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Original Research

Implementing Green Pharmacy in the UAE: Knowledge, Perceptions, and Practice Gaps – A Cross-Sectional Analysis

Nadia Al Mazrouei , Eiman M. Almulla, Maryam Mohammad Bin Hafiz, Shikhah D. S. Alfarhan , Osama Mohamed Ibrahim, Khalid Awad Al-Kubaisi , Rana Ibrahim , Mohamed Fathelrahman Fageeri , Ali Awadallah Saeed , Mohamed H Ahmed , Safaa Badi

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Abstract

Background: Medical waste is considered one of the most hazardous types of waste. Improper disposal of medical waste, whether by medical institutions or households, can lead to serious environmental pollution, such as soil and groundwater contamination, harm to aquatic wildlife, and the spread of infections. The purpose of this study was to investigate the behavior of the public and pharmacists toward expired or unused medicines and their knowledge of green pharmacy. Furthermore, the study aimed to explore the benefits, concerns, and barriers to adopting green pharmacy practices in the UAE to help preserve the environment and public health. **Materials and Methods:** A cross-sectional prospective study was conducted. Data was collected using two instruments: a questionnaire survey distributed to two populations—the public and pharmacists. Data analysis was performed using IBM SPSS Statistics version 29. **Results:** The questionnaire was completed by 344 members of the public and 57 pharmacists. Among the public, 79.7% reported disposing of expired medicines by throwing them in the trash. Notably, 23,788 expired medicines were collected, the majority of which were tablets and capsules. Responses regarding knowledge of green pharmacy and related attitudes were as follows (pharmacists vs. public): Unaware of green pharmacy: 40.4% vs. 52.5%, Recycling is a main issue: 75% vs. 79.7%, Support green pharmacy initiatives: 56.9% vs. 62.7%, Believe green pharmacy can be implemented in the UAE: 23.5% vs. 96.6%. These differences between pharmacists and the public were statistically significant ($p < 0.05$). **Conclusion:** Implementing green pharmacy practices in the UAE is a vital component of medical waste management, aimed at reducing the release of hazardous chemicals into the environment and safeguarding public health.

Keywords: Green pharmacy, Sustainable Pharmacy, UAE, Eco-friendly practices, Pharmaceutical waste

Nadia Al Mazrouei. Department of Pharmacy Practice and Pharmacotherapeutics, Faculty of Pharmacy, University of Sharjah, United Arab Emirates. nalmazrouei@sharjah.ac.ae
Eiman M. Almulla. B. Pharm Graduate, Faculty of pharmacy, University of Sharjah. U18102692@sharjah.ac.ae
Maryam Mohammad Bin Hafiz. B. Pharm Graduate, Faculty of pharmacy, University of Sharjah, U18101093@sharjah.ac.ae
Shikhah D. S. Alfarhan. B. Pharm Graduate, Faculty of pharmacy, University of Sharjah, U18102732@sharjah.ac.ae
Osama Mohamed Ibrahim. School of Pharmacy at Newgiza University, Egypt, Osama.Hussein@ngu.edu.eg
Khalid Awad Al-Kubaisi. Department of Pharmacy Practice and Pharmacotherapeutics, College of Pharmacy-University of Sharjah, United Arab Emirates. kalkubaissi@sharjah.ac.ae
Rana Ibrahim. Department of Pharmacy Practice and Pharmacotherapeutics, Faculty of Pharmacy, University of Sharjah, United Arab Emirates. ribrahim@sharjah.ac.ae
Mohamed Fathelrahman Fageeri. Postgraduate student and research assistant at faculty of Pharmacy, University of Sharjah, United Arab Emirates. U24200468@sharjah.ac.ae
Ali Awadallah Saeed*. Department of Pharmacology and therapeutics, Faculty of Clinical and Industrial Pharmacy, National University-Sudan, Clinical Pharmacy Department, Mycetoma Research Center, University of Khartoum, Sudan. alimhsd@gmail.com
Mohamed H Ahmed. Department of Medicine and HIV Metabolic Clinic, Milton Keynes University Hospital NHS Foundation Trust, Eaglestone, Milton Keynes, Buckinghamshire, UK; Department of Geriatric Medicine, Milton Keynes University Hospital NHS Foundation Trust, Eaglestone, Milton Keynes, Buckinghamshire, UK; Honorary Senior Lecturer of the Faculty of Medicine and Health Sciences, University of Buckingham, UK, mohamed.hassan-ahmed@mkuh.nhs.uk
Safaa Badi. PhD, Department of Clinical Pharmacy, Faculty of Pharmacy, Omdurman Islamic University, Khartoum,

