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Pharmaceutical Waste Management: A Comprehensive Analysis of Romanian Practices and Perspectives

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Abstract: Pharmaceutical waste management represents a global issue. There is a significant gap in consumers' education regarding the proper disposal of pharmaceutical waste. A significant amount of pharmaceutical waste is generated in health care facilities, including expired medicines, unused doses, and contaminated materials. Inadequate disposal of pharmaceutical waste can have effects on human health and on the environment. Managing pharmaceutical waste requires coordinated efforts from policymakers, health care providers, pharmaceutical manufacturers, waste management companies, and consumers. The purpose of this paper is to examine the current state of activities that may impact the efficiency of Romanian pharmacists in collecting and disposing of pharmaceutical waste, as well as the intentions of pharmacists/technicians to recycle this type of waste. Furthermore, this paper aims to identify institutional and behavioral barriers that affect effective waste management. This research was conducted using quantitative and qualitative research methods. An exploratory factor analysis was used to identify the elements of satisfaction and their attribution levels in the pharmaceutical industry. The statistical significance of the differences across different occupations regarding satisfaction with pharmacists' activities to reduce waste at each stage was tested using an analysis of variance. Cross-tabulation and a Pearson's chi-square test were used to analyze the relationship between occupational segments and intention regarding recycling and reusing pharma waste. This research was augmented using qualitative analysis based on the Delphi technique, focused on the barriers to waste management in the pharmaceutical sector. This study presents a general perspective on the current situation of pharmaceutical waste in Romania. The results indicate that the selection of appropriate pharmaceutical waste practices is primarily determined by the attitude of individuals and organizations, followed by regulatory, economic, and technical criteria. In developing sustainable pharmaceutical waste policies, this research provides practical implications for governments, organizations, and citizens. A comprehensive approach to overcoming barriers in pharmaceutical waste management was developed by combining institutional strategies that focus on organizational policies and infrastructure with behavioral strategies that target individuals and communities.

Keywords: medication wastage; pharmaceutical sector; recycling behavior; sustainable future; waste management

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1. Introduction

The pharmaceutical waste management market size is forecasted to grow over the period of 2024–2032, driven by the increasing demand for specialized pharmaceutical waste management practices that limit environmental and health risks. The global medical waste management market is estimated to grow at a compounded annual growth rate (CAGR) of 8.0% from 2024 to 2030 and is expected to reach USD 34.06 billion in 2024 [1]. The pharmaceutical industry presents an important extent in central and eastern Europe

(CEE). In 2021, the pharmaceutical market in Romania recorded revenues of more than EUR 3.9 billion. These outcomes placed Romania as the second-largest specialized market in the CEE region, following Poland [2]. Romania's pharmaceutical industry is forecasted to generate investment in the near future due to the national tax benefits, the increase in the number of online pharmacies, and the competitive labor costs. In Romania, the number of pharmacies has varied in the last years. In 2021, there were 8181 units recorded, while in 2022, 8135 units were recorded, indicating a downward trend [2]. In urban areas, Romania has recorded a rate of 6.1 pharmacies per 10,000 inhabitants. Hence, the country can be ranked among the top five European countries with the highest rates of pharmacies per capita [2].

The COVID-19 pandemic led to an increase in pharmaceutical sales by almost 30% from 2020 to 2022, peaking at RON 5.7 billion [2]. In the first quarter of 2023, 185.4 million boxes of medicines were sold in Romania. In the last years, the production, consumption, and waste of medicinal products has been remarkably increasing [3,4]. Moreover, the advent of the COVID-19 pandemic has led to an increase in the number of requests for medicines in conjunction with an increase in the number of medicines stored in households. This has resulted in an increase in the volume of pharmaceutical waste [5,6]. Most households are filled with medicines; some are out of date, and some are usable, but not needed. The COVID-19 pandemic made the purchasing behavior and the consumption of medicines less sustainable [7]. Due to this overcrowding, most people throw liquid medicines into toilets and the solid ones into rubbish containers, leading to environmental pollution. Economically, this waste of pharmaceuticals implies a loss of financial resources that the government spends for treatment [8]. The unjustified use of medicines is a worldwide problem. The World Health Organization (WHO) evaluates that more than half of all medicines are prescribed and sold inadequately, and that half of patients do not take them correctly [9].

Scholars define pharmaceutical waste in various ways. Pharmaceutical waste represents "drugs and medicines that can no longer be used" [10] (p. 1). For prescription medicines, pharmaceutical waste includes any medicine that stands unused or expires anywhere along the medicine's supply chain [11,12]. The most significant reasons for medication wastage in households are improvements or recoveries in patients' conditions, forgetfulness, adverse effects, changes in dosage or medication, death of the patient, and expiry of the medication [13–16].

Pharmaceutical waste represents any pharmaceutical product that is no longer usable due to expiration, unuse, spillage, withdrawal, recall, damage, contamination, or other causes. It also encompasses disposables that have been heavily contaminated by the handling of medicines, such as bottles, vials, boxes containing residual medicines, gloves, masks, and tubing [17,18]. Waste management involves collecting, packaging, storing, sorting, moving, treating, and disposing of waste and requires more science-based approaches. Pharmaceutical waste should be separated from other types of waste. Additionally, waste management budgets should be meticulously devised, and waste management practices should be optimized [10,17,19].

Pharmaceutical waste is potentially generated by a wide range of health care activities. The increased utilization of these substances has resulted in an elevated risk to public health. This is due to the increased exposure of the environment to pharmaceutical effluents and waste during their use and disposal [20]. Inadequate care in the management of waste can lead to serious problems for health care employees, waste workers, patients, and the public. Health care is compromised by a higher risk of pharmaceutical waste associated with lower knowledge of waste segregation [19]. Recycling is anticipated to become a key element in pharmaceutical waste management, which can bring economic and environmental benefits. The COVID-19 pandemic has contributed to the need for more sustainable medical product recycling due to the ongoing storage of medical supplies.

