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Review

Human excreta recycling in Sweden: a PESTEL-SWOT framework analysis – Review

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ABSTRACT

Source-separating sanitation systems can maximise resource recovery from wastewater and mitigate the environmental impacts of conventional wastewater treatment plants, including eutrophication and climate change. This study conducts a comprehensive review of the literature on source-separating sanitation systems in Sweden, aiming to identify the challenges hindering their diffusion and potential expansion opportunities. Employing a rapid evidence synthesis approach, we extracted data from the Web of Science and supplemented findings through hand-searches in additional electronic databases. Of the 713 studies initially identified, 24 met our stringent inclusion criteria. The analysis was structured around a combined PESTEL (Political, Economic, Technical, Social, Environmental, Legal) and SWOT (Strengths, Weaknesses, Opportunities, Threats) framework to synthesise the existing body of work and discern main patterns. The findings underscore the untapped strengths in these technologies' potential in enhancing nutrient recovery and food security, in addition to reducing eutrophication and greenhouse gas emissions. The studies analysed reported Sweden's strengths in source separation, highlighting organisational diversity, market benefits, social acceptance, technological readiness, and nutrient recovery, all contributing to the SDGs and addressing challenges such as eutrophication and limited sanitation access. The primary challenges were identified as social and cultural taboos towards the recycling of human excreta, disbelief in its quality as a fertiliser, concerns about hazardous substances like pharmaceuticals, and a preference for using it to grow non-food crops. Our article main contribution lies in proposing 12 structured upscaling strategies addressing these barriers and leveraging the opportunities identified including policy measures to incentivise circular practices, building support through stakeholder engagement, updating building codes to require double piping, and enhancing municipal-utility cooperation. While grounded in Sweden, our study contributes to research on the broader shift towards sustainable food systems by leveraging internal strengths and external opportunities in circular wastewater systems.

1. Introduction

In recent years, interest in recycling human excreta has increased, advancing research and leading to new applications in this field (Harder et al., 2020; Larsen et al., 2021; Simha et al., 2023). Interest is driven by the need for sustainable solutions that address concerns over high nutrient loss and pollution that increase eutrophication, also considering that more than half of Europeans surface waters are in threatened ecological status (European Environment Agency, 2024). Several currently available technologies can recover nutrients from wastewater and development is ongoing in the field (Harder et al., 2020). However, concerns about pollutants like heavy metals and pharmaceuticals remaining after recycling have led to resistance from industries and consumers (Kirchmann et al., 2017). Separating and dehydrating urine at the source overcomes this concern by producing a nutrient-rich fertiliser for further use (Senecal et al., 2018). Despite technological advancements in nutrient recovery from wastewater, its diffusion and large-scale application remain limited (Aliahmad et al., 2023;

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McConville et al., 2017b). Public and private stakeholder acceptance of utilising nutrients derived from human waste is a crucial barrier to technological advancements and implementation of source separation technologies (McConville et al., 2017a).

Recycling human excreta contributes to meeting the goals outlined in several policy measures. In 2000, Europe enacted the Water Framework Directive (European Union, 2000) aimed at minimising nutrient losses from urban and rural areas to improve water quality. Further, EU members adhering to the Urban Wastewater Treatment Directive (European Union, 1991) progressively developed regulations governing wastewater nutrient discharges. Their efforts significantly cut anthropogenic nitrogen (N) and phosphorus (P) disposal in the Baltic Sea. Yet high nutrient pollution continues, and the Baltic remains one of the world's largest nutrient-induced hypoxic zones (Callesen et al., 2022; McCrackin et al., 2018). Attention to agricultural practices is needed to further decrease nutrient loads. Mineral fertilisers, for example, contribute 46.5 % and 35.7 % of total N and P riverine loads in the Baltic Sea (HELCOM, 2018). The Baltic Sea Action Plan (HELCOM, 2021), signed by all countries bordering the Baltic and the EU, includes objectives aimed at decreasing nutrient discharges from wastewater, recognising the need to mitigate its impact on the marine environment.