INTRODUCTION

Medicine is one of the most significant components in the medical industry when it comes to treating and diagnosing. It has helped save millions of lives and improves the quality of life for people over the years. However, improper disposal of these medicines increases the risk of drug misuse, poses environmental hazards, and leads to financial waste, thereby reducing the availability of medications for those in need[1,2]. Pharmaceutical waste refers to any discarded material that contains pharmaceuticals, including expired, unused, contaminated, or damaged medications. In some countries, medicines are marketed as pre-packed medications containing the optimal quantity of doses. However, in many regions, packaging sizes are often too large or inappropriate. As a

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result, pharmaceutical waste increases due to medications reaching their expiry date with intact dosage units. Factors such as poor therapy compliance, over-prescription, therapy changes, patient recovery, hospitalization, or death contribute to the accumulation of unused drugs in households, which are ultimately discarded[3,4].

Pharmaceutical production waste has harmful effects on both human health and ecosystems, and efforts to manage regulate, or treat these wastes before they are released into the environment are often inadequate. When discharged as untreated effluents into water bodies or landfills, pharmaceutical waste can negatively impact fish, marine life, soil organisms, domestic animals, and wildlife. The increasing presence of untreated pharmaceutical waste may contribute to several health concerns. Some pharmaceutical compounds found in drinking water may render it unsafe for human consumption. Additionally, the accumulation of active pharmaceutical ingredients (APIs), bulk medications, or pharmaceutical formulations in ecosystems can lead to the development of antimicrobial-resistant microbes (ARM) and the spread of antibiotic resistance genes (ARGs), which pose serious health risks to humans, especially those who are immunocompromised. Furthermore, pharmaceutical wastes may break down into more toxic substances, which can reach humans through the consumption of contaminated plant-based foods and fruits[5-8].

Waste in the medical field can include neglected general practitioner consultations, discarded letters and reports, unnecessary hospital visits, and—most critically—pharmaceutical waste[9]. It is estimated that 8–10% of pharmaceutical substances found in the environment are the result of improperly disposed medications. These are often flushed down toilets, poured down drains, or discarded in household trash, both by patients and medical institutions. These practices may significantly contribute to environmental degradation, which we aim to highlight and address through the concept of green pharmacy. In this research, we aim to evaluate the feasibility of implementing green pharmacy practices in the UAE[3,10].

Green pharmacy is defined as the development of pharmaceutical products and processes that reduce or eliminate the use and generation of hazardous substances, while minimizing environmental and human health impacts at the source. Certain pharmaceuticals cause environmental damage in the countries where they are consumed, but the impact is often greater in the countries where they are manufactured. While some active pharmaceutical ingredients (APIs) are produced in environmentally responsible facilities with effective sewage treatment systems, many are not. As a result, pollution of local water bodies—such as lakes and rivers—occurs, potentially serving as breeding grounds for antibiotic-resistant genes, among other threats[11,12].

Growing worries about the effects of pharmaceutical waste on the environment and public health, particularly as new contaminants in soil and water systems, have brought this idea a lot of attention on a global scale. The buildup of active pharmaceutical ingredients (APIs) in the environment, which endangers ecosystems, human health, and antimicrobial resistance, is caused by improper medication disposal, overprescription, and ineffective waste treatment systems[6,13,14,15].

Green pharmacy practices support sustainable drug production, eco-friendly packaging, responsible prescribing, patient education, and appropriate disposal systems in accordance with the Sustainable Development Goals (SDGs) of the UN, particularly SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), and SDG 12 (Responsible Consumption and Production). In the healthcare industry, these methods seek to minimize pharmaceutical pollution, maximize resource utilization, and promote a circular economy[16]. With an emphasis on drug lifecycle assessments, take-back initiatives, and regulatory frameworks for eco-toxicological evaluation, nations in Europe, North America, and some parts of Asia have started integrating green pharmacy principles into their national pharmaceutical policies. But in many LMICs, where infrastructure and regulatory deficiencies still exist, adoption is still restricted[17].

