doi.org/10.36721/PJPS.2026.39.6.171.1

Challenges to antibiotic stewardship: A cross-sectional study on self-reuse and disposal practices of leftover antibiotics

Uroosa kanwal[1], Syed Shaukat Ali Muttaqi Shah[2], Saba Razzak[3], Muhammad Ali[4]*, Ale Zehra[5], Sana Ejaz[1], Sana Bibi[1], Raahim Ali[6], Shoaib Nawaz[7] and Sana Ali[8]

[1]Department of Pharmacy Practice, Faculty of Pharmacy, Salim Habib University, Karachi, Pakistan
[2]College of Pharmacy, Al-Farahidi University, Baghdad, Iraq
[3]Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Salim Habib University, Karachi, Pakistan
[4]Department of Pharmaceutics and Pharmacy Practice, Faculty of Pharmacy, Salim Habib University, Karachi, Pakistan
[5]Department of Pharmacy Practice, Faculty of Pharmaceutical Sciences, Dow College of Pharmacy, Dow University of Health Sciences, Karachi, Pakistan
[6]Baqai Institute of Pharmaceutical Sciences, Baqai Medical University, Karachi, Pakistan
[7]Department of Pharmacy, University of Lahore, Sargodha Campus, Pakistan
[8]Department of Pharmacy, Dow Hospital, Dow University of Health Sciences, Karachi, Pakistan

Abstract: **Background**: Antimicrobial resistance (AMR) is a growing global health threat, primarily driven by the inappropriate use of antibiotics and unsafe disposal practices. In developing countries like Pakistan, the misuse of leftover antibiotics through self-medication and improper disposal remains a poorly addressed public health concern. **Objectives**: This study aimed to describe the prevalence, patterns and associated factors of self-reuse and disposal practices of leftover antibiotics among residents of Karachi, Pakistan and to identify gaps affecting antibiotic stewardship. **Methods**: A descriptive, cross-sectional study was conducted using a validated online questionnaire targeting adults (≥18 years) residing in Karachi. A total of 385 responses were collected via non-probability sampling. The study was conducted from 10/02/2025 to 03/06/2025. Descriptive statistics and chi-square tests were applied using SPSS version 26 to evaluate associations between sociodemographic factors and antibiotic-related behaviours. **Results**: Approximately 24% of participants did not complete their prescribed antibiotic course, predominantly because of symptom resolution. Over half (56%) reported retaining leftover antibiotics and 43% admitted to reusing them without professional consultation, largely due to previous successful outcomes. A significant association was observed between educational level and perceptions of the safety of antibiotic reuse ($p < 0.001$). Disposal practices were suboptimal, with 70% discarding expired antibiotics in household trash and only 8% utilizing pharmacy take-back services. Counselling on proper disposal varied significantly by socioeconomic status (SES) ($p = 0.009$), with the highest rate reported among low SES participants (37.5%), but overall awareness of disposal programs remained low. **Conclusion**: The findings highlight concerning patterns in antibiotics storage, self-use and disposal practices in Karachi. These patterns suggest a need for public educational, pharmacist-led interventions and improved access to medication take-back programs to promote safer practices and reduce AMR risk.

Keywords: Antimicrobial stewardship; Cross-sectional studies; Drug resistance; Medication adherence; Microbial; Pharmaceutical; Self medication; Waste disposal

*Submitted on 26-12-2025 – Revised on 24-01-*2026 *– Accepted on 04-02-2026*

INTRODUCTION

Antimicrobial resistance (AMR) is considered one of the most significant global public health challenges, predominantly driven by the misuse and overuse of antibiotics (Khan *et al.*, 2022b; Tang *et al.*, 2023). One of the key contributors to AMR is the inappropriate handling of leftover antibiotics, such as self-reuse, sharing with others and unsafe disposal practices (Shahid *et al.*, 2024). When patients fail to complete their prescribed course of antibiotics, they often retain leftover medications, leading to self-medication without medical consultation, increasing the risk of antibiotic resistance and causing potential health consequences (Rather *et al.*, 2017). The growing global consumption of pharmaceutical products has led to a considerable increase in medication wastage. On the other hand, many studies indicate that a substantial amount of these medications eventually expire or remain unused. Factors such as poor patient adherence to prescribed regimens, resolution of medical conditions before treatment completion, alterations in therapy plans and the common practice of retail pharmacies selling whole medication packs instead of prescribed doses also contributes to medication wastage (Insani *et al.*, 2020; Vellinga *et al.*, 2014).

Improper disposal of antibiotics, such as discarding them in household waste, flushing them into sewage systems, or donating them to others, can lead to environmental contamination and further contribute to the AMR burden (Insani *et al.*, 2020). Despite global and national efforts to

**Corresponding author:* e-mail: Qazi.ali@shu.edu.pk

promote antimicrobial stewardship (AMS), gaps in public awareness and inadequate regulatory enforcement continue to hinder progress (Sitotaw and Philipos, 2023).

Numerous studies have investigated antibiotic misuse and self-medication practices worldwide. Research in developing countries, including Pakistan, highlights that easy over-the-counter (OTC) access, lack of awareness and financial constraints often drive individuals to reuse or share antibiotics (Anwar *et al.*, 2020; Nepal and Bhatta, 2018). A study in Khyber Pakhtunkhwa, Pakistan, found that only 20% of participants were aware of AMR, highlighting the need for public health policies, awareness campaigns and an enhanced role for community pharmacists to address this issue (Nazir and Azim, 2017). Furthermore, one study conducted in Hawassa City, Ethiopia, assessing the knowledge, attitudes and practices (KAP) regarding antibiotic use and disposal reported that despite 99.8% of participants having used antibiotics, 64% lacked proper knowledge, 60.4% held negative attitudes, 55% demonstrated poor practices, 29.4% obtained antibiotics without a prescription and 86.5% lacking antibiotic-related training (Sitotaw and Philipos, 2023).

Moreover, a survey-based study conducted on the Indian population revealed widespread inappropriate antibiotic use with 72.3% and 57.8% of participants using antibiotics for fever and common cold, respectively, with low course completion rates of 23% and 40%, improperly dispose of unused/expired antibiotics by around 75% of participants, while only 2–3% use safe methods, highlights the need for public awareness to combat AMR (Sharma *et al.*, 2021).

In addition, a study in Mwanza city, Tanzania, assessing the disposal practices of expired and unused medications at the household level reported that 70.19% had medications at home, with 96% keeping unused medications primarily due to incomplete treatment courses (82.2%) and common disposal practices included discarding medications in domestic trash (75.5%) and pit latrines (15.5%), underscoring the need for immediate tailored interventions (Marwa *et al.*, 2021).

