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Pharmaceuticals in the environment - perspectives on drug utilisation and mitigation strategies

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Abstract

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The environmental impact of pharmaceuticals has emerged as a critical concern. As global pharmaceutical consumption steadily increases, the environmental issues linked to their production, use, and disposal are becoming ever more pressing. This thesis aimed to study drug utilisation in relation to environmental risk and to explore the role and responsibility of healthcare professionals in reducing the environmental impact of pharmaceuticals. The focus was on promoting environmentally informed pharmaceutical use, emphasising use-oriented measures and the roles of various healthcare stakeholders. Four interconnected studies were conducted: an analysis of analgesic sales in the region surrounding Lake Mälaren to investigate use patterns of substances with environmental concern (Paper I); interviews with key decision makers representing Swedish national and regional authorities, the pharmaceutical industry, research institutes, and academia to evaluate the content, use, and impact of two Swedish environmental knowledge support systems for pharmaceuticals (Paper II); a national questionnaire to general practitioners exploring attitudes towards integrating environmental aspects into prescribing decisions (Paper III); and focus group discussions and individual interviews with community pharmacy staff on their role in reducing the environmental impact of pharmaceuticals (Paper IV).

The findings reveal that awareness of pharmaceuticals as an environmental problem exists within healthcare, however, important prerequisites for integrating environmental aspects into practice are still lacking. Access to reliable environmental risk data for many active pharmaceutical ingredients remains limited, decision-making criteria are often unclear, and there is little concrete guidance on how to incorporate environmental considerations into everyday clinical routines.

Healthcare professionals are essential in promoting environmentally informed pharmaceutical use. Physicians and pharmacists both consider themselves to have a role and responsibility in promoting more environmentally informed use of pharmaceuticals. Their contributions include preventing pharmaceutical waste and supporting pharmaceutical stewardship. However, there is a need for education and institutional support in enabling them to take action.

Findings show that addressing pharmaceutical pollution requires action beyond the efforts of individual healthcare professionals. Strong governance and clear direction, both at the national and international levels, are essential to enable change. Environmental considerations should be systematically integrated into established decision-making structures, such as treatment guidelines, so that sustainable choices become the default rather than the exception.

By combining analyses of pharmaceutical sales data with insights into healthcare professionals' attitudes, drug utilisation studies can generate the evidence base needed to support the systematic and broadly accepted inclusion of environmental considerations in healthcare.

Keywords: Environment, Sustainability, Rational Use of Medicines, Drug Utilisation, One Health, Pharmaceutical pollution

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"Man's attitude toward nature is today critically important simply because we have now acquired a fateful power to alter and destroy nature. But man is a part of nature, and his war against nature is inevitably a war against himself. We are challenged as mankind has never been challenged before to prove our maturity and our mastery, not of nature, but of ourselves."

Rachel Carson

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I. **Villén J**, Nekoro M, Kälvemark Sporrong S, Håkonsen H, Bertram MG, Wettermark B. Estimating environmental exposure to analgesic drugs: A cross-sectional study of drug utilization patterns in the area surrounding Sweden's largest drinking water source. *Environ Adv*. 2023;12:100384.

II. Linder E, **Villén J**, Nekoro M, Wettermark B, Kälvemark Sporrong S. Stakeholders' perspectives and use of web-based knowledge support for environmental information on pharmaceuticals. *Explor Res Clin Soc Pharm*. 2023;11:100303.

III. **Villén J**, Laux J, Wettermark B, Kälvemark Sporrong S, Nekoro M, Håkonsen H. Towards greener prescribing? Swedish general practitioners' support for policies to reduce pharmaceutical pollution. *Br J Clin Pharmacol*. 2025;91(6):1623-1631.

IV. **Villén J**, Ljungdahl N, Håkonsen H, Wettermark B, Nekoro M, Sporrong SK. "We throw away an incredible amount of unused medicines": Community Pharmacy Staff Perspectives on Environmental Responsibility. *Explor Res Clin Soc Pharm*. 2025;20:100662.

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Other work not included in the thesis

Contributions were made to the following publications during this doctoral project, but are not included in the thesis:

- Giunchi V, Fusaroli M, Linder E, **Villén J,** Wettermark B, Nekoro M, Raschi E, Lunghi C, Poluzzi E. The environmental impact of pharmaceuticals in Italy: Integrating healthcare and eco-toxicological data to assess and potentially mitigate their diffusion to water supplies. *Br J Clin Pharmacol*. 2023;89(7):2020-2027.
- Giunchi V, Fusaroli M, Linder E, **Villén J,** Wettermark B, Nekoro M, Raschi E, Lunghi C, Poluzzi E. Environmental sustainability-an essential component of rational use of medicines. *Int J Pharm Pract*. 2025;33:102-112.
- Jazzaa A, **Villén J,** Linder E, Bergström U, Wettermark B. Do Swedish universities educate future doctors and pharmacists about the environmental impact of pharmaceuticals? *Curr Pharm Teach Learn*. 2025;17(9):102386.
- Nekoro M, **Villén J,** Thomas A. The environment and drug utilization research. In: Drug Utilization Research: Methods and Applications. 2nd ed. John Wiley & Sons, Ltd; 2024:464-481.

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Abbreviations

API	Active Pharmaceutical Ingredient
ATC	Anatomical Therapeutic Chemical Classification System
DUR	Drug Utilisation Research
DTC	Drug and Therapeutics Committee
EC	European Commission
EMA	European Medicines Agency
ERA	Environmental Risk Assessment
EU	European Union
FGD	Focus Group Discussion
GP	General Practitioner
HCP	Healthcare Professional
MPA	Medical Products Agency
NSAID	Non-Steroidal Anti-Inflammatory Drug
OR	Odds Ratio
OTC	Over-the-Counter
PiE	Pharmaceuticals in the Environment
SDG	Sustainable Development Goals
UN	United Nations
WHO	World Health Organisation
WWTP	Wastewater Treatment Plant

Key concepts

Drug utilisation research	Quantitative and qualitative studies to describe, evaluate, understand, and improve the use of medicines.[1]
Ecological footprint	A measure of how much area of biologically productive land and water an individual, population, or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices.[2]
Ecopharmacovigilance	Monitoring and minimising the environmental risks of pharmaceuticals after they enter the market. It focuses on detecting pharmaceuticals in the environment, assessing their impact on non-target organisms, and preventing their adverse effect.[3]
One Health	An approach that recognises the interconnectedness of human, animal, and environmental health. It promotes collaboration across sectors to address health challenges that affect all three domains.[4]
PBT	P = persistence in the environment, B = bioaccumulation in organisms, T = toxicity towards organisms. Active substances that are persistent, bioaccumulative, and toxic are classified as PBT substances, or as very persistent and very bioaccumulative (vPvB).[5]

Pharmacoenvironmentology	A field that studies the environmental effects of pharmaceuticals, including how they enter ecosystems and what risks they pose to wildlife and water systems.[6]
Planetary boundaries	A scientific framework that defines the environmental limits within which humanity can safely operate. Crossing these boundaries increases the risk of destabilising Earth's systems, potentially leading to irreversible environmental change.[7]
Rational use of medicines	Patients receive medication appropriate to their medical needs, in doses meeting their own individual requirements, for an adequate period of time and at the lowest costs to them and to the community.[8]
Sustainability	Meeting current needs without compromising the ability of future generations to meet theirs. In healthcare, it involves reducing environmental impact while maintaining quality care.[9]

The author's prior knowledge and professional context

In line with recommendations for transparency in qualitative research, it is important to acknowledge my own professional background and prior knowledge that may have influenced the research process. I am a licensed pharmacist with some professional experience from the pharmacy sector in Sweden. Since beginning my doctoral studies, my research has focused on pharmaceuticals in the environment and strategies to promote environmentally responsible use of pharmaceuticals. I have a strong personal interest in environmental issues, which has contributed to my motivation and engagement in this field and my conviction that it is an important area of research.

Through my academic work I have been engaged in national and international networks on this topic, collaborated with authorities and professional organisations, and been involved in developing educational material for pharmacy students. This professional and academic context has provided me with insights into both pharmacy practice and healthcare systems. While such experience has shaped the perspectives I bring to the research, I have sought to remain reflexive throughout the process, for example, by discussing interpretations within the research group and with colleagues outside academia, and by grounding the analysis in participants' accounts. I am aware that my professional background may introduce certain biases when in interpreting participants' views.

This thesis is grounded in both a post-positivistic and constructivist epistemological approach, acknowledging that while some knowledge can be objectively measured and quantified, knowledge can also be socially constructed and shaped by context, experience, and interaction. The qualitative parts of my research explore how healthcare professionals perceive and interpret their roles in promoting environmentally responsible pharmaceutical practices. Rather than seeking objective truths, the aim is to understand meaning-making processes and how professional attitudes are shaped. My research is at the same time informed by a pragmatic approach as I am not only concerned with understanding how environmental considerations are conceptualised within healthcare, but also with contributing to meaningful change.

Introduction

Pharmaceuticals are one of the most essential healthcare interventions, playing a critical role in treating and preventing disease. Their use has significantly improved health outcomes and life expectancy, making them indispensable to modern society.[10] However, as global pharmaceutical consumption continues to rise, driven by an ageing population, increasing prevalence of chronic diseases, improved access to healthcare in low- and middle-income countries, medical advancements, and a growing "a pill for every ill" culture, so do the challenges associated with their sustainability.[11,12]

Research on pharmaceuticals in the environment (PiE) emerged in the late 1970s, when early studies reported residues of human pharmaceuticals in wastewater and surface waters.[13] Since then, the field has moved from detection to understanding sources, fate, and effects. It has been well confirmed that pharmaceuticals can pose a risk to ecosystems and human health.[14–16] Examples include feminisation of fish,[17] heightened susceptibility of fish to predation[18,19] and the selection for antibiotic-resistant bacteria.[20] Pharmaceuticals are chemical compounds designed to produce a therapeutic response at low doses, thus making them of environmental concern even at low concentrations. In addition, their persistent and bioaccumulating properties have led to pharmaceutical residues becoming an increasing problem in the environment.[15,21,22] Consequently, pharmaceutical residues in the environment have become an emerging issue.

PiE represents both a global and a local challenge. Residues of pharmaceuticals have been detected in rivers, lakes, groundwater, and soils worldwide.[15,23,24] A recent global-scale study by Wilkinson et al., covering 258 rivers across all continents and representing the environmental influence of 471.4 million people, found widespread pharmaceutical pollution. At 25.7% of the sampling sites, concentrations of at least one active pharmaceutical ingredient (API) exceeded levels considered safe for aquatic organisms or levels of concern for the selection of antimicrobial resistance.[22] This issue is not confined to regions with limited wastewater treatment or areas with extensive pharmaceutical production; traces of pharmaceuticals are also found in countries with advanced infrastructure, including Sweden. Monitoring of Swedish lakes, rivers, and coastal waters has detected psychoactive pharmaceuticals at

concentrations that may alter normal fish behaviour.[19] Diclofenac, a substance known to be harmful to the environment, has also been found at levels exceeding environmental quality standards.[25] Such findings illustrate that pharmaceutical pollution is not only a distant problem but a reality in Swedish environments, with potential implications for ecosystem health.

