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Attitudes toward Environmentally Friendly Medicines: A Survey of Pharmacy and Health Sciences Students

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Abstract

This study aimed to examine the preferences of university students in Gothenburg, Sweden, regarding medicines with varying environmental impacts relative to their effectiveness, and to determine whether prior exposure to information about the environmental risks of pharmaceuticals influences these preferences. A questionnaire-based survey was carried out among students enrolled in various programs at the University of Gothenburg, Sweden. A total of 704 students were provided with both oral and written explanations about the study at the conclusion of a lecture and invited to participate (response rate: 83.5%). The survey included questions about knowledge of medicines' environmental impact and two hypothetical scenarios offering medicines for the treatment or relief of minor human ailments.

Overall, 53.3% of participants (pharmacy students: 57.8%) reported having received information on the environmental effects of medicines, and 79.6% (pharmacy students: 80.6%) expressed concern about such effects. About 20% (pharmacy students: 9.0%) cited the university as their information source. Students generally favored medicines that were least effective but most environmentally friendly. Pharmacy students consistently rated the most environmentally harmful medicines higher than medical or health care students. Despite receiving similar information about environmental impacts, pharmacy students were less inclined to prefer environmentally friendly medicines with lower effectiveness. Pharmacy students rated medicines higher overall than other student groups, even while acknowledging their potential environmental harm.

Keywords: Environment, Medicines, Pharmacy education, Students

Introduction

The environmental hazards of pharmaceuticals have been studied by environmental scientists for several decades [1, 2]. Over 25 years ago, Halling-Sørensen *et al*. [3] provided a detailed review of studies showing that pharmaceuticals and their residues can enter the environment through multiple pathways. Recent studies have further demonstrated that these substances can affect living organisms even at low concentrations after entering natural ecosystems [4, 5]. The concept of green pharmacy has emerged to mitigate these harmful impacts [6, 7], encompassing strategies to reduce environmental burdens throughout a medicine's life cycle, from research and development to prescribing, dispensing, and safe disposal. The term originates from "green chemistry," emphasizing reduced use of harmful reagents and alternative synthesis routes, as outlined by Daughton [6]. In 2016, the International Pharmaceutical Federation issued a policy on Green Pharmacy Practice, highlighting the global significance of pharmaceutical environmental effects [8]. They recommended that pharmacy curricula incorporate the environmental implications of medicines and teach "green principles" [8]. Similarly, the Pharmaceutical Group of the European Union urged the inclusion of environmental considerations in pharmacy education and continuing professional development, following a One Health approach [9]. European pharmaceutical companies have also implemented

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policies to minimize environmental contamination, focusing on risk assessment and management of manufacturing effluents [10].

Education of pharmacists about pharmaceutical pollution and its consequences is therefore crucial. Pharmacists, alongside other healthcare professionals, serve as intermediaries between academia and the public, influencing awareness and medication use patterns [11]. Pharmacy students, as future medicine experts, should be trained to assess prescription appropriateness and consider environmental aspects in practice, as recommended by the International Pharmaceutical Federation [12]. The green pharmacy approach includes advising on environmentally preferable options while avoiding medicines with minimal benefit.

In Sweden, a country known for strong environmental regulations, these topics are largely absent from pharmacy curricula, though recent attention to Agenda 2030 and the Sustainable Development Goals may have increased environmental considerations in courses [11, 13, 14].

A prior study examined whether basic information on environmental harm affects medicine choices in hypothetical scenarios [15]. Participants made trade-offs between effectiveness and environmental impact, showing that Swedes may accept slightly less effective medicines if they are environmentally friendlier. According to Luís *et al*. [16], laypeople perceive lower environmental risk from pharmaceuticals than experts, with younger adults perceiving less risk than older adults [17]. Building on this, the present study aimed to assess university students' preferences for medicines with different environmental impacts relative to their effect in Gothenburg, Sweden, comparing pharmacy students to peers in other disciplines and evaluating the influence of prior information about pharmaceutical environmental harm.