Pharmacists represent a key element in the process of minimizing waste because they could reduce the number of medicines held in stock, gather unused medicines, inform the

population about waste, and restrict the volume of medicines that are dispensed [21]. As drug experts, pharmacists are able to contribute to reducing pollution resulting from the disposal of pharmaceutical waste [22]. In Croatia, pharmacies are required by law to accept unused and expired medicines from patients. By law, pharmacies are considered manufacturers and holders of medicines and are, therefore, obliged to accept medicines from patients and to pay for them [23]. In Serbia, pharmacies are required to offer pharmaceuticals to patients only when necessary. Any excess or expired medications must be returned to the manufacturers, wholesalers, or specialized companies for proper disposal [24,25]. Significant progress has been made in pharmaceutical waste management in developed countries, including pharmaceutical waste regulatory frameworks, pharmaceutical take-back programs, industry initiatives, and international collaborations.

In Romania, pharmaceutical waste is forecasted to increase due to the aging population, national programs for increasing public spending on health, as well as health awareness, which is raised by online platforms and information, all resulting in a higher demand for pharmaceutical products. An increase of 27.7% in Romania's population aged 65 and over is forecasted by 2050, in conjunction with an increasing demand for health products [26]. Current legislation states that expired medicines can be taken to pharmacies for disposal, but they are not obliged to receive the medicines, and the procedure of acceptance is not simple. Additionally, pharmacies should have a contract with a company for picking up the medications, and both the pharmacist and the customer handing over the medicines must fill out numerous forms. The procedure that specialized companies must follow for collecting, treating, and recycling pharmaceutical waste includes provision of specialized containers; collection and transport of waste medicines; separation and sorting of packaging; recycling of packaging; energy recovery or incineration of pharmaceutical substances; ensuring traceability of the disposal of expired medicines; and providing proof of the disposal of waste medicines. Pharmacies must have a special area dedicated to the storage of expired medicines, according to the Ministry of Health's order 444/2019 [27]. The Agency for Medicines and Medical Devices represents the institution that is authorized to destroy unneeded medicines. Citizens are required to hand in their medicines to pharmacies. However, due to bureaucratic obstacles and high disposal costs, many citizens do not receive proper disposal services. A new law is in the works, which stipulates that, from 2024 onwards, expired and unused medicines could be taken to collection points placed in hospital courtyards. Hospitals, whether public or private, will receive funds from the state budget for these actions. These funds will be provided by the Ministry of Health from the budget of the Single National Health Insurance Fund. An order of the Minister of Health will lay down the methodological rules for this purpose.

The aim of this paper is to identify the current situation regarding the activities that may affect the efficiency of Romanian pharmacists in collecting and disposing of pharmaceutical waste and pharmacists'/technicians' intentions regarding recycling and reusing pharmaceutical waste after COVID-19, and to identify institutional and behavioral barriers regarding waste management. To achieve this aim, there are two objectives: to implement quantitative research methods on the capabilities of pharmacies in the collection and disposal of medicinal waste and pharmacists'/technicians' intentions regarding recycling and reusing pharmaceutical waste; and to identify experts' perspectives regarding waste management for a better understanding of the barriers to the management policies for the pharmaceutical sector. This paper is structured by Introduction, Materials and Methods, Results, Discussions, and Conclusion Sections.

2. Materials and Methods

The aim of the quantitative research methods is to determine the activities that may affect pharmacies' capabilities of collecting and disposing of pharmaceutical waste and pharmacists'/technicians' intentions regarding recycling and reusing pharmaceutical waste. The qualitative research methods focus on experts' opinions using a two-step Delphi study

regarding pharmaceutical waste management, indicating the barriers to the management policies for this sector.

2.1. Research Objectives

O1: to identify the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce waste;

O2: to examine whether different occupation segments report different levels of satisfaction with pharmacies' activities to reduce waste;

O3: to determine whether there is a relation between occupational segments and intention regarding recycling and reusing pharmaceutical waste;

O4: to identify the institutional barriers that prevent the development of sustainable waste management in the pharmacy sector;

O5: to identify the behavioral barriers that encompass various challenges that hinder effective waste management practices.

2.2. Research Design and Data Collection

The quantitative research is based on a survey of pharmaceutical waste in Romania. During the data collection phase, a questionnaire was used to collect information about the current situation regarding activities that may affect the efficiency of Romanian pharmacists in collecting and disposing of pharmaceutical waste, and to determine the intentions of pharmacists and technicians regarding the recycling and reuse of pharmaceutical waste.

The current study uses previously validated scales. The items that indicated the satisfaction level of the respondents regarding the pharmacy's activities to reduce waste were measured with a 5-point Likert scale with equally distanced levels (from 1 = very dissatisfied to 5 = very satisfied). These elements were obtained from previous studies [28–39] and adjusted to the specificities of the subject being analyzed as follows:

1. Removing medication from the original package;
2. Using a unit-dose distributing system;
3. Adapting or renewing the prescribed quantity of medications by pharmacists;
4. Managing medication quantities held in stock-by-stock rotation;
5. Verifying medication quantities held in stock by checking expiry dates;
6. Controlling medications that are unused;
7. Removing medications that are expired;
8. Cooperating with other organizations to trade almost expired medications;
9. Dispatching unopened medications that can be 'reutilized' back to the manufacturer;
10. Notifying prescribers/managers about the unused medications in order not to be commanded;
11. Offering patients information on how to manage expired or unwanted medications;
12. Permitting patients to give back their leftover medicines to the pharmacy;
13. Advising the patients on the quantity needed for symptom recovery;
14. Collecting unutilized medications so they can be recycled;
15. Donating unused medications;
16. Understanding the legislation concerning waste disposal;
17. Poor education regarding waste management;
18. Insufficient dustbins; inadequate recycling facilities;
19. Insufficient landfill disposal places;
20. Attitude of the pharmacists' communities.