Green pharmacy is a timely and strategic way to align healthcare in the United Arab Emirates with the nation's larger environmental sustainability agenda, including the UAE Vision 2030 and its commitments under the Paris Agreement. By incorporating these practices, the UAE can become a regional leader in sustainable healthcare innovation, improve public health, and lessen pollution associated with healthcare[18].

Given the foregoing background, the purpose of this study was to investigate the knowledge, attitudes, and practice gaps pertaining to green pharmacy among pharmacists and the general public in the United Arab Emirates. The study intends to ascertain the level of awareness regarding environmentally sustainable pharmaceutical practices as well as the opportunities and challenges for implementing green pharmacy, as part of the UAE's larger healthcare sustainability and medical waste management strategies.

MATERIALS AND METHODS

Study design and participants

This cross-sectional, prospective observational study was carried out from February to April 2023. The study is done over three months through questionnaire surveys. We decided to include two types of populations in this study: the public and pharmacists. Each survey has four sections with 19-20 questions.

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Sample size calculation and sampling method

The sample size was calculated using Cochran's formula [20] to achieve an ideal level of precision, confidence, and population proportion. The formula used was:

$N = Z^2 \times P \times Q / d^2$, where N is the required sample size, P is the estimated prevalence (assumed to be 0.5 for maximum variability), Q = 1 − P, Z is the standard normal deviate corresponding to the desired confidence level (1.96 for 95%), and d is the acceptable margin of error (0.05). Based on this, the sample size was calculated as:

$$((1.96)^2 \times 0.5 \times 0.5) / (0.05)^2 = 385 \text{ participants.}$$

Out of the targeted 385 participants, 344 completed the questionnaire, yielding a response rate of 89.4%. Additionally, a subgroup of 62 pharmacists based in Sharjah was invited to participate, of whom 57 responded, representing a 91.9% response rate for that group.

Questionnaire development and validation

In the attempt to meet the study purposes, the research team has developed the first draft of the study questionnaire, which was further discussed through a series of virtual and physical meetings. Several points were clarified, ambiguous questions were removed, and duplicates were corrected through these meetings. Content validation of the questionnaire was done. The questionnaire was originally developed in the English language. The public questionnaire survey was translated into Arabic by an Arabic Language teacher. The questionnaire was distributed in English to pharmacists. Cronbach's alpha test was performed to estimate the internal consistency of the items and good level of reliability were achieved ($\alpha = .874$) and ($\alpha = .741$) for knowledge and practice subscales respectively.

Before initiating full-scale data collection, a pre-test was conducted in which the questionnaire was administered to 15 participants, including individuals from both the public and pharmacy professionals. The purpose was to assess the clarity, relevance, and comprehensibility of the survey items. Based on the feedback received, minor adjustments were made to improve question clarity. All responses from the pre-test were excluded from the final analysis.

The corrected version of the public survey included three main parts. The first part comprised socio-demographic questions. The second part included questions about drug disposal and saving the environment. The third part is the awareness of green pharmacy. The study questionnaire of the pharmacists included socio-demographic data in the first part. The second part was about drug disposal and saving the environment. The third part includes awareness and education of green pharmacy. The final fourth part comprised rules and regulations needed to perform green pharmacy in the UAE and feedback on the environment and public expectations, as well as challenges and benefits of green pharmacy.

Sampling Technique for the General Population

A convenience sampling technique was utilized to enlist participants from the general population. This method was chosen for its practicality and effectiveness in reaching a wide range of individuals in different community environments, including students in the universities, public spaces, pharmacies, and digital platforms. Although convenience sampling may restrict the generalizability of results, it facilitated the inclusion of a diverse array of respondents with differing levels of awareness regarding green pharmacy practices. Efforts were undertaken to guarantee equitable representation concerning age, gender, and geographic location within the UAE.

