LOGISTICS SYSTEM IN BRAZIL

Using the research of Marcos *et al.* (2025) as a basis, Ambrozi *et al.* (2020) and Pokriwieski *et al.* (2025), this topic addresses factors considering four dimensions of study: Product lifespan (planned obsolescence; manufacturer's warranty; weather; equipment maintenance; availability of spare parts; new technologies), Effective compliance with environmental standards (compliance with current regulations), Consumer behavioral issues (environmental awareness; incentives; cost x benefits of maintenance; consumer style; access to information; accidents/breakdowns/misuse) and Reverse logistics system management (good input controls; reduced cycle time ; information systems; standardized and mapped processes; planned logistics network).

2.5.1 Product Lifetime

The useful life of a product has a great influence on Reverse Logistics, since it encompasses everything from its launch to its destination, and can be related to the life cycle of living beings, going through several phases, from birth to old age, being susceptible to several unforeseen events throughout this period (Silva et al., 2006; Frossard , 2013; Marcos *et al.* , 2025).

In the introductory phase, the product is launched on the market, initially with reduced sales and low profits; followed by increased sales until maturity is reached; at which point manufacturers tend to improve existing products and launch new products to stimulate consumption, seeking to delay their obsolescence (Kotler and Keller, 2006).

Regarding possible unforeseen events throughout the useful life of a product, it is worth noting that there is no logical sequence, and the product may end up having to be taken off the market due to its lack of acceptance, without even reaching the maturity stage, for various reasons (Kotler and Keller, 2006; Reis, 2007; Marcos *et al.* , 2025).

2.5.1.1 Planned Obsolescence

Planned obsolescence occurs when the useful life of the product is reduced or limited on purpose, that is, the end of the product's life is terminated early, causing them to be discarded more frequently, stimulating consumerism and thus increasing the company's profits (Dannoritzer , 2011; Furtado, 2011; Efing and Paiva, 2016; González, 2017).

Obsolescence can be characterized by ten key points , as shown in Table 4.

Table 4

Characteristics of planned obsolescence.

Artificial	It goes against natural obsolescence and therefore against the essence of the product itself, because it will become obsolete before the normal time.
Deliberate	It is an intentional or premeditated process. First, the idea is initiated, which is then materialized. There is a prior analysis process, which evaluates the potential benefits of carrying out this practice. Specifically, for: (a) the time that the product should last adequately before becoming obsolete and (b) the economic gains that can be obtained.
Unilateral	The decision to reduce the useful life is solely in the hands and will of the employer/businessperson and is therefore not subject to negotiation with the purchaser/client.
Secret	The reduction in useful life is not communicated to the customer or end consumer.
Reduction of Service Life	The design of the product shows that less time can be spent on it. In this context, the useful life of a product is understood as the time it will operate, fulfilling all the functions for which it was designed. It is the cycle in which the product was designed/created to be problem-free, without compromising proper maintenance. Planned obsolescence consists of reducing this life span, either by causing the disappearance of the main function, reducing its complementary functions, making it difficult to use, or convincing the consumer of the need to replace the good through psychological obsolescence.
Fixed Date	The businessman knows precisely the date or time when the good will become useless. That is why he says that it is "repaired" within the period of its useful life.
Design Defect	It implies that the defect is present in all products that are manufactured, so that "the manufacturing process itself causes defects (...) and the deficiency does not exclusively affect a single copy, but will be reproduced in all copies of the series". Design defects

	are in contrast to manufacturing defects, involving "a divergence between the product initially designed and the product actually manufactured".
Economic Purpose	It is an instrument to stimulate consumption, increase sales and, consequently, increase economic benefits for companies.
Without Legitimate Cause	The characteristic expressed in the previous note, and the reason for its implementation, is illegitimate, because it harms consumer rights and the environment.
Cautious Customers	Consumers' awareness of a product's planned obsolescence makes them more resistant to purchasing it, and neither companies nor the market can force the customer to consume or replace a certain product. However, in many cases, the customer has no other way out and ends up entering a vicious cycle (purchase, use, replacement).

Source: Marcos *et al.* (2025, p.12), adapted from González (2017).