The World Health Organization (WHO) has developed a guide on healthcare waste management, focusing on the disposal of unused and expired medicines (WHO, 2025). Programs like New Zealand's disposal of unwanted medication properly and Canada's ENVIRx have been introduced to ensure proper pharmaceutical disposal (Braund *et al.*, 2009; Rogowska and Zimmermann, 2022). However, many developing countries lack official guidelines and protocols for disposing of expired, unwanted and unused medications (Anwar *et al.*, 2020). Many developed countries have implemented drug take-back programs, with pharmacies playing a key role; however, some pharmacies have occasionally declined to accept expired medications (Wang *et al.*, 2024). While physicians in Pakistan are traditionally the primary source of antibiotic prescriptions and patient counseling, pharmacists represent a critical but often underutilized resource in the antibiotics stewardship chain. Due to their accessibility, direct involvement in medication dispensing, and regular interaction with consumers and handling of both prescription and OTC drugs, they are ideally positioned to complement physician advice by evaluating patients' reasons for returning medications and ensuring their safe disposal through take-back programs. These programs are vital for proper medication disposal and reducing environmental and health risks (Husain *et al.*, 2017).

While antibiotic misuse and disposal practices have been explored in other populations, there is limited evidence among residents of Karachi, Pakistan and unlike prior research on general medication disposal, this study specifically focuses on leftover antibiotics use, self-reuse behavior and stewardship as a key factor contributing to AMR (Ahmed and Mushtaq, 2013; Anwar *et al.*, 2020). This study also presents recent post-pandemic data from Karachi, providing current insights into stewardship initiatives (Filimonovic *et al.*, 2024).

Moreover, few studies have examined the role of pharmacists in guiding safe disposal practices and promoting take-back programs (Garau and Bassetti, 2018). By focusing on the unique contribution of pharmacists educating the public about the importance of drug take-back programs and proposing strategies for their implementation in Pakistan, this study provides valuable data to inform public health policies and support awareness campaigns aimed at promoting the safe disposal of medications (Essilini *et al.*, 2021).

MATERIALS AND METHODS

Study design

The current study is a cross-sectional online survey-based study exploring the challenges to antibiotic stewardship, leftover antibiotics, self-reuse and disposal practices among residents of Karachi, Pakistan (Aldhuwayhi *et al.*, 2021; Lin *et al.*, 2020). The research flow chart is presented in the supplementary fig. S1.

Study sample and size

A non-probability convenience sampling method was employed due to feasibility and access constraints. The sample size of 385 was estimated using the WHO sample size calculator for population surveys, assuming a 50% prevalence of leftover antibiotics practices (to maximize sample size), a 95% confidence interval and a 5% margin of error (Lwanga and Lemeshow, 1991).

Study duration

Following approval from the Institutional Review Committee (IRC), the data collection was conducted from 10/02/2025 to 03/06/2025.

Recruitment and informed consent

The participants were recruited through non-probability convenience sampling using online platforms, including social media (Facebook, WhatsApp, Instagram, Viber), email distribution list and professional networks of the research team. The survey was hosted on Google Forms and settings were configured to allow only one response per email address to prevent duplicate submissions. All participants had to provide written informed consent before filling out the specified Google form. This multiple recruitment strategy, conducted across various platforms was used to reduce selection bias.

Study tool validation

An evidence-based online questionnaire was developed after an extensive literature review to assess the challenges to antibiotic stewardship, leftover antibiotics, self-reuse and disposal practices. The questionnaire's variables were also compared to previously reported studies and discussed by a focus group of clinical researchers, epidemiologists and other medical practitioners. Content validity was established through review by a panel of three clinical researchers, one epidemiologist and two pharmacists.

The final online questionnaire was tested for content validity using a pilot study on 20 participants and a focus group discussion to identify any missing variables or clinical scenarios related to this topic. The Cronbach's alpha test was performed to ensure reliability, yielding a value of 0.7 for the awareness and practice sections, indicating acceptable reliability (Bujang *et al.*, 2018). Measurement bias was mitigated through the use of questionnaire validation, expert review, pilot testing and assessment of internal consistency (Cronbach's $\alpha = 0.7$). Following validation, the final version of the questionnaire was used throughout the study. The final questionnaire is provided in the supplementary questionnaire S1.

Study variables and operational definitions

The primary outcomes of this study were: "Leftover antibiotics, defined as unused antibiotics remaining after a prescribed course. Measured as a binary variable (Yes/No); "Self-reuse of antibiotics", defined as the use of leftover antibiotics without medical consultation. Measured as a binary variable (Yes/No); 'Disposal practices' categorized as safe (e.g., pharmacy return) or unsafe (e.g., trash, flushing, donation, keeping for future use); "Awareness of safe disposal" assessed through (A) knowledge of reusing antibiotics without prescription (Yes/No/Don't know) (B) receipt of disposal counseling from a pharmacist (Yes/No/Don't know); "Perceptions of reuse safety", belief regarding the safety of reusing antibiotics through a prescription (Yes/No/Don't know). Furthermore, sociodemographic variables included age, gender, educational level, employment status, and marital status. Socioeconomic status (SES) was derived from a composite of educational level and occupational status. SES categories were assigned as: low SES (low educational with non-medical occupation); middle SES (middle educational, or low educational with medical employment); high SES (high educational, or middle educational with medical employment), aligning with the classification of SES in urban Pakistani medication practice studies (Noreen *et al.*, 2023; Wahid *et al.*, 2022).

Ethical considerations

Data confidentiality and its compliance with the Declaration of Helsinki were ensured by the IRC (Ali *et al.*, 2019, Ashcroft, 2008, Holm, 2019). The study adhered to ethical principles, ensured voluntary participation, informed consent and confidentiality of all participants. Written informed consent was obtained from all the participants of the study and the study did not include any minors. No personal identifiers were collected and participants had the right to withdraw at any time without repercussions. The collected data is solely to be used for research purposes, with strict measures in place to protect anonymity and data security.

Inclusion criteria

Adults (≥18 years) residing in Karachi, who reported the use of antibiotics in the past and were willing to complete an online questionnaire regarding their practices related to leftover antibiotics, self-reuse and disposal, were included. Both males and females were eligible to participate.

Exclusion criteria

Individuals under 18 years of age, those who had never used antibiotics and those who declined to participate or provide informed consent were excluded from the study.

Assessment of bias

In order to minimize bias, the study employed a validated questionnaire and rigorous methodology. The tool/questionnaire used in the study was developed and validated through expert focus groups, face and content validation and a Cronbach's alpha test. The Sample size was calculated using the WHO sample size calculator. Random sampling technique was employed. Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS), with $p<0.05$ considered significant. Data collection and analysis were blinded to minimize observer bias. There was no selection bias, measurement bias, or confirmation bias. All these measures ensured the study's robustness and minimized bias.

Statistical analysis

Descriptive statistics were used to summarize sociodemographic and behavioural variables. All completed questionnaires were reviewed for completeness; responses with more than 20% missing data in primary outcome variables were excluded from the analysis (n=5).

Table 1: Socio-demographic profile of participants enrolled in the study.