Data Analysis

After completion of the data collection, the research team created two databases using Microsoft Excel 2013. Then, both datasets were entered into SPSS version 26, whereby a comprehensive descriptive analysis was performed. Inferential analysis (Chi square test) was needed to compare awareness and opinions regarding green pharmacy among pharmacists and other groups. Data are presented as absolute values with percentages.

The pharmacists (n = 57) and the public (n = 344) were surveyed using two distinct questionnaires (each with some overlapping items). Their responses were analyzed separately, with results reported in separate tables. When the study aimed to compare perspectives (e.g., awareness, support, or belief in feasibility of Green Pharmacy), the two groups' responses to comparable questions were directly compared using Chi-square tests.

RESULTS

This cross-sectional survey was conducted on a sample consisting of two groups. The initial cohort comprised 57 pharmacists. The alternative group consisted of non-pharmacists (public) and comprised 344 participants.

Regarding the pharmacist group, it was found that most of the pharmacists were working in the hospital pharmacies (78.4%) while the minority was in the community pharmacies (21.6%). The experience within the pharmacist group varied, with the majority possessing less than 5 years of experience (59.6%), followed by those with over 10 years of experience (30.8%), and the smallest proportion having 5 to 10 years of experience (9.6%).

Among the non-pharmacist cohort, 78% were students, with a predominant preference for the Arabic language to complete

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the survey (83.9%), compared to a minority favoring English (16.1%) (Table 1).

Awareness, opinions, benefits, and challenges to Green Pharmacy among pharmacists

45.5% of the participating pharmacists indicated that the primary responsibility of pharmacists in environmental protection is to educate their patients. 40.4% of the participating pharmacists acknowledged the concept of a green pharmacy. 35.5% of pharmacists indicated that green pharmacy contributes to mitigating environmental harm. Nevertheless, 27% of the participating pharmacists indicated that the expense associated with the green pharmacy application will pose a considerable challenge. 23.5% of participants concurred that green pharmacy is applicable in the UAE (Table 2).

Awareness, practices, and perspectives on the implementation of Green Pharmacy among non-pharmacist group

79.7% of the non-pharmacist group indicated that they disposed of their expired and unused medication by discarding it in the trash. 72.9% of the participants indicated that recycling will positively impact the environment. 81% of this cohort indicated that pharmacists are suitable for educating individuals on the disposal of unused medications. 96.6% of participants concurred that Green Pharmacy is applicable in the UAE (Table 3).

When comparing responses to similar questions between the two groups, statistically significant differences were observed in the majority of items. For example, awareness of the concept of green pharmacy differed significantly (40.4% pharmacists vs. 52.5% public; p=0.003), as did belief in its feasibility in the UAE (23.5% vs. 96.6%, p<0.001), and support for green pharmacy initiatives (56.9% vs. 62.7%, p=0.026). The only non-significant finding was the belief that pharmacists can raise awareness about green pharmacy practices (26.6% vs. 26.5%, p=0.52), indicating a shared perception of the pharmacist's role in promoting environmental sustainability (Figure 1).

DISCUSSION

The environmental impact is detrimental due to improper medical waste disposal methods[5,20]. This resulted in a heightened demand for the implementation of green pharmacy in the UAE. Pharmacists must educate individuals on the proper disposal methods for pharmaceutical waste and establish programs for the collection of expired and unused medications[21-23]. Significant progress will not be achieved unless Green Pharmacy is executed. Home delivery plays a crucial role in educating individuals and

Table 1. Demographic data for the sample of the study (pharmacist group and public group)

Group	Variable	Responses	N (5)
Pharmacist group (n= 57)	Work location	Hospital pharmacy	45 (78.4)
		Community pharmacy	12 (21.6)
	Years of experience	less than 5 years of experience	34 (59.6)
		more than 10 years of experience	18 (30.8)
		5 to 10 years of experience	4 (6.9)
Public group (n=344)	Occupation	Students	268 (78)
		Health care provider	23 (6.8)
		Engineering	29 (8.5)
		Other	23 (6.8)
	Preferred language among participants	preferred Arabic language	289 (83.9)
		preferred English language	55 (16.1)

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Table 2. Distribution of Pharmacists according to their awareness, opinions, benefits, and challenges to Green Pharmacy (n = 57)