In the case of agrochemical packaging, due to the entire reverse logistics system already implemented, where recycling is already considered an integral part of its life cycle, it is assumed that planned obsolescence does not apply to these.

2.5.1.2 Warranty provided by the manufacturer

In order to give consumers greater credibility regarding the products being manufactured, the warranty is used by the manufacturer to attract consumers, stimulating sales. This responsibility is supported by the Consumer Protection Code, through LAW 8.078/90, which protects the end customer under Brazilian law (Brasil, 2007; Marcos *et al.* , 2025).

For plastic packaging of pesticides, this warranty applies until the packaging is no longer fit for use, and has been damaged, with a hole or a lid that does not allow for proper insulation. For metal packaging, the warranty may be void if the packaging has been stored in inappropriate or humid locations, accelerating the deterioration and rusting process.

2.5.1.3 Weather

Inclement weather refers to climatic conditions, when they undergo some change, anomaly; adverse environmental conditions to which the product is exposed (Significados, 2025; Marcos *et al.* , 2025).

Therefore, pesticide packaging is subject to changes depending on its chemical composition, and specific environmental limit conditions are therefore defined for each type of packaging.

2.5.1.4 Equipment maintenance

Refers to the operation intended to maintain the product's functionalities (Marcos *et al.* , 2025).

This influencing factor, in the case of pesticide packaging, does not apply, since from the moment they can no longer be used, they will be destroyed, incinerated or given another environmentally correct destination, with available technologies.

2.5.1.5 Existence of spare parts

Refers to the availability of parts that can replace damaged parts of the product (Marcos *et al.* , 2025).

In the case of pesticide packaging, replacement parts are manufactured to meet the market demand and ensure that there is no shortage of products used by farmers.

2.5.1.6 New Technologies

New technologies concern the insertion of innovative products into the market (Marcos *et al.* , 2025).

Among the newest technologies applied to pesticide packaging, a polyurethane-based foam coating is responsible for absorbing pesticide residues. It is a type of plastic used in sponges, thermal or acoustic insulation, according to Orética (2018).

New technologies are constantly being improved to minimize the negative effects caused by pesticides.

2.5.2 Effective Compliance with Environmental Standards

It is important to emphasize the importance of the user's role in effectively complying with environmental standards, which, according to SINIR (2025a), are presented in the package insert or supplementary leaflet acquired when purchasing the product. After use and before returning it, the farmer is responsible for washing the packaging in the field, leaving it stored in an appropriate place until it is returned. NBR 13968:1997 of the Brazilian Association of Technical Standards (Abnt , 1997) defines "triple washing" and pressure washing, a technique that allows packaging waste to be diluted in different concentrations and reused in the field.

However, some risks are inherent, such as the large volume of contaminated packaging that is used in the field, if not disposed of correctly, will generate high contamination of the soil, water and air.

Furthermore, exposure to toxic substances without proper personal protection can have an impact on the farmer's health and the environment. Even if these packages are not treated properly, they can take hundreds of years to degrade in the environment, hence the importance of proper disposal.

2.5.3 Consumer Behavioral Issues

Through the analysis of consumer behavior, determining the factors relevant to the development and creation of the behavioral profile can be identified by internal and external factors. External factors are determined by the expectations of a group, which may or may not influence the consumer's choices. Internal factors are more personal, as they start from the consumer's curiosity in seeking information about products or services, and may also depend on their consumer lifestyle, among others (Blackwell *et al.* , 2005; Pinheiro, 2016).

Table 5 presents possible influencing factors considering consumer behavioral issues.

Table 5

Consumer Behavioral Issues.