The survey was conducted between October 2023 and January 2024 throughout Romania. Nominal and binary scales for questions about subjects' intentions, opinions regarding pharmaceutical waste, and demographic characteristics were used. The questions referring to subjects' demographics included age, job sector, education, occupation, years of experience, and the type of pharmaceutical waste respondents mostly try to reduce. The subjects consisted of pharmacists and pharmacy technicians, from both the private and public sectors, working in hospital pharmacies, drugstores, and pharmaceutical companies.

To ensure adequate reliability, a pilot test was conducted on a sample of 21 respondents to identify any issues with the questionnaire. The questionnaire was distributed face-to-face to the subjects by volunteer operators. Participation was voluntary throughout the research. Confidentiality of the responses was ensured. Only questionnaires with valid responses were analyzed. A total of 14 questionnaires were excluded from the final sample due to their unclear responses. The research employed a convenience sampling method to collect respondents from a wide geographical area (Romania), resulting in a large sample. The final sample included 1123 questionnaires from pharmacists and pharmacy technicians.

This study is augmented by qualitative research based on the Delphi technique. Delphi is a popular technique for reaching a consensus among a small group of experts and has been applied to various sustainability and management aspects [40]. This research focused on the Delphi technique because researchers can obtain complex perspectives and structured feedback from respondents. This tool can help researchers explore a wide range of perspectives on waste minimization and forecasting the sustainable future of the analyzed topic. The Delphi technique is used as a decision-making instrument [41,42]. The technique is based on the concept that answers agreed upon by a group of experts are more dependable than those provided by a single respondent [43]. This study brought together a group of academics, industry specialists, and policymakers to gain a comprehensive understanding of pharmaceutical waste management systems and practices. The Delphi method can involve an expert group of between 10 and 18 experts [42]. Of the 23 experts contacted via e-mail, 15 experts agreed to participate in the study. The sample group was composed of three academicians from three different universities, five pharmacy managers, two Ministry representatives, and five pharmacy manufacturer managers. Their anonymity was ensured. Participants were selected through their research contributions to the field, professional backgrounds, and expertise fields.

2.3. Data Processing

The data was analyzed using IBM SPSS Statistics 25.0 software. The data was checked for missing values, outliers, and errors. The items with many missing values were not included in the analysis. The cases with random missing values were substituted with the mean values accordingly. Additionally, the errors occurring in the process of entering data were corrected.

An exploratory factor analysis (EFA) was used to identify the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce waste (O1). EFA represents a statistical technique used to identify underlying relationships between identified variables and to uncover the latent factors that explain the patterns in the data. Its aim was to obtain a reduced number of items with similar, but uncorrelated information regarding the pharmacists' and pharmacy technicians' satisfaction [44]. Following the analysis, three factors were obtained. The factors were chosen after eliminating the items that contained many missing cases. The EFA was calculated based on the following 11 items/activities:

1. Removing medication from the original package;
2. Managing the medication quantities held in stock-by-stock rotation;
3. Verifying the medication quantities held in stock by checking expiry dates;
4. Controlling the medications that are unused or expired;
5. Dispatching unopened medications that are 'reusable' back to the manufacturer;
6. Offering patients information on how to manage expired or unwanted medications;
7. Permitting patients to give back their leftover medicines to the pharmacy;
8. Advising the patients on the quantity needed for symptom recovery;
9. Collecting unutilized medications so they can be recycled;
10. Understanding the legislation concerning waste disposal;
11. Inadequate recycling facilities.

The analysis of the resulting scale was based on Cronbach's alpha coefficient, which returned a value of 0.71. The value confirmed the consistency of the form [45]. The Kaiser–

Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity were applied.

The statistical significance of the differences across different occupations regarding satisfaction with pharmacies' activities to reduce waste at each stage was tested using analysis of variance (ANOVA), (O2) [46].

A cross-tabulation and Pearson's chi-square test were used to analyze the relationship between the occupational segments and intention regarding recycling and reusing pharmaceutical waste (O3).

Regarding the qualitative research, the questionnaire focused on the barriers to waste management in the pharmaceutical sector. The items were selected after a complex study of literature and specialized practitioner publications [47–56]. The questionnaire contains items from legislation, economic elements, voluntary and community actions, education, performance, and technology areas (O4, O5). The barriers are the following:

1. Insufficient control for implementing legal content by the responsible specialists;
2. Ineffective control over pharma recycling costs and inappropriate budgeting;
3. Limited knowledge about pharma waste management;
4. An inadequate framework for facilitating stakeholder dialogue;
5. The general assumption that the government is the exclusively responsible for pharmacies' waste management;
6. Declining volunteerism and increasing personal profit-seeking behaviors address underlying economic, social, and cultural factors;
7. A lack of national expired or unused medicines storage programs to create and strengthen connections with the community;
8. Limited political commitment;
9. Insufficient educational programs regarding recycling/reusing pharma products;
10. Weak involvement of the citizens, health care professionals, and specialized organizations;
11. An absence of different activities to plan, monitor, and assess performance;
12. Limited information regarding the technical capabilities and objectives of the specialized institutions;
13. An absence of standardization in packaging and materials creates challenges in developing recycling processes that can be applied universally;
14. Reduced recycling feasibility due to the multi-material packaging of pharmaceutical products;
15. Limited specialized facilities and equipment to manage the unique challenges associated with pharmaceutical waste;
16. The implementation of advanced recycling technologies and offering compliance with international regulations involve high costs;
17. Establishing efficient reverse-logistics systems to collect and transport pharmaceutical waste back to recycling facilities can be a logistical challenge, especially when dealing with diverse and widespread sources;
18. Pharmaceutical products are not designed for recyclability at the development stage;
19. Coordinating recycling across different regions and ensuring consistency can be complex due to the international supply chains with multiple stakeholders;
20. Consumer habits regarding pharma product recycling.