Scholars argue that human urine could serve as a continuous, year-round reservoir of essential nutrients for agriculture, including urea, phosphorus, potassium, and micronutrients (Vinnerås et al., 2006). Urine recycling increases the resilience of local food systems by reducing dependence on synthetic and mineral fertilisers and mitigates adverse environmental effects associated with agriculture and inadequate wastewater management (Perez-Mercado et al., 2022). Akram et al.'s (2019) work concentrated on optimising organic waste use and wastewater through source separation and nutrient recovery. Larsen et al. (2021) argued for the necessity of a systemic approach to transmit innovations in source separation and nutrient recovery from human urine. McConville et al. (2023) argued that overcoming the lack of social acceptance of reclaimed nutrient use is crucial. The difficulties of implementing source separation on a large scale notwithstanding, scholars consider source separation technologies a crucial leverage point to address multiple Sustainable Development Goals (SDG) by establishing a circular economy of urban sanitation and food production (Larsen et al., 2021).

Although research on source separation has advanced in recent years, the focus has been predominantly on the technical and environmental aspects. In contrast, socio-technical studies delve deeper into the intricate dynamics of various source separation systems, highlighting their complexities and interactions. This focus reveals the essential interplay between technology and social factors, offering valuable insights to decision-makers and involved stakeholders for improving these systems. For example, exploring the available urine treatment processes (Larsen et al., 2021; Senecal and Vinnerås, 2017), analysing the acceptance of human excreta-derived fertilizers (McConville et al., 2023), studying the barriers facing urine recycling diffusion and upscaling (Aliahmad et al., 2023), assessing the circular developments in Sweden (Akram et al., 2019; Drangert and Kjerstadius, 2023; Lorick et al., 2021), and exploring the Swedish experience with source-separated wastewater from the internal perspective of Technology Innovation Systems approach (McConville et al., 2017b). However, to the best of our knowledge, a synthesized market assessment focusing on internal and external factors has not been performed, which underscores the need for this study and its novelty.

This study addresses the identified literature gap by conducting a comprehensive analysis of existing research on source-separating sanitation systems in Sweden. The primary goal was to identify both internal and external challenges that impede the adoption of such systems. Additionally, the study identified potential opportunities that could facilitate overcoming these challenges and foster the diffusion of these systems. To achieve this goal, the study has employed a combined PESTEL and SWOT analysis to examine the political, economic, social, technological, environmental, and legal contexts and the strengths, weaknesses, opportunities, and threats of the source separation system in Sweden, a pioneer in this field. The analysis has focused on developing theory-derived strategies for actors in the source separation wastewater sector to foster the implementation of technologies and increase source separation and nutrient recovery. In the final step of analysis, the strategies developed are discussed in the context of external factors to highlight scaling scenarios. The analysis answers the following research questions: 1) What notable strengths characterize Sweden's approach to source separation? 2) What are the primary weaknesses and obstacles hindering the diffusion and expansion of source separation in Sweden? 3) How can actors leverage opportunities to devise strategies for scaling up and diffusing solutions that overcome existing barriers?

1.1. Site description

Sweden's unique nutrient recovery system spans urban and metropole regions to remote areas with high tourism activities. Furthermore, Sweden identified regions vulnerable to or at risk from nutrient emissions without preventative measures (HELCOM, 2018). The Swedish government classified all bodies of water in the country, inclusive of coastal areas, as susceptible to phosphorus discharge. Thus, concern over the environmental condition of the coastal seas surrounding Sweden has recently increased in recent years. The primary issue in the Baltic Sea is eutrophication through excess phosphorus and nitrogen (Savchuk, 2018; HELCOM, 2018).

At the national level, Sweden invests in innovative environmental practices and is pioneering source separation. This concept goes beyond traditional waste disposal methods and focuses on human-derived nutrients aiming for their capture and reuse in alignment with circular economy principles (McConville et al., 2017a).