Sustainability and pharmaceuticals

Sustainable development entails meeting present needs without compromising future generations' ability to meet theirs.[26] In the context of healthcare, sustainability is challenged by economic, social, and environmental constraints. The economic and social deficits are well recognised, and the environmental impact of healthcare, particularly pharmaceuticals, is now gaining increasing attention.[27]

One lens through which sustainability is viewed is the concept of planetary boundaries. It emphasises the delicate balance within nature, urging us to operate within a defined space to prevent the overuse of natural resources and the subsequent strain on our environment.[7,28] One of the nine planetary boundaries is chemical pollution, and there is increasing evidence that we are already operating outside of this, risking irreversible environmental change.[29] The United Nations' (UN) Sustainable Development Goals (SDGs) is a comprehensive framework for pursuing sustainability. While only one SDG explicitly addresses good health (Goal 3: "Ensure healthy lives and promote well-being for all at all ages"), many other goals, for example, Goal 6 ("Ensure availability and sustainable management of water and sanitation for all") are closely linked to health outcomes and are of particular relevance to this thesis.[30] The World Health Organisation (WHO) positions health at the core of the sustainability narrative, asserting that it serves as both the foundation for and the purpose of all discussions on sustainability.[31] There is a strong correlation between a country´s ecological footprint and dimensions of human development, such as a long and healthy life, meaning that health improves with the use of resources.[2] Addressing this challenge is essential for enhancing global health, striving to improve well-being for everyone while simultaneously minimising our ecological footprint.

One promising way forward is to adopt a systemic approach through the approach of "One Health".[32] The One Health approach acknowledges the intricate relationships between human health, animal health, and the health of the ecosystems we share. It underscores the importance of a holistic and collaborative approach to mitigate the environmental consequences of, among other things, pharmaceutical use.[4] An illustrative example of how

pharmaceutical practices can disrupt this balance is the collapse of vulture populations in India in the 1990s, linked to the veterinary use of diclofenac.[16] Vultures feeding on carcasses of treated cattle suffered fatal kidney failure due to drug residues, leading to dramatic population declines. This ecological disruption had far-reaching public health consequences, including increased carcass exposure, a rise in feral dog populations, and a subsequent surge in rabies cases.[33,34] Such cascading effects underscore the importance of integrated thinking. The One Health approach encourages collaboration between medical, pharmaceutical, and veterinary professionals to develop strategies that account for the shared impact of human activities on health and the environment. By bridging disciplinary boundaries, it offers a pathway to more resilient and responsible healthcare systems.[4,32]

Pathways of pharmaceutical emissions to the environment

Pharmaceuticals can find their way into the environment through multiple pathways (Figure 1). When humans or animals consume pharmaceuticals, the active compounds or metabolites are excreted in urine and faeces. In urban areas, such residues typically end up in wastewater treatment systems.[15,21] Conventional wastewater treatment plants (WWTP), while effective at removing organic matter, generally do not eliminate pharmaceutical compounds, which can reach rivers, lakes, and other water bodies.[35,36] Alarmingly, it is estimated that over 80% of the world's wastewater is discharged into the environment without any treatment.[37] Another significant source of contamination is the improper disposal of unused or expired pharmaceuticals, including flushing them down the toilet or discarding them in the trash, contributing to pharmaceutical presence in the environment.[38] Agricultural runoff from livestock treated with pharmaceuticals and aquaculture practices further contributes to environmental contamination.[10] Pharmaceuticals can also enter ecosystems through industrial discharges from manufacturing.[39] While the exact contribution of each pathway to the overall environmental burden remains uncertain, it is clear that use is a major driver of pharmaceutical pollution.[40]

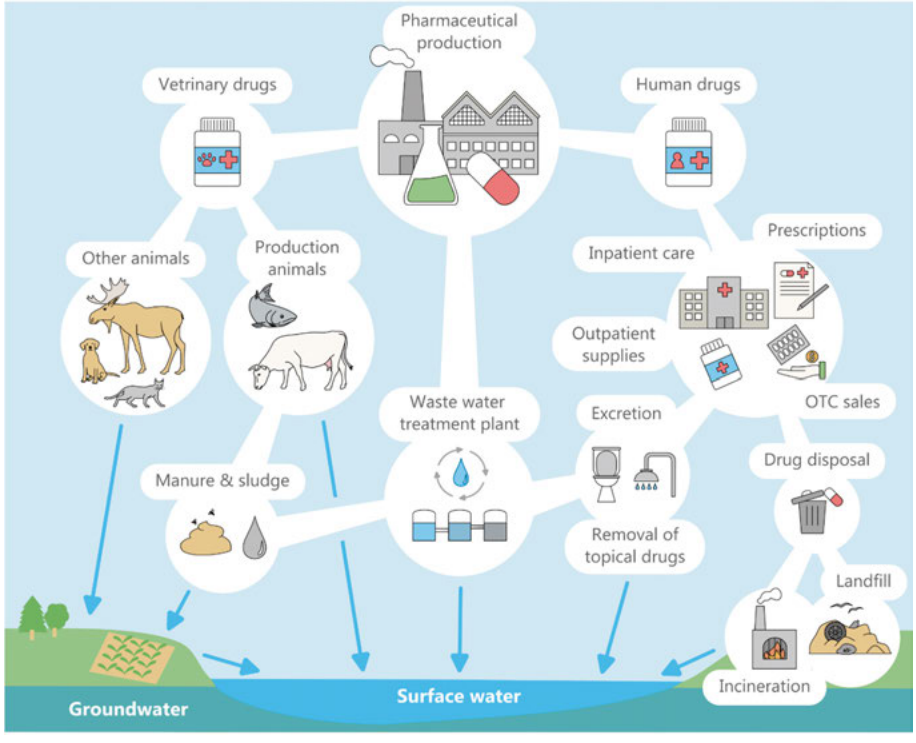

Figure 1 Pathways of pharmaceutical emissions into the environment.

Addressing the issue

Strategies addressing the negative environmental impact of pharmaceuticals are often categorised as either source-directed, use-oriented, or end-of-pipe measures. Source-directed measures aim to prevent pharmaceutical pollution and minimise its effects at the source. These measures are primarily directed at pharmaceutical companies and focus on developing "greener" pharmaceuticals.[41] Potential strategies include developing pharmaceuticals with greater target specificity and reduced off-target effects, enabling lower dosing or targeted delivery and prioritising substances without persistent, bioaccumulative, or toxic properties.[42,43] Meanwhile, use-oriented measures target healthcare professionals (HCPs) and patients, aiming to reduce the use and indirectly limit the environmental release of residues. Source-directed and use-oriented measures can both be referred to as upstream measures, and are often more effective and sustainable than trying to remediate or clean up pollution after it has entered the environment.[10,41] End-of-pipe measures, also known as downstream measures, are strategies and interventions that are implemented to control or reduce the release of pollutants or contaminants into the environment

after they have been manufactured and used. Advanced wastewater treatment technologies play a significant role as they are capable of removing a wider range of pharmaceutical residues from effluents before they are released into the environment.[42] Source-directed, use-oriented, and end-of-pipe measures involve different stakeholders and entail different burdens and advantages. The choice and design of measures should be informed by research and be subject to continuous evaluation.[41]

As the understanding of PiE improves, so does the need for policy interventions and regulations to reduce the environmental risks. In the European Union (EU), market authorisation for pharmaceuticals is granted by the European Medicines Agency (EMA). Since 2006, environmental risk assessments (ERAs) have been required as a part of this process. These assessments estimate environmental impact by considering both the intrinsic hazards of the APIs and the likelihood of environmental exposure.[5] Hazard refers to the intrinsic potential of a substance to cause harm, whereas risk considers both hazard and the level of exposure in the environment. A key element in hazard assessment is the evaluation of a substance's persistence (P), bioaccumulation potential (B), and toxicity (T). Persistence describes how slowly a substance degrades in the environment, meaning it can remain for extended periods once released. Bioaccumulation refers to the tendency of a substance to build up in the tissues of living organisms, potentially increasing in concentration through the food chain. Toxicity captures the capacity of a substance to cause adverse effects on organisms, ranging from acute lethality to more subtle effects on reproduction or behaviour. Substances that are persistent, bioaccumulative, and toxic (PBT) are of particular concern because they can pose long-term, difficult-to-reverse risks to ecosystems. Under current EU legislation, marketing authorisation cannot be refused on the grounds of an unacceptable environmental risk.[5]

Comprehensive environmental hazard and risk data are lacking for many APIs currently in use, as they are not required for products authorised before 2006 and because environmental monitoring remains limited. It is estimated that 88% of all APIs intended for human use lack ERAs.[44] Even where data exist, they are not always publicly accessible, and the quality, methods, and update frequency vary across sources.[45]

The European Commission (EC) has taken steps to address the environmental and societal challenges linked to pharmaceuticals. In 2019, two key policy frameworks were launched: the European Green Deal, aiming for climate neutrality and sustainable development by 2050,[46] and the Strategic Approach to Pharmaceuticals in the Environment.[47] These frameworks reflect a recognition that pharmaceuticals, while essential for human and animal health,

also contribute to ecological strain and must be addressed within wider sustainability goals. The Strategic Approach applies a lifecycle perspective, calling for coordinated action from HCPs, the pharmaceutical industry, authorities, and the public to reduce environmental impact from drug design, production, prescribing, use, and disposal. One use-oriented measure highlighted in the Strategic Approach is the promotion of prudent use of pharmaceuticals that pose environmental risks, particularly antimicrobials. This involves encouraging HCPs and Member States to adopt environmentally informed prescribing practices, supported by EU-level actions such as guideline development, training initiatives, and international collaboration.[47]

Sweden has played a leading role in advocating sustainability, for example, by organising the first UN conference on the environment in Stockholm in 1972.[48] This early commitment to environmental awareness has laid the foundation for Sweden's progressive approach to addressing the impact of pharmaceuticals on the environment. Much of Sweden's contribution to understanding the environmental impact of pharmaceuticals can be attributed to the MistraPharma research program (2008-2015),[49] funded by The Swedish Foundation for Strategic Environmental Research (Mistra). Since 2011, Sweden has had a National Pharmaceutical Strategy, which has been revised over the years. The previous version of the strategy included, among its five main goals, a commitment to minimising the adverse environmental impacts of pharmaceuticals. This strategy proposed a variety of initiatives involving all relevant stakeholders, including governmental agencies, the pharmaceutical industry, pharmacies, and HCPs.[50] Sweden also has a national framework for environmental policy that includes several long-term Environmental Quality Objectives, which describe the state of the environment that Sweden aims to achieve, and a Generational Goal, which defines the overall direction of environmental policy: to hand over a society to the next generation where the major environmental problems have been solved. To support these overarching goals, Sweden has defined several milestone targets. These targets describe important steps or transitions that need to happen in society to reach the long-term environmental objectives. One of the milestone targets focuses on pharmaceuticals in the environment. Its main aim is to minimise the release of pharmaceutical residues into the environment. The target specifies that by 2030, regulations and other measures to reduce the environmental impacts of pharmaceuticals should be in place in Sweden, within the EU, or internationally.[51]