Variables	n (%)
Age (years)	
18-27	288 (74.80)
28-37	82 (21.29)
38-47	14 (3.63)
48-57	1 (0.25)
Gender	
Male	117 (30.38)
Female	266 (69.09)
Prefer not to say	2 (0.5)
Educational status	
No formal education	2 (0.5)
Primary education (1-5 classes)	1 (0.25)
Secondary education (6-10 classes)	6 (1.55)
Higher Secondary Education (11th and 12th)	24 (6.23)
Undergraduate	190 (49.35)
Bachelor's degree	82 (21.29)
Master's degree	58 (15.06)
Doctorate	22 (5.7)
Marital status	
Single	299 (77.66)
Divorced	8 (2.07)
Widow	1 (0.25)
Married (No kids)	28 (7.27)
Married (with kids)	47 (12.2)
Extended family	2 (0.5)
Employment status	
Student	222 (57.66)
Employed (medical-related)	93 (24.15)
Employed (Non-medical related)	43 (11.16)
Unemployed	24 (6.23)
Retired	3 (0.77)
Socioeconomic (SES) status	
Low SES	32 (8.3)
Middle SES	233 (60.5)
High SES	120 (31.2)

For variables with minimal missing responses (<5%), missing values were handled using pairwise deletion in chi-square analysis. Associations between categorical variables were examined using Pearson's chi-square test, with Fisher's exact test applied where expected cell counts were below 5 (Das *et al.*, 2022; Turhan, 2020). All the parameters were correlated and the data were transcribed on SPSS version 26 software for analysis.

RESULTS

Demographic characteristics of study participants

A total of 385 participants were included in the study, with the majority (n = 288; 74.8%) aged between 18 and 27 years. The gender distribution revealed that the sample predominantly comprised females (n = 266; 69%). In terms of educational attainment, undergraduate students comprised the largest group (n = 190; 49.35%), followed by participants holding a bachelor's degree (n = 82; 21.29%), a master's degree (n = 58; 15%) and a doctorate (n = 22; 5.7%). Furthermore, a small proportion of participants reported having no formal education (n = 2; 0.5%) and only primary education (n = 1; 0.3%). Regarding marital status, 299 participants (77.6%) were single. Additionally, the employment status revealed that 222 participants (57.66%) were students, 93 (24%) were employed in medical-related fields and 43 (11%) were working in non-medical fields. Moreover, 24 (6%) were unemployed and 3 (0.8%) were retired. Regarding SES, the majority of participants were from middle SES (n=233; 60.5%), followed by high SES (n=120; 31.2%) and low SES (n=32; 8.3%), as detailed in table 1.

Patterns and associations in antibiotic use and leftover medications

As shown in table 2, out of 385 participants, 292 (76%) reported completing the full prescribed course of antibiotics, whereas 93 (24%) did not. Among those who discontinued treatment, the most commonly cited reasons

were symptom resolution before completing the course (n = 60; 64.5%), forgetting to take doses (n = 24; 26%) and experiencing side effects (n = 5; 5.4%). Unresolved symptoms and medication cost concerns were reported by 2 participants each (2.2%). A statistically significant association was identified between incomplete antibiotic course completion and the underlying reasons for discontinuation ($p < 0.001$) (Fig. 1).

In addition, 216 (56%) participants reported having leftover or unused antibiotics, while 169 (44%) did not, as presented in table 2. The most frequently reported reason was symptom improvement before completing therapy (n = 91; 42%), followed by purchasing a greater quantity than the prescribed amount (n = 49; 23%), forgetting doses (n = 30; 14%), physician-advised discontinuation (n = 22; 10%), switching to an alternative antibiotic (n = 17; 8%) and experiencing side effects (n = 7; 3%). A significant association was found between the presence of leftover antibiotics and the reasons for their use ($p < 0.001$).

Moreover, table 2 highlights that 167 (43%) acknowledged using leftover antibiotics without consulting a healthcare professional. The leading reason was prior successful treatment with the same antibiotic (n = 104; 62%), followed by not considering medical consultation necessary (n = 25; 15%), saving time (n = 19; 11%), cost-saving concerns (n = 12; 7%) and relying on recommendations from family or friends (n = 7; 4%). Conversely, 185 (48%) participants stated they had never engaged in self-medication with leftover antibiotics, while 33 (8.5%) were uncertain about their past practices. A statistically significant association was found between the reuse of antibiotics without consultation and the reasons for such behavior ($p < 0.001$), indicating that previous treatment success and perceived lack of need for consultation were primary drivers of inappropriate antibiotic reuse (Fig. 2).

Impact of sociodemographic factors on inappropriate antibiotic use

As illustrated in table 3, a statistically significant association was observed between the level of education and the belief that it is safe to reuse antibiotics without a prescription if they had previously helped with similar symptoms ($p < 0.001$). Participants with higher educational attainment, undergraduate (n = 132; 69%), graduate (n = 60; 73%), master's (n = 36; 62%) and doctorate (n = 16; 73%), predominantly believed that self-medication was unsafe. In contrast, those with lower or no education showed greater uncertainty or misconceptions, with n=5 (55.6%) believing that reuse was safe and n=4 (44.4%) responding "don't know." Participants with higher secondary education were more evenly distributed across categories: safe (n = 6; 25.0%), unsafe (n = 8; 33.3%) and don't know (n = 10; 41.7%) (Fig. 3).

In contrast to the significant association observed with educational level, no statistically significant relationship was found between employment status and the practice of sharing leftover antibiotics ($p = 0.412$), as demonstrated in table 3. Across all employment groups, the majority of participants denied sharing antibiotics, including students (n = 132; 59%), those employed in medical-related fields (n = 64; 69%) and those working in non-medical professions (n = 23; 53%). A similar pattern was observed among unemployed participants (n = 15; 62.5%). Among retired individuals (n=3), two reported sharing antibiotics and one denied it. These findings suggest that while antibiotic sharing is generally uncommon, it may still occur across all employment sectors.

In addition to this, participants across all educational levels expressed varied perceptions regarding the reuse of leftover antibiotics. As outlined in table 3, the most frequently cited reasons were "treat symptoms early" and "complicate the disease," particularly among undergraduates (n = 43; 22.6% and n = 49; 25.8%, respectively) and bachelor's degree holders (n = 19; 23.2% and n = 18; 22%, respectively). Participants with higher secondary education most commonly endorsed early symptom management (n = 10; 41.7%), whereas those with a master's degree predominantly associated reuse with disease complications (n = 18; 31%). A considerable proportion expressed uncertainty, especially among undergraduates (n = 51; 26.8%) and bachelor's degree holders (n = 25; 30%). Although responses were fewer among those with lower educational levels, they still reflected diverse beliefs. No statistically significant association was observed between educational level and perceived reasons for reuse ($p = 0.468$).