3. Results

3.1. Demographic Characteristics

The construction of the sample, conforming to the pharmacists'/pharmacy technicians' demographic features, is presented in Table 1. Most of the subjects were drugstore pharmacists/technicians (58.2%) from the private sector (78.4%) with bachelor's degrees (33.5%), aged between 25–34 years old (39.3%), who had experience between 5–10 years (38.6%) and a monthly income of under 1000 EUR (68.08%). Regarding the type of pharmaceutical waste that should be reduced, most of the respondents mentioned non-hazardous waste (71.2%).

Table 1. Demographic characteristics of quantitative research respondents.

Characteristics	Percent from Total Sample
Age	
Under 24 years	5.7%
25–34 years	39.3%
35–44 years	31.1%
Over 45 years	23.9%
Job sector	
Public (hospital) pharmacy	21.6%
Private pharmacy	78.4%
Education	
Pharmacy technician's Degree	28.4%
Bachelor's Degree	33.5%
Master's Degree	27.3%
Ph.D. Degree	10.8%
Occupation	
Hospital pharmacist/technician	18.7%
Drugstore pharmacist/technician	58.2%
Pharmaceutical company pharmacist/technician	23.1%
Years of work experience	
<5 years	36.2%
5–10 years	38.6%
>10 years	25.2%
Monthly income	
Under 1000 EUR	68.08%
Between 1000–1500 EUR	21.02%
Over 1500 EUR	10.9%
The type of pharmaceutical waste you mostly try to reduce	
Hazardous waste	28.8%
Non- hazardous waste	71.2%

The experts participating in the qualitative research interviews presented in Table 2 included nine males and six females, all of whom resided in various urban and rural areas across different cities and possessed expertise in the pharmaceutical sector.

Table 2. Demographic characteristics of qualitative research respondents.

Type	Work Position	Respondent	Work Experience -Years-
University	University 1	Professor Ph.D.	21
	University 2	Associate Professor Ph.D.	15
	University 3	Professor Ph.D.	28
Pharmacy	Pharmacy 1	General Manager	17
	Pharmacy 2	Sales Manager	12
	Pharmacy 3	General Manager	9
	Pharmacy 4	General Manager	19
	Pharmacy 5	Sales Manager	6
Ministry	Representative 1	Specialist	23
	Representative 2	Manager	11
Manufactory	Manufactory 1	Production Manager	8
	Manufactory 2	Logistic Manager	9
	Manufactory 3	General Manager	16
	Manufactory 4	General Manager	10
	Manufactory 5	Production Manager	5

3.2. Pharmacies' Activities to Reduce Waste

The means for all satisfaction items are presented in Table 3. The items have mean scores on a 5-level scale (1 = very dissatisfied; 5 = very satisfied) [57,58].

Table 3. Descriptive statistics of satisfaction items—pharmacies' activities to reduce waste.

Items	Mean	SD
Removing medication from the original package	4.0907	0.73212
Using a unit-dose distributing system	1.9003	0.67821
Adapting or renewing the prescribed quantity of medications by pharmacists	2.0420	0.78904
Managing the medication quantities held in stock-by-stock rotation	3.1370	0.76247
Verifying the medication quantities held in stock by checking expiry dates	4.8602	0.90423
Controlling medications that are unused	4.0202	0.87653
Removing medications that are expired	4.5612	0.90012
Cooperating with other organizations to trade almost expired medications	1.8756	0.56792
Dispatching unopened medications that can be 'reutilized' back to the manufacturer	2.2452	0.45023
Notifying prescribers/managers about the unused medications in order not to be commanded	1.0075	0.12095
Offering patients information on how to manage the expired or unwanted medications	3.2023	0.98730
Permitting patients to give back their leftover medicines to the pharmacy	2.1280	0.89345
Advising the patients on the quantity needed for symptom recovery	3.1063	0.78903
Collecting unutilized medications so they can be recycled	1.1301	0.89054
Donating unused medications	2.0989	0.78903
Unclear legislation concerning waste disposal	3.1234	0.69045
Poor education regarding waste management	2.3990	0.08563
Insufficient dustbins	4.0074	0.87383
Insufficient landfill disposal places	3.4750	0.20938
Inadequate recycling facilities	1.7845	0.79032
Attitude of the pharmacists' communities	2.0912	0.74656

The highest mean values were registered by the following items: "Verifying medication quantities held in stock by checking expiry dates" (mean 4.8602), followed by "Removing medications that are expired" (mean 4.5612) and "Removing medication from the original package" (mean 4.0907). The lowest means were registered by "Notifying prescribers/managers about the unused medications in order not to be commanded" (mean 1.0075), "Collecting unutilized medications so they can be recycled" (mean 1.1301), and "Inadequate recycling facilities" (mean 1.7845).

EFA was applied to O1: Identify the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce waste. Principal component analysis with varimax rotation was used as the extraction method. After eliminating irrelevant response items, only 11 items from Table 3 were used, resulting in a 3-factor solution presented in Table 4. The 3 factors had eigenvalues of greater than 1 and explained 63.71% of the total variance.

The extraction method is deemed acceptable based on the statistical results. The Kaiser–Meyer–Olkin (KMO) value of 0.648 is above the acceptable threshold of 0.5, and Bartlett's Test of Sphericity resulted in a chi-square value of 289.61 with a significance level of less than 0.01.