Materials and Methods

The study was carried out at the University of Gothenburg during the spring semesters of 2020 and 2022. Before initiating recruitment, permission was obtained from the responsible course instructors. Students were then informed about the study both verbally and in writing and invited to participate at the end of a lecture. The participants included students from pharmacy, medicine, other health-related programs, as well as economics, law, and social sciences. Students at all stages of their programs were eligible. Out of 704 students present at the lectures, 83.5% completed the survey. Questionnaires and consent forms were distributed by a research assistant and collected in separate envelopes to ensure anonymity. Responses were de-identified, preventing any linkage to specific student cohorts. According to the Swedish Ethical Review Authority, formal ethical approval was not required under national regulations.

The data were collected via a paper-based questionnaire, adapted from instruments used in prior studies [15, 17] and adjusted for the target population. The first section gathered demographic information, including gender and age, recent medicine purchases (past 12 months), prior exposure to information about the environmental effects of medicines, and environmental concerns. The second section presented two hypothetical scenarios involving the use of medicines for minor human ailments. The first scenario concerned treatments for common cold symptoms, while the second addressed pain relief for muscle inflammation.

After each scenario, participants were provided a table showing the effectiveness and environmental impact of three fictitious medicines. The proportion of patients recovering completely was 90% (fluvonox and lumenoxin), 70% (oroflexol and blenasirad), and 50% (minohydren and reganolox), whereas the corresponding environmental harm, expressed as reductions in fish stocks, was 40%, 20%, and 0%, respectively. Participants were asked to imagine that only the first medicine was available and rate their satisfaction based on both effectiveness and environmental impact, using a scale from 1 ("not at all satisfied") to 10 ("extremely satisfied"). The same procedure was repeated for the second and third medicines. Participants also ranked the three medicines as first, second, or third preference.

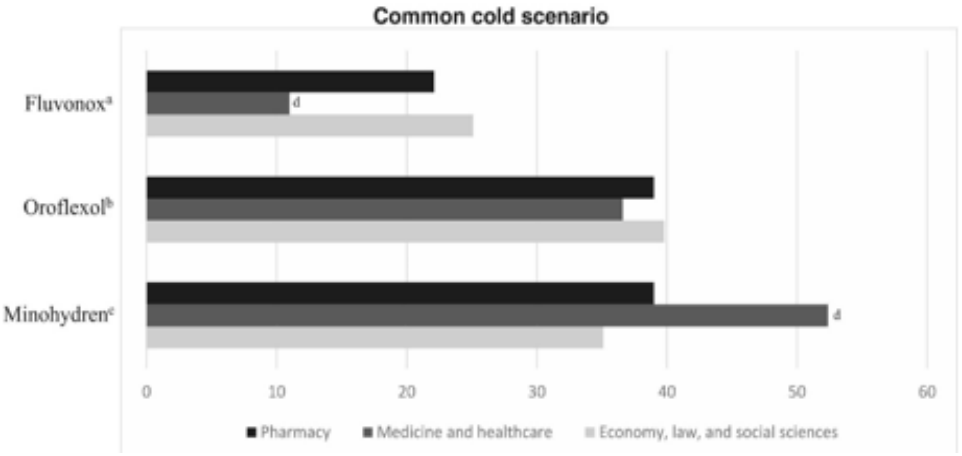
Statistical analyses were conducted using SPSS Statistics version 26 (SPSS Inc). Differences between fields of study regarding demographic variables, information received about environmental effects, and related concerns were examined with Pearson χ^2 tests and Bonferroni-Holm corrected post hoc tests **(Table 1)**. Fields of study were grouped as "pharmacy," "medicine and health care," and "economics, law, and social sciences." In Sweden, pharmacy education consists of a 5-year pharmacy program and a 3-year dispensing pharmacy program; both were combined as "pharmacy students." Age was categorized into 19–24 years and 25–54 years. Participants identifying as "other gender" were

excluded due to low numbers. Pearson χ^2 tests were also used to assess potential associations between prior information about environmental harm and medicine preferences. P-values below 0.05 were considered significant. Mean satisfaction scores for each medicine were calculated, and a one-way ANOVA with Bonferroni-Holm post hoc adjustments compared scores between fields of study **(Table 2)**. Effect sizes were determined using Cohen's criteria ($\eta^2 = 0.01$: small; $\eta^2 = 0.06$: medium; $\eta^2 = 0.14$: large) [18]. Logistic regression was applied to estimate odds ratios for selecting the most or least environmentally friendly medicines based on background variables.