Both the EC's Strategic Approach to Pharmaceuticals in the Environment and the Swedish National Pharmaceutical Strategy emphasise the importance of promoting the rational use of medicines, not only to safeguard individual

and public health but also to mitigate environmental impact. WHO defined rational use of medicines in 1985, emphasising that "Patients receive medication appropriate to their medical needs, in doses meeting their own individual requirements, for an adequate period of time and at the lowest cost to them and the community".[8] This definition covers social and economic considerations, guiding policymakers, payers, and HCPs toward a safer, more accessible, and more efficient utilisation of pharmaceuticals for both individual patients and society as a whole. Recently, there have been proposals to expand the concept of rational use of medicines to explicitly include environmental considerations, alongside the traditional social and economic dimensions.[52] This shift reflects a growing recognition of pharmaceutical pollution as a pressing issue that warrants prioritisation within healthcare policy and practice. In line with this, Orive et al. (2021) proposed an updated definition: "Rational use of drugs requires that patients receive medications appropriate to their clinical needs, in doses that meet their own individual requirements for an adequate period of time, and the lowest cost to them and their community, considering the interconnection between people, animals, plants, and their shared environment."[53]

One important stakeholder in this context is HCPs, including physicians and pharmacists, as they play a vital role in use-oriented measures. They can contribute to reducing pharmaceutical pollution, for example, by responsible prescribing, educating patients and the public about correct disposal and how individual patients can take sustainable action, as well as by advocating for environmentally friendly healthcare policies.[54] Coupled with the significant contribution of prescribed pharmaceuticals to the overall residues of PiE, it is clear that HCPs have an important role in reducing pharmaceutical pollution.

Healthcare professionals' attitudes toward the environmental impact of pharmaceuticals

Existing research on HCPs' attitudes toward the environmental or climate impact of pharmaceuticals suggests a general willingness to consider environmental aspects in clinical decision-making.[55–63] However, the literature is fragmented and often limited to specific subgroups or contexts. Studies involving anaesthesiologists and surgeons, for example, have found that while these professionals are generally positive toward incorporating environmental considerations into their work, they frequently encounter structural barriers such as insufficient institutional support, limited education, and rigid clinical protocols that constrain environmentally informed practices.[55–57,61] Similarly, hospital pharmacists have demonstrated awareness of issues such as the carbon

footprint of inhalers and national take-back schemes.[64,65] Previous research has also focused much on specific areas of concern, for example, attitudes and practices regarding the disposal of pharmaceutical waste.[66–70]

Knowledge gaps

Despite growing research on the environmental effects of pharmaceuticals, substantial knowledge gaps continue to hinder progress toward more environmentally informed practices. For instance, little is known about how pharmaceutical use relates to environmental risk. Drug Utilisation Research (DUR), which aims to describe, evaluate, understand, and improve the use of pharmaceuticals through both quantitative and qualitative methods, has the potential to bridge this gap by combining data on sales and prescribing with insights into attitudes and perceptions on environmental risk. Yet, few studies have applied DUR methods with this specific focus.

Although there is a growing body of research on HCPs' attitudes, much of it is conducted in countries with healthcare systems and contexts that differ from those in Northern Europe. Additionally, many studies focus on specific professionals, while relatively little research has been conducted on community pharmacists or general practitioners (GPs) in Sweden or similar healthcare contexts. This highlights a need for more locally relevant studies to better understand the attitudes and practices of HCPs in these settings. While physicians and pharmacists are key actors in shaping pharmaceutical practices, their perspectives, motivations, and perceived barriers have received relatively little attention in environmental research. Without insight into how these professionals engage with the issue, it is difficult to design interventions that are both effective and feasible in clinical settings.

Aims of the thesis

The overall aim of this thesis was to study drug utilisation in relation to environmental risk and to explore the role and responsibility of healthcare professionals in reducing the environmental impact of pharmaceuticals. This has been addressed through the following four specific aims:

I. to investigate drug utilisation in relation to environmental hazard - using analgesics in the region surrounding Lake Mälaren as an example,

II. to explore stakeholders' perspectives on, and use of knowledge support systems for pharmaceuticals in the environment,

III. to investigate to what extent general practitioners in Sweden are willing to integrate environmental aspects in treatment decisions and their opinions on policies to reduce pharmaceutical pollution,

IV. to explore how community pharmacy staff perceive their role in reducing pharmaceutical pollution and identify the opportunities and challenges they face in promoting the environmentally informed use of pharmaceuticals.

The focus of this thesis was on use-oriented measures, with an emphasis on the roles and responsibilities of HCPs. As its primary focus is pharmaceutical pollution arising from human use; other sources, such as manufacturing emissions and, for the most part, veterinary use, fall outside the scope. The analysis is grounded in the Swedish context; however, some of the findings may apply more broadly.

Methods

This chapter provides an overview of the studies included in the thesis (Table 1), including the setting, study designs, data collection, data analysis, and ethical considerations. Four studies were conducted, comprising both quantitative and qualitative methods: Studies I and III were quantitative with cross-sectional designs, while Studies II and IV employed qualitative interviews and focus group discussions (FGDs).

Table 1 Overview of the studies that form the basis for this thesis.

	Design	**Data collection**	**Material/ Study population**	**Study period**
Paper I	Cross-sectional	Swedish eHealth Agency: National sales data	Municipalities surrounding Lake Mälaren	2021 - 2022
Paper II	Qualitative	Interviews	Stakeholders from regional and national authorities, the pharmaceutical industry, a research institute and academia	2021 - 2022
Paper III	Cross-sectional	Questionnaire	Swedish general practitioners	2023 - 2024
Paper IV	Qualitative	Focus group discussions and individual interviews	Community pharmacy staff in the Uppsala/Stockholm region, Sweden	2024 - 2025

The Swedish healthcare setting

All studies included in this thesis were conducted within the Swedish healthcare system, although in different healthcare contexts. Sweden operates a universal healthcare system, publicly funded through taxation. The system is decentralised, with 21 geographical regions responsible for organising and delivering healthcare services, including primary care and hospital services.[71] Sweden also has a long-standing commitment to environmental protection and

sustainable development, which is reflected in national policies, healthcare strategies, and educational frameworks.[72–74]

The Swedish Medical Products Agency (MPA) is responsible for the approval and regulation of pharmaceuticals. Environmental aspects are not permitted to influence the approval process of new pharmaceuticals.[71] However, the MPA has taken steps to address pharmaceutical pollution. For example, in 2019, the Knowledge Centre for Pharmaceuticals in the Environment was established with the main task to coordinate and disseminate knowledge about the environmental impact of pharmaceuticals and promote sustainable practices across the pharmaceutical lifecycle.[75]

The pricing and reimbursement of pharmaceuticals in Sweden is managed by the Dental and Pharmaceutical Benefits Agency (TLV). TLV determines whether a pharmaceutical should be included in the national reimbursement system, which covers the cost of prescribed medications for patients, subject to a high-cost threshold.[71] While environmental impact is not currently a formal criterion in TLV's pricing decisions, a pilot project has been developed to explore the possibility of awarding a bonus to manufacturers that can demonstrate environmentally safe manufacturing practices. This initiative targets specific pharmaceutical groups identified as particularly harmful to the environment (antibiotics, sex hormones, and non-steroidal anti-inflammatory drugs (NSAIDs)). Manufacturers who meet defined environmental criteria may receive a premium, incentivising greener production practices.[76]

Many Swedish regions have taken proactive measures to promote environmentally friendly prescription practices. This work has in large been conducted by Drug and Therapeutics Committees (DTCs), which are legally mandated bodies responsible for developing regional treatment guidelines. Each of Sweden's 21 regions has its own DTC, ensuring that pharmaceutical recommendations are adapted to local healthcare needs. First-line pharmaceuticals are selected based primarily on their efficacy, safety, and cost-effectiveness.[74,77] In recent years, some regions have included environmental aspects as a selection criterion.[45] The DTCs are also responsible for continued professional education, and many regions have educational material about PiE available for HCPs.

There are two publicly accessible web-based knowledge platforms, providing environmental information on pharmaceuticals: Janusinfo, developed by Region Stockholm, and Fass, Sweden's national drug formulary.[45,78] Janusinfo presents environmental data at the substance level, while Fass provides information at the product level. In addition to environmental data, both platforms offer a wide range of pharmaceutical information that serves as decision support for HCPs.

Primary care centres and hospitals may be either publicly or privately operated, but the vast majority work under contract with the public payer and are required to follow guidelines and policies.[71] Physicians in Sweden hold broad prescribing rights and are legally authorised to prescribe nearly all pharmaceuticals available on the Swedish market. Prescribing practices are expected to be evidence-based and aligned with national and regional treatment guidelines. While healthcare units operate within budgetary restraints, individual treatment decisions remain at the discretion of the prescriber, guided by clinical judgement and therapeutic recommendations.[71]

The Swedish pharmacy market is dominated by a few large chains, complemented by a smaller number of independent pharmacies. All pharmacies operate under the supervision of the Swedish MPA. Swedish pharmacies are legally required to ensure the availability of all prescribed pharmaceuticals and to provide guidance on their safe and effective use. In addition, most pharmacies include self-selection areas where customers can access over-the-counter pharmaceuticals (OTC) and related health products. OTC sales outside of pharmacies, such as in grocery stores, are also permitted for a limited range of pharmaceuticals.[79] As part of their responsibility for environmentally responsible handling of pharmaceuticals, community pharmacies in Sweden are required to accept unused and/or expired pharmaceuticals from the public to ensure proper disposal.[80]

Study designs

Drug utilisation research (DUR) applies a range of quantitative and qualitative methods to describe and evaluate how pharmaceuticals are prescribed, dispensed, and used within healthcare systems. Although DUR has a long tradition in examining appropriateness, safety, quality, equity, and cost, it has far less been applied to research on PiE.[81] Environmental aspects of drug utilisation can be studied in several complementary ways: by analysing prescribing, dispensing or sales data, by gathering patient and provider perspectives through surveys or interviews, and by triangulating with environmental monitoring (e.g., measurements in wastewater or surface waters).[82] In this thesis, I adopt this perspective using two study designs: cross-sectional studies (Papers I and III) and qualitative studies (Papers II and IV).