The satisfaction factors were classified as follows: Factor 1—"The release stage—pharmacy-associated activities"; Factor 2—"The release stage—pharmacy patient-associated activities"; and Factor 3—"The remaining stage". The means of the items contributing to a factor were calculated for each respondent using SPSS Statistics 25.0 software to compute new variables. The analysis of the responses' frequency was: the release stage—pharmacy-associated activities (79.4%); the release stage—pharmacy patient-associated activities (87.3%); and the remaining stage (52.1%).

Table 4. Exploratory factor analysis results.

Satisfaction Items	Factor 1	Factor 2	Factor 3
Removing medication from the original package	0.828		
Managing the medication quantities held in stock-by-stock rotatio	0.558		
Verifying the medication quantities held in stock by checking expiry dates	0.502		
Controlling medications that are unused or expired	0.898		
Dispatching unopened medications that are 'reusable' back to the factory	0.634		
Offering consumers information on how to manage expired or unwanted medications		0.890	
Permitting patients to give back their leftover medicines to the pharmacy		0.887	
Advising the patients on the quantity needed for symptom recovery		0.609	
Collecting unutilized medications so they can be recycled			0.621
Unclear legislation concerning waste disposal			0.612
Inadequate recycling facilities			0.512
Eigenvalues	2.89	1.85	1.32
Percent of variance explained	32.17%	18.23%	13.38%

The second research objective was "to identify if different occupation segments report different levels of satisfaction with pharmacies' activities to reduce waste". The means for each factor were analyzed in relation to the occupational segment. Factor 1—The release stage—pharmacy-associated activities and Factor 2—The release stage—pharmacy patient-associated activities recorded the highest mean for drugstore pharmacists/technicians (4.83 points/4.41 points). Factor 3—The remaining stage reported the highest mean for pharmaceutical company pharmacists/technicians. The ANOVA results presented in Table 5 showed significant differences among the three occupational segments analyzed for the satisfaction factors (Sig < 0.01).

Table 5. The means of factors and occupational segments' analysis.

Occupation	Satisfaction Factor		
	The Release Stage—Pharmacy-Associated Activities	The Release Stage—Pharmacy Patient-Associated Activities	The Remaining Stage
	Mean	Mean	Mean
Hospital pharmacist/technician	4.59	4.01	3.08
Drugstore pharmacist/technician	4.83	4.41	3.14
Pharmaceutical company pharmacist/technician	3.89	3.78	3.98
General mean	4.44	4.07	3.4
ANOVA F	11.298	5.321	0.911
Sig.	0.000	0.001	0.325

Hospital pharmacists/technicians and drugstore pharmacists/technicians recorded the highest means for Factor 1—The release stage—pharmacy-associated activities and the lowest for Factor 3—The remaining stage, while pharmaceutical company pharmacists/technicians received the highest means for Factor 3 and the lowest for Factor 2—The release stage—pharmacy patient-associated activities.

The third research objective was "to determine if there is a relation between occupational segments and intention regarding recycling and reusing pharmaceutical waste". Regarding the influence of each of the three analyzed occupational segments on their intention to recycle and reuse pharma waste, the dissemination obtained by cross-tabulation presented a high percentage of pharmacists who intend to recycle and reuse pharma waste (see Table 6).

Table 6. The relationship between occupational segments and the intention regarding recycling and reusing pharma waste.

Recycling/Reusing Intentions	Hospital Pharmacist/Technician	Drugstore Pharmacist/Technician	Pharmaceutical Company Pharmacist/Technician	Pearson Chi-Square	Sig.
Yes	71.4%	84.1%	74.9%	49.87	0.00
No	28.6%	15.9%	25.1%		

However, there may be differences among pharmacists in different occupational segments. The highest percentage of respondents with recycling and reusing pharma waste intensions was recorded for drugstore pharmacists/technicians, while the lowest percentage was for hospital pharmacists/technicians. An explication for these results is the difference between the segments' profiles: 21.6% of the respondents work in the public sector, while 78.4% work in the private sector; they have different monthly incomes, years of work experience, and education levels. In conclusion, the results of the Chi-square test, with a Pearson Chi-square value of 49.87 and a significance level of lower than 0.01, demonstrated a significant statistical relationship between the variables.

3.3. Delphi Technique Results

The survey involved 30–40 min to complete at each round. Data was collected individually and anonymously to ensure authoritative responses from the experts. The questionnaire asked the respondents to rate the importance level of items with a score ranging from 1 to 5, from least to most important. To explicate the rating data, the range of scores and their corresponding levels of importance are presented in Table 7.

Table 7. Range of scores and level of importance.

Range	Level
1.00–1.80	unimportant
1.81–2.60	of little importance
2.61–3.40	moderately important
3.41–4.20	important
4.21–5.00	very important

Descriptive statistics (percentage, mode, and mean) were performed on the first-round data. The mean scores of all the executives' ratings were presented to the fifteen participants in the second round. They were then asked to review each activity and rate each item again on a scale of 1 to 5 based on its level of importance. At the end of the second round of data collection, a consensus was reached.

The mean scores of each barrier in Romania's pharmacy waste management were computed by analyzing the data collected from a sample group of fifteen respondents in two rounds. The institutional barriers are presented in Table 8.

The rankings of the most important institutional barriers remained the same in both rounds among the 14 activities listed in the Romanian pharmaceutical sector gained from the participants in the first round. The rankings of the second most important barrier differed.

The most important institutional barrier in the experts' opinion was the lack of national expired or unused medicine storage programs to create and strengthen connections with the community (mean = 4.94). The mean recorded an increase from 4.88 in the first round of data collection to 4.94 in the second round. The proper disposal of leftover medications is crucial for environmental protection and public well-being. In the absence of national disposal programs, individuals lack guidance on safe disposal practices. Enhanced community education is essential to provide citizens with effective disposal techniques. Furthermore, the lack of disposal programs hinders both public awareness campaigns and the recovery of valuable materials from discarded medications.

