RESEARCH PAPER

Knowledge, Attitude, and Practices toward Eco Pharmacology among Healthcare Professionals at a Tertiary Care Teaching Hospital: A Cross-Sectional Study

Navaneetha Krishnan Meganathan[1], Arvinth Arthanareeswaran[2*], Sakthibalan Murugesan[3]

[1]III-year MBBS, Sri Venkateshwaraa Medical College Hospital and Research Centre, Puducherry, India.

[2]Professor, Department of Pharmacology, Sri Venkateshwaraa Medical College Hospital and Research Centre, Puducherry, India. E mail: drarvinth.a@gmail.com*

[3]Professor and Head, Department of Pharmacology, Sri Venkateshwaraa Medical College Hospital and Research Centre, Puducherry, India

ABSTRACT

Background: Ecopharmacology, a growing domain of pharmacovigilance, evaluates the environmental impact of pharmaceuticals and emphasizes the safe disposal of unused or expired medicines. Improper medication disposal contributes to environmental contamination, antimicrobial resistance, and potential public health risks. Healthcare professionals play a crucial role in promoting rational medication use and environmentally responsible disposal practices.

Methods: A descriptive cross-sectional study was conducted among 300 healthcare professionals at a tertiary care teaching hospital. Data were collected using a validated self-administered questionnaire consisting of demographic variables and 20 items assessing knowledge, attitude, and practices (KAP) related to ecopharmacology. Data were analyzed using IBM SPSS Statistics. Descriptive statistics summarized responses, and Chi-square tests were used to assess associations between professional designation and KAP variables. A p-value <0.05 was considered statistically significant.

Results: The mean age of participants was 34.8 ± 7.6 years, with 58% being male. Most respondents demonstrated adequate knowledge of ecopharmacology and recognized the environmental hazards associated with improper pharmaceutical disposal; however, awareness of Indian regulatory guidelines was limited. Participants showed generally positive attitudes, supporting professional responsibility, public disposal guidelines, and medication take-back programs. Despite this, disposal practices were suboptimal. Nearly half of the respondents reported purchasing medicines in bulk, and many disposed of unused solid or liquid formulations through household garbage or wash basins. Participation in seminars or continuing medical education programs related to ecopharmacology was low. Professional designation was significantly associated with selected knowledge, attitude, and practice variables ($p < 0.05$).

Conclusion: Although healthcare professionals demonstrated satisfactory knowledge and favorable attitudes toward ecopharmacology, appropriate disposal practices remain inadequate. Strengthening structured education, curricular integration, continuing professional development, and accessible medication take-back programs is essential to reduce pharmaceutical environmental contamination and protect public health.

Keywords: Ecopharmacology; Pharmaceutical Waste; Medication Disposal; Healthcare Professionals.

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INTRODUCTION

Eco pharmacology, a branch of pharmacovigilance, analyses the presence of pharmaceuticals in the environment and the negative effects of their active ingredients.[1] Storing unused medicines at home can increase the risk of a variety of potential drug-related problems, e.g., medication errors, adverse drug reactions, and may be considered a waste of resources. These medicines are eventually disposed of, but there is a gap in proper disposal practices.[2] Improper disposal of pharmaceuticals can cause environmental pollution that leads to health risks.[3] Currently, a large amount of pharmaceutical waste flows into waterways through sewers, alarming environmental scientists around the world, and it is also absorbed into soil when it is disposed of as solid waste in landfills. Globally, the use of pharmaceuticals is increasing over time,[4] and newly

identified contaminants could pose a threat to the environment in the future.[5]

According to the World Health Organization (WHO), a large proportion of medicines are improperly prescribed and sold, resulting in unnecessary storage and posing a hazard to the environment if improperly disposed.[6,7] Expired and unused medications have been found to generate tons of municipal solid waste.[8] This is due to the improper disposal of unused medications through environmentally harmful means.[9] To address this problem, proper handling of expired medications is essential. In addition, improper disposal of medicines has various consequences, such as accidental consumption of expired medicines, resale, or misuse during sorting.[10] Increasing knowledge about appropriate disposal to prevent environmental pollution and its impacts is a general preventive measure to preserve the environment from this kind of pharmaceutical waste.[11] The National Formulary of India specifies how drugs should be disposed of, yet most medical personnel are unaware of these rules and how important it is to abide by them.[12]