Quantitative studies

In study I, a retrospective cross-sectional approach was employed to describe sales of analgesics in the Lake Mälaren region over a defined period (2016–

2020). A cross-sectional design enabled the analysis of aggregated sales data across multiple years, providing a snapshot of utilisation trends without requiring longitudinal follow-up of individual patients. A cross-sectional method is well-suited for identifying patterns in prescribing and dispensing practices, as well as for assessing potential environmental risks associated with pharmaceutical use at a population level.[83]

In study III, a cross-sectional questionnaire was used to capture GPs' attitudes, priorities and self-reported practices regarding the inclusion of environmental aspects in prescribing. This design was chosen to estimate the prevalence of specific views and to compare subgroups.

Qualitative studies

In study II, a qualitative interview design was used to examine stakeholders' perspectives on two Swedish environmental knowledge support systems for pharmaceuticals (Janusinfo.se and Fass.se). This approach was chosen to investigate how such tools are perceived, trusted, and applied in practice, or which features facilitate or hinder their use in clinical and policy settings. Semi-structured interviews enabled flexible probing around credibility, transparency, decision-making criteria, and implementation barriers, and allowed participants to provide concrete examples from their own contexts.[84]

In study IV, qualitative methods were employed to explore community pharmacy staff's views on their role in reducing the environmental impact of pharmaceuticals. A combination of FGDs and semi-structured individual interviews was used. The focus groups enabled participants to react to and build on each other's reflections, revealing areas of consensus and divergence regarding current practice, desired future roles, and perceived barriers and enablers. Individual interviews with pharmacy managers were conducted to complement the focus groups, thereby reducing the risk of power imbalances in group discussions.

Paper I

Data collection

Sweden has a tradition of maintaining high-quality registers, and all dispensed prescriptions are included in a national database.[85] In Study I, aggregated sales data of analgesics were collected from the Swedish E-health Agency. Total sales of the following analgesics were included: Anatomical Therapeutic Chemical (ATC)-groups: (Q)M01A (NSAIDs), (Q)M02A (NSAIDs for topical use), (Q)N02A (opioids), and (Q)N02B (paracetamol and other non-opioid

analgesics) for human and veterinary use. Data encompassed pharmaceuticals sold by prescriptions, OTC, and supplies to hospitals/health facilities; OTC sales were split into pharmacy and non-pharmacy outlets. Veterinary use covered pharmaceuticals that were prescribed, sold OTC, and sold as outpatient supplies, with animals classified as food-producing, companion, or other (per the Swedish Board of Agriculture).[86] Extemporaneous preparations and unlicensed products were excluded.

Analysis

Data were analysed and measured in kilograms by API. The total mass was divided by the population in the region (1.15 million inhabitants) and the total land area (24,523 km²) to assess the intensity of environmental emissions from a population and geographical perspective, respectively. The utilisation was presented in relation to the inherent environmental hazard of the API. Classification data on the environmental hazard of the APIs were collected from the database Pharmaceuticals and Environment at Janusinfo.se.[87] This classification system includes data on persistence, bioaccumulation, and ecotoxicity. Each property is assigned a value between 0 and 3, resulting in a total hazard score of 0 and 9. A high score indicates a higher environmental hazard.[45] In this paper, the classification was simplified by classifying APIs with a hazard score of 0–3 as low hazard, 4–6 as medium hazard, and 7–9 as high hazard. Proportions of low, medium, and high-hazard pharmaceuticals were calculated by dividing the number of kilograms of the API in each group by the total mass of the APIs in the study.

Paper II

Data collection

Semi-structured interviews were conducted with stakeholders with experience with Janusinfo/Fass, pharmaceutical policy, and inter-sectoral collaboration. Purposeful sampling ensured relevant expertise, and snowball sampling was used to reach additional information-rich participants.[88]

An interview guide was developed, including questions on participants' professional background, their use of the knowledge support systems, and suggestions for improvement. The guide allowed for adaptation during the interviews, such as reordering questions, reformulating them, or probing more deeply when needed, to capture richer and more nuanced insights.[84]

In total, 21 expert stakeholders were interviewed during November and December 2021. All interviews were moderated by a female pharmacy student

from the US (E.L). A Swedish female co-moderator (J.V) took field notes and assisted in asking follow-up questions. Interviews were conducted either face-to-face or via videoconferencing platforms, depending on participants' preferences and practical considerations. After each interview, the moderator and the co-moderator discussed their spontaneous impressions and perceived key themes. All interviews were audio recorded and transcribed.

Analysis

Data were analysed using an inductive content analysis approach.[89] The two interviewers (E.L and J.V) independently coded the first three transcripts to develop preliminary themes. In an early consensus meeting, relationships among themes were identified and consolidated into three overarching themes. The thematic structure was reviewed and validated by an additional researcher. The remaining analysis was conducted by E.L with input from the team. Two subsequent consensus meetings further refined the analytic framework and specified subthemes.

Paper III

Data collection

Primary data were collected using a questionnaire distributed to GPs. Questionnaires are a common research tool in pharmacoepidemiology and health sciences as they enable researchers to collect large amounts of data from many participants simultaneously, often at relatively low cost, and on aspects not captured in existing registers. They are flexible in design, allowing specific questions to be tailored to the research objectives. Questionnaires are particularly valuable for capturing attitudes, beliefs, and self-reported behaviours, and they also make it possible to compare responses across different groups.[90]

For this paper, a structured digital questionnaire was developed, consisting of two main parts. The first part included three clinical patient cases focused on pharmaceuticals used for pain management, blood pressure reduction, and contraception. These cases were inspired by previous questionnaires[91,92] and refined with input from clinicians to ensure clinical relevance.

Each patient case presented respondents with two hypothetical pharmaceuticals, described by two attributes: therapeutic effect and environmental impact. These attributes were categorised as low, medium, or high. Each respondent received a unique combination for each case and was asked to indicate which pharmaceutical they would prescribe and to rate their level of

satisfaction. Hypothetical pharmaceuticals were used to prevent bias from known pharmaceutical properties.

The second part of the questionnaire included 10 statements on measures for environmentally responsible use of pharmaceuticals and responsibility allocation, reflecting ongoing discussions in Sweden and the EU. Respondents were asked to indicate their attitudes toward these statements. The questionnaire also included items on prescribing behaviour, such as the frequency of considering cost, user-friendliness, dosage interval, DTC recommendations, and environmental impact. Demographic and professional background questions covered age, sex, region, year of graduation, educational status, and involvement in quality improvement, professional networks, and environmental organisations.

All 21 regional DTCs in Sweden were invited to assist in distributing the questionnaire to GPs. In total, the questionnaire was sent to 1,233 potential respondents across Sweden. Distribution was managed via REDCap (version 13.7.14, © 2023 Vanderbilt University) between September 2023 and June 2024.

Analysis

Data were processed and analysed using R software (version 4.2.1).[93] To examine the trade-off between therapeutic effect and environmental impact, mixed effects linear regression was used, accounting for repeated measures from individual respondents. Descriptive statistics were used to analyse pharmaceutical choices across cases. Logistic regression estimated odds ratios (OR) for choosing the less environmentally harmful option, based on sex, age, and educational status. Responses to environmental statements were analysed using descriptive statistics and the Wilcoxon signed-rank test.

Paper IV

Data collection

Both FGDs and individual interviews were conducted with community pharmacy staff for Paper IV. A semi-structured interview guide was developed and used in both the focus groups and individual interviews. The interview guide covered current practices, desired future roles, and perceived barriers to contribute to environmentally informed pharmaceutical use.

Participants were recruited using purposeful sampling with maximum variation.[88] Interviews were conducted from May 2024 to February 2025, either online or face-to-face. The moderator (J.V) facilitated the discussion and

ensured that participants interacted with each other rather than only responded to the moderator's questions. Efforts were made to create space for all participants to share their views. In addition to the moderator, an observer (N.L) was present during the discussions, taking notes on participants' behaviour and the group interaction. The observer also supported the moderator by keeping track of emerging issues and potential follow-up questions. After each FGD/interview, the moderator and observer carried out a short debrief, where spontaneous impressions and perceived key themes were discussed. All interviews were audio-recorded and transcribed.

Analysis

An inductive, Krueger-inspired content analysis[94] was conducted. After familiarisation, open coding produced a preliminary scheme and overarching categories. A second researcher (S.K.S) independently analysed four transcripts (two focus groups and two individual interviews), and a consensus meeting reconciled the differences and refined the scheme. The remaining transcripts were coded to this framework, which was iteratively updated through further consensus meetings until satisfactory intercoder agreement was reached. Interpretations were reviewed in team meetings, and the assistant moderator (N.L) audited the final coding.

Ethical considerations in the research process

Study I is based on already published environmental classification information and aggregated readily available pharmaceutical sales data, with no personal data. It did, therefore, not require any ethical approval.[95] Even if there is no risk for an invasion of privacy for individuals, there could still be ethical dilemmas in conducting research on aggregated registry data. Potential concerns include the risk that findings are misinterpreted as quality metrics and used to justify restrictive measures that could undermine appropriate treatment.

Primary data was collected for studies II, III, and IV. These studies all explored professional opinions, and no sensitive data was collected. However, ethical aspects were considered throughout the studies. All participation was voluntary, and each participant could withdraw their participation at any time. Informed consent was given by participants before participating in the interviews/questionnaire. Audio files and transcriptions as well as survey data are stored anonymised on a secure server. Participants in studies II, III and IV were informed about the project before agreeing to participate. An advisory statement from the Ethical Review Authority was applied for concerning

studies III and IV. The Ethical Review Authority had no ethical objections to these research projects (Dnr: 2023-01949-01). Ethical reflections and implications of the research are further discussed in the Discussion section.

Results

This chapter provides a summary of the results.

Paper I

Between 2016 and 2020, a total of 454 tonnes of analgesics were sold in the Lake Mälaren region, corresponding to 396 kg per 1,000 inhabitants or 18.5 kg per km². In total, 45 different APIs and 26 million packages were sold during the study period. Paracetamol, ibuprofen, and acetylsalicylic acid, classified as low environmental hazard, were the three most sold APIs and together accounted for 95% of the total mass (Figure 2). Naproxen (medium hazard) ranked fourth, and diclofenac (high hazard) ranked fifth. Tramadol (1,802 kg) and codeine (1,015 kg) dominated opioid sales, environmental hazard data were not available for these and most other opioids.

For human use, 95% of the most sold APIs (in total mass) were classified as low hazard. For veterinary use, 82% of the sold APIs lacked hazard data. Prescription sales represented the largest share of the total mass (60%), followed by OTC sales (36%), with hospital and outpatient sales together accounting for approximately 4%. Urban municipalities accounted for the highest total mass of analgesic sales, although per capita differences across municipalities were less pronounced.

Tablets were the dominant formulation. Ibuprofen and diclofenac were the only APIs available in topical formulations. During the study period, 118 kg of topical ibuprofen and 1,156 kg of topical diclofenac were sold; for diclofenac, topical products accounted for roughly half of total sales. A total of 1,073 kg of topical diclofenac was sold OTC. For veterinary use, carprofen, phenylbutazone, and firocoxib were the top APIs, together accounting for 401 kg (none of these had available environmental hazard data). A total of 1,023 kg of analgesics were sold for veterinary use, with companion animals accounting for 58% of documented sales and food-producing animals 42%.

