

# Ecopharmacology: Knowledge, Attitude, and Medication Disposal Practice Among Pharmacy Students

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**Background:** Ecopharmacology, as a form of drug management for the environment, focuses on the impact of drugs on the environment. Pharmacists, and by extension pharmacy students, are expected to play an important role in ecopharmacology. Therefore, this study was conducted to determine the knowledge and attitude towards ecopharmacology and the practice of disposal of leftover or expired medicines among pharmacy students.

**Methods:** This was a descriptive cross-sectional study among pharmacy students in Northwestern Ethiopia. The study took place from May 1 to June 15, 2023. A self-administered questionnaire was used for data collection.

**Results:** Four hundred and forty-five students were included in the study. Only 91 (20%) of the students were aware of the term ecopharmacology, 27% knew that excretion from the human or animal body is the major route by which pharmaceutical agents enter the environment, and 42% were aware of the risk of increased antimicrobial resistance due to antibiotic residues in the environment. In addition, only 27% of respondents reported receiving information about the disposal of pharmaceuticals. The most common method of disposing of medications was throwing them away in household trash (61.8%).

**Conclusion:** Our results suggest that while most pharmacy students in Ethiopia have a positive attitude toward ecopharmacology, they do not know enough about ecopharmacology and dispose of their medicines poorly. More uniform education in ecopharmacology and pharmaceutical pollution might be warranted in the pharmacy curriculum.

**Keywords:** ecopharmacology, pharmacy students, medication disposal, Ethiopia

## Introduction

Drugs are generally recalcitrant molecules; they can persist in different environmental compartments and always negatively interact with the environment.<sup>1</sup> This has led to harmful effects on aquatic species and the ecosystem.<sup>2-5</sup> More so, it may even endanger human health.<sup>6-8</sup> Therefore, pharmaceuticals are increasingly recognized as chemicals of emerging concern (CECs).<sup>9,10</sup> The entry of these so-called CECs into the environment by any route and at any concentration that disturbs the balance of the ecology (ecosystem) is described by ecopharmacology (ecosystem + pharmacology).<sup>11-13</sup>

Improper disposal of pharmaceuticals by the general public has been cited as a contributing factor,<sup>14,15</sup> although its importance in the observed concentrations of pharmaceuticals in wastewater samples is still controversial.<sup>16</sup> However, given the consistent observation of generally poor disposal of unwanted medicines in both highly developed and low- and middle-income countries,<sup>14,17</sup> and the increasing consumption of medicines worldwide, there is sufficient cause for concern to take precautions, on safe disposal of unused medicines. The literature also shows that there seems to be a gap in information and awareness of the problem of disposal of medications in the population at large, regardless of geographic region.<sup>18</sup>

In Ethiopia, the situation is no different. In fact, the most contaminated river samples in a recent study were primarily from sampling campaigns in African countries, of which river pollution was highest in Ethiopia.<sup>19</sup> Despite the existence of a policy and manual that provide helpful guidance on the application of various healthcare waste management strategies in different circumstances, the practices of Ethiopian healthcare facilities in dealing with pharmaceutical waste are still poor.<sup>20,21</sup> The general public's practice of pharmaceutical waste disposal is also generally poor.<sup>20</sup> In addition, most people have not been educated by pharmacists and other health professionals on how unused medicines should be disposed of.

To bridge this information gap and ensure the most environmentally sound disposal of pharmaceutical waste, pharmacists are expected to play the primary role in educating people about public health and the environment.<sup>22–25</sup> However, pharmacists are also implicated with poor drug disposal practice,<sup>26–28</sup> and even may not consider providing information about proper disposal as a required component of counseling,<sup>23,26</sup> which could be an indication of a gap in the curriculum. This could be improved with small educational efforts.<sup>29–31</sup> Effective communication, especially directly from pharmacists could then improve disposal practice of the public.<sup>15,24,32</sup>

Therefore, it has been suggested that initial pharmacy education regarding pharmaceutical waste management could be an important driver of change. And if we are to make the best use of the expertise of pharmaceutical experts and produce environmentally oriented pharmacists, the integration of ecopharmacology seems to be an important prerequisite. To make this possible, a prior assessment of their knowledge, attitude, and practice of drug disposal is important. However, to our knowledge, there is not a single study that has investigated the pharmaceutical behavior of young adults, especially pharmacy students. Therefore, this study aimed to assess pharmacy students' medication disposal practices along with knowledge and attitudes toward ecopharmacology. This will provide the impetus to develop and implement strategies for future pharmacists to play a greater role in the safe disposal of pharmaceutical waste and in educating other health care professionals and the public about this issue. It will also help raise awareness of this issue among policymakers.