The development of source separation originated in the early 1990s from local experiments and small-scale research projects (McConville et al., 2017b; Söderholm et al., 2023). By the late 1990s, political actors and the construction industry players realised the significance of these practices. Söderholm et al. (2023) highlighted the political shift during this period, focusing on climate actions and the incorporation of sustainable development goals (SDGs) in political agendas. McConville et al. (2017a, p. 145), stressed the "Free People's Home" concept, fostering investment in green development programs and technology. Researchers also advanced source separation through several tests and pilot projects on urine diversion systems and nutrient recovery. However, the lack of necessary technical improvement and functionality of the systems implemented generated problems in the early 2000s. Sweden invested significant resources and standardised systems that failed to reuse the collected urine or struggled with effective waste management further down the chain, causing the re-transformation of existing source separation toilets to conventional systems (McConville et al., 2017a; Vinnerås et al., 2006).

European laws and guidelines such as the Horizon 2020 framework or the European Green Deal renewed interest in source separation. Several municipalities are currently testing source separation treatments and their implementation in existing municipal infrastructure (Larsen et al., 2021). However, McConville et al. (2027b) highlighted the importance of a whole system approach for nutrient recycling and their implementation through infrastructure development. For example, in 2018, the Swedish government established the Circular Economy Delegation to enhance its national and regional transition towards a resilient and eco-based economy. Initially, the delegation concentrated on three key areas: "a design for circularity, plastic materials, and public procurements" (Heshmati and Rashidghalam, 2021, p. 3). The delegation's mission is to shift the Swedish economy and society on various levels towards a circular and eco-based system.

Approximately 90 % of Sweden's households remain linked to traditional wastewater treatment facilities, many of which employ advanced denitrification techniques that emit nitrogen into the air and collect phosphorus in the sludge that can be used in agriculture (McConville et al., 2017a). Efforts to enhance the recycling rate face challenges from concerns about unwanted chemicals and contamination in the sludge, hindering the implementation of source separation technologies on large scale (McConville et al., 2017b).

Given the ongoing interest and environmental motivations behind source separation, it is crucial to fully understand both the effectiveness of this innovation and its potential for seamless integration into existing wastewater systems.

2. Methods

We employed rapid review approaches to conduct searches of literature on recovery and the re-use of human excreta in the agricultural sector in Sweden (Barquet et al., 2020; Khangura et al., 2014). Rapid reviews streamline traditional systematic review methods to expedite the evidence-gathering process while remaining procedurally objective, repeatable, and transparent at all stages of the review process (Barquet et al., 2020; Khangura et al., 2014). The data from the literature was analysed using a framework synthesis approach. Below, we provide a detailed explanation of each methodological step.

2.1. Data collection and search strategy

As part of rapid review approach, this review was limited to one major database, Web of Science, which offers comprehensive coverage across numerous scholarly journals and types of publications (Birkle et al., 2020; Dioba et al., 2024). This choice was aligned with the flexible framework for rapid evidence reviews as outlined Smela et al. (2023). The search was restricted to peer-reviewed English language articles published between 2003 and October 15, 2023 to ensure timely results and to balance the efficiency and comprehensiveness of the review (Moons et al., 2021). The restriction on the time of publication enables this review to focus on all studies conducted on recovery and the use of human excreta-derived fertiliser in the agricultural sector in Sweden, reflecting academic and policy interest in circular wastewater management driven by Directive (2003)/35/EC, Government Offices of Sweden (2002), and the Swedish Strategy for Sustainable Development (2003/04:129). The exclusion and inclusion criteria were developed in line with the research questions using the standard PICOS format as a flexible framework tailored to meet the time-sensitive objectives of our study (Tricco et al., 2017; Haby et al., 2023) (Appendix A, Table A.1). The search strategy was developed iteratively from the inclusion/exclusion criteria and trialled across one database.

The search was carried out iteratively to ensure the extraction of all relevant articles on the subject from a bibliometric database. Keywords were adopted from related reviews, including Lam et al. (2015), Aliahmad et al. (2022), and Gwara (2021). We adapted the following search string to be in line with our aim, utilising exhaustive and comprehensive keywords, synonyms, and Boolean operators in the search criteria:

"Nutrient recovery" OR "Re-utilization of nutrients" OR "Circular nutrient flow" OR "Bio-based fertilizer" OR "Nutrient cycle" OR "Urine separation" OR "Nutrient cycle of dry toilets" OR "Stable faecal compost" OR "Human waste" OR "Faecal sludge" OR "Human manure" OR "Solid waste" OR "Humanure" OR "Fece" OR "Human excreta" AND "Agriculture" AND "Sweden".