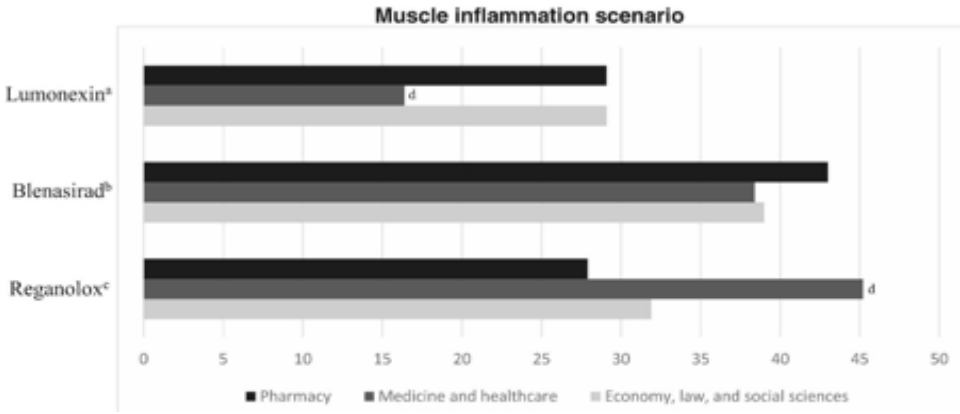
Table 1. Background characteristics of participants by field of study (N = 588)

Participant characteristic	Economics, law, and social sciences students		Medicine and health care students		Pharmacy students		Overall		P value
	n	%	n	%	n	%	n	%	
Sex									
Female	151	57.0	118	79.7	152	86.9	421	71.6	
Male	113	42.6	27	18.2	22	12.6	162	27.6	< .001[b]
Other[a]	1	0.4	3	2.0	1	0.6	5	0.9	
Age range (years)									
19–24	160	60.6	72	50.3	142	82.6	374	63.6	
25–54	104	39.4	71	49.7	30	17.4	205	34.9	< .001[c]
Bought medicines within the previous 12 months	243	92.4	133	92.4	168	96.6	544	93.6	.169
Ever received details about the ecological effects of drugs	125	47.2	87	58.8	100	57.8	312	53.3	.024[d]
Worried about how pharmaceuticals affect the environment	200	75.5	127	85.8	141	80.6	468	79.6	.041[e]

aExcluded due to low numbers.
bGender distribution differed significantly across the three fields of study (Bonferroni-Holm post hoc).
cAge distribution differed significantly between pharmacy and medical/health care students (Bonferroni-Holm post hoc).
dFewer economics, law, and social sciences students reported receiving environmental information compared with pharmacy and health-related students (Bonferroni-Holm post hoc).
eNo significant differences between fields for this variable (Bonferroni-Holm post hoc)



a)



b)

Figure 1. Medicine Preference across Two Hypothetical Scenarios by Field of Study.
aHighest efficacy but greatest environmental impact.
bIntermediate efficacy and moderate environmental impact.
cLowest efficacy but minimal environmental impact.
dStatistically significant differences between medical/health care students and other groups based on Bonferroni-Holm adjusted post hoc analyses.

Table 2. Comparison of average satisfaction scores for medicines across three fields of study using one-way ANOVA.