Environmental Awareness	Ecologically conscious consumption can be established through the choice of certain products, according to consumer preference based on the impacts they have on the environment. Environmental awareness is understood as a change in behavior, both in activities and in aspects of the lives of individuals and society linked to the environment. Numerous companies and brands are joining a movement that has been expanding over the years called "environmental awareness" or green marketing, through advertising, offering environmentally friendly products, by means of products from recycling, reforestation, among others (Costa and Ignácio, 2011; Butzke , 2014; *et al.* , 2001; Mesquita Junior *et al.* , 2013; Marcos *et al.* , 2025). Therefore, the real awareness of the farmer is extremely relevant.
Incentives	In its history, inpEV has accumulated approximately 30 recognitions. Most recently, in 2020, it was one of the finalists for the Agrow Awards 2020 , in the Best Stewardship category . Program (Best Management Program), with the management of the Campo Limpo System. However, incentives for farmers are still minimal or non-existent, which must be improved so that this process can be carried out (Inpev , 2025).
Cost-Benefit of Maintenance	Not applicable, as pesticide packaging does not require maintenance. According to InpEV (2025), in the end, they are recycled or incinerated for other uses.
Consumer Style	There are three consumer styles: the impulsive consumer, who looks, likes and buys; the mature consumer, who considers his/her financial situation and determines his/her purchases with a degree of rationality and may even give in to some impulse, but "habitually" does not stray from a "shopping list". The other consumer style is the rational one who plans his/her consumption and takes into account his/her real needs. Observing the three styles, the ideal – regardless of the consumer style – is to consume

	responsibly (Cavalcanti, 2011; Solomon , 2011; Marcos *et al.* , 2025). Therefore, the rational consumer style is the one that most applies to the consumption of packaging, as it is used to meet the needs of products produced in agribusiness.
Access to information	The lack of information can directly lead to an increase in the amount of waste disposed of inappropriately. Therefore, the promotion of access to environmental information must be intensified, mainly covering the mass media, in order to encourage conscious disposal initiatives in companies, schools and the community in general (Barros, 2006; Marcos *et al.* , 2025).
Accidents/Breakages/ Misuse	Among the various factors that contribute to the early disposal of a given product are its misuse by the end consumer, as well as accidents and malfunctions (Andrade *et al.* , 2011; Fernandes, 2015; Piechnicki , 2011; Marcos *et al.* , 2025). Therefore, packaging must receive proper treatment and care so that its reuse is beneficial, preventing new packaging from being produced, helping to reduce pollution.

2.5.4 Reverse Logistics System Management

The management of the reverse logistics system depends on how this program will be defined and monitored. Lacerda (2002), Ambrozi *et al.* (2020) and Pokriwieski (2025) , define five factors that can be critical and that definitely contribute to the positive performance of the Reverse Logistics system:

a) Good input controls are the correct identification of materials found in the system, where it is possible to avoid the collection and transportation of products that are not part of the system and also avoid rework and future friction between customer and supplier regarding trust in the system;
b) Standardized and mapped processes are essential for the reverse logistics process, in which mapping processes and procedures is the best way to obtain controls and improvements;
c) Reduced cycle time is the beginning of the cycle at the end of the operation, therefore, the beginning occurs when the importance of recycling is recognized, the return of packaging to the system and then its processing;
d) Information systems are extremely important because they allow us to measure supplier performance and cycle time. Creating a database makes it possible to obtain information for future negotiations and identify excess consumer returns;
e) A planned logistics network is the infrastructure required to control the input of used materials and the output of materials that have been processed. The transportation of these materials in an organized and planned manner to connect the points of consumption, collection and facilities for reprocessing is extremely important to ensure that costs are kept to a minimum.