The full search returned 713 results. Articles were then assessed for relevance according to the study title and abstract. The first filter applied the inclusion and exclusion criteria to the title and abstract. The second filter consisted of an analysis of the full paper. The full text of the 34 remaining articles was then reviewed to determine their relevance. A total of 21 articles met the full-text inclusion criteria, and an additional 3 articles were included by hand-searching using the snowballing technique (Aliahmad et al., 2023; Heshmati and Rashidghalam, 2021; Lennartsson et al., 2019) (Appendix A, Table A. 2). A flow chart showing the total sample size at each point in the search process can be seen in Fig. 1.

2.2. Data analysis

The included papers were explored and analysed with NVivo. A mixed-method coding was used based on three coding methods. First, a deductive approach was followed in which we applied predefined categories (such as the PESTEL framework) to the data. In the following step, in Vivo coding was applied in which we used paper citations as codes. Finally, we applied theme coding to identify recurring themes across the dataset (Miles et al., 2019). Throughout the coding process, we rigorously verified that codes were consistently attributed. This iterative verification ensured data integrity.

A sequential combination of PESTEL and SWOT analysis was applied to the literature (Laitinen et al., 2022; Srdjevic et al., 2012; Tsangas et al., 2019). PESTEL analysis is a valuable tool for evaluating the political, economic, social, technological, environmental, and legal aspects influencing an organisation, sector, or actor. SWOT analysis explores internal strengths and weaknesses along with external opportunities and threats (Fertel et al., 2013; Islam and Mamun, 2017). Strengths and weaknesses are related to internal factors, while opportunities and threats represent system interactions with the environment (Srdjevic et al., 2012).

Combining these analyses enables comprehensive evaluation of the status of actors and sectors. PESTEL analysis provides a detailed contextual description, while the SWOT matrix identifies issues that require enhancement or mitigation (Tsangas et al., 2019). Thus, the combination of these tools is most suitable for identifying internal and external factors within the respective PESTEL indicator to understand nutrient recovery in the wastewater sector of Sweden. The synergistic integration of both analyses provides a matrix to enhance the depth and accuracy of data about complex multi-level contexts as well as synergies and interactions (Srdjevic et al., 2012).

Combining PESTEL and SWOT analysis results in matrices with 24 quadrants instead of the classic four-quadrant analysis. Each row of the matrix corresponds to a PESTEL factor (6 rows), and columns correspond to the four SWOT factors (Appendix A, Table A.3). The PESTEL rows are organised following the distribution of the codes within the dataset. The first row corresponds to the most representative aspect within each PESTEL factor.

3. Results and discussion

The analysis examined the strengths, weaknesses, opportunities, and threats related to source separation and recycling of human excreta (Table 1), focusing on the PESTEL factors. This matrix encompasses all factors that impact the present condition and future progress of the source separation sector in Sweden. At first glance, the results showed that environmental strengths were dominant compared to other PESTEL factors. This may be because grassroots movements reacting to emerging environmental concerns were the primary initial driver of source separation, followed by political strength manifested through the introduction of initiatives such as the "Free People's Home" concept in the late 90s (McConville et al., 2017a, p. 145). On the other hand, legal factors are the dominant weakness compared to other PESTEL factors, overlapping with some political weakness regarding the lack of international goals and policies. Source separation, though not yet fully diffused and implemented, presents numerous opportunities across various aspects. Harnessing these opportunities could potentially help overcome many of the current obstacles and weaknesses.