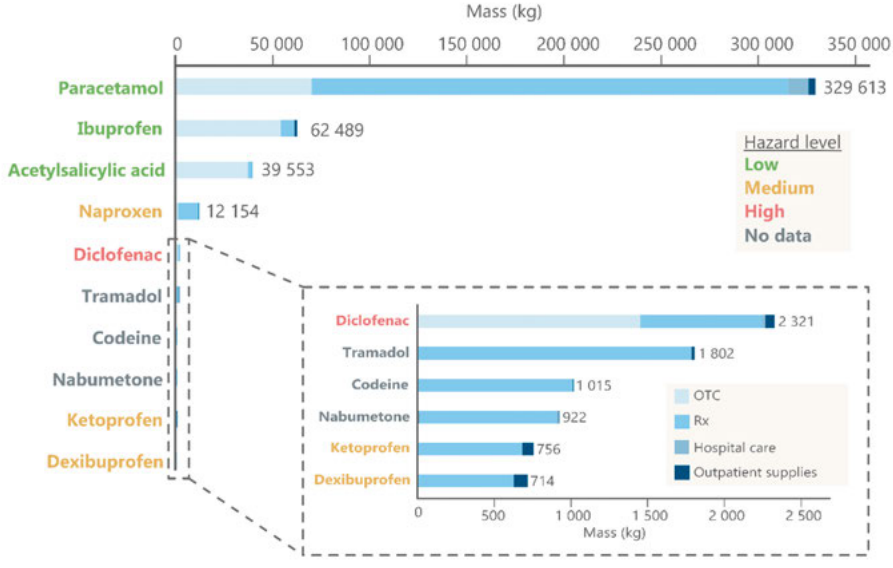

Figure 2 From paper I: Sales, in kilograms, of the 10 most-used analgesics and non-steroidal anti-inflammatory pharmaceuticals for both human and veterinary use, from 2016–2020.

Paper II

A total of 21 stakeholders representing Swedish national and regional authorities, the pharmaceutical industry, research institutes, and academia were interviewed regarding Fass and Janusinfo. Participants had expertise spanning healthcare governance, policy, regulation, consultancy, and research related to pharmaceuticals and the environment. Content analysis of the interviews identified three main themes: transparency, impact, and barriers to impact.

Transparency was considered a key determinant of the value of the knowledge support systems, encompassing both accessibility and credibility. Respondents valued public availability of environmental data but expressed concerns regarding the ownership of Fass by the pharmaceutical industry, citing conflicts of interest, voluntary participation, removal of data, and inconsistent environmental classifications. Janusinfo was generally viewed as more up-to-date, consistent, and user-friendly, particularly because it presents information per API rather than per product. Suggestions to improve credibility included greater involvement of national or international authorities, external expert review, and the inclusion of manufacturing emissions data.

Both knowledge supports were recognised for facilitating awareness, research, policy development, and, in the case of Janusinfo, supporting DTCs in integrating environmental considerations into treatment recommendations.

However, their overall impact was limited by competing decision-making criteria, with efficacy, safety, and cost typically outweighing environmental aspects. Ethical constraints, such as the inability to restrict access to essential pharmaceuticals lacking alternatives, were also noted. Additional barriers included a lack of ERA data for older pharmaceuticals, limited resources, insufficient time for prescribers to consider environmental aspects, and the complexity of interpreting the information.

Paper III

A total of 272 GPs and physicians in training responded to the questionnaire (22% response rate), of whom 254 completed it in full. The majority were women (58%), born in 1980 or later (63%), and nearly one-third (29%) were physicians in training. Most respondents (88%) considered environmental and climate issues to be fairly or very important, and 38% reported involvement in quality improvement initiatives, professional networks, or environmental organisations, including 14% who were members of a DTC.

When evaluating hypothetical pharmaceuticals, satisfaction ratings were highest for pharmaceuticals with medium therapeutic effect and low environmental impact and lowest for those with medium therapeutic effect and high environmental impact. Each increase in environmental impact level was associated with an average 1.2-unit decrease in satisfaction (on a 1–10 scale) (Figure 3). In patient case scenarios, the majority chose to prescribe the least environmentally harmful option: 77% for pain and high blood pressure treatment and 50% for contraception. Older respondents were more likely to select the less environmentally harmful option (adjusted OR = 1.3 per age category), while sex was not associated with choice. Physicians in training were less likely than those with a full medical degree to select the less environmentally harmful option in unadjusted analysis, but this difference was not statistically significant after adjustment for age and sex.

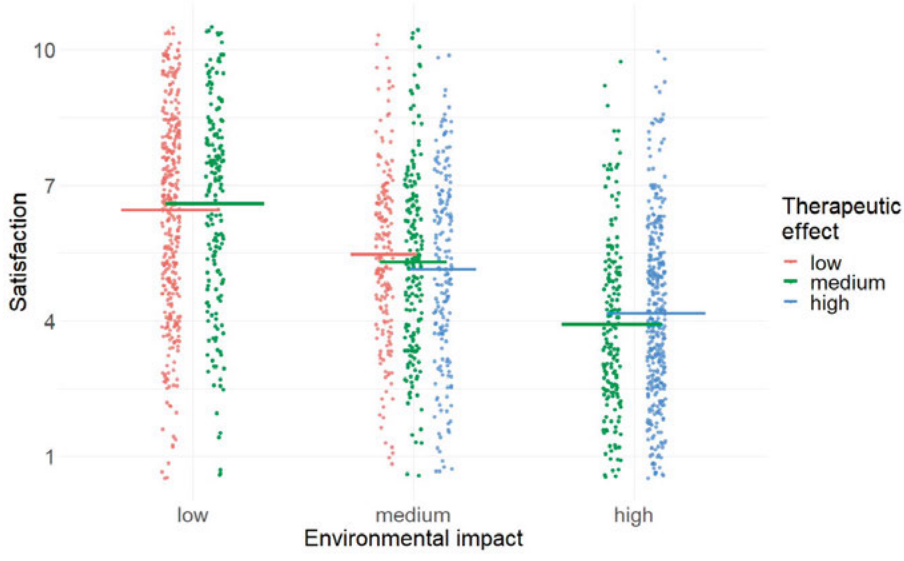

Figure 3 From paper III: Jitter plot illustrating satisfaction rating by therapeutic effect and environmental impact. Respondents rated their satisfaction with the pharmaceuticals across 3 scenarios and, in total, 6 hypothetical pharmaceuticals. Each point in the plot represents an individual response (N = 1603). Satisfaction ratings range from 1 (low satisfaction) to 10 (high satisfaction). The coloured lines indicate the mean satisfaction for each combination of therapeutic effect and environmental impact. Points have been jittered to avoid overplotting.

Environmental impact was infrequently considered in prescribing decisions: 24% stated that they considered it often or always when treating individual patients; however, only 6% reported often searching for environmental information. DTC recommendations were the most influential factor in prescribing (86% often or always), followed by dosage interval and user-friendliness, with cost and environmental impact ranking lower.

There was strong support for measures to reduce the environmental impact of pharmaceuticals, particularly for stricter environmental regulations on pharmaceutical companies (94%) and mandatory publication of environmental data (92%) (Figure 4). Support was also high for integrating environmental considerations into market authorisation decisions (78%) and influencing prescription-only status (69%). Women, older respondents, and those with a full medical degree were generally more supportive of the proposed measures.

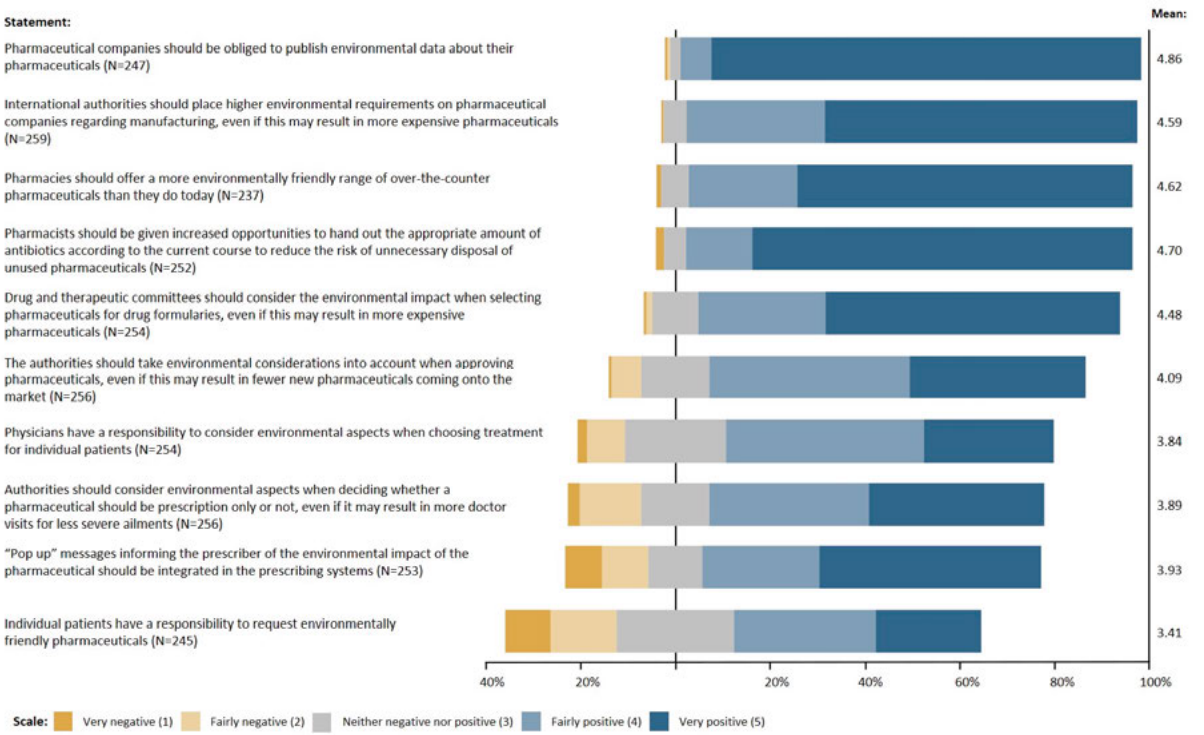

Figure 4 Likert graph showing the extent to which respondents agreed with ten statements on environmentally sustainable use of pharmaceuticals, reported as a percentage of total respondents. Responses indicating 'No opinion' or missing answers are not included in the figure.

Paper IV

Nineteen pharmacy staff participated in the study, comprising four focus groups with two to six participants each and five individual interviews with pharmacy managers. Participants represented all four major Swedish pharmacy chains, most were women with a university degree in pharmacy, and the median work experience was nine years. The analysis generated three main categories. First, while participants were aware of environmental issues, they expressed a lack of concrete guidance and requested more information, such as lists of environmentally harmful pharmaceuticals. Second, pharmaceutical waste, originating both from households and pharmacies, was highlighted as a significant concern. Third, there appeared to be a sense of limited agency and a wish for support from, for example, regulatory authorities to address pharmaceutical pollution.