## Methods and Materials

### Study Design, Setting, and Duration

We conducted a questionnaire-based cross-sectional study among pharmacy undergraduate students. The study was conducted from May 1 to June 15, 2023. The study took place in four Universities in in Northwestern Ethiopia. The Universities were Debre Tabor University (DTU), University of Gondar (UoG), Bahir Dar University (BDU), and Debre Markos University (DMU).

### Population

All pharmacy students studying at DTU, UoG, BDU, and DMU during the data collection period formed the baseline population. All volunteers who were in their third to fifth year of study and who completed and submitted the questionnaire constituted the study population. We used nonprobability sampling (convenience method) and made every effort to include all eligible students.

### Data Collection Procedure and Instrument

Data were collected with a self-administered questionnaire. The questionnaire was written in English. The instrument was self-developed using information from relevant literature. The items used to assess knowledge were based on the current body of evidence about ecopharmacology.<sup>2–8,14,15,33–44</sup> Similar knowledge, attitude, and practice studies were used in framing the questions and to further substantiate and structure the instrument.<sup>45–47</sup> Therefore, the questions had already been tested, which probably resulted in a high degree of validity. The initial draft of the questionnaire was then appraised by two researchers with experience in pharmacology and pharmacy practice-related studies for content validity, clarity, relevance, and conciseness of the items. Furthermore, to obtain feedback on the wording and usability of the questionnaire from the target population, the questionnaire was tested with 15 randomly selected students, three from

each year group (from third to fifth year). Finally, some of the items were modified and the data from this pilot test were excluded from the analysis.

The questionnaire included the following categories: sociodemographic characteristics, questions on knowledge, attitude, and practice of medication disposal. The questions on knowledge and attitude were all answered with “yes/no” responses. The questions on medication storage and disposal included a “yes/no/I do not know” item, tabular items that allowed students multiple responses, and an open-ended question about the name(s) of the unused or unwanted medication(s) they had.

In an effort to include all eligible students and to avoid future student performance problems related to the subject, data were collected in students’ classrooms during lecture time. The questionnaire was distributed to all available students. The introductory section of the questionnaire, which included the purpose of the study, voluntariness of participation, informed consent with a statement of anonymity, and the response procedure, was briefly described. The data represent only those who returned the questionnaire with signed informed consent and a complete response. Therefore, all students had the opportunity to read the questions regardless of whether they were willing to participate in the study or provide complete responses.

## Data Analysis

Data were revised, coded, and entered into the Statistical Package for the Social Sciences version 26. Descriptive analysis was performed to estimate each variable. A chi-square test was used to examine whether there was an association between student characteristics and medication disposal methods. The test was also used to examine whether information about appropriate disposal of medications influenced students’ disposal practices. Statistical significance was a P value of < 0.05.

## Ethical Approval

Ethical approval with reference number (CHS/18747/2023) was obtained from the Ethics Committee of Debre Tabor University, College of Medicine and Health Sciences. This study was conducted in accordance with the Declaration of Helsinki. To ensure the privacy and confidentiality of the students, no names or addresses were included in the questionnaire. Data were collected unanimously using codes as identifiers. Written informed consent was obtained from all participants.

## Result

A total of 445 pharmacy students were included in this study. Of them, 287 (65.5%) were male. The mean age of the participants was 23 ( $\pm 1.59$ ) years. Regarding the year of study, 151 (33.9%) were in the third year of study, 141 (31.7%) were in the fourth year of study, and 153 (34.4%) were in the fifth year of study.