Table 8. Institutional barriers.

Institutional Barrier	Round	Mean
Lack of national expired or unused medicine storage programs to create and strengthen connections with the community	First round Second round	4.88 4.94
Limited specialized facilities and equipment to manage the unique challenges associated with pharmaceutical waste	First round Second round	4.79 4.86
Ineffective control over pharmaceutical recycling costs and inappropriate budgeting	First round Second round	4.72 4.78
Insufficient control over implementing legal content for the responsible specialists	First round Second round	4.67 4.71
Limited political commitment	First round Second round	4.53 4.46
Insufficient educational programs regarding recycling/reusing pharmaceutical products	First round Second round	4.40 4.45
Absence of different activities to plan, monitor, and assess performance	First round Second round	4.32 4.29
Limited information regarding the technical capabilities and objectives of specialized institutions	First round Second round	4.28 4.20
Absence of standardization in packaging and materials creates challenges in developing recycling processes that can be applied universally	First round Second round	4.21 4.29
Reduced recycling feasibility due to the multi-material packaging of pharmaceutical products	First round Second round	4.19 4.20
Implementation of advanced recycling technologies and offering compliance with international regulations involve high costs	First round Second round	3.98 4.17
Establishing efficient reverse-logistics systems to collect and transport pharmaceutical waste back to recycling facilities can be a logistical challenge, especially when dealing with diverse and widespread sources	First round Second round	3.83 3.97
Pharmaceutical products are not designed for recyclability at the development stage	First round Second round	3.76 3.71
Coordinating recycling across different regions and ensuring consistency can be complex due to the international supply chains with multiple stakeholders	First round Second round	3.63 3.57

In opposition to this perspective, the least important barrier in the first and second round of data collection refers to coordinating recycling across different regions and ensuring consistency, which can be complex due to international supply chains with multiple stakeholders (mean = 3.57). The mean recorded a decrease from 3.63 in the first round of data collection to 3.57 in the second one. Harmonizing international regulatory environmental legislation and waste management transportation standards can be challenging due to their diversity. Factors such as infrastructure, economic considerations, technologies, and dynamic capabilities can affect pharmaceutical recycling practices.

In both rounds of the survey, the participants in the sample were asked to rate the importance level of the behavioral barriers. Table 9 presents the mean scores for each of them.

The most important behavioral barrier in the experts' opinion is represented by consumer habits regarding the recycling of pharmaceutical products (mean = 4.64). The mean recorded an increase from 4.53 in the first round of data collection to 4.64 in the second round. To address consumer habits related to pharmaceutical recycling, various approaches are required. These include education, preferred disposal options, and efforts among health care providers, pharmacies, regulators, and the pharmaceutical industry. The environmental impact of the inadequate disposal of medicines and recycling options may not be known to many consumers. The disposal of pharmaceutical products in normal waste trash is a common practice because it is convenient. Limited access to convenient collection points

may discourage consumers from actively seeking proper disposal options. Consumers may not understand all the recycling symbol elements on pharmaceutical packaging or may be uncertain about which of the components can be recycled. Some consumers may keep unused medicines for a long time without considering their practical disposal. Consumers may not associate pharmaceutical products with general recycling practices.

Table 9. Behavioral barriers.

Behavioral Barrier	Round	Mean
Consumer habits regarding pharma product recycling	First round Second round	4.53 4.64
An inadequate framework for facilitating stakeholder dialogue	First round Second round	4.48 4.59
Limited knowledge about pharmaceutical waste management	First round Second round	4.33 4.39
Declining volunteerism and increasing personal profit-seeking behaviors	First round Second round	4.26 4.21
The general assumption that the government is exclusively responsible for pharmacy waste management	First round Second round	3.33 3.21
The general weak involvement of the citizens, health care professionals, and specialized organizations	First round Second round	3.25 3.16

The least important barrier in the data collection refers to the general weak involvement of the citizens, health care professionals, and specialized organizations (mean = 3.16). The mean recorded a decrease from 3.25 in the first round of data collection to 3.16 in the second one. This could be the result of an unreal understanding of pharmaceutical waste disposal. Hence, limited education may be the issue. Citizens may be discouraged from participating in recycling initiatives by limited access to practical waste disposal facilities. There is an apparently weak collaboration between the government, health services, and environmental organizations.

4. Discussion

4.1. Research Findings

The present research offers a significant contribution to the knowledge of the pharmaceutical waste field. A particular aspect of this study is represented by the analysis performed to identify the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce waste to examine whether different occupation segments report different levels of satisfaction with pharmacies' activities to reduce waste; to determine whether there is a relation between occupational segments and intention regarding recycling and reusing pharmaceutical waste; and to identify the expert perspective regarding the barriers that affect the adequate development of this sector.

Firstly, the objective of this research was to identify the activities and the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce pharmaceutical waste. Most of the respondents try to implement the studied activities to reduce pharmaceutical waste in Romania. The items are: removing medication from the original package; managing medication quantities held in stock-by-stock rotation; verifying medication quantities held in stock by checking expiry dates; controlling medications that are unused or expired; dispatching unopened medications that are 'reusable' back to the factory; offering consumers information about how to manage expired or unwanted medications; permitting patients to give back their leftover medicines to the pharmacy; advising patients on the quantity needed for symptom recovery; collecting unutilized medications so they can be recycled; unclear legislation concerning waste disposal; and inadequate recycling facilities.

Secondly, the research objective was to identify whether different occupation segments report different levels of satisfaction with pharmacies' activities to reduce waste. Hospital pharmacists/technicians and drugstore pharmacists/technicians focused more on the release stage, pharmacy-associated activities, while pharmaceutical company pharmacists/technicians paid more attention to the remaining stage factors.