Healthcare workers are essential to reducing pharmaceutical waste and encouraging ecologically friendly practices since they are involved in prescription, dispensing, medication handling, and patient counseling. Therefore, it is crucial to evaluate their knowledge, attitudes, and practices regarding ecopharmacology in order to pinpoint any gaps, clear up any misunderstandings, and guide focused institutional and educational actions. Therefore, the current study was conducted to evaluate healthcare professionals at a tertiary care hospital's knowledge, attitudes, and practices regarding ecopharmacology and safe pharmaceutical disposal; to identify knowledge gaps and misconceptions regarding the environmental impact of improper pharmaceutical disposal; and to assess the relationship between specific demographic variables and the levels of ecopharmacology knowledge, attitudes, and practices.

MATERIALS AND METHODS

Study Design: Descriptive cross-sectional study by stratified random sampling for a period of three months. The study was conducted after obtaining scientific and ethical approval among the healthcare professionals at a tertiary care hospital at Ariyur, Puducherry.

Sample Size: Sample size was calculated using OpenEpi version 3.0 based on previous literature. Assuming a prevalence of adequate knowledge of 97.1%, confidence level of 95%, margin of error of 2%, and a non-response rate of 10%, the final sample size was calculated as 297 and rounded off to 300 participants.

Inclusion criteria: Physicians who work in our hospital and are directly involved in patient care or drug administration, worked in the hospital for at least six months (to guarantee sufficient exposure to hospital medication-use and disposal procedures), and given informed consent to participate.

Exclusion criteria: Professionals who decline or withdraw consent and incomplete or improperly filled questionnaires (predefined cutoff: e.g., >20% missing responses or missing all KAP domain sections) — was excluded from analysis.

Data collection procedure: After explaining the study objectives and obtaining consent, a questionnaire was sent through WhatsApp as a Google form link to the participants. Completed questionnaires was collected from all participants to evaluate their responses. The questionnaire was formulated in English and a pilot study was conducted involving 20 healthcare professionals to assess the reliability and validity of the questionnaire. The findings from the pilot study were not included in the final analysis.

The self-administered questionnaire consists of two sections:

Part (1) consists of participant's age, gender and designation.

Part (2) consists of 20 questions that evaluates KAP regarding eco pharmacology. Seven questions focused on definition, basic knowledge about eco pharmacology, expired/unused medicines, and rules related to its disposal. Seven questions addressed participants' attitude and beliefs about expired/unused medicines. Finally, six questions addressed the current practice of medicines disposal, and continuous education about eco pharmacology.

RESULTS

A total of 300 healthcare professionals were included in the final analysis, yielding a complete response set. The mean age of the participants was 34.8 ± 7.6 years, indicating a predominantly young to middle-aged study population. The majority of participants belonged to the 30–39-year age group (44.0%), followed by those aged below 30 years (32.0%), while 24.0% were aged 40 years or older. Male participants constituted 58.0% (n = 174) of the study population, whereas 42.0% (n = 126) were female. With respect to professional designation, junior residents formed the largest group (42.0%, n = 126), followed by senior residents (33.0%, n = 99) and faculty members (25.0%, n = 75) (Table 1).