3.1. RQ 1: what are the notable strengths in Sweden's approach to source separation?

The SWOT matrix illuminates the strengths, opportunities, threats, and weaknesses within the identified PESTEL categories. Overall, the

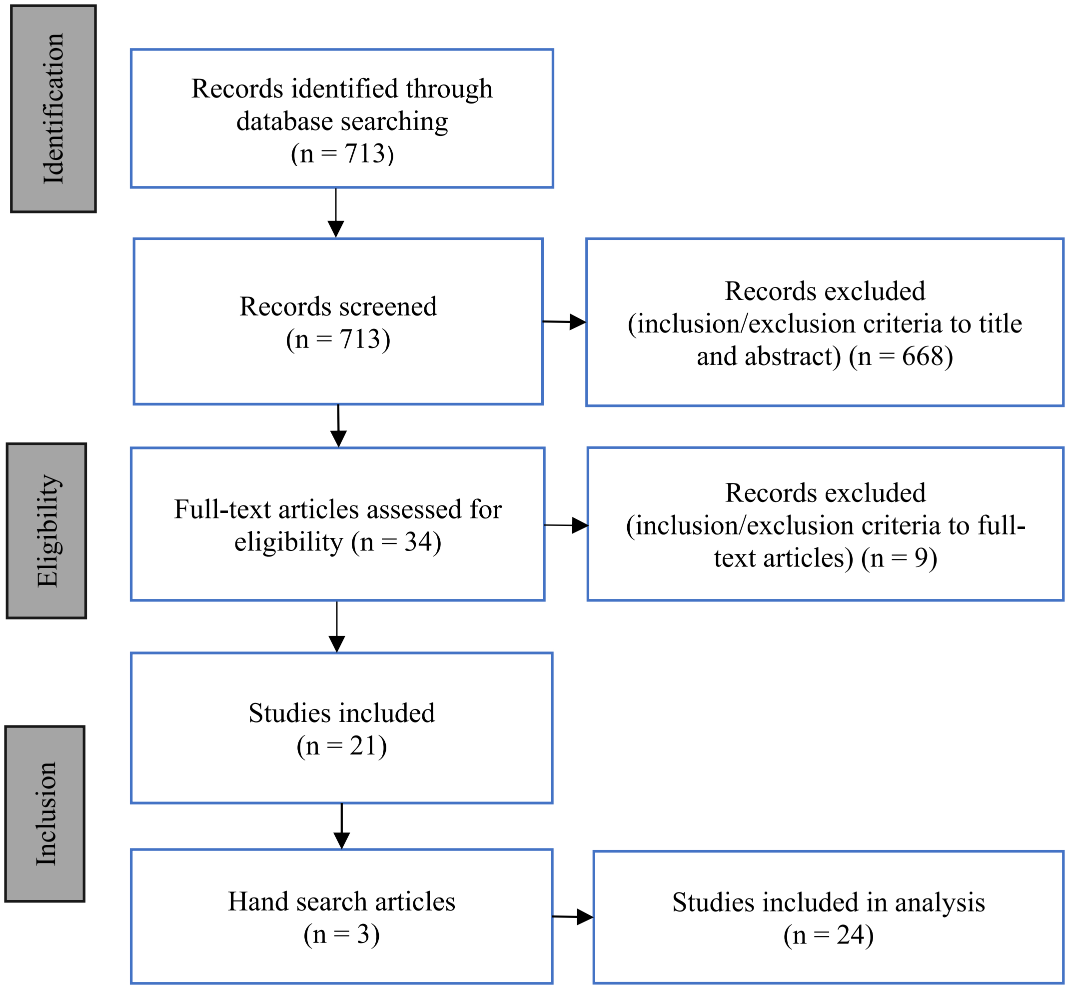

Fig. 1. Flow chart for standard PICOS format based literature selection.

analysis identified 26 PESTEL subfactors as strengths (Appendix B, Figure B.1).

Within the political factor, the most referenced strengths mentioned in the literature involve supportive organisational diversity (Bisschops et al., 2019; Koskiaho et al., 2020). Diverse national organisations and research institutes support experimentation and learning in this domain in Sweden. For example, the municipalities of Helsingborg and Stockholm are actively exploring source separation with new technologies within existing wastewater jurisdictions, particularly in planned development areas (McConville et al., 2023). Larsen et al. (2021) emphasised a strategic focus on domestic fertiliser production, aligning with EU-level strategies, such as the farm to fork strategy to increase domestic fertiliser production and reduce overall fertiliser use by 20 % by 2030 (European Union, 2020). Contributing to the SDGs is a critical aspect discussed in the literature, notably SDG 6 (provision of safe drinking water and adequate sanitation) and SDG 14.1 (reducing nutrient emissions to the marine environment) (Larsen et al., 2021). Decentralisation is recognised as a political strength to upscale source separation. For example, Bisschops et al., 2019, highlighted the importance of collaboration among diverse local stakeholders such as local governments, water agencies, and private actors.