The third objective of this research was to determine whether there is a relation between occupational segments and intention regarding recycling and reusing pharma waste. The results demonstrated a significant statistical relationship between the variables. Pharmacists/pharma technicians believe that pharmacy- and pharmacy patient-associated activities and the remaining stage are important in the process of reducing waste. Returning unused medications to pharmacies to be re-dispensed was ranked as neutral by the respondents. This result suggests the need for developing new solutions regarding the topic.

The issue of pharmaceutical waste can be tackled through various approaches. The first approach involves educating consumers. The second approach is to improve prescribing practices to reduce waste. The third approach is to engage patients in their health care to enhance their medication adherence [11,59].

The fourth research objective was to identify the institutional barriers that prevent the development of sustainable waste management in the pharmacy sector. The fifth research objective was to identify the behavioral barriers that encompass various challenges that hinder effective waste management practices.

Other studies on this topic include the one by Wajid et al. [60], who studied the situation of unutilized and expired medications among the Saudi population and showed that the disposal techniques were moderate in the Saudi community. Also, Abuassonon et al. [61] studied the situation of residents of Jeddah regarding the topic and proved that a moderate percentage of inhabitants knew how to dispose of medications correctly.

Currently, Romania has no schemes for the return of unused pharmaceuticals. The return of leftover medicines to pharmacies is not encouraged. According to the present policies, pharmacies are not legally obliged to accept expired or unused medicines from individuals. If they return unused or expired pharmaceutical products, pharmacies have no guidelines for their safe disposal. The National Public Health Institute manages information on a national scale regarding pharmaceutical waste. Pharmaceutical facilities are permitted to sort on-site waste according to predetermined categories, based on the kind of waste generated through procedures. These regulations provide actual guidance on the proper management of pharmaceutical waste. Therefore, the Romanian Ministry of Health should cooperate and encourage clear legislation that establishes pharmaceutical take-back programs to collect unused and expired medications from consumers. This can be done through pharmacies, health care facilities, or designated collection points.

This study makes two contributions to the field. Firstly, it provides information from experts regarding pharmaceutical waste management barriers. Secondly, it offers implications for sustainable waste management practices, including clear directions. Delphi is widely considered a highly effective technique for exploring dynamic environments and making better predictions [62]. Hence, the Delphi technique is a suitable research tool for investigating the pharmaceutical sector, which involves numerous dynamic factors. The 15 experts achieved a consensus, which was used to decrease deviation and reach an agreement.

This study's conclusions contribute to the theoretical knowledge of and practical guidance for the development of suitable pharmaceutical waste management. From an academic perspective, this study provides support for the analysis of pharmaceutical waste in Romania. It contributes to the literature by highlighting the current status of waste in the pharmaceutical industry and the correlation between occupational segments and intentions regarding recycling and reusing pharmaceutical waste. It studies the level of pharmacists'/pharmacy technicians' satisfaction regarding specific activities that could reduce waste and identifies the institutional and behavioral barriers that prevent the

development of sustainable waste management in the pharmacy sector. Moreover, this study offers an expert perspective on the topic due to the interviews conducted with specialists from the pharmaceutical industry. From a practical perspective, the results of this study provide useful management and marketing information for pharmaceutical decision-makers. The novelty of this study consists of its complex research in the context of Romanian pharmaceutical waste management. The research methodology could be used in an international context to analyze the pharmaceutical waste management situation. Also, the suggestions from this paper could be suitable for other countries.

4.2. Implications and Suggestions

This research offers practical implications for the government, organizations, and citizens to develop sustainable waste policies in the pharmaceutical sector. A comprehensive approach to overcoming pharmaceutical waste management barriers can be developed by combining institutional strategies focusing on organizational policies and infrastructure with behavioral strategies targeting individuals and communities. The aim is to build an accountable and sustainable culture within institutions and society in general. Comprehensive policies should be established within health care institutions and pharmaceutical companies to outline proper pharmaceutical waste management practices, including segregation, storage, and disposal procedures. Regular training should be organized for health care professionals, pharmacists, and staff on pharmaceutical waste management protocols. Hence, the participants will implement adequate waste management procedures, and the risk of inappropriate disposal will be reduced. The creation of specialized teams can ensure ongoing compliance, monitor waste management practices, and implement improvements as needed.

Resources regarding the waste management infrastructure and technologies may enhance the effectiveness of the pharmaceutical waste management processes. Regular evaluation should be implemented to identify the issues and develop new strategies based on dynamic capabilities. Sustainable practices should be embraced by health care facilities and pharmaceutical companies. This includes reducing unnecessary packaging, using ecological materials, and implementing resource recovery practices. Attention should be paid to developing perceptions of the correct disposal of medicines through education campaigns targeting health care professionals, consumers, and communities. Organizing regular collection events to which people can bring their unused medicines for safe disposal is another solution to pharmaceutical waste. These events can be coordinated by local pharmacies, health care providers, or environmental organizations. Health care facilities should implement in-house pharmaceutical recycling programs. This may involve separating pharmaceutical waste at the source and recycling or disposing of it through specialized waste management services. Educational programs and campaigns regarding expired and unused medicine storage should be created to generate strong relations with the community. Knowledgeable individuals are more likely to adopt responsible waste management behaviors. Convenient disposal options increase the likelihood of compliance. Additionally, developing disposal systems that are simple to use in pharmacies will facilitate real disposal. Social influence can shape individual behavior within institutional settings. Hence, this aspect should be included in marketing strategies. Another suggestion is to create feedback mechanisms within health care solutions to enable the staff to provide input into the waste management processes, promoting a sense of ownership and responsibility.