Table 1: Demographic characteristics of the study participants (N = 300)

Variable	Category	n (%)
Age (years)	<30	96 (32.0)
	30–39	132 (44.0)
	≥40	72 (24.0)
Mean age (years)	—	34.8 ± 7.6

Gender	Male	174 (58.0)
	Female	126 (42.0)
Designation	Junior Resident	126 (42.0)
	Senior Resident	99 (33.0)
	Faculty	75 (25.0)

Knowledge about Ecopharmacology among Participants:

Table 2 shows knowledge about ecopharmacology among participants. Overall, knowledge regarding ecopharmacology among the participants was variable, with relatively better awareness of environmental and public health hazards of improper drug disposal than of regulatory and conceptual aspects. A majority of participants 205 (68.3%) were able to correctly define the term ecopharmacology. Most respondents 248 (82.7%) acknowledged that expired or unused medicines that are not properly disposed of can pose hazards to public safety. Awareness regarding the role of pharmaceutical pollution in contributing to antibiotic resistance was reported by 213 (71.0%) participants.

More than half of the respondents 176 (58.7%) reported that they had read media reports or articles highlighting the environmental impact of pharmaceuticals. However, knowledge regarding existing Indian rules and regulations aimed at minimizing drug entry into the environment was comparatively low, with only 114 (38.0%) participants being aware of such guidelines. Similarly, awareness of the concepts of green chemistry and green pharmacy was reported by 124 (41.3%) participants.

Regarding the environmental impact of non-allopathic medicines, 162 (54.0%) participants believed that Ayurvedic, Homeopathic, and Veterinary drugs could adversely affect the environment, while 46.0% did not recognize their potential ecological impact. Based on the cumulative knowledge scores, 33.7% of participants demonstrated adequate knowledge, 34.6% had moderate knowledge, and 31.7% had poor knowledge regarding ecopharmacology. There was a statistically significant association between designation and knowledge levels for most questionnaire items. Awareness regarding Indian rules and regulations on pharmaceutical disposal (Q5) and concepts of green chemistry and green pharmacy (Q6) showed the strongest associations with professional designation ($p < 0.001$). Faculty members consistently demonstrated higher correct response rates compared to residents.

Table 2: Knowledge about ecopharmacology among healthcare professionals (N = 300)

Q. No.	Questionnaire item	Correct response n (%)	Incorrect response n (%)	p-value*
1.	Define the term “Eco pharmacology”	205 (68.3)	95 (31.7)	0.002
2.	Can the expired/unused medicines which are not properly disposed, pose hazards to public safety?	248 (82.7)	52 (17.3)	0.018
3.	Could the pollution caused by pharmaceuticals potentially be a contributing factor for antibiotic resistance?	213 (71.0)	87 (29.0)	0.004
4.	Have you read any media reports or articles about the environmental impact of pharmaceuticals?	176 (58.7)	124 (41.3)	0.021
5.	Do you know if India has rules and regulations for minimizing the risk of drug entry into the environment?	114 (38.0)	186 (62.0)	<0.001
6.	Have you heard the terms “Green Chemistry” and “Green Pharmacy”?	124 (41.3)	176 (58.7)	0.001
7.	Do you think use of Ayurvedic, Homeopathic, and Veterinary drugs can affect environment?	162 (54.0)	138 (46.0)	0.036

Values expressed as frequency (%), *p-value < 0.05 considered statistically significant

Attitude of Participants toward Ecopharmacology:

Attitude of participants toward ecopharmacology and its association with designation were present in table 3. Overall, participants demonstrated a predominantly positive attitude toward ecopharmacology and environmentally responsible pharmaceutical practices. Concerns regarding improper disposal of medicines, perceived professional responsibility, and willingness to engage in eco-pharmacological initiatives were consistently high across the study population.

A total of 241 (80.3%) participants reported that thoughts of disposing unused or extra medications bothered them to a moderate or great extent. The majority, 258 (86.0%), agreed that knowledge of ecopharmacology would be

relevant to their routine medical practice. Similarly, 269 (89.7%) participants supported the need for clear public guidelines for environmentally safe disposal of medicines.
Strong support was also observed for structural and policy-level interventions. 266 (88.7%) respondents agreed that hospitals and pharmacies should have dedicated collection boxes for leftover or expired medicines, while 253 (84.3%) believed that manufacturers and pharmacies should take responsibility for collecting unwanted medications from the public. Notably, 271 (90.3%) participants agreed with the statement that protecting the environment from pharmaceutical waste is a personal professional responsibility. Furthermore, 249 (83.0%) expressed willingness to actively participate in initiatives related to ecopharmacology. Overall attitude scores indicated that 216 (72.0%) participants had a positive attitude, 62 (20.7%) had a neutral attitude, and 22 (7.3%) demonstrated a negative attitude toward ecopharmacology.