Within the economic factor, the primary focus lies in the market benefits through revenue and savings as key strengths (Akram et al., 2019; McConville et al., 2017a). The analysed studies situate the implementation of source-separating wastewater systems as a contributor to generating values and benefits. For example, Callesen et al. (2022) indicated these outcomes extend beyond the jurisdiction of water utilities, as improving water quality in the Baltic Sea would enhance its recreational value for society. McConville et al. (2023) emphasised that safe recycling of nutrients from human excreta back to agriculture is a vital element of the circular economy and could help stabilise food supply and associated costs. It was repeatedly mentioned that source-separating wastewater systems, in comparison to conventional systems, offer greater benefits to market system (Bisschops et al., 2019; Lennartsson et al., 2019). Additionally, it was stressed that reduced nutrient loss risks by implying of sustainable wastewater management is contributing to the economic growth (Akram et al., 2019; McConville et al., 2017b).

Within the social factor, the most referenced strength was social gains in areas with limited access to sanitation (Aliahmad et al., 2023; Larsen et al., 2021; Wald, 2022). For example, Aliahmad et al. (2023) stressed that this approach provide opportunity to move closer to the "sanitation for all people" goal, that mean having sustainable sanitation systems and effective use of the nutrients in agriculture system (p. 2). The promise of human urine recycling was stressed in regions facing sanitation challenges where advanced treatment systems might not be practical. This aligned with the overarching SDG 6.2 target, aiming to ensure availability and sustainable management of water and sanitation for all (Aliahmad et al., 2023; Larsen et al., 2021). The importance of growing social acceptance was also stressed (McConville et al., 2023). For example, research on the readiness of Swedish food retailers indicates a positive attitude, with respondents expressing that these nutrient-recycling techniques are unlikely to be harmful and might even be beneficial for the environment (McConville et al., 2023).

Table 1
PESTEL-SWOT matrix for the source separation sector in Sweden.

	Strength	Weakness	Opportunities	Threats
Political	Supportive organisational diversity (5; 12)[a] Decentralized treatment and resource recovery (5) Contribution to sustainable development goals (13) Influence of food retailers in promoting sustainability (16) Strategic focus on domestic fertiliser production (13)	Resistance and slow transition (5, 8; 11, 17) Lack of common vision and cross-sectoral cooperation (8; 17) Inconsistencies in policy implementation (17) Divergence in policy adoption (18) Institutional rigidities (11)	Paradigm Shift towards Circularity (9, 18, 23) Recognition of critical raw materials (3) Clear policy measures (6) Advocacy and institutional support (11) The policy documents show a growing awareness (16)	
Economic	Market benefits: revenues and savings (3, 17) Source-separating wastewater systems offer significantly greater benefits compared to conventional systems (5, 23) Reduction in nutrient loss risks (3, 18) Stabilise food prices (16)	High logistics costs (2, 3,11,12, 21) Organisational challenges (12, 21) High investment (6, 12) High infrastructure costs (11) Lack of demand from consumers (16)	Transition into mass market (3, 23, 24) Engagement of dedicated service providers and users (17, 24) Tax incentives for circular businesses (4, 17) Increased system flexibility (8) Decentralisation of systems (17) The soaring price of natural resources (8)	Economic recessions (17)
Social	Social gains in areas with limited access to sanitation (13, 20, 24) Growing social acceptance (16) Increasing public environmental awareness (17) Growing knowledge (17)	Low social acceptance (17, 24, 8, 11, 15, 20) Weaknesses in knowledge dissemination (17, 24, 8, 9, 15) Lack of trust in new technologies (15, 18) Risk aversion of main stakeholders (15, 18) Cultural taboos and concerns (16)	Improved knowledge dissemination (4, 16, 17, 18) Engaging with relevant stakeholders (5, 18, 24) Changing to a vegetarian diet (16, 22) Generation shift (18) Including users in the design process (17) Successful leadership (21) Societal support (12)	
Technological	Technological readiness (7,11, 13, 17, 18, 19, 24) High nutrient concentrations (1, 8, 11, 16, 21) Enhanced food security (16, 18)	Limited scale implementation (16) Low diversity of treatment methods (18) Unimproved urine-diverting toilet design (20)	Technological innovation (16, 17) Technical research & development (5, 17)	Power outages (23)
Environmental	Environmental impact optimisation: eutrophication potential, carbon emission reduction (5, 6, 11,12, 16, 20, 21, 22, 24) Energy conservation (9, 14, 18, 19, 21) Improved potential for nutrient recycling (3, 16, 23) Resource recovery (11, 21, 23) Reduced phosphorus and fossil fuel-derived fertilisers dependency (1, 15) Increased biogas generation (11, 23) Reduction of eutrophication and GHG emission (6, 16) Decreased emissions of nitrogen and phosphorus to water (11, 21) Water conservation (20)	Human excreta harbour numerous pathogens, pharmaceuticals, and organic micro-pollutants (7, 18) Loss of environmental benefits in autumn spreading (21)	Considering human and environmental health (5, 11) Addressing regional differences to avoid over or under-fertilising (3)	Environmental disasters (17)
Legal	At a national level legislation supports the idea of nutrient reuse (18)	EU Organic Farming Restriction (17, 19) National laws only provide vague guidelines (24) Highly institutionalised (17) Lack of coordination between laws (17) Municipal budget integration gap: activities for the development of their source separation systems have not become integrated into municipal budgets and planning (18) Low legitimacy creation (23) Lack of national vision and strategy (23) Weak national advocacy coalition (23) Lack of national incentives (23)	Mandatory double piping: double piping should be made mandatory in all new buildings (8) Enhanced municipal-utility cooperation: increased cooperation between the municipality and its utilities for water, waste, and energy services (23) Stricter pollution and climate legislation (17)	