Association between educational level and disposal practice of leftover and expired antibiotics

The association between the disposal practices of leftover antibiotics and educational level is reported in table 4. The most prevalent practice across all educational levels was keeping antibiotics for future use, with a notable proportion of participants in higher educational groups reporting this behavior. Specifically, undergraduates (n = 73; 38.4%), bachelor's (n = 30; 36.6%), master's (n = 27; 46.6%) and doctoral degree holders (n = 8; 36.4%) reported this practice. This practice was less common among participants with lower educational attainment. The second most common practice was discarding antibiotics in the trash, reported by undergraduates (n = 53; 27.9%), bachelor's (n = 24; 29.3%) and master's degree holders (n = 17; 29.3%). A smaller proportion of participants, including undergraduates (n = 16; 8.4%) and bachelor's degree holders (n = 13; 15.9%), opted to return antibiotics to pharmacies or participate in take-back programs. Additionally, a few participants from lower educational levels reported donating leftover antibiotics to others.

Table 2: Factors affecting antibiotic adherence and reasons for retaining and using leftover antibiotics without medical consultation (n=385)

Variables	Category	n (%)	p-value
Completed full antibiotic course	Yes	292 (76.0)	
	No	93 (24.0)	
Reasons for not completing the course *(n = 93)*	Symptoms resolved	60 (64.5)	<0.001
	Forgot doses	24 (25.8)	
	Side effects	5 (5.4)	
	Symptoms not resolved	2 (2.2)	
	Medication cost	2 (2.2)	
Leftover/unused antibiotics at home	Yes	216 (56.1)	
	No	169 (43.9)	
Reasons for having leftover antibiotics *(n = 216)*	Symptoms improved early	91 (42.1)	<0.001
	Purchased more than prescribed	49 (22.7)	
	Forgot doses	30 (13.9)	
	Doctor advised stop	22 (10.2)	
	Antibiotic switched	17 (7.9)	
	Side effects	7 (3.2)	
Self-reuse of leftover antibiotics	Yes	167 (43.4)	
	No	185 (48.1)	
	Unsure	33 (8.5)	
Reasons for self-reuse *(n = 167)*	Previous successful use	104 (62.3)	<0.001
	Did not think consultation needed	25 (15.0)	
	Save time	19 (11.4)	
	Save money	12 (7.2)	
	Advised by family/friends	7 (4.1)	

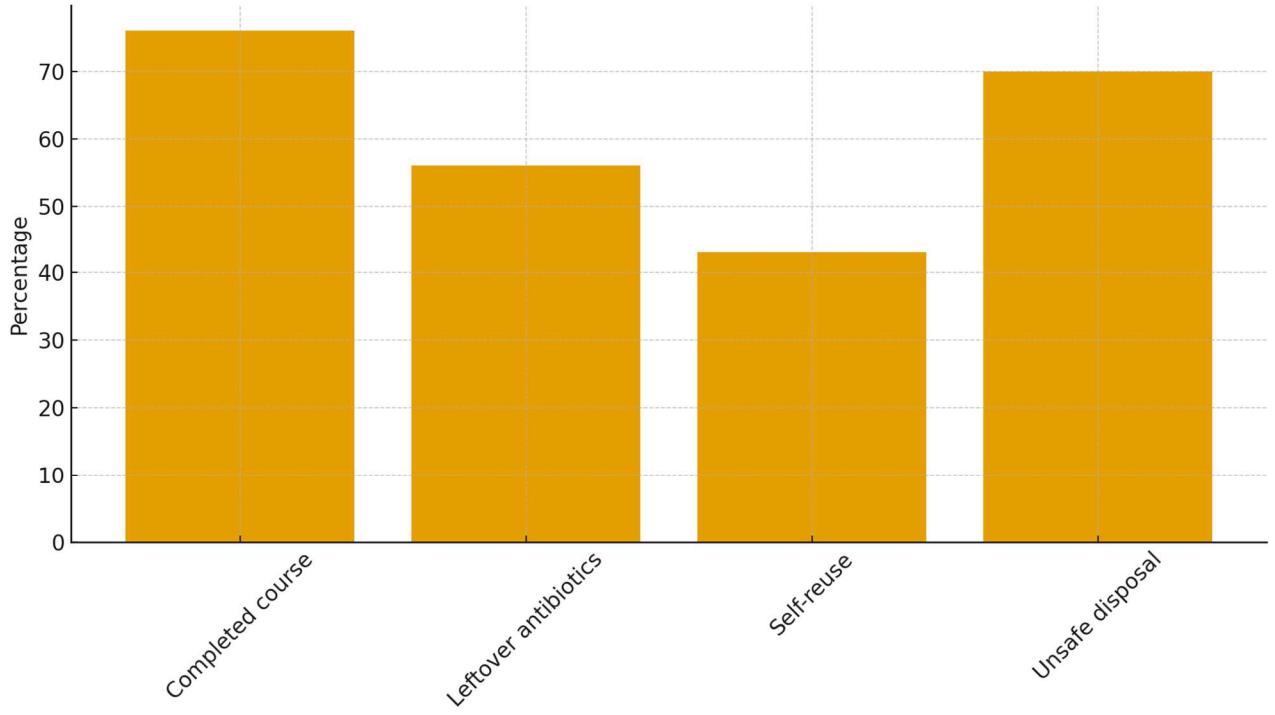

Fig. 1: Key antibiotic-related behaviours (%)

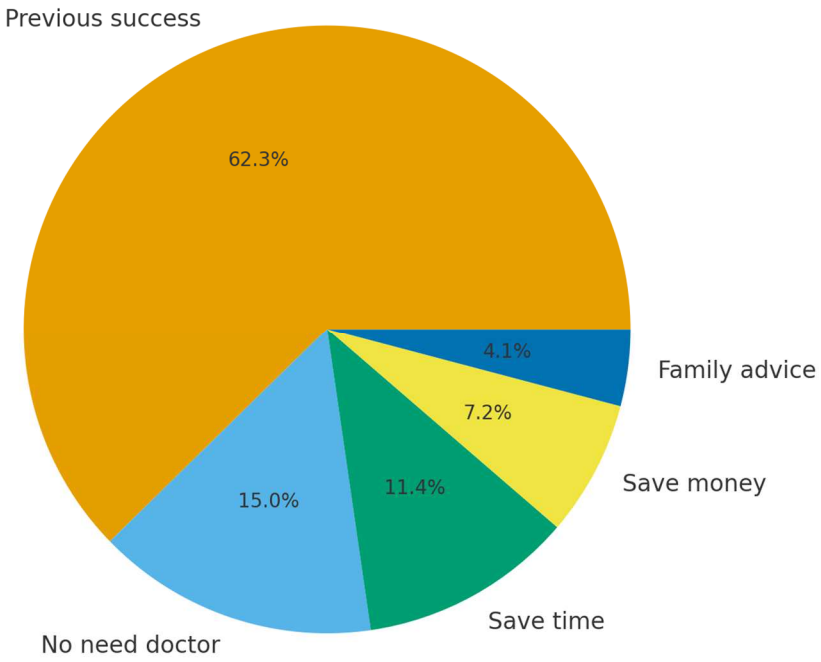

Fig. 2: Reasons for self-reuse

Table 3: Association of educational and employment status with beliefs, practices and perceived reasons for reusing leftover antibiotics