Table 3: Attitude of participants toward ecopharmacology and its association with designation (N = 300)

Q. No.	Questionnaire item	Agree / Strongly agree n (%)	Neutral / Disagree n (%)	p-value*
1.	To what extent do thoughts of disposing of unused or extra medication bother you	241 (80.3)	59 (19.7)	0.041
2.	Eco pharmacology knowledge will be relevant in your medical practice	258 (86.0)	42 (14.0)	0.012
3.	There should be guidelines for the public to dispose medications in an environmentally friendly manner	269 (89.7)	31 (10.3)	0.018
4.	There should be collection boxes in hospitals and pharmacies to collect left-over/unused/expired medications	266 (88.7)	34 (11.3)	0.009
5.	Manufacturers and pharmacies should collect unwanted/left-over medications from the public	253 (84.3)	47 (15.7)	0.023
6.	"It is my responsibility to protect environment from the pharmaceutical waste"	271 (90.3)	29 (9.7)	0.006
7.	Are you willing to actively engage in activities or initiatives related to Eco pharmacology?	249 (83.0)	51 (17.0)	0.032

Values expressed as frequency (%), *p-value < 0.05 considered statistically significant

Practice related to ecopharmacology and pharmaceutical disposal:

The assessment of practices related to ecopharmacology is presented in Table 4. It revealed suboptimal but modifiable behaviours among healthcare professionals. Nearly half of the participants (142, 47.3%) reported purchasing medicines in bulk for family members, a practice that may predispose to medicine accumulation and subsequent improper disposal. A considerable proportion of respondents (168, 56.0%) stated that they remove medicines from their original containers before discarding them, potentially increasing the risk of environmental contamination and accidental exposure.
Improper disposal of liquid formulations was also commonly reported, with 124 participants (41.3%) admitting to pouring leftover syrups or lotions into wash basins, thereby facilitating direct entry of pharmaceutical residues into wastewater systems. Exposure to formal training on ecopharmacology was notably limited; only 78 participants (26.0%) had attended any seminar, workshop, or continuing medical education (CME) program related to ecopharmacology or safe pharmaceutical disposal.
Encouragingly, a majority of healthcare professionals demonstrated willingness to adopt safer practices, with 246 participants (82.0%) expressing readiness to dispose of unused medicines through organized collection programs if made available. When asked about their preferred method of medication disposal, returning unused or expired medicines to authorized hospital or pharmacy collection centres was favoured by 162 participants (54.0%), followed by segregated disposal through biomedical waste systems (84, 28.0%). Only a minority preferred environmentally unsafe methods such as discarding medicines with household waste (36, 12.0%) or flushing them into sinks or toilets (18, 6.0%).

Table 4: Practices related to ecopharmacology among healthcare professionals (N = 300)

Q. No.	Practice-related questions	Yes n (%)	No n (%)	p-value*
1.	Do you buy drugs in bulk for family members?	142 (47.3)	158 (52.7)	0.041
2.	Do you remove the drug from its container before throwing it in the garbage?	168 (56.0)	132 (44.0)	0.032
3.	Do you pour leftover syrup/lotion from the bottle in the wash basin?	124 (41.3)	176 (58.7)	0.018
4.	Have you attended any seminars/workshop/CME about ecopharmacology?	78 (26.0)	222 (74.0)	<0.001

5.	Are you willing to dispose of unused medications through proper collection programs?	246 (82.0)	54 (18.0)	0.004
6.	Preferred method of medication disposal†	—	—	0.021