	Questions	Most common response	N
Drug disposal / saving the environment	Is medicine recycling done in the workplace?	No	41 (71.2)
	What is the role of pharmacists in protecting the environment?	Patient Awareness	26 (45.5)
	How do medicines destroy the environment?	Water pollution	15 (25.9)
	How would the pharmacist educate patients about drug disposal/ recycling?	Educate the patient when counselling	18 (31.6)
	Which department is responsible for medicine recycling?	Pharmaceutical companies and Environmental authorities	17 (30.4)
Awareness of green pharmacy	What is green pharmacy?	Yes	23 (40.4)
	Resources about green pharmacy?	Social media	24 (42.4)
	Do using eco-friendly materials impact the health of the patient?	Yes	42 (73.1)
	Recycling is a main concern of green pharmacy	Yes	43 (75)
	People are highly agreeable to support the green Pharmacy	Yes	32 (56.9)
	Pharmacists can raise awareness towards the green pharmacy	Agree	15 (26.6)
Rules/feedback expected	What rules need to be applied for green pharmacy?	It should be approved by the authorities or the government	23 (41)
Benefits	How is applying green pharmacy beneficial?	Reduce environmental damage	20 (35.5)
	How does green pharmacy give a significant difference in environments?	Highly protecting environment	50 (88)
Challenges	What will be the risk in applying to a green pharmacy?	Cost	15 (27)
Implementation	Green pharmacy can be applied in UAE	Agree	13 (23.5)
	Which authority is responsible for implementing the green pharmacy?	Ministry of health & prevention	39 (68)

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Table 3. Summary of the most common responses from non-pharmacist group (n=344).

Area	Variable	Most common Responses	N (%)
Drug disposal / saving the environment	To what extent do you think medication harms the environment?	To a very small extent	181 (52.5)
	How do you get rid of your expired and unused medication?	Throw them in the trash	274 (79.7)
	How concerned are you about protecting the environment?	Moderately concerned	181 (52.5)
	How often do you use eco-friendly materials, “not environmentally harmful”, in your life?	Sometimes	186 (54.2)
	Do you think drug recycling will help the environment?	Yes, it will make a difference in the environment	251 (72.9)
	Which part of medicine is the most harmful to the environment?	Chemical ingredients	274 (79.7)
	How often do you get rid of expired/ unused medications?	Every year	169 (49.2)
	Recycling is a main concern of green pharmacy	Yes	274 (79.7)
Awareness of green pharmacy	Do you know what a green pharmacy is?	Yes	181 (52.5)
	Which will you choose from the two effective and safe drugs for health, but one of them causes harm to the environment?	Safe and effective medicine	332 (96.9)
	Who is the appropriate person to inform about the disposal of unused medicine?	Pharmacist	279 (81)
	Do you follow the pharmacist instructions about drug disposal/ recycle?	Yes	134 (39)
	Should consumers be more aware of unsafe material/ chemicals to the environment?	Yes	172 (49.9)
	People is highly agreeable to support green Pharmacy	Yes	216 (62.7)
	Pharmacists are able to raise awareness towards the green pharmacy	Agree	91 (26.5)
Implementation	Green pharmacy can be applied in UAE	Agree	332 (96.6)