Belief that reusing antibiotics without a prescription is safe				
Educational level	Safe n (%)	Unsafe n (%)	Don't know n (%)	p-value
Lower or no education	5(55.6)	0 (0.0)	4(44.4)	
Higher secondary education (11th and 12th)	6 (25.0)	8 (33.3)	10 (41.7)	
Undergraduate	37 (19.5)	132 (69.5)	21 (11.0)	<0.001
Bachelor's degree	14 (17.1)	60 (73.2)	8 (9.8)	
Master's degree	16 (27.6)	36 (62.1)	6 (10.3)	
Doctorate	5 (22.7)	16 (72.1)	1 (4.5)	
Shared leftover antibiotics to family/friend/relative for a similar illness				
Employment status	Yes n (%)	No n (%)	Don't remember n (%)	
Student	71 (32.0)	132 (59.5)	19 (8.6%)	
Employed (medical-related)	22 (23.7)	64 (68.8)	7 (7.5)	0.412
Employed (non-medical related)	16 (37.2)	23 (53.5)	4 (9.3)	
Unemployed	5 (20.8)	15 (62.5)	4 (16.7)	
Retired	2 (66.7)	1 (33.3)	0 (0.0)	
Reason for the reuse of leftover antibiotics				
Educational level	Save time n (%)	Save money n (%)	Treat symptoms early n (%)	Complicate disease n (%)	Don't know n (%)	
Lower or no education	1 (11.1)	3 (33.3)	3 (33.3)	1 (11.1)	1 (11.1)	
Higher secondary education (11th and 12th)	1 (4.2)	3 (12.5)	10 (41.7)	2 (8.3)	8 (33.3)	
Undergraduate	18 (9.5)	29 (15.3)	43 (22.6)	49 (25.8)	51 (26.8)	0.468
Bachelor's degree	7 (8.5)	13 (15.9)	19 (23.2)	18 (22.0)	25 (30.5)	
Master's degree	5 (8.6)	7 (12.1)	15 (25.9)	18 (31.0)	13 (22.4)	
Doctorate	3 (13.6)	4 (18.2)	6 (27.3)	6 (27.3)	3 (13.6)	

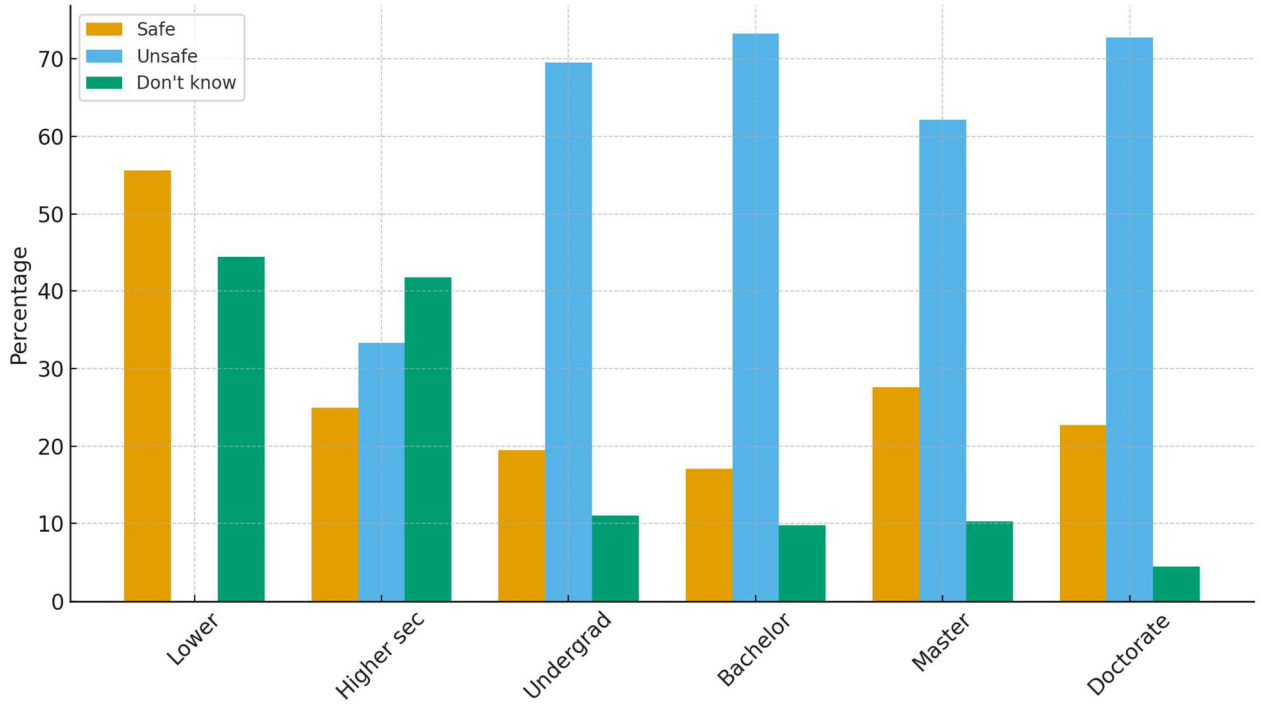

Fig. 3: Belief about antibiotic reuse by educational level.

Table 4: Association between educational level and disposal practices of leftover and expired antibiotics

Educational status	Keep them for future use. n (%)	Dispose of in the trash n (%)	Flush down toilet n (%)	Return to the pharmacy n (%)	Don't dispose n (%)	Donate to others n (%)	p-value
Disposal practices of leftover antibiotics							
Lower or no education	1 (11.1)	2 (22.2)	0 (0.0)	2 (22.2)	2 (22.2)	2 (22.2)	
Higher secondary education (11th and 12th)	5 (20.8)	12 (50.0)	0 (0.0)	3 (12.5)	3 (12.5)	1 (4.2)	
Undergraduate	73 (38.4)	53 (27.9)	14 (7.4)	16 (8.4)	30 (15.8)	4 (2.1)	0.693
Bachelor's degree	30 (36.6)	24 (29.3)	6 (7.3)	13 (15.9)	4 (4.9)	5 (6.1)	
Master's degree	27 (46.6)	17 (29.3)	2 (3.4)	7 (12.2)	3 (5.2)	2 (3.4)	
Doctorate	8 (36.4)	6 (27.3)	1 (4.5)	2 (9.1)	3 (13.6)	2 (9.1)	
Disposal practices of expired antibiotics							
Lower or no education	0 (0.0)	6 (66.7)	0 (0.0)	0 (0.0)	3 (33.3)	0 (0.0)	
Higher secondary education (11th and 12th)	0 (0.0)	22 (91.7)	0 (0.0)	0 (0.0)	1 (4.2)	1 (4.2)	
Undergraduate	11 (5.8)	134 (70.5)	20 (10.5)	9 (4.7)	11 (5.8)	5 (2.6)	0.001
Bachelor's degree	3 (3.7)	55 (67.1)	16 (19.5)	6 (7.3)	2 (2.4)	0 (0.0)	
Master's degree	2 (3.4)	45 (77.6)	6 (10.3)	3 (5.2)	2 (3.4)	0 (0.0)	
Doctorate	1 (4.5)	19 (86.4)	1 (4.5)	1 (4.5)	0 (0.0)	0 (0.0)	