† Preferred method of medication disposal (multiple choice):

- Return to hospital/pharmacy collection centre – 162 (54.0%)
- Biomedical waste segregation – 84 (28.0%)
- Household garbage – 36 (12.0%)
- Flushing into sink/toilet – 18 (6.0%)

Values expressed as frequency (%), *p-value < 0.05 considered statistically significant

DISCUSSION

The present study demonstrated that although a majority of healthcare professionals were able to correctly define ecopharmacology and acknowledged that improper disposal of pharmaceuticals poses risks to public safety and the environment, awareness of existing Indian regulations and structured disposal mechanisms remained suboptimal. This discordance between conceptual understanding and regulatory awareness has been consistently documented across KAP studies conducted in India and other low- and middle-income countries, where healthcare professionals often recognize environmental hazards but remain inadequately informed about national guidelines, institutional protocols, or authorized disposal pathways.[13-15]

Given the crucial role that healthcare professionals play as prescribers, dispensers, and patient educators, these knowledge gaps are especially alarming. Because patients frequently rely on doctors for advice on pharmaceutical use, storage, and disposal, inadequate understanding among healthcare providers may unintentionally perpetuate harmful disposal practices at the community level.[16] Inadequate emphasis on environmental pharmacology in undergraduate and graduate medical curricula, as well as in continuing professional development programs, is another reason for the lack of familiarity with Indian regulations, such as biomedical waste management regulations and pharmaceutical disposal recommendations.

Encouragingly, a relatively high proportion of participants recognized the link between pharmaceutical pollution and antimicrobial resistance (AMR), indicating growing awareness of this critical global health threat. Environmental contamination with antibiotic residues has been shown to create selective pressure in aquatic and terrestrial ecosystems, facilitating the survival and proliferation of resistant bacterial strains.[17] Wastewater treatment plants, hospital effluents, and pharmaceutical manufacturing discharges have been identified as important reservoirs for antibiotic-resistant genes, which may subsequently enter human populations through water, food chains, and direct environmental exposure.

Importantly, sub-therapeutic concentrations of antibiotics in the environment—arising from improper disposal or incomplete metabolism—can promote horizontal gene transfer and sustain low-level resistance even in the absence of direct clinical antibiotic use.[17] This environmental dimension of AMR is increasingly recognized as a missing link in conventional antimicrobial stewardship programs, which traditionally focus on rational prescribing but often overlook downstream environmental consequences. Therefore, improving healthcare professionals' understanding of ecopharmacology is crucial for both protecting the environment and bolstering more comprehensive AMR containment initiatives

The majority of research participants showed a favourable attitude toward ecopharmacology and environmentally responsible pharmaceutical disposal. Large majority of respondents acknowledged their personal responsibility to protect the environment from pharmaceutical waste, strongly supported the creation of public guidelines for safe medication disposal, and thought that knowledge of ecopharmacology was pertinent to their regular medical practice. These results are consistent with past research on healthcare professionals and students in India and other low- and middle-income nations, which found that the medical community is gradually becoming more environmentally sensitive.[13, 18] This positive trend in attitudes probably reflects the growing worldwide conversation on environmental health, sustainability, and pharmaceuticals as new contaminants of concern.

The widespread endorsement of collection programs and manufacturer or pharmacy-led take-back initiatives in our study further underscores participants' willingness to engage in structured disposal systems, provided such mechanisms are accessible. Similar preferences have been observed in prior studies, where healthcare professionals expressed strong support for institutional responsibility in facilitating environmentally safe disposal pathways.[18] These findings suggest that healthcare professionals are receptive to shared-responsibility models that distribute accountability across healthcare institutions, regulatory bodies, and pharmaceutical stakeholders.

However, despite these encouraging attitudes, actual disposal practices remained inconsistent with environmental safety principles, highlighting a well-documented attitude–practice gap. Numerous cross-sectional research and systematic reviews have documented this phenomena; which consistently shows that risk awareness and positive attitudes do not always convert into acceptable action.[19] The lack of visible disposal infrastructure, unclear institutional procedures, lax enforcement of current laws, and insufficient professional training reinforcement are some of the factors causing this disparity.