[a] Coded articles are referenced in Appendix A, Table A.2.

Additionally, increasing public environmental awareness and growing knowledge as essential social subfactors was stressed (McConville et al., 2017a). Within the technological factor, the analysed literature predominantly highlighted high nutrient concentrations, emphasising the potential use of nutrients from human urine for fertiliser production in the agriculture sector as a key strength (Drangert and Kjerstadius, 2023; Kjerstadius et al., 2017; McConville et al., 2023; Senecal and Vinnerås, 2017; Tidåker et al., 2007). The significance of technological readiness was stressed, citing Sweden as a pioneer in urine research and in the technological advancement of multiple tested technologies (Aliahmad et al., 2023; Došek et al., 2014; Larsen et al., 2021; Spångberg et al., 2014).

Within the environmental factor, the reduction of eutrophication and greenhouse gas (GHG) emissions have been repeatedly discussed (Aliahmad et al., 2023; Callesen et al., 2022; Tidåker et al., 2007; Wu et al., 2016). The significance of safe nutrient recycling from human excreta was highlighted by Lennartsson et al. (2019). For example, resource recovery, particularly increasing nutrient recovery and enhancing of biogas generation, emerged as a key driver for source-separating wastewater systems, initially implemented in Helsingborg and Stockholm (Lennartsson et al., 2019). The environmental benefits of minimising Nitrogen and Phosphorus (P) emissions into water were also repeatedly discussed (Kjerstadius et al., 2017; Tidåker et al., 2007). Tidåker et al. (2007) argued that human urine separation is a more favourable alternative than conventional systems as it reduced the need for mineral fertilisers. Other environmental outcomes frequently highlighted as important aspects of source separation in wastewater systems include energy conservation (Burgman and Wallsten, 2021; Spångberg et al., 2014), water conservation (Wald, 2022), and increasing biogas generation (Kjerstadius et al., 2017; Lennartsson et al., 2019).

Within the legal factor, strengths were not extensively discussed. The primary topic identified is the support for nutrient reuse practices at the national level, particularly in Swedish legislation (McConville et al., 2017b). The Environmental Code, dating to 1998, outlined several objectives dedicated to recycling and the efficient utilization of natural resources. Additionally, Sweden established sixteen National Environmental Quality Objectives in 1999, including the recirculation of natural resources, containing nutrients, as part of these objectives. This legal framework signifies Sweden's commitment to promoting nutrient reuse.