Table 5: Impact of socioeconomic status on counseling received for antibiotic disposal and knowledge of pharmacy-based take-back initiatives

Category / Educational level	Yes n (%)	No n (%)	Don't know n (%)	p-value
Received counseling on the disposal of antibiotics from a pharmacist				
Low SES	12 (37.5)	15 (46.9)	5 (15.6)	0.009
Middle SES	50 (21.5)	172 (73.8)	11 (4.7)	
High SES	28 (23.3)	88 (73.3)	4 (3.3)	
Awareness of the pharmacies' take-back programs for leftover/expired antibiotics				
Lower or no education	3 (33.3)	3 (33.3)	3 (33.3)	0.098
Higher secondary education (11th and 12th)	7 (29.2)	11 (45.8)	6 (25.0)	
Undergraduate	60 (31.6)	110 (57.9)	20 (10.5)	
Bachelor's degree	28 (34.1)	48 (58.5)	6 (7.3)	
Master's degree	14 (24.1)	36 (62.1)	8 (13.8)	
Doctorate	7 (31.8)	12 (54.5)	3 (13.6)	

SES = Socioeconomic status. Data are n (%). P-value is from chi-square test comparing response distribution across SES groups; $p < 0.05$ indicates a statistically significant association. Percentages may not total 100% due to rounding.

No significant association was observed between educational level and disposal method ($p = 0.693$).

The data further indicate a statistically significant association between educational level and the disposal practices for expired antibiotics ($p = 0.001$). As summarized in table 4, the most common method of disposal across all educational groups was discarding expired antibiotics in the trash, with the highest frequency among participants with undergraduate (n = 134; 70.5%), followed by those with bachelor's (n = 55; 67.1%), master's (n = 45; 77.6%) and doctorate degrees (n = 19; 86.4%). A substantial number of participants with higher educational levels also reported flushing antibiotics down the toilet, particularly undergraduates (n = 20; 10.5%), bachelor's (n = 16; 19.5%) and master's degree holders (n = 6; 10.3%). Notably, keeping expired antibiotics for future use was reported by a small number of undergraduates (n = 11; 5.8%) and a few participants across higher educational groups, indicating unsafe storage practices. A concerning trend was observed among participants who did not dispose of expired antibiotics, especially among the undergraduate students (n = 11; 5.8%), suggesting a gap in awareness regarding appropriate disposal. Very few respondents of higher studies returned antibiotics to pharmacies or participated in take-back programs. These findings reflect varying degrees of awareness and disposal behavior, highlighting the need for targeted educational interventions to promote safe and responsible antibiotic disposal practices.

Knowledge, counselling and practices related to antibiotic disposal across sociodemographic groups

The counseling provided to participants regarding the disposal of antibiotics varied significantly by SES (p = 0.009). Participants from low SES backgrounds reported the highest rate of receiving counseling (n = 12; 37.5%), followed by high SES (n = 28; 23.3%) and middle SES (n = 50; 21.5%). However, the majority of participants across all SES groups reported not receiving counseling, with middle SES (n = 172; 73.8%) and high SES (n = 88; 73.3%) participants most likely to report no counseling. These findings highlight socioeconomic disparities in pharmaceutical education regarding safe antibiotic disposal (Table 5).

As shown in table 5, a substantial proportion of participants across all educational levels were unaware of pharmacy take-back programs for the disposal of leftover or expired antibiotics ($p = 0.098$). The highest levels of unawareness were observed among undergraduates (n = 110; 57.9%), followed by bachelor's degree holders (n = 48; 58.5%) and master's degree holders (n = 36; 62.1%). These findings indicate a considerable lack of awareness of formal disposal mechanisms, underscoring the need for targeted educational interventions and proactive counselling by pharmacy professionals to promote responsible antibiotic disposal practices.

DISCUSSION

This study describes self-reuse and disposal practices for leftover antibiotics among a predominantly young, educated sample from Karachi (Table 1). The findings highlight challenges in antibiotic stewardship and show patterns consistent with and in some cases differing from, regional and global studies. While there have been several studies in the past from Pakistan exploring antibiotic misuse and disposal, this study offers several novel contributions. First, it examines both self-reuse and disposal practices within the same population, which has not been addressed in previous studies (Afridi *et al.*, 2015; Ahmed and Mushtaq, 2013; Husain *et al.*, 2017). Second, unlike previous studies on the general disposal of medication, this study specifically target leftover antibiotics stewardship as a factor of AMR. Third, a validated questionnaire (see supplementary questionnaire S1) used in this study captures behaviors like previous treatment success and safety perception, which have not been assessed previously. Finally, this study presents

recent, post-pandemic data from Karachi that provide current insights into stewardship initiatives.

Reasons for leftover antibiotics

In this study, the majority (76%) of participants completed their full course of prescribed antibiotics, but a significant percentage (24%) of participants did not complete their prescribed antibiotic course and the primary reason for this was symptom resolution before finishing the medication (Table 2). Over half (56%) of the participants reported having leftover antibiotics, which aligns with the findings of a global survey (Kardas *et al.*, 2007). The most common reason for keeping the antibiotics at home was improvement in the symptoms before completing the course (42%) (Table 2). These results are consistent with a study conducted in Pakistan, which documented 56.1% households reported leftover antibiotics (Khan *et al.*, 2022a). However, finds of this study revealed that this storage is mostly for intentional future self-reuse rather than accumulation. A study in China found that almost half of the participants were keeping antibiotics at home and the majority of them were leftovers originating from previous prescriptions (Sun *et al.*, 2019). In a study in the US, 45% of the respondents stopped their treatment early (Shah *et al.*, 2024). The other reason identified for leftover antibiotics was purchasing more than prescribed medications (22.7%) (Table 2), which aligns with findings of other studies (Kardas *et al.*, 2007). “Saving for later use” was also a frequently cited reason for leftover medicines (Asmamaw *et al.*, 2023), which was not assessed in this study.