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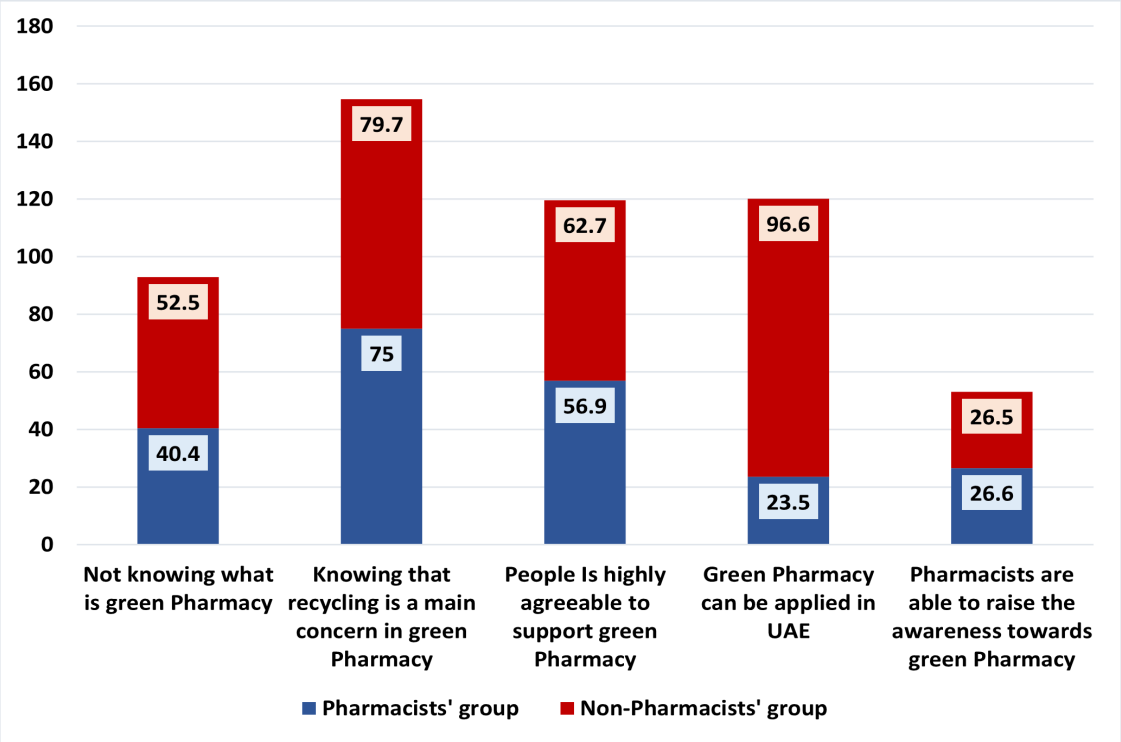

Figure 1. Comparative analysis of responses between the pharmacist group (n=57) and the non-pharmacist group (n=344)

developing programs that utilize eco-friendly materials, ensure precise medication distribution to minimize waste, and replace plastic packaging with biodegradable alternatives or cardboard. All these strategies will be implemented in Green Pharmacy to prevent any additional adverse effects on the environment[12,24].

This cross-sectional observational study surveyed the awareness and practices of pharmacists and the public regarding green pharmacy. This study's findings revealed a substantial disparity in knowledge regarding green pharmacy between pharmacists and non-pharmacists. Contrary to expectations, a higher proportion of pharmacists demonstrated a lack of knowledge regarding green pharmacy compared to non-pharmacists on most questions. This affirms that green pharmacy is a contemporary subject within the field of pharmacy[25,26]. This fact compels us to diligently implement green pharmacy practices in the UAE. The United Arab Emirates is committed to environmental support and protection. Two potential explanations can account for the diversity of knowledge regarding green pharmacy, the American Association of Colleges of Pharmacy (AACP) report indicates that pharmacy education is overly concentrated on a few primary domains, which inadequately prepares pharmacists for patient guidance and collaborative professional practice[27]. The second reason is that patients' knowledge is expanding due to social media, enabling them to acquire highly specific and specialized information presented in a straightforward manner[28].

In the context of implementing green pharmacy in the UAE, 23.5% of pharmacists endorse its applicability, whereas 96.6% of non-pharmacists share this belief. A plausible explanation for this is that pharmacists, through their professional experience, comprehend the barriers that may impede any alterations to the existing working protocol, such as: approval from the Ministry of Health and Prevention, financial implications, extensive advertising campaigns, collaboration with manufacturing companies, and partnerships with recycling entities[2]. Furthermore, our findings indicate that 71.2% of pharmacists do not engage in the recycling process of medicine. Considering that the majority of pharmacists are employed in hospital pharmacies, we can comprehend the scope of the issue.