Medication profile	Pharmacy (n)	Mean	SD	Economics, Law & Social Sciences (n)	Mean	SD	Medicine & Health Sciences (n)	Mean	SD	P-value	F-value	df	Effect size (η^2)
Highest efficacy with lowest environmental friendliness (Fluvonox)	174	5.32[a]	2.242	265	5.04[b]	2.343	147	4.37[ab]	2.245	< .001	7.25	2, 583	0.02
Moderate efficacy and environmentally friendly profile (Oroflexol)	174	5.97[a]	1.752	265	5.65	1.956	147	5.26[a]	2.202	.006	5.25	2, 583	0.02
Lowest efficacy with highest environmental friendliness (Minohydren)	174	6.22	2.132	265	5.83	2.174	147	6.03	1.845	.150	1.91	2, 583	0.01
Maximum efficacy and minimal environmental friendliness (Lumonexin)	173	5.87[c]	2.275	264	5.34[c]	2.413	148	4.69[c]	2.276	< .001	10.12	2, 582	0.03
Intermediate efficacy with environmentally friendly attributes (Blenasirad)	173	6.32[ad]	1.666	264	5.92[d]	1.864	148	5.58[a]	2.014	.002	6.42	2, 582	0.02

Lowest efficacy combined with highest environmental friendliness (Reganolox)	173	6.01	1.936	264		5.95	2.097	148	5.95	1.814	.95	0.05	2, 582	< 0.01

Abbreviations: ANOVA, analysis of variance; M, mean; SD, standard deviation.
aSignificant mean differences between pharmacy and medical/health care students (Bonferroni-Holm post hoc).
bSignificant mean differences between medical/health care students and economics, law, and social sciences students (Bonferroni-Holm post hoc).
cSignificant differences among all three groups (Bonferroni-Holm post hoc).
dSignificant differences between pharmacy students and economics, law, and social sciences students (Bonferroni-Holm post hoc).

Results and Discussion

The study included 588 students, with 359 (61.1%) participating in 2020 and 229 (38.9%) in 2022. Participants came from a variety of study programs in both years. Female students were predominant, accounting for 71.6% of the sample, and the overall mean age was 24.7 years (SD 4.86). Nearly all respondents (93.6%) reported purchasing medicines in the previous 12 months, with similar percentages in 2020 and 2022 (92.8% vs. 92.1%). Comparisons across different academic fields showed no significant differences in reported medicine purchases **(Table 1)**.

Regarding exposure to environmental information, 53.3% of the students indicated that they had received guidance about the ecological impact of medicines, and 79.6% reported being concerned about such effects. **Table 1** details these results according to field of study. No notable change in concern was observed between the two survey years (80.5% in 2020 vs. 78.2% in 2022).

When asked about sources of environmental information, students most frequently mentioned mass media—including social media—followed by medicine packaging or leaflets, and advice from family or friends. In comparison, only 9.0% of pharmacy students identified their university as a source of information **(Table 3)**.

Table 3. Sources of information on medicines' environmental impact by field of study (N = 312; multiple responses allowed)

Information source	Total	Pharmacy	Medicine and health care	Economics, law, and social sciences
	n %	n %	n %	n %
Media (including social media)	180 57.7	47 47.0	39 44.8	94 75.2
Medicine packaging (including leaflets)	107 34.3	48 48.0	25 28.7	34 27.2
Friends and relatives	72 23.1	15 15.0	20 23.0	37 29.6
Pharmacy staff	67 21.5	42 42.0	9 10.3	16 12.8
University courses	63 20.2	9 9.0	27 31.0	27 21.6
Healthcare facilities (center or hospital)	28 9.0	10 10.0	6 6.9	12 9.6

In both cases, participants expressed contentment with the provided medications, noting that these were the sole options accessible to them. The highest average ratings were assigned to the medicines with the lowest efficacy but greatest environmental benefits (minohydren: 6.00; reganolox: 5.97). In contrast, the medicines offering the highest efficacy but poorest environmental profiles received the lowest ratings (fluvonox: 4.95; lumonexin: 5.33). For the intermediate options balancing efficacy and environmental impact, average ratings were 5.65 (oroflexol) and 5.95 (blenasirad).

One-way ANOVA revealed significant variations in rating distributions across the three academic disciplines for the medications in both scenarios. According to **Table 2**, students in pharmacy tended to assign higher ratings to the medicines with greater environmental harm (fluvonox and oroflexol; lumonexin and blenasirad) than did students from other fields. Overall, the effect sizes remained small **(Table 2)**.