## Pharmacy Students’ Knowledge of Ecopharmacology and Prior Guidance on Drug Disposal

In this study, we found that more than half of the students were aware of the potential risk of environmental pollution from improper disposal of pharmaceutical (60%) and the negative impact of pharmaceuticals on ecosystems and wildlife species (54%). However, only 91 (20%) of the students knew the term ecopharmacology, 90 (20.2%) had read reports or articles about environmental pollution from pharmaceuticals, and 120 (27%) had been taught about proper disposal of pharmaceuticals in pharmacy school or by health professionals. [Table 1](#).

## Attitudes of Pharmacy Students Towards Ecopharmacology

Nearly two-thirds (63%) of respondents expressed concern about the presence of unused or unwanted medications in the home and supported the implementation of policies to safely dispose of such medications (87%). More than three-quarters of students (79%) were willing to dispose of medications in specific locations or in an appropriate place. Students were also asked if they thought manufacturers and pharmacies should collect unwanted/excess medications from the public. Most of them (82.5%) agreed with this statement. [Table 2](#).

**Table 1** Knowledge of Ecopharmacology of Pharmacy Students Participated in the Study (n = 445)

| Variables  | Categories | Frequency | %    |
|--|------------|-----------|------|
| Do you know what ecopharmacology is?   | Yes        | 91        | 20.4 |
|  | No         | 354       | 79.6 |
| Removal of pharmaceuticals by sewerage treatment plants is poor.   | Yes        | 77        | 17.3 |
|  | No         | 368       | 82.7 |
| Excretion of drugs after normal use (pharmacotherapy) contributes to environmental pollution.  | Yes        | 122       | 27.4 |
|  | No         | 323       | 72.6 |
| Improper disposal of unused and expired medications can contribute to environmental pollution.   | Yes        | 266       | 59.8 |
|  | No         | 179       | 40.2 |
| Pharmaceutical residues in the environment endanger the ecosystem and wildlife species.  | Yes        | 242       | 54.4 |
|  | No         | 203       | 45.6 |
| Antimicrobial residues in the environment contribute to antimicrobial resistance.  | Yes        | 188       | 42.2 |
|  | No         | 257       | 57.8 |
| There are laws or guidelines for proper disposal of pharmaceuticals.   | Yes        | 185       | 41.6 |
|  | No         | 260       | 58.4 |
| Have you read any reports or articles about how pharmaceuticals can contribute to pollution?   | Yes        | 90        | 20.2 |
|  | No         | 355       | 79.8 |
| Have you been taught the proper disposal of medications in pharmacy school or have you received information from healthcare professionals? | Yes        | 120       | 27.0 |
|  | No         | 325       | 73.0 |

**Table 2** Attitudes of Pharmacy Students Toward Ecopharmacology (n = 445)

| Variables   | Categories | Frequency | %    |
|---|------------|-----------|------|
| Has the thought of disposing of unused or extra medication ever bothered you?   | Yes        | 281       | 63.1 |
|   | No         | 164       | 36.9 |
| Do you think there should be guidelines for the public to dispose of medications in an environmentally friendly?                                    | Yes        | 388       | 87.2 |
|   | No         | 57        | 12.8 |
| Do you think there should be safe places to dispose of medications that are no longer needed, such as collection boxes in hospitals and pharmacies? | Yes        | 352       | 79.1 |
|   | No         | 93        | 20.9 |
| Do you think manufacturers and pharmacies should collect unwanted/leftover medications from the public?   | Yes        | 367       | 82.5 |
|   | No         | 78        | 17.5 |
| Will you participate in efforts to address this issue, such as a campaign?  | Yes        | 351       | 78.9 |
|   | No         | 94        | 21.1 |
| Do you think you (pharmacists) are responsible for protecting the environment from pharmaceutical waste?  | Yes        | 401       | 90.1 |
|   | No         | 44        | 9.9  |

## Medication Storing and Disposal Practice of Pharmacy Students

Two hundred eighty-four (64%) of students reported storing leftover or unwanted medications in their room. The most common reasons that medications were kept were improvement in medical condition (self-discontinuation) (44.4%) and keeping for future use (26.4%). Ninety-eight (34.5%) students reported that the stored medications had expired. Students reported a total of 418 medications. Among the reported drugs, analgesics (38.9%), antimicrobials (26.5%), and