Leftover rates of antibiotics were lower (20-30%) in studies from Ireland (Vellinga *et al.*, 2014) and the U.S. (Glassmeyer *et al.*, 2009), mainly due to better public awareness and availability of medication "take-back" programs. The higher prevalence of leftover medication in Karachi points out the gaps in healthcare access and education. Interventions such as dispensing antibiotics corresponding to the duration of the treatment and raising awareness among patients on completing the antibiotic treatment can reduce the magnitude of the problem (Kardas *et al.*, 2007). The precision of observed estimates for leftover antibiotics (56.1%, 95% CI: 51.0–61.1%) in this study suggest this is a stable and prevalent issue in Karachi’s studied population.

Self-medication of leftover antibiotics

In this study, 43.4% (95% CI: 38.4–48.5%) of participants reported self-medication with leftover antibiotics without consulting a physician (Table 2). Similar rates of self-medication (45%) were reported in a previous study from Pakistan (Nazir and Azim, 2017) and a slightly higher rate (60%) was observed in India (Sharma *et al.*, 2021). A considerably low prevalence of self-medication (30%) was observed in Sri Lanka (Nepal and Bhatta, 2018), mostly due to stringent regulations. In this study, the main reason for self-medication was successful treatment with a certain antibiotic in the past, accounting for (62.3%) (Table 2), which was far higher than the percentage observed (21%) in the study conducted in Egypt (Zeid *et al.*, 2020). The prevalence of self-medication aligns with a study conducted in Karachi, reporting 41% as the self-medication rate for general medications (Afridi *et al.*, 2015).

A study from the USA found that individuals having proper knowledge of antibiotics mostly completed the treatment, but they had a higher chance of self-medicating and storing the remaining antibiotics for future use (Vanden Eng *et al.*, 2003). This highlights the complexity of self-medication and leftover antibiotics. These findings suggest that perceptions and prior experiences may influence self-medication with antibiotics, a behavior that could contribute to antibiotic resistance (Ali and Khan, 2015). Interventions focusing on educating the public about the risk of self-medication and the dangers of antibiotic resistance (Rather *et al.*, 2017, Rodrigues, 2020), along with interventions to discourage the storage of leftover antibiotics and promote patient adherence to complete the prescribed antibiotics course, can also be helpful (Kardas *et al.*, 2007).

Education and beliefs about antibiotic reuse

An association between educational level and the perception of safety was found of reusing antibiotics without a doctor’s consultation; more than 69.5% (95% CI: 62.4–75.9%) of undergraduates and 73.2% (95% CI: 62.2–82.4%) of bachelor’s degree holders believed it is unsafe to self-medicate (Table 3). In a study from Turkey, it was evident that highly educated people are more likely to recognize the danger of self-medication with antibiotics (Okyay and Erdoğan, 2017), while people who have lower levels of education are more likely to believe that it is safe to self-medicate (Dhedhi *et al.*, 2021). A study conducted in Ethiopia found similar trends, with illiterate individuals three times more likely to misuse antibiotics (Sitotaw and Philipos, 2023). On the contrary, studies conducted in the European region show a minimum level of education-based disparities in these trends (Vellinga *et al.*, 2014). These findings emphasize the importance of education in promoting responsible antibiotic use. There is a need for targeted interventions to address misconceptions (Marwa *et al.*, 2021) and knowledge gaps, especially among individuals with lower levels of education.

Perception about the reuse of leftover antibiotics

It appears that a common reason (22-23%) for reusing antibiotics is to "treat symptoms early" However, there's also an awareness, particularly among the masters and bachelor’s degree group and that reuse of leftover antibiotics can "complicate the disease" (23-31%), while there was a lack of clear understanding about the risks and benefits of reusing antibiotics in graduate and undergraduate students (Table 3). A survey in the US reported 51% of participants showed the intention for future use of leftover antibiotics; another study showed that

people with proper knowledge of antibiotics self-medicate and keep leftover antibiotics (Shah *et al.*, 2024; Zaidi *et al.*, 2021). These perceptions may influence behavior, underscoring the potential value of public health messaging regarding safe use of antibiotics (Kardas *et al.*, 2007).

Antibiotic disposal practices

The most common disposal method was keeping medication for future use, as also observed in other studies (Kardas *et al.*, 2007). The second most common method for antibiotic disposal was disposal in the trash, 70.5% (95% CI: 63.5–76.9%), with no major difference across educational levels (Table 4). This high prevalence rate of disposal of antibiotics in the trash is consistent with the patterns observed in Karachi and Quetta, suggesting it as a national issue (Ahmed and Mushtaq, 2013; Hussain and Ibrahim, 2011; Shoaib *et al.*, 2022). In a study conducted in India (60%) majority of the participants mentioned disposing of the antibiotics in the trash (Patil and Agarwal, 2019; Sharma *et al.*, 2021), while in Indonesia, this percentage was observed to be (65%) (Insani *et al.*, 2020). Other antibiotic disposal practices were flushing them (10%) and returning to the pharmacy (8%) (Table 4). A far higher percentage (40%) was observed in the U.S., utilizing take-back programs for return of antibiotics (Glassmeyer *et al.*, 2009); overall, improper disposal practices in Pakistan align with studies from India (Sharma *et al.*, 2021). A study in India revealed 60% of the population is unaware of disposal practices and discards them in the trash (Patil and Agarwal, 2019). Unsafe disposal of antibiotics with the domestic trash may contribute to environmental contamination and potentially exacerbate AMR risks, as suggested by studies in similar settings (D *et al.*, 2020; Marwa *et al.*, 2021).

Several strategies can be implemented to improve disposal practices, such as promotion and expanding access to the drug take-back programs (Marwa *et al.*, 2021); education of the general public about the health and environmental risks linked to unsafe drug disposal (D *et al.*, 2020); and providing clear guidelines for the appropriate and safe disposal of drugs at home (Ruhoy and Daughton, 2008). Despite emphasis on AMR, the gap in awareness related to the disposal of antibiotics persists in the country (Shamim, 2018). The findings of this study reveals socioeconomic disparities in counseling on antibiotic disposal, with low SES participants reporting a higher rate of counseling, a finding that warrants further investigation into the factors driving these differences. It is also very important to address the misconceptions about antibiotic use and AMR, as this can influence disposal practices (Chalkidou *et al.*, 2023), which makes it a behavioral issue, because of convenience, cost and cultural beliefs. Therefore, a comprehensive approach of health behaviors, like the health belief model, could help design interventions needed to address the underlying reasons for these behaviors, like convenience, cost and cultural beliefs (Anwar *et al.*, 2020).