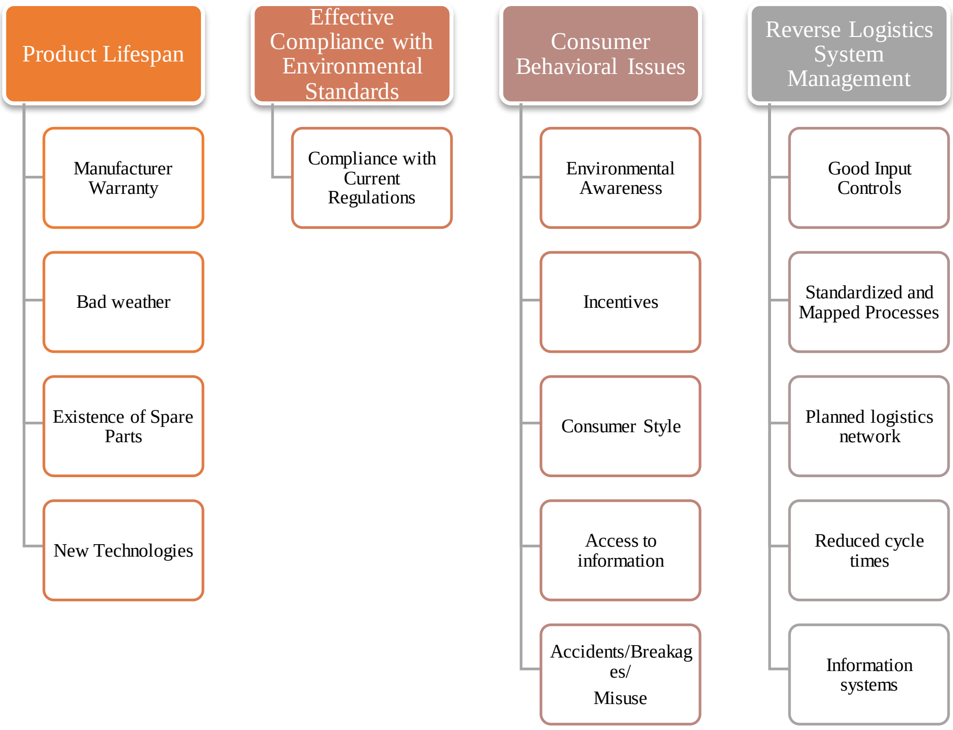
3 INFLUENCE FACTORS TO BE CONSIDERED WHEN RETURNING POST-CONSUMER AGROCHEMICAL PACKAGING THROUGH REVERSE LOGISTICS

It is understood that, for the reverse logistics process of post-consumer pesticide packaging, all the items previously mentioned structure the basis of this logistics, making the logistics chain more efficient and producing positive results.

Finally, considering an extract from the analyses of this research, Figure 6 presents influencing factors to be considered in the return of post-consumer pesticide packaging through reverse logistics.

Figure 6

Influencing factors to be considered in the return of pesticide packaging post - consumption through logistics reverse .



4 FINAL CONSIDERATIONS

The good performance of Reverse Logistics Systems results in the mitigation of the harmful effects of inadequate waste disposal.

In this sense, the ideal premise for the performance of Reverse Logistics Systems can be considered to be the receipt and environmentally appropriate disposal of close to 100% of post-use/consumption products (waste generated).

In practice, when analyzing the data made available by the National Information System on Solid Waste Management, considering the various Reverse Logistics Systems implemented in Brazil (SINIR, 2025b), the implementation of this premise has not proven feasible to date, presenting performance limitations that frustrate necessary and urgent mitigations of adverse impacts in a more comprehensive manner, possibly due to the particularities of each type of waste, in addition to other intervening factors, which may be negatively influencing the return of these post-use/consumption products (waste generated) and consequent adequate disposal through Reverse Logistics Systems.

Considering the research by Rocha and Leite (2015), the contemporary inclusion of Reverse Logistics in business activities is pointed out as one of the probable implications for the lack of performance elements in this theme.

Thus, aiming at the balance between economic and social development and environmental preservation, under the understanding that the most appropriate destination of waste objects from each Reverse Logistics System has a proportional relationship with the increase in the efficiency of the performance indicators of these Systems, the best definition and improvement of these indicators is configured as an important factor of promotion.

The search for excellence in the management of the Reverse Logistics System for Agrochemical Packaging, in line with the ideal premise of performance from an environmental point of view, led to reflections on the influence of different variables, pertinent to four dimensions of study: Product shelf life, Effective compliance with environmental standards, Consumer behavioral issues and Management of the reverse logistics system.

Under these biases, it was understood that variables that could receive greater attention, in the sense of overall improvement in results, were the behavioral issue of consumers and the effective compliance with environmental standards, focused on consumers and receiving stations of this waste.

Thus, and from a focused perspective, this research sought to contribute to an intended improvement of the Reverse Logistics Systems for Agrochemical Packaging, providing possible subsidies to assist in establishing strategies for the sector; also providing the opportunity for the applicability of this research as a reference for additional considerations regarding the performance analysis of other Reverse Logistics Systems currently operating in the country.

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