Participants recognised pharmaceuticals as an environmental concern, frequently mentioning diclofenac, antibiotics, and hormones, but described their knowledge as limited and requested practical tools, such as lists of high-risk pharmaceuticals, to guide their work. Pharmaceutical waste emerged as the most prominent issue discussed, with frustration expressed over large volumes of unused pharmaceuticals. Contributing factors included overprescribing, large package sizes, limited availability of starter packs, systemic incentives such as the Swedish reimbursement system, and employer pressure to dispense all prescribed pharmaceuticals. Strategies to reduce waste included patient counselling, questioning unnecessary refills, and inventory management, although barriers such as legal restrictions on breaking packages and rigid generic substitution rules were mentioned.

Although participants expressed willingness to address pharmaceutical pollution, they perceived limited ability to act at the pharmacy level, emphasising that key decisions must be made by regulatory authorities and higher-level management. Views on the commitment of pharmacy chains to environmental issues varied, and financial considerations were often perceived as outweighing sustainability efforts. Responsibility was also placed on pharmaceutical manufacturers to ensure environmentally safe production and on physicians to consider environmental aspects in treatment choices. Low public awareness was seen as a barrier to change, and public campaigns were suggested to increase knowledge and promote environmentally informed use of pharmaceuticals.

Discussion

This thesis has examined drug utilisation in relation to environmental risk, with a focus on how environmentally responsible use of pharmaceuticals can be promoted within healthcare systems. The emphasis is on use-oriented measures and the roles of different healthcare professionals. The findings underscore that reducing the environmental burden of pharmaceuticals is a complex challenge that requires active involvement of multiple actors, each with different responsibilities and roles.

This general discussion seeks to combine the findings of this thesis and to put them in a broader perspective of environmentally responsible use of pharmaceuticals. For this purpose, I will address the following topics:

1. Awareness to action gap: This thesis highlights that despite growing awareness, a significant gap remains between awareness and action. Here, I discuss the need for a system shift among all stakeholders, emphasising that the perceived lack of ability to act is often linked to limited data, unclear decision-making criteria, and a lack of concrete guidance.
2. Physicians' and pharmacists' role and responsibility: One of the central findings of this thesis concerns how the role and responsibility of HCPs in promoting environmentally informed pharmaceutical use can be understood. This section outlines the role and responsibility of physicians and pharmacists, including their role in preventing waste, contributing to pharmaceutical stewardship, and the importance of education and support to strengthen their capacity to act.
3. A systematic approach to mitigate pharmaceutical pollution: A key result from this thesis is that in order to ensure environmentally responsible use of pharmaceuticals, a systematic approach is required. This section elaborates on how such an approach can be embedded in decision-making processes, including policy developments at the EU level. It also explores how DTCs can integrate environmental criteria into treatment recommendations and quality indicators.

Awareness to action gap

The findings of this thesis reveal a gap between awareness of pharmaceutical pollution and the perceived ability to act upon it. Across the studies, participants, including stakeholders in Paper II, GPs in Paper III, and pharmacy staff in Paper IV, expressed engagement with the issue and a willingness to contribute to solutions. However, this engagement was often accompanied by a sense of powerlessness and uncertainty about how to translate concern into concrete action. This gap between awareness and action among HCPs is consistent with results from similar studies.[63,65,66,96]

A key factor contributing to this gap is the lack of reliable and accessible environmental risk data. As highlighted in Paper II, even among experts and decision-makers, the absence of environmental risk data, particularly for older APIs, was a barrier to concrete action. This lack of data is not merely a technical issue; it also has practical consequences. Without robust and transparent environmental risk data, HCPs face significant challenges in making informed decisions, as it is difficult to compare alternatives or to justify environmentally motivated substitutions.

This uncertainty is further exacerbated by unclear decision-making criteria. While several Swedish regions have begun to incorporate environmental aspects into treatment guidelines, as shown in Paper II, cost and patient ethics often take precedence. Participants noted that it would be ethically problematic to withhold treatment due to environmental concerns when no clinically equivalent alternative exists. This reflects a complex balancing act between immediate patient needs and broader sustainability goals. However, the ethical dimension of pharmaceutical pollution extends beyond the individual patient encounter. The healthcare decisions we make today have long-term consequences, not only for current populations but also for future generations. Continued environmental degradation caused by pharmaceuticals may compromise access to clean water, healthy ecosystems, and ultimately, the effectiveness of medical treatments in the future. Ensuring that future generations have access to safe and effective healthcare requires that environmental considerations be integrated into clinical guidelines and policy decisions rather than leaving individual prescribers to make these trade-offs. This tension between short-term clinical priorities and long-term environmental responsibility underscores the need for clearer guidance on how environmental criteria should be weighted in clinical and policy decisions, guidance that could also help bridge the gap between awareness and action.

The discrepancy between awareness and action was also evident in study III, where many GPs expressed a willingness to accept modest trade-offs, in terms of increased costs or reduced convenience, if it meant reducing

environmental harm. Yet, environmental impact ranked lowest among the factors influencing prescribing, trailing behind cost, regional guidelines, dosing schedules, and user-friendliness. This suggests that while attitudes are positive, environmental concerns remain peripheral unless they are embedded in formal structures. Indeed, a majority of physicians preferred that environmental aspects should be incorporated into treatment guidelines rather than left to individual decision-making.

Similarly, Paper IV showed that pharmacy staff were open to engaging with PiE-related issues but lacked structured opportunities and institutional support to do so. These findings point to a broader need for concrete, operational guidance that can translate environmental concern into practice. Although national and international guidelines and toolkits exist,[97–99] they appear to be insufficiently embedded in everyday routines. Without clear guidance, the willingness to act risks remaining just that: a willingness, rather than a change in practice.

This gap between awareness and action reflects what is also commonly referred to as the knowledge–action gap or the theory-practice gap. It describes the disconnect between what individuals know or care about and the extent to which that knowledge informs their behaviour.[100] In the context of PiE, this gap is not unique to HCPs. Climate change serves as another prominent example of this wicked problem: despite overwhelming scientific evidence and widespread public awareness of its causes and consequences, individual and collective actions remain insufficient.[101]

Physicians' and pharmacists' roles and responsibilities

HCPs play a pivotal role in promoting environmentally informed pharmaceutical practices. Physicians and pharmacists in particular are well-positioned to support rational and environmentally responsible use. Through informed prescribing, patient education, and advocacy for environmentally preferable alternatives, they can contribute meaningfully to reducing pharmaceutical pollution.

Physicians bear significant responsibility for what and how much they prescribe. Findings from Paper III show that GPs are willing to integrate environmental considerations into prescribing decisions. However, this is not always straightforward: environmental risk data are often missing for many APIs,[10] and even when such data exist, they are not sufficient on their own. To make informed choices, comparative data on therapeutic alternatives are needed to avoid simply shifting the risk from one API to another. Furthermore,

pharmaceuticals with similar clinical effects frequently share similar environmental risks, which limits the availability of genuinely greener options.[102]

Since switching to a more environmentally friendly alternative is not always straightforward, this issue can also be addressed through broader approaches such as pharmaceutical stewardship. As illustrated in Paper I, the case of diclofenac raises important questions. Although the majority of diclofenac sales in Sweden occur as OTC sales, a substantial portion is still prescribed. This invites reflection on whether such prescribing is always clinically necessary, and whether more can be done to reduce unnecessary prescribing. For NSAIDs, stewardship should begin with necessity: before replacing diclofenac with a "greener" option, first consider whether an NSAID is needed at all. NSAIDs are widely used and can cause serious gastrointestinal, cardiovascular, and renal harm.[103] In this context, there are clear synergies between what is good for the patient and what is good for the environment. Reducing unnecessary use not only improves patient safety but also mitigates pharmaceutical emissions. The prevailing "a pill for every ill" culture is neither clinically nor environmentally rational. The principle of non-maleficence, do no harm, must extend beyond the individual patient to include ecological and intergenerational dimensions.[12,104] In this light, the continued use of environmentally harmful substances like diclofenac raises uncomfortable questions: is its prevalence driven by clinical necessity, or by the enduring influence of industry marketing?

The issue of pharmaceutical waste further underscores the importance of HCPs' role. According to WHO, more than half of all pharmaceuticals are prescribed, dispensed, or sold inappropriately, and approximately half of all patients do not use them as intended.[105] Such patterns of overuse, underuse, and misuse contribute not only to the inefficient use of limited healthcare resources and pose significant risks to public health, but also contribute to environmental harm. Inappropriate prescribing practices can also reinforce the belief that every symptom requires pharmacological treatment. This mindset may lead to unnecessary use of pharmaceuticals and exacerbate the issue of pharmaceutical pollution. Paper IV, along with previous research,[66,67,106,107] highlights that HCPs consistently view pharmaceutical waste as a recurring and substantial problem. Estimates of household pharmaceuticals becoming waste vary widely (≈3% to 50%).[108] National take-back schemes illustrate the scale: in France, households disposed of ~17,600 tonnes in 2018,[108] and in Sweden, ~1,400 tonnes were returned to pharmacies in 2024.[80] Some disposal is inevitable (e.g., dose adjustments, adverse effects, therapy discontinuation, end-of-life care), underscoring the need for accessible, well-communicated take-back programmes. However, much of

this waste is preventable through responsible prescribing and dispensing, medication reviews, and deprescribing.[108,109]

Pharmacists in Sweden are obligated to dispense the prescribed pharmaceutical and have limited influence over the choice of drug. As shown in Paper IV, their most immediate sphere of impact in this context lies in promoting safe and effective use, as well as preventing avoidable waste, through counselling and ensuring that pharmaceuticals are dispensed at the appropriate time and in pack sizes aligned with the intended treatment duration. In the OTC context, community pharmacies carry substantial responsibility and have greater autonomy to influence consumer choices. Paper IV indicates that staff are willing to steer customers toward clinically appropriate, lower environmental impact OTC options. However, they lack the knowledge and tools to do so. In Sweden, pharmacy chains have sought to raise awareness through shelf labelling and by introducing the Well selected label (Välvald). This transparency and sustainability label signals products that meet specified criteria, including a publicly available sustainability report aligned with recognised standards and verified by a third party.[110] Particular attention has been paid to diclofenac: an industry-wide agreement has for several years encouraged staff to inform customers about its environmental effects and to recommend cautious use, and since 2023, diclofenac has been placed behind the counter, enabling targeted counselling at the point of sale; this change has coincided with a decline in sales volumes.[111] By contrast, the effect of the Well selected label appears less clear. Findings by Salehi et al.,[112] suggests that many pharmacists misunderstand the label's content and purpose, making it difficult to convey its meaning to customers.