Proper disposal of drugs

In this study, a significant gap in awareness of pharmacy take-back programs was observed regarding leftover/expired antibiotics across all educational levels; more than half of undergraduates (57.9%; 95% CI: 50.5–65.0%) were unaware of these programs (Table 5). Pharmacy take-back programs are a safe way to dispose of unused medications (Lystlund *et al.*, 2014). In this study, counseling on antibiotic disposal varied by SES, with low SES participants reporting the highest rate of receiving counseling (37.5%). This finding contrasts with typical patterns where higher SES groups often report better access to healthcare information. The higher counseling rate in the low SES group may reflect targeted public health interventions in underserved communities or different patterns of pharmacist-patient interactions (de Souza *et al.*, 2022). However, the majority across all SES groups still reported no counseling, indicating systemic gaps in pharmaceutical education. Similar low awareness rates (50–60%) were reported in Ethiopia (Sitotaw and Philipos, 2023) and Nigeria, where the unavailability of infrastructure is a challenge to the proper disposal of drugs. This lack of awareness points to a need for enhancing knowledge of people for the proper disposal of drugs. Pharmacist counseling related to take-back programs (Lystlund *et al.*, 2014) and proper disposal of drugs (Athern *et al.*, 2016) along with a public awareness campaign, can significantly reduce the unsafe disposal of drugs and reduce the risk of environmental contamination and spread antibiotic resistance (Anwar *et al.*, 2020; Lystlund *et al.*, 2014; Paut Kusturica *et al.*, 2017). There is a need for multi-faceted intervention providing knowledge of safe disposal of drugs, along with educational and practical solutions like accessible take-back programs and drug disposal bins (Calise *et al.*, 2022; Zaidi *et al.*, 2021).

The finding that low SES participants reported the highest rate of pharmacist counseling on antibiotic disposal (37.5%) is noteworthy. This could reflect increased interaction with healthcare systems due to higher disease burden in lower socioeconomic groups, targeted public health interventions in underserved communities, or differences in communication patterns between healthcare providers and patients (Evans *et al.*, 2023; Schoen *et al.*, 2025). However, it is important to note that despite higher counseling rates, this group also had the highest proportion of 'Don't Know' responses (15.6%), suggesting variability in the quality or retention of counseling information. Future qualitative research could explore these socioeconomic patterns in pharmacist-patient interactions regarding antibiotic stewardship.

Implications for policy and practice

The patterns of antibiotic misuse and improper disposal identified in this study warrant a coordinated, multi-stakeholder response, in addition to changes in individual behavior. The high prevalence of self-reuse (43.4%) and

unsafe disposal (70% discarding medications in trash) highlights a systemic gap requiring engagement from government agencies, healthcare institutions, the pharmaceutical sector and community organizations. First, the regulatory agencies, such as the Drug Regulatory Authority of Pakistan (DRAP) should enforce 'prescription-only' dispensing of antibiotics as recommended in Pakistan's National Action Plan on AMR (Ministry of National Health Services, 2017). Second, health care professionals, particularly physicians and pharmacist must ensure patient counseling on antibiotic adherence and safe disposal at the time of discharge, addressing the knowledge-practice gap where 56.1% patients store leftover medications despite being aware of the risks (Atif *et al.*, 2021). Third, pharmaceutical manufacturers should promote and introduce patient-centered packaging (e.g., exact course of therapy) to reduce 22.7% of leftovers resulting from the purchase of extra pills and also to include clear disposal instructions on the label of the drugs. Fourth, community pharmacies (only 8.4% utilized as disposal sites) should be formally integrated into take-back networks and should be trained for safe handling (Husain *et al.*, 2017). Finally, public health authorities should launch awareness campaigns using media, social media and community outreach to reinforce safe practices and address the gap in counseling. Such an integrated approach that aligns policy, practice and public education is essential to address the behavioral factors of AMR identified in this study.

Strengths of the study

This study provides insights into critical public health issues. The strengths included a focus on a large, understudied urban population in a developing country and novel data on antibiotic misuse and improper disposal, which directly impact stewardship efforts. Furthermore, the use of a validated questionnaire and strong statistical analysis enhances the reliability of associations, especially between educational attainment and antibiotic-related perceptions.

Limitations of the study

Despite the study having an adequate sample size, participants being predominantly young, highly educated females, recruited via non-probability sampling, might have limited the generalization of the results to the broader, more diverse population of Karachi and wide confidence intervals for smaller subgroups (e.g., lower educational levels) reflect limited precision in those estimates. As this study used self-reported data, which is susceptible to social desirability bias, it may lead to underreporting of inappropriate practices, such as self-medication or antibiotic sharing. Despite these limitations, this study highlights key knowledge gaps and behavioral patterns in antibiotic stewardship, offering preliminary insights that could inform future public health interventions.

CONCLUSION

This study describes behavioral patterns related to antibiotic use and disposal in Karachi, Pakistan. The high prevalence of leftover antibiotics, coupled with widespread self-reuse without medical consultation, may contribute to the risk of AMR emergence and spread. The primary drivers identified include symptom resolution before course completion, lack of awareness and perceived prior effectiveness of antibiotics, trends consistent with literature from other low- and middle-income countries. Moreover, the predominance of unsafe disposal practices, such as discarding antibiotics in household trash or retaining them for future use, underscores the environmental and public health risks associated with improper pharmaceutical waste management.

Statistically significant associations between educational attainment and antibiotic-related beliefs and behaviors indicate that targeted health literacy initiatives may help address these issues. Socioeconomic disparities in counseling on antibiotic disposal point to differential access to pharmaceutical education, highlighting the need for equitable interventions such as pharmacist-led public education and the promotion of structured take-back programs across all socioeconomic groups. Overall, the findings suggest that both behavioral and systemic gaps may contribute to inappropriate antibiotic use and disposal. Addressing these challenges requires an integrated approach involving public health education, regulatory reinforcement, and the institutionalization of community pharmacy-based disposal mechanisms. Such measures are essential to preserve antibiotic efficacy and combat the escalating threat of AMR.

Acknowledgments

Not applicable.

Authors' contributions

UK: Conceptualization, data curation, project administration, supervision and writing – original draft; SSAMS: Data curation, investigation, writing – review and editing. SR: Data curation, investigation, validation and writing – original draft. MA: Methodology, supervision, writing – original draft, writing – review and editing. AZ: Validation, visualization, writing, review and editing. SE: Formal analysis, software and validation. SB: Formal analysis and investigation. RA: Investigation and software. SN: Visualization, writing, review, and editing. SA: Formal analysis and software. All authors have read and approved the final version of the manuscript.

Funding

There was no funding.

Data availability statement

All data generated or analyzed during this study are included in this published article.

Ethical approval

Ethical approval was obtained from the Institutional Review Committee (IRC) of Salim Habib University, Karachi, Pakistan (Letter number: SHU-IRC/Pharmacy/P-001/2025). This study was performed in adherence with the STROBE guidelines. See Supplementary file for the STROBE checklist.

Conflict of interest

The authors declare that they have no conflicts of interest regarding the publication of this manuscript.

Supplementary questionnaire S1: Questionnaire used in the study.
Supplementary figure S2: Research flow chart.

Supplementary data

https://www.pjps.pk/uploads/2026/04/SUP1775374564.pdf

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