**Table 3** Medication Storing and Disposal Practice of Pharmacy Students

| Variables  | Categories                           | Frequency | %    |
|--|--------------------------------------|-----------|------|
| Leftover, unused, or unwanted medications stored in the home | Yes                                  | 284       | 63.8 |
|  | No                                   | 145       | 32.6 |
|  | Do not know                          | 16        | 3.6  |
| Reasons for keeping medications <sup>a</sup>                 | Improvement in medical condition     | 126       | 44.4 |
|  | Change of medication by a prescriber | 43        | 15.1 |
|  | Finished the dose and remained       | 40        | 14.1 |
|  | Keeping for future use               | 75        | 26.4 |
| Storing expired medications at home <sup>a</sup>             | Yes                                  | 98        | 34.5 |
|  | No                                   | 101       | 35.6 |
|  | Do not know                          | 85        | 29.9 |
| Types of stored medications <sup>b</sup>                     | Analgesics                           | 173       | 41.4 |
|  | Antimicrobials                       | 118       | 28.2 |
|  | Antiulcerants                        | 42        | 10.0 |
|  | Antitussives                         | 27        | 6.1  |
|  | Laxatives                            | 23        | 5.2  |
|  | Multivitamins                        | 29        | 6.5  |
| Methods of medication disposal <sup>c</sup>                  | Flushing in the toilet or sink       | 144       | 32.4 |
|  | Give to friends or relatives         | 97        | 21.8 |
|  | Place in household garbage           | 275       | 61.8 |
|  | Burn                                 | 90        | 20.2 |
|  | Returned to pharmacy or hospital     | 27        | 6.1  |

**Notes:** <sup>a</sup>Only those who stored medications were included (n = 284), <sup>b</sup>Percentages are calculated from the total number of reported drugs (n = 418), <sup>c</sup>Percentages exceed 100 due to multiple responses (n = 445).

antiulcerants (included antacids, H<sub>2</sub> receptor antagonists, and proton pump inhibitors) (10%) were the most commonly stored medications. Details are presented in Table 3.

Three hundred sixty-five (82%) of the students reported disposing of unused medications. The remainder of the students, 63 (14.2%), never disposed of medications. The most common methods of disposing of unused or unwanted medications were throwing them away in the household trash (61.8%) and flushing them down the toilet or sink (32.4%). Only a few students, 27 (6.1%), returned medications to the pharmacy or hospital.

Drug disposal methods were not statistically related to students' gender or year of study. However, students' disposal methods were influenced by information about appropriate drug disposal, as indicated by cross-tabulation of two items. Seventy-eight percent of students who reported receiving information about disposal methods returned unused or unwanted medications to a pharmacy or hospital (while 22% did not). Among students who had never received information about disposal methods, 76% did not return unused or unwanted medications to a pharmacy or hospital (while 24% did). The association between receiving information about disposal methods and returning unused or unwanted medications to a pharmacy or hospital was significant ( $p < 0.001$ ).

## Discussion

In this study, we assessed drug disposal practice of pharmacy students along with their knowledge and attitude toward ecopharmacology. The results showed an overall unsafe practice of drug disposal and poor knowledge but a positive attitude towards ecopharmacology.

Of the seven knowledge questions, students scored the highest (60% and 54%, respectively) on whether improper disposal of pharmaceuticals contributes to environmental pollution and whether pharmaceuticals (water and soil) can endanger the ecosystem. This is likely a result of their academic (professional) knowledge of the pharmacology and toxicology of pharmaceuticals and is consistent with other studies.<sup>48–51</sup>

We found that few pharmacy students were aware of the concept of ecopharmacology. Considering that ecopharmacology is a new and developing science, this would not be surprising. However, a considerable proportion of the students also missed the major route by which pharmaceutical agents enter wastewater treatment plants, namely via excretion from the human body, and these plants are often unable to remove all pharmaceuticals. In addition, less than half of the students were aware of the risk of increased antimicrobial resistance due to antibiotic residues in the environment and the existence of laws or guidelines for handling pharmaceutical waste.