The figure illustrates participants' preferred medication selections when required to choose among the options, broken down by field of study.

In the cold scenario, 40.6% selected the least effective yet most environmentally friendly medicine (minohydren) as their top choice, compared to 34.1% for the equivalent option (reganolox) in the muscle inflammation scenario. The shares preferring the most effective but least environmentally friendly medicines (fluvonox and

lumonexin) were 20.7% in the cold scenario and 25.9% in the muscle inflammation scenario. As presented in **Table 4**, pharmacy students were significantly less likely to choose the most environmentally friendly medicine as their preference and significantly more likely to select the least environmentally friendly one compared to medical and health care students. Additionally, medical and health care students showed a greater tendency toward environmentally friendly selections than did those studying economy, law, or social sciences. Age emerged as a significant predictor of preferences, alongside self-reported concern for the environmental effects of pharmaceuticals **(Table 4)**.

Table 4. Presents adjusted odds ratios (ORs) for preferring the most versus least environmentally friendly medicine relative to various background factors.

Background variable		Scenario 1 Most effective and least environmentally friendly medicine as preferred choice	Scenario 2 Most effective and least environmentally friendly medicine as preferred choice			Scenario 1 Least effective and most environmentally friendly medicine as preferred choice	Scenario 2 Least effective and most environmentally friendly medicine as preferred choice
		n (%)	OR (95% CI)	*n* (%)	OR (95% CI)	*n* (%)	OR (95% CI)
Sex	Female	68 (16.2)	1.0	95 (22.6)	1.0	178 (43.1)	1.0
	Male	51 (31.5)	1.3 (0.81-2.02)	52 (32.1)	1.8 (1.13-2.98)	55 (34.8)	0.9 (0.58-1.35)
Age group	19-24 y	70 (18.7)	1.0	97 (25.9)	1.0	133 (36.0)	1.0
	25-54 y	45 (22.0)	0.9 (0.56-1.34)	47 (22.9)	1.3 (0.81-2.05)	100 (50.3)	1.8 (1.26-2.70)
Field of study	Pharmacy	38 (21.7)	1.0	50 (28.6)	1.0	67 (39.0)	1.0
	Medicine and health care	16 (10.8)	0.5 (0.25-0.84)	24 (16.2)	0.3 (0.16-0.68)	76 (52.4)	1.4 (0.89-2.34)
	Economics, law, and social sciences	65 (24.5)	0.9 (0.53-1.37)	74 (27.9)	0.8 (0.49-1.40)	91 (35.1)	0.8 (0.52-1.23)
Received information about medicines' environmental impact	No	58 (21.2)	1.0	69 (25.3)	1.0	98 (36.6)	1.0
	Yes	60 (19.2)	1.3 (0.88-2.00)	79 (25.3)	1.2 (0.77-1.88)	135 (44.3)	1.1 (0.78-1.60)
Concerns about the environmental impact of medicines	No	49 (40.8)	1.0	54 (45.0)	1.0	24 (20.5)	1.0
	Yes	70 (15.0)	0.3 (0.20-0.50)	94 (20.1)	0.3 (0.18-0.48)	210 (45.8)	3.0 (1.82-5.05)

Percentages reflect the share within each subgroup (e.g., women or men) who selected the given medicine as their top preference. The table does not explicitly display the proportions who did not rank it first.
Abbreviation: OR, odds ratio; CI, confidence interval.

The findings of this study indicate that students at a Swedish university exhibit some willingness to factor in environmental aspects when selecting medicines for minor health issues. In line with prior research [15, 17], this study weighed therapeutic effect against environmental impact, although these scenarios do not perfectly mirror real-world medicine selection. One practical example could be choosing diclofenac as an anti-inflammatory for muscle inflammation. Pharmacy students, despite reporting similar exposure to environmental information as medical and health care students, were less inclined to select environmentally preferable medicines with lower efficacy. Although relatively few pharmacy students cited their academic training as a source of environmental knowledge compared with medical students, many had obtained information directly from the pharmacy, which is also a credible source. Across scenarios, pharmacy students consistently assigned higher ratings to environmentally harmful medicines compared with medical and health care students, except when evaluating the least harmful options. In one of the two scenarios, their ratings were even higher than those of economics, law, and social science students.