One critical area to improve HCPs' role and responsibility is to strengthen education and training on the environmental aspects of pharmaceuticals. Findings from this thesis suggest that both GPs and pharmacists require concise, clinically oriented education to effectively integrate environmental aspects into their routine practice. The EC's Strategic Approach to Pharmaceuticals in the Environment calls for exploring how environmental considerations can be integrated into medical education and continuing professional development.[47] These competencies are best introduced within a One Health framework, to strengthen preparedness for climate- and pollution-related health challenges and to improve population health.[113,114] Positive signals are emerging, for example, the University of Helsinki's Faculty of Pharmacy has established what is described as the first professorship in Sustainable Pharmacy, targeting sustainability gaps across the pharmaceutical lifecycle and the reduction of pharmaceutical pollution.[115] Equipping HCPs with such knowledge and resources is essential to enable meaningful change.

A systematic approach to mitigate pharmaceutical pollution

The studies presented in this thesis emphasise a central conclusion: addressing the environmental impact of pharmaceuticals cannot rely on the actions of individual HCPs alone. While personal engagement and awareness are important, they must be supported by coordinated, system-level strategies that enable and encourage environmentally informed choices.

Findings from Paper II highlight that knowledge support tools, especially the Janusinfo database, are perceived as particularly valuable for stakeholders operating at a systemic level, especially policymakers and DTCs. One of the most significant impacts of these tools has been their role in enabling the integration of environmental aspects into treatment recommendations. Additionally, many participants noted that individual physicians often lack the time and capacity to consider environmental information during patient consultations, and that such information can be difficult to interpret without clear guidance. Paper III further reinforces the importance of system-level interventions. Participants cited DTC recommendations as the most influential factor in treatment choices. Statements advocating for structural measures, such as stronger legislation regarding PiE, received broad support, underscoring the need for regulatory frameworks that facilitate environmentally sound prescribing. Paper IV adds to this by revealing that pharmacy staff feel constrained by factors beyond their control. There was a clear call for regulatory support and decision-making at higher levels, with participants emphasising that meaningful change requires action from national and international authorities.

One recurring theme across the studies is the need for strong governance and clear direction, both nationally and at the EU level. Encouragingly, developments are, notably, underway. The newly revised EU ERA guidelines,[116] effective from September 2024, aim to strengthen environmental protection by improving transparency and harmonising ERA procedures. Additionally, the proposed new human pharmaceutical legislation will give greater weight to environmental impact, potentially influencing the approval process for new pharmaceuticals,[116] a limitation identified in this thesis and by other stakeholders.[117] These developments reflect a growing recognition of the need for publicly available environmental data to support informed decision-making.

At the regional level, DTCs play a pivotal role in operationalising environmental responsibility. Their treatment recommendations and first-line selections shape everyday prescribing, education, and decision support.[74] Integrating environmental criteria into DTC guidelines, together with concise substitution advice where clinically equivalent options exist, can support

environmentally responsible choices. Equally important is the provision of accessible, up-to-date knowledge support. As shown in Paper II, the Janusinfo database on PiE, provided by Region Stockholm, functions as a strong reference point in the Swedish context, with stakeholders such as government agencies and DTCs using the data to make an impact on prescribing guidelines as well as research. There have been calls for authorities such as the EMA to take responsibility for providing a centralised, openly accessible database.[45,118]

Another systematic approach to addressing the environmental impact of pharmaceutical use, where DTCs play a crucial role, is through benchmarking and continuous quality improvement. By comparing prescribing patterns across departments or regions, DTCs can identify outliers and best practices. This enables the development and monitoring of quality indicators that link process measures, such as adherence to prescribing guidelines or reduction targets for specific substances, to outcome measures, including signals of environmental load. Through this, DTCs can embed audit-and-feedback mechanisms and align incentives, ensuring that financing structures support rational and environmentally responsible prescribing. To support such efforts, access to structured, reliable data and analytical tools is essential. In this context, the methodological approach developed in Paper I offers a valuable contribution. By applying drug utilisation data to identify environmental "hotspots"-specific therapeutic areas or geographic regions with high usage of environmentally hazardous pharmaceuticals, the model provides a practical framework for prioritising interventions. This type of analysis can help DTCs and other stakeholders to target efforts where they are most needed, guide policy development, and support evidence-informed decision-making. It also enables the integration of environmental considerations into existing monitoring systems, helping to align sustainability objectives with clinical priorities in a systematic and actionable way.

The findings from this thesis point to a critical interplay between individual actors and the system level. While individual HCPs can make choices that reduce environmental impact, such as selecting lower environmental risk pharmaceuticals, avoiding unnecessary prescribing, or ensuring proper disposal, their capacity to do so is strongly shaped by broader frameworks. National guidelines, reimbursement systems, and access to reliable environmental data all influence what is possible in practice. Strengthening HCPs' mandate to act, whether through clearer guidance, institutional support, or professional empowerment, is essential.

Methodological considerations

Research in any field faces a range of methodological challenges. These challenges differ depending on study design and whether the approach is quantitative or qualitative. In this section, I discuss key methodological considerations, with a focus on bias, trustworthiness, and generalisability.

Bias

This thesis combines quantitative and qualitative approaches, each with potential sources of bias that merit consideration.

In study I, register-based sales data were used to estimate the use of analgesics in the Lake Mälaren region. While such data provide high coverage and are valuable for identifying general usage patterns, they also carry inherent limitations: dispensing does not equate to actual consumption, and neither the timing nor the location of use can be verified. It has been estimated that approximately 5-10% of all pharmaceuticals sold in Sweden are never used, but instead returned to pharmacies or disposed of improperly.[119] These factors complicate efforts to link sales data directly to environmental concentrations. Consequently, using sales data as a proxy for environmental exposure must be approached with caution. A recently published study investigated the relationship between pharmaceutical utilisation data and concentrations in WWTPs.[120] The authors concluded that, for most APIs, usage could be estimated from wastewater traces with a typical error margin of less than twofold. While that study used environmental measurements to infer pharmaceutical use, the approach in Paper I takes the opposite direction, using sales data to identify potential environmental "hotspots." This inversion of perspective highlights the potential for triangulating different data sources to improve understanding of pharmaceutical pollution.

In the questionnaire study (Paper III), selection bias is possible, particularly if physicians with a stronger interest in environmental issues were more likely to respond. Self-reported attitudes and practices are also susceptible to social desirability, which is especially relevant in studies on environmental responsibility where respondents may overstate pro-environmental intentions or behaviours.[121] To mitigate these limitations, we used neutral item wording and ensured anonymous responses. The questions were also designed to avoid obvious "correct" answers, instead requiring respondents to consider trade-offs between different values or priorities. Additionally, associations were interpreted with caution. Variations in dissemination methods may have affected response rates. While outreach visits and email distribution were both used, these channels likely differ in effectiveness. Nonetheless, multiple

dissemination strategies were employed to ensure broader regional representation, despite some methods being less optimal. There are also limitations related to the experimental design. The study presented a simplified model of reality that does not fully capture the complexity of real-world prescribing decisions. In the questionnaire, the least environmentally harmful option was consistently framed as having a lower therapeutic effect, requiring respondents to make a trade-off. This scenario does not necessarily reflect clinical reality, where environmentally preferable pharmaceuticals are not always less effective. Furthermore, the patient case design focused solely on therapeutic effect and did not account for other relevant factors such as dosage frequency, side effects, or patient preferences, all of which may influence prescribing behaviour.

In the qualitative studies, purposive and snowball sampling in Papers II and IV were used to recruit information-rich participants, but may lead to over-representation of stakeholders who are already engaged with the topic (selection bias). To mitigate this risk, efforts were made to include a diversity of professional roles, organisational affiliations, and local contexts. In Paper II, participants were recruited not only from environmental professions but also from broader healthcare and regulatory settings. In Paper IV, pharmacy staff from both urban and rural areas, as well as from different types of pharmacies (e.g., different chains and sizes), were invited to participate. These strategies aimed to capture a wider range of perspectives and reduce the likelihood that findings would reflect only the views of highly engaged individuals. Interviewer and moderator effects, social desirability, and group dynamics (e.g., dominance and conformity in focus groups) can shape what is said and how it is said. To mitigate these risks, interviews and discussions followed neutral, open-ended prompts ("what"/"how"), space was created for divergent views, an observer documented interactional features in focus groups, and immediate debriefs supported reflexivity and consistency in data collection. FDGs were used in one of the qualitative studies (Paper IV) to capture a range of perspectives through group interaction. This method allows participants to build on each other's ideas, challenge viewpoints, and generate richer data than might be obtained from individual interviews alone. However, group dynamics can also influence what is shared, for example, dominant participants may steer the conversation, while others may be reluctant to express dissenting opinions.[122] These aspects were considered in the study design and during moderation, by encouraging contributions from all participants and using follow-up questions to ensure a diversity of views. During analysis, an inductive, team-based process and attention to both convergences and divergences were used to reduce the influence of individual preconceptions. Taken together, these

measures do not eliminate bias but help to make its potential effects explicit and to reduce its impact.

Trustworthiness

In the qualitative components of this thesis, trustworthiness was carefully considered and enhanced through adherence to established criteria: credibility, dependability, confirmability, and transferability.[123] These principles guided both the design and execution of the studies, as well as the interpretation of findings.

Credibility was supported through continuous peer debriefing within the research team. Interviews were analysed collaboratively, which enabled the identification of alternative interpretations and helped mitigate the influence of individual preconceptions. This collective approach strengthened the analytical rigor and ensured that the findings were grounded in the data rather than shaped by personal bias. To address dependability, an audit trail was maintained throughout the research process. This included documentation of methodological decisions, changes in study design, and reflections on analytical choices. Such transparency allows others to follow the research process and assess its consistency over time. Confirmability was enhanced through reflexive practices, including ongoing discussions about the researchers' preunderstandings and potential biases. These reflexive dialogues were crucial in acknowledging the subjective nature of qualitative inquiry while striving for analytical rigour. Finally, transferability was considered by providing rich descriptions of the study context and participant characteristics. By offering detailed contextual information, readers are equipped to judge the relevance and applicability of the findings to other settings. Ultimately, it is the reader who determines whether the insights presented can be meaningfully applied to different contexts.

Generalisability

All studies in this thesis were conducted within the Swedish healthcare context, characterised by strong national and regional governance, established DTCs, and widely used national knowledge support systems. The Swedish healthcare system provides universal coverage for patients and is highly digitalised, with electronic health records and e-prescriptions facilitating clinical practice. These contextual features shape pharmaceutical use and the roles of different stakeholders, and should be taken into account when considering generalisability. Nevertheless, several core findings are likely to be applicable beyond Sweden, particularly the observed awareness-to-action gap regarding

PiE, the importance of clear decision criteria and accessible environmental information, and the complementary roles of authorities, physicians, pharmacists, patients, and industry in advancing more environmentally responsible use of pharmaceuticals.