A significant finding in this study is that the majority of patients (72.9%) believe that drug recycling will benefit the environment. Nonetheless, the majority of these patients (79.7%) indicated that expired and unused medications are disposed of in the trash, which adversely impacts and devastates marine life, as well as flora and other organisms. This action can be elucidated and influenced by various factors, including motivation, available resources, education, and anticipated outcomes from this action[29,30]. Concerning the International Pharmaceutical Federation (FIP) policy on the implementation of Green Pharmacy, member organizations play a pivotal role in pharmaceutical practices by enhancing the

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awareness of healthcare professionals and the general public. These organizations are tasked with offering leadership to their governments and memberships to address any environmental issues associated with medicines or their usage. The concepts of green pharmacy for practice can also be cultivated and advocated through these organizations. Moreover, the FIP member organizations advocate for the implementation of "friendly pharmaceutical waste disposal" through the promotion of take-back programs that do not impose any financial burdens on pharmaceutical practices[31].

The FIP advised that pharmacists should oversee the implementation of green chemistry in all manufacturing processes and research activities. It is advisable to collaborate with prescribers to enhance awareness of the medicine's environmental classifications in practice. Eco-friendly practices are also advised in distribution and procurement processes. Collaboration with allied health professionals can promote rational prescription practices. Counselling should be integrated into the assessment of potential risks and environmental impacts associated with all pharmaceuticals and medical practices. Furthermore, pharmacists must acknowledge the role of regimen prescription in the generation of pharmaceutical waste[31].

Limitation of the study

The primary limitations of this study were its absence of national representation, predominantly reflected in responses from Sharjah, constrains the generalizability throughout the UAE. The limited sample size of pharmacists (n=57) may not encompass the complete range of professional experiences, and the lack of formal validation for the survey instrument could compromise the reliability of the results. This study used a convenience sample technique, which, while useful for reaching a varied pool of participants, may introduce selection bias and restrict the findings' generalizability to the larger UAE population.

Implication of the study

This study underscores significant knowledge and practice deficiencies in the implementation of green pharmacy in the UAE, particularly among pharmacists. It emphasizes the necessity for specialized education, regulatory assistance, and cooperation with environmental agencies to advance sustainable pharmaceutical practices. The results advocate for the synchronization of national initiatives with global sustainability objectives, especially in minimizing pharmaceutical waste and safeguarding public health. These insights can inform future policy formulation and environmental health initiatives in the region (Figure 2).

CONCLUSION

The improper disposal of medical waste adversely impacts the environment. Owing to its composition of hazardous chemicals and packaging materials, including plastic. This elucidates the necessity of implementing Green Pharmacy in the UAE, regarded as an innovative concept that promotes recycling and environmental protection through its operations and services. This will positively influence the environment and enhance public knowledge and education. As a healthcare provider, we bear complete responsibility for safeguarding the environment and human health.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

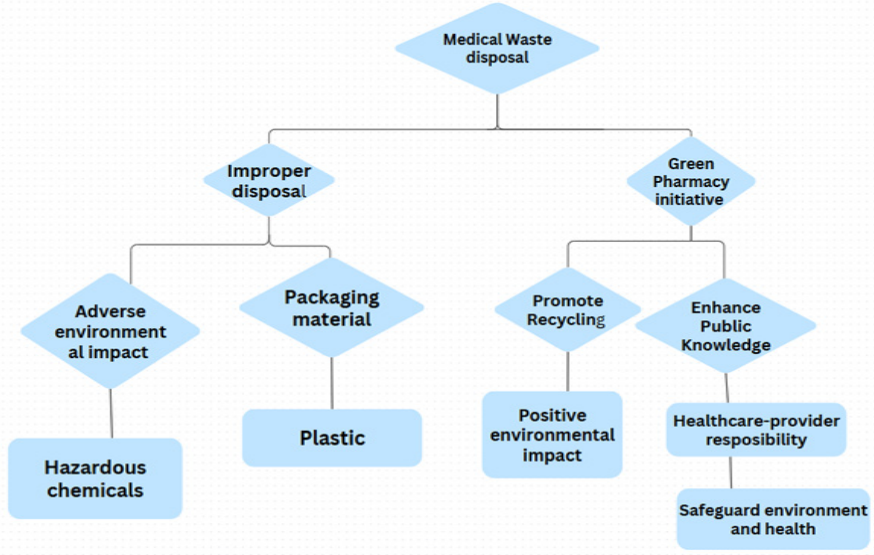

Figure 2. Environmental Implications of Medical Waste Disposal and the Role of Green Pharmacy Initiatives

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