Artificial intelligence systems can be employed to optimize inventory levels in pharmacies and health care facilities, reducing the likelihood of overstock and subsequent waste. A method for storing and recovering medication data could be based on using a website that permits searching for medicines through filters such as price or type [63]. Predictive analytics can help predict medication expiration dates, enabling proactive measures to prevent waste. AI-powered applications can help patients track their medication usage, send reminders, and provide information on proper disposal methods. Chatbots and virtual assistants can answer patient queries about medication storage, use, and disposal. Comen-

dador et al. [64] created a "pharmabot", which represents a pediatric generic medicine advice chatbot. It provides pediatric patients with the appropriate medication after a set of conversations with the chatbot. AI can be used to analyze data related to medication disposal practices, identifying patterns and areas for improvement in waste management processes [8]. Software programs have been created to manage waste in this field, such as the Preservation of Grace Association (2005) that collects and reuses medications [65]; the Dwaa website (offers medicines from donations) [66]; Tameeni software application, version 3.1.2 (record medicines and their details); and "the smart help Sara" WhatsApp chatbot developed by The Saudi Food and Drugs Authority [67].

Smart packaging can monitor the temperature and humidity conditions of medicines. This ensures their efficacy and safety. AI algorithms can analyze data from these sensors and provide alerts for potential issues. Present trends in medical packaging involve the expansion of intelligent and cost-effective packaging, as well as the combination of environmental protection aspects [68]. New medical packaging is characterized by modern design and new, eco-friendly features containing printed circuits and displays. However, they can pose difficulties for recycling. The challenge of recycling pharmaceutical waste in accordance with circular economy principles is a significant issue for packaging manufacturers. The COVID-19 pandemic has led to a surge in the production and use of pharmaceutical medicines, resulting in a significant increase in waste pharmaceutical blisters (WPBs) [31,69,70]. A sustainable solution has been developed to recycle pharmaceutical blisters (PB), a form of medical waste, by substituting them with fine aggregates [71]. Pharmaceutical blister waste recycling could be achieved with biogenic sulfuric acid [72]. Three-dimensional printing could be an innovative solution for patients and the pharmaceutical industry in waste management practices because the technology provides a precise construction of dosage [73]. Investing in research and finding new eco-friendly packaging for medicines is important. This can cut down on how much packaging trash damages the environment. Funds should be allocated to developing ways to manage medicine trash.

The implementation of reverse-distribution systems in cooperation with pharmaceutical manufacturers and wholesalers is essential. This involves returning unused medicines to the manufacturer for proper disposal or recycling. Implementing tracking systems to monitor pharmaceutical waste is a solution that will help identify opportunities for improvement and ensure compliance. A proper segregation of pharmaceutical waste should be ensured in health care facilities by separating hazardous pharmaceutical waste from non-hazardous waste to facilitate appropriate disposal methods.

The presence of pharmaceuticals can pose a threat to human health, biota, and the environment in various environmental areas, including surface water, groundwater, soil, and sediments [74].

5. Conclusions

The findings of this study indicate that there are deficiencies in the pharmaceutical waste collection service provided by pharmacies in Romania. The most significant shortcomings are the absence of legislation establishing clear procedures that can be uniformly applied to both pharmacists and to the population, as well as the absence of take-back programs.

Health care solutions should adopt best management practices for the disposal of pharmaceutical waste, following guidelines established by regulatory authorities. Cooperation between stakeholders to develop sustainable solutions for pharmaceutical waste management should be encouraged. Solutions and best practices that can be implemented to manage pharmaceutical waste more sustainably could focus on various fields, including take-back programs, inventory/waste management, pharmaceutical collection events, smart packaging, reverse distribution, educational campaigns, encouragement of in-house recycling, pharmaceutical waste tracking, and research and development.

Funding for initiatives to collect, treat, and recycle pharmaceutical waste can originate from different sources. The government must provide grants to support pharmaceutical waste management projects. Local, regional, and national environmental agencies should

offer funding specifically designated for pharmaceutical waste management programs. Private foundations focusing on environmental conservation and public health may offer grants or donations to organizations working on pharmaceutical waste management projects. Programs created to manage pharmaceutical waste may be sponsored by corporations and nonprofit organizations with an interest in the environment and public health. Public–private partnerships and research grants could improve the pharmaceutical waste management process. Industries specialized in the production or use of pharmaceuticals may offer financial resources for the responsible disposal and recycling process as part of their corporate social responsibility efforts.

The research results may aid in establishing measures for building a sustainable future regarding the pharmaceutical sector. This study presents various solutions and practices that could be implemented not only in Romania. This study's findings provide practical information for health care decision-makers, health institutions, and governments. The novelty of the research is represented by its multidisciplinary approach, which addresses compound environmental, health, legislation, technological, and socioeconomic dimensions. Researchers aim to contribute to sustainable and responsible pharmaceutical waste management in a dynamic global landscape by advancing knowledge, informing policy and practice, and fostering interdisciplinary collaboration.

This study presents the following limitations: The period during which the survey was conducted was brief (October 2023–January 2024); this study was applied only to pharmacists and pharmacy technicians, not to patients/medicine consumers; and it is possible that some activities were not reported, as not all pharmacists/pharma technicians from a particular county responded to the survey. The qualitative survey was not based on a particular product; it offers a general view of the issues regarding the analyzed topic. The implementation of this study in other contexts, both within and outside Romania, would have a positive impact on the management of pharmaceutical waste. It would also define future economic incentives that could be introduced for the industry to acquire environmentally friendly technology. Future research will focus on pharmaceutical product consumers and innovative technologies for reducing waste management and developing a sustainable future. The development of more efficient and cost-effective recycling methods, as well as the exploration of innovative approaches such as nanotechnology, could be the focus of future research. The effectiveness of educational campaigns, incentive programs, and policy interventions to encourage responsible waste management behavior could be evaluated in future studies.

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