The quantitative components (register-based utilisation data and a cross-sectional questionnaire) provide estimates of patterns and associations at a defined point in time. They are most readily generalisable to settings with comparable formularies, reimbursement systems, OTC policies, and clinical guidelines. However, the relatively low response rate in Paper III may limit the generalisability of those findings, as it increases the risk of selection bias. Respondents may differ systematically from the broader population of GPs, particularly in terms of engagement or interest in environmental issues.

The qualitative components were not intended to have statistical power or to be representative or generalisable in a probabilistic sense. Instead, they offer context-rich insights into experiences, perceptions, and perceived barriers and enablers. Transferability of these insights depends on the similarity of organisational structures, professional roles, and policy frameworks in other settings. By providing contextual detail on participants and setting, the thesis aims to support readers in judging the relevance of these findings to their own contexts.

Ethical reflections and implications

Ethical considerations are central to all research, guiding the assessment of potential benefits and risks. In studies on sustainability and the environment, these ethical concerns extend beyond human participants to include animals, ecosystems, and future generations.

Research on PiE can potentially raise ethical concerns, as there could be a risk of misinterpretation that may lead people to believe the research discourages the necessary use of pharmaceuticals. It is therefore important to emphasise that the goal of this thesis is not to discourage necessary pharmaceutical treatment but rather to promote responsible pharmaceutical use. While there are some ethical aspects to consider (see the Methods section on *Ethical considerations in the research process),* the purpose of this research is to provide important knowledge about PiE, which allows policymakers, HCPs, and the public to make more informed decisions about the use and regulation of pharmaceuticals.

Importantly, responsible pharmaceutical use also has implications for future generations. By reducing unnecessary environmental contamination, this research contributes to safeguarding access to clean water, preserving ecosystem

health, and supporting the long-term sustainability of healthcare resources. In this way, the findings not only promote more environmentally responsible pharmaceutical practices today but also help ensure that future generations can benefit from safe, effective healthcare and a healthy environment.

Concluding remarks

Overall, this thesis highlights that ensuring environmentally safe use of pharmaceuticals requires both systemic action and individual responsibility. It calls for a shared commitment among authorities, physicians, pharmacists, patients, and industry to ensure that medicines are used rationally, not only in terms of clinical efficacy and cost-effectiveness, but also with regard to their environmental footprint.

This thesis presents three overarching conclusions. First, although HCPs are generally aware of the issue of pharmaceutical pollution, this awareness does not consistently lead to changes in practice. Several barriers hinder this translation, including limited access to environmental risk data for many active substances i.e. limited knowledge, unclear criteria for decision-making, and a lack of practical guidance on how to incorporate environmental considerations into everyday healthcare routines. Participants expressed feeling that their ability to influence change was limited, emphasising the need for stronger governance and clearer direction at both national and international levels.

Second, physicians and pharmacists both consider themselves to have a role and responsibility in promoting more environmentally informed use of pharmaceuticals. Their contributions include preventing pharmaceutical waste and supporting pharmaceutical stewardship. However, there is a need for education and institutional support in enabling them to take action.

Finally, environmental sustainability in pharmaceutical use requires a systematic approach. This means that environmental considerations should be embedded in decision-making processes and included in policy developments at both regional, national, and international levels. DTCs play an important role here, especially in integrating environmental criteria into treatment recommendations and developing quality indicators.

By combining analyses of pharmaceutical sales data with insights into HCP's attitudes, results from this thesis can support the systemic and broadly accepted inclusion of environmental considerations in healthcare.

Implications and future perspectives

This thesis reinforces a simple but demanding message: environmental considerations must be embedded in clinical practice, rather than merely an afterthought. Real progress depends on turning awareness into concrete, system-supported choices at the points of prescribing, dispensing, and use, but also further upstream in the pharmaceutical lifecycle. Concretely, environmental information and knowledge need to be embedded where decisions are made, into treatment guidelines, reimbursement decisions, and electronic prescribing systems, using transparent, harmonised criteria. National (and ideally global) governance should set those criteria, ensure timely and accessible data on environmental hazards, and align incentives so that environmentally preferable, clinically equivalent options are the default. System-supported choices can be powerful levers here, and they should be used alongside clear responsibilities for each stakeholders group.

The willingness to act is real but under-resourced. Experts value existing knowledge supports, but ask for clearer decision rules and better data. GPs express readiness to choose lower environmental impact options when clinically appropriate. Pharmacy staff are engaged and well placed to help, but need mandates, practical tools and guidance. In short, the system must make it easy to do the right thing.

On that basis, the priority should be to ensure that environmental aspects are integrated into global, national, and regional recommendations; support efforts to reduce unnecessary pharmaceutical use wherever clinically appropriate; provide concise, clinically actionable substitution advice (for example, where a high-impact pharmaceutical has an equivalent alternative); strengthen education for physicians and pharmacists; and require full transparency on environmental data from industry, including lifecycle information that can inform both policy and clinical choices. To achieve meaningful change, environmental considerations must be addressed early in the pharmaceutical lifecycle, starting with drug development, manufacturing practices, and regulatory approval processes. Without upstream integration, downstream efforts risk being reactive and insufficient. Advanced wastewater treatment will remain a useful complement, but upstream, use-oriented measures are essential.

A central concept in this context is the rational use of medicines. Traditionally, this has been understood as ensuring that patients receive appropriate medicines for their clinical needs, in doses that meet their requirements, for an adequate period, and at the lowest cost to them and their community. Based on the results from this thesis, I believe that rational use should also be considered from an environmental perspective.

Several areas warrant further research to advance our understanding and management of pharmaceutical pollution. First, there is a need for intervention studies that evaluate the effectiveness of upstream measures, such as changes in prescribing practices or waste management, on downstream environmental outcomes. To enable this, studies that link registry data with environmental monitoring data are essential, as they can provide a more integrated view of the pathways from pharmaceutical use to environmental impact. For this, expanded environmental monitoring efforts are needed to identify geographic and temporal hotspots of pharmaceutical pollution, thereby informing where mitigation measures are most urgently required.

Moreover, the development and systematic evaluation of educational programmes targeting both HCPs and the public should be prioritised. These initiatives must be integrated not only into undergraduate curricula across relevant disciplines, but also into continuing professional education to ensure that environmental considerations become a routine part of clinical decision-making.

Finally, there is a need for more ecotoxicological studies, particularly those that go beyond traditional endpoints. Research should include sub-lethal effects, such as behavioural changes in aquatic organisms, and the combined effects of pharmaceutical mixtures, which better reflect real-world exposure scenarios. Importantly, long-term effects, both at the individual and ecosystem level, must also be considered, as chronic exposure to low concentrations of pharmaceuticals may lead to subtle but significant ecological disruptions over time. Such studies are crucial for guiding regulatory action.

Sammanfattning på Svenska

Läkemedel används för att förebygga, diagnostisera, lindra och bota sjukdomar. De bidrar till att förlänga människors liv och förbättra deras livskvalitet. Samtidigt har deras omfattande användning uppmärksammats som en källa till miljöpåverkan. Eftersom läkemedel är designade för att påverka fysiologiska processer redan i mycket små doser kan de även oavsiktligt påverka andra organismer när de hamnar i naturen. Den höga potensen och kemiska stabiliteten – egenskaper som gör dem effektiva som läkemedel – gör också att de kan ge effekt vid låga koncentrationer och kvarstå länge i miljön. Till skillnad från många andra miljöskadliga ämnen kan läkemedel inte enkelt förbjudas, eftersom de är oumbärliga för människors hälsa. Detta ställer särskilda krav på hur de utvecklas, används och hanteras.

Den här avhandlingen fokuserar på att belysa läkemedelsanvändning ur ett miljöperspektiv samt på hur hälso- och sjukvården kan bidra till en mer miljövänlig läkemedelsanvändning.

Avhandlingen omfattar fyra studier: studie 1 är en kartläggning av försäljningen av smärtstillande läkemedel i Mälardalsregionen; studie 2 bygger på expertintervjuer om kunskapsstöd för läkemedel och miljö (Janusinfo och FASS); Studie 3 är en enkätstudie riktad till allmänläkare om hur miljöaspekter vägs in i förskrivningsbeslut; och studie 4 undersöker, genom fokusgruppdiskussioner och intervjuer, hur apotekspersonal uppfattar sin roll i att minska läkemedlens miljöpåverkan.

Studie 1 visade att paracetamol och ibuprofen stod för en stor del av den totala volymen sålda smärtstillande läkemedlen. Dessa bedöms ha en låg miljörisk, men de stora mängderna är ändå anmärkningsvärda ur ett belastningsperspektiv. Diklofenak, som har hög miljörisk, var det femte mest sålda läkemedlet (räknat i volym). En betydande del av försäljningen av diklofenak skedde receptfritt. Det finns därmed skäl att minska onödig användning när likvärdiga alternativ finns att tillgå.

I studie 2 bedömde experterna att de undersökta kunskapsstöden som användbara. Janusinfo upplevdes som mer transparent och praktiskt förmedlande av miljöinformation än FASS. Samtidigt pekade de på flera hinder som försvårar användningen: otydliga beslutsregler, begränsade resurser och brist

på miljödata för många substanser. Flera efterlyste dessutom tydligare styrning från myndigheter, både nationellt och på EU-nivå.

I studie 3 uttryckte en majoritet av allmänläkarna en vilja att välja läkemedel med lägre miljöpåverkan när det bedömdes medicinskt rimligt, särskilt vid behandling av smärta och blodtryck. Samtidigt framkom dock att andra faktorer - som kostnad, rekommendationer, dosering och användarvänlighet - ofta vägde tyngre än miljöhänsyn. Många ansåg att läkare bör ta hänsyns till miljön, men få söker regelbundet upp miljöinformation. Det fanns dessutom ett tydligt stöd för riktade åtgärder mot andra aktörer, såsom myndigheter och läkemedelsindustrin.

Apotekspersonalen i studie 4 beskrev ett tydligt engagemang och en vilja att bidra till en mer miljövänlig läkemedelsanvändning. De upplevde att de framför allt kunde bidra genom rådgivning samt genom att uppmuntra till korrekt återlämning och kassering av oanvända läkemedel. Samtidigt upplevde de sitt inflytande som begränsat och efterlyste bättre tillgång till information och stöd.

Sammantaget visar resultaten i studierna på ett glapp mellan medvetenhet och handling. Vården vill göra rätt, men saknar ofta förutsättningar för att kunna agera. För att driva arbetet vidare behövs tillgängliga och uppdaterade beslutsstöd med transparenta kriterier, utbildning för vårdpersonal om läkemedel och miljö som inkluderar praktiska tumregler, samt styrning på systemnivå som underlättar hållbara val.

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Johanna Villén, Uppsala, December 2025

AI statement

This thesis was partially created with the assistance of GPT-5, Open AI's large-scale language generation model. Upon generating draft language, I reviewed, edited, and refined the text to my own liking and retain full responsibility for the content presented in this publication.

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