This suggests that their knowledge of the life cycle of a drug is incomplete. As drug experts, pharmacy students need to know that the life cycle of a drug does not end with the intended or undesired effect on the patient. Some portion of a drug begins its journey into the immediate environment and the natural environment almost immediately when a patient begins taking a drug.<sup>44</sup> Most importantly, between 30% and 90% of the orally administered dose is excreted as active ingredients in the urine of humans and animals.<sup>33</sup> And this measurable amount is discharged directly into wastewater treatment plants, which are not specifically designed to remove pharmaceuticals<sup>34</sup> and are therefore generally considered the main and most direct source of pharmaceutical pollution.<sup>35–40</sup>

Equally important, if not more, is knowing the potential for antimicrobials to promote resistance, no matter how low their concentration in the environment.<sup>41–43</sup> In addition, pharmacy students should be aware of the World Health Organization<sup>52</sup> and Ethiopian Federal Ministry of Health (FMOH)<sup>53</sup> guidelines for proper disposal of pharmaceutical waste so that they can safely dispose of leftover/expired medications in their subsequent work at facilities, as well as the United States Food and Drug Administration (USFDA) guidelines<sup>54–56</sup> to effectively educate the public on proper disposal methods. The low response rate for the knowledge questions may be due to the fact that most students had not read/heard reports or articles about the presence of pharmaceuticals in the environment, nor had they been taught about proper disposal of pharmaceuticals in pharmacy school or by healthcare professionals.

Consistent with several studies conducted among pharmacy students, we also found high medication storage.<sup>48–51,57–59</sup> Also in agreement is that the most common method of disposing of medications was to throw them in the household trash.<sup>48,49,51,57–60</sup> This could also be because most of the respondents in our study were not informed about the proper disposal of medicines. Indeed, in our study and in other studies,<sup>48,60</sup> pharmacy students who were already familiar with proper medication disposal were more likely to return unused drugs to a pharmacy. This suggests that one possible factor is a lack of education about medication disposal. In addition, Ethiopia does not have guidelines for the disposal of medicines by the public or allow pharmacies to receive unused medicines from the public. Thus, in the absence of an established system the students' poor disposal methods would not be surprising.

Therefore, pharmacy students should be equipped with a solid and better understanding of the effect of pharmaceuticals on the environment so that they can fulfill their responsibilities as pharmaceutical experts. More uniform education on ecopharmacology in pharmacy education and mandatory teaching of drug disposal, similar to knowledge of drug consumption,<sup>22</sup> so that humans and the environment are treated as a single, holistic patient,<sup>44</sup> could help to convey the importance of this information to students. Therefore, it is important that other pharmacy schools in Ethiopia assess their students in this area and ensure that students are well prepared and confident to educate patients about drug disposal. Students' empathic attitudes could be a possible input. In addition, the FMOH of Ethiopia should consider investing in pharmaceutical take-back programs. Campaigns could be conducted to raise awareness and contribute to successful take-back programs.

## Limitations of the Study

Because this is a cross-sectional study, causal relationships cannot be established. Results are based on self-report and therefore may be biased by recall. Our decision to include only students at public universities may have affected the external validity of the results. However, this study is the first to assess medication disposal practices from the perspective of knowledge and attitudes toward ecopharmacology. In addition, it focused on a population that has not received attention in Ethiopia with regard to pharmaceutical behavior: pharmacy students, who are the main actors in the proper use and disposal of medications.

## Conclusion

This first survey on ecopharmacology among pharmacy students indicated that most pharmacy students in Ethiopia know little about ecopharmacology but have a positive attitude toward ecopharmacology. The study also showed that pharmacy students do not dispose of their medicines in an environmentally sound manner and that good disposal practices are significantly influenced by prior information. Our findings therefore suggest the need for interventions that emphasize the importance of proper medication disposal and the pharmacist's responsibility in pharmaceutical pollution.

## Data Sharing Statement

The raw data supporting the conclusions of this article will be made available by the corresponding author to any qualified researcher without undue reservation.

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## Disclosure

The authors declare no conflicts of interest in this work.

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