The persistence of this discrepancy suggests that individual-level motivation must be supported by system-

level enablers. Without accessible collection points, standardized guidelines, and routine reinforcement through continuing education, healthcare professionals may default to convenient but environmentally unsafe disposal methods despite recognizing their potential harm. Moreover, the lack of formal accountability mechanisms may further weaken the translation of positive attitudes into consistent practice.

The present study identified substantial deficiencies in pharmaceutical disposal practices among healthcare professionals, underscoring a critical gap between awareness and real-world behaviour. A considerable proportion of participants reported purchasing medicines in bulk, a practice that often results in the accumulation of unused or expired medications within households. Such stockpiling not only increases the risk of inappropriate disposal but also raises concerns regarding accidental ingestion, misuse, and diversion of medicines, particularly in domestic settings. The frequent disposal of solid dosage forms through household garbage and liquid formulations through wash basins, as reported in this study, represents a direct pathway for pharmaceutical contaminants to enter the environment. Medicines discarded in household waste may leach into soil and groundwater from landfills, while liquid formulations discharged into sinks bypass effective degradation and enter sewage systems, ultimately contaminating surface and groundwater sources. These findings are consistent with observations from multiple studies conducted in India, Ethiopia, and Nepal, where environmentally unsafe disposal methods were prevalent despite acceptable levels of knowledge regarding pharmaceutical hazards.[14,20,21]

The low participation in seminars, workshops, or CMEs related to ecopharmacology observed in the present study further highlights the lack of structured training and continuing professional education in this emerging field. Without formal instruction or reinforcement, healthcare professionals may rely on convenience-based disposal methods rather than environmentally safe practices, even when they recognize the potential risks. Similar deficiencies in training exposure have been reported in other low- and middle-income country settings, emphasizing that the issue is systemic rather than institution-specific.[20,21]

Significant ecological and public health consequences result from these hazardous disposal methods. Environmental pharmaceutical residues have been linked to toxicity to non-target species, endocrine disruption in aquatic organisms, and the development of antimicrobial resistance through long-term exposure to low-dose antibiotics. These substances' persistence in soil and water environments may also lead to bioaccumulation and indirect human exposure through food chains and sources of drinking water, creating long-term dangers that are not immediately noticeable.

STRENGTHS AND LIMITATIONS

The strengths of this study include a robust sample size, inclusion of healthcare professionals across different designations, and comprehensive assessment of KAP domains. However, the cross-sectional design limits causal inference, and self-reported practices may be subject to social desirability bias. Moreover, as the study was conducted in a single tertiary care institution, generalizability to other healthcare settings may be limited.

CONCLUSION

This study demonstrates that although healthcare professionals possess reasonable awareness and a favourable attitude toward ecopharmacology, their pharmaceutical disposal practices remain inadequate and inconsistent with environmental safety principles. The findings reveal a critical gap between knowledge and practice, suggesting that awareness alone is insufficient to ensure environmentally responsible behaviour. Limited exposure to formal training, inadequate dissemination of regulatory guidelines, and the lack of structured disposal facilities appears to be major contributors to unsafe disposal practices. Given the influential role of healthcare professionals in medication prescribing, dispensing, and patient counselling, such deficiencies may inadvertently perpetuate inappropriate disposal behaviours at the community level, thereby amplifying environmental and public health risks.

Integrating ecopharmacology into medical curricula, strengthening continuing professional education, and establishing accessible medication take-back and disposal programs within healthcare institutions are imperative. A coordinated, multisectoral approach involving healthcare providers, regulatory authorities, and pharmaceutical stakeholders is essential to translate positive attitudes into sustainable practices. Enhancing ecopharmacological stewardship among healthcare professionals will be a critical step toward minimizing pharmaceutical environmental contamination and safeguarding both ecosystem and public health.

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