Age appears to play a role in risk perception [17]. In this study, students over 24 years were more likely to favor environmentally friendly medicines than younger students. Nonetheless, **Table 4** shows that differences between fields of study remained significant even after controlling for age and gender. As expected, participants' concern about environmental impacts also significantly influenced medicine preferences.

When compared with a prior Swedish study of the general adult population [15], a larger proportion of students expressed concern about the environmental effects of medicines (79.6% vs. 55.7%) and reported receiving information about environmental impacts (53.3% vs. 34.7%) [15]. Interestingly, students were less likely than the general population to select environmentally friendly medicines (e.g., 40.6% vs. 68.2% for the most environmentally friendly medicine for common cold treatment). Two potential explanations include age and the influence of professional education. Previous research has shown that pharmacy and medical students strongly believe in the therapeutic benefits of medicines, despite recognizing possible overuse or harm [19]. This contrasts with findings by Luís *et al*. [16], which showed that laypeople tend to perceive pharmaceuticals as posing a lower environmental risk.

Overall, the results highlight a discrepancy between students' environmental concern and their actual medicine choices. The reasons behind this behavior are not fully understood. One possibility is that students adopt a patient-centered perspective and consider environmental issues to be system-level responsibilities. Another factor may be the general tendency of younger individuals to be less proactive in preventive measures when tested, as observed during the recent pandemic [20]. Social desirability bias is also difficult to quantify. In Sweden, public interest in environmental issues has been consistently high, which might encourage reporting proenvironmental attitudes. However, research suggests that self-reported environmental attitudes among students are generally reliable indicators of actual ecological behavior [21].

Few pharmacy students indicated that their education was the primary source of environmental information; rather, pharmacies themselves were cited, potentially due to internships, part-time work, or consumer experience. This is encouraging for green pharmacy initiatives in Sweden, which include voluntary environmental labeling of over-the-counter medicines ("well selected") and programs that incentivize safe disposal of unused or expired medicines.

Several limitations should be noted. Participants responded to simplified hypothetical scenarios featuring two ailments, three medicines varying in effect and environmental impact, and equal risk of side effects. While simplified, such models cannot fully capture real-world decision-making. Nevertheless, intention-based studies indicate that stated intentions predict behavior approximately 50% of the time, suggesting that such measures are reasonably accurate [22]. Furthermore, students' environmental attitudes, which strongly shape intentions, are closely linked to ecological behavior [21]. Evidence also suggests that enhancing perceived effectiveness of environmental policies can improve proenvironmental behavior and reduce intention-behavior gaps [23]. These findings emphasize the importance of education in cultivating proactive green pharmacy advocates among future pharmacists.

It is important to recognize that these results reflect a single university and may not generalize to other Swedish institutions, even with a shared national curriculum. For instance, Uppsala University offers an elective course on pharmaceuticals in the environment for master's pharmacy students. As research on pharmaceuticals' environmental impacts expands, additional courses addressing these issues may be introduced. Lessons could also be drawn from the University of Helsinki, which integrates environmental considerations across all higher education programs in pharmaceutical and medical sciences [24].

Conclusion

Pharmacy students, as future professionals, can significantly influence how medicines are designed, prescribed, and disposed of from an environmental perspective. This study demonstrates that just over half of pharmacy students were aware that medicines can negatively affect the environment. Moreover, they were less likely than other student groups to cite their education as the source of this knowledge. Despite this, pharmacy students consistently rated medicines higher than other students, even when the medicines were environmentally harmful. Although the study focused on hypothetical personal use scenarios, the findings are relevant because individual preferences can shape future professional decisions and advice. To strengthen the implementation of green pharmacy practices in Sweden, educational programs should ensure that students acquire a thorough understanding of the environmental consequences of their professional responsibilities.

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