In summary, the studies analysed reported Sweden's strengths in source separation, highlighting organisational diversity, market benefits, social acceptance, technological readiness, and nutrient recovery, all contributing to the SDGs and addressing challenges such as eutrophication and limited sanitation access.

3.2. RQ 2: what are the primary weaknesses and threats hindering the diffusion and expansion of source separation in Sweden?

Overall, the analysis identified 29 PESTEL subfactors as weaknesses (Appendix B, Figure B.2).

Within the political factor, system resistance and slow transition (Bisschops et al., 2019; Drangert and Kjerstadius, 2023; Kjerstadius et al., 2017; McConville et al., 2017a) along with lack of common vision and cross-sectoral cooperation (Drangert and Kjerstadius, 2023; McConville et al., 2017a) were repeatedly mentioned as key weaknesses of source separation in Sweden. For example, Lindqvist et al. (2021) emphasised that there is a policy resistance that may lead to the failure of well-intended sustainable policy implementations. Inconsistencies in policy implementation (McConville et al., 2017a) and divergence in policy adoption of source separation in Sweden (Kjerstadius et al., 2017) were also identified in the articles analysed. For example, McConville et al. (2017a) stressed that the cooperation of two Swedish municipalities, Kullön and Tanum, is weak due to a divergence of goals and a lack of communication.

Within the economic factor, the primary focus was on high logistics costs (Akram et al., 2019; Kjerstadius et al., 2017; Koskiaho et al., 2020; Simha et al., 2023). It was frequently noted that transporting human excreta-derived fertilisers to meet crop needs incurs significantly higher costs compared to the market value of the synthetic fertilisers they aim to replace. For example, Akram et al. (2019) pointed out the regional differences in these costs: "in the case of Stockholm, it only cost 29 % of the fertiliser value of P to transport excreta (which is mostly human excreta) to deficit municipalities" (Akram et al., 2019 p. 5). The complicated processes of nutrients collection and transporting were frequently mentioned as difficulties that raise costs. The need for high levels of investment (Callesen et al., 2022; Koskiaho et al., 2020) and the existing organisational challenges (Koskiaho et al., 2020; Tidåker et al., 2007) were also identified as weaknesses of source separation in Sweden. Semi-structured interviews with wastewater management experts, conducted by Barquet et al. (2020), highlighted that the wastewater sector in the entire Baltic Sea region is characterised by large-scale infrastructure with long-term investment horizons. These factors create lock-in effects, making it difficult to adopt source separation technologies and treatment systems. McConville et al. (2017b) reported that high initial financial investments for novel sanitation systems are one of the major challenges in upscaling source-separation systems in Sweden. It is noteworthy that the lack of demand from consumers was also identified as a barrier to the source separation development (McConville et al., 2023).

Within the social factor, low social acceptance was repeatedly mentioned as a major weakness (Aliahmad et al., 2023; Drangert and Kjerstadius, 2023; Kjerstadius et al., 2017; Lorick et al., 2021; McConville et al., 2017a). McConville et al. (2023) reported that there are social and cultural taboos regarding recycling human sanitary waste based on concerns about its safety due to potential hazardous pharmaceuticals and other contaminants. Weaknesses in knowledge dissemination was also identified as one of the major barriers to the expansion of source separation practices in Sweden (Aliahmad et al., 2023; Drangert and Kjerstadius, 2023; Burgman and Wallsten, 2021; McConville et al., 2017a). Risk aversion among the main stakeholders in this sector was also identified as a significant challenge (Lorick et al. 202; McConville et al., 2017a). McConville et al. (2017b) reported that there is reluctance among farmers in many Swedish municipalities to adopt fertilisers derived from human excreta, influenced in part by opposition from risk-averse groups including end users and local politicians. Weak knowledge development means that source-separation systems are often regarded as immature and risky by decision-makers. Additionally, the lack of trust in new technologies was also highlighted as a weaknesses of source separation in Sweden as source-separation systems are often perceived as immature and risky by decision-makers (Lorick et al., 2021; McConville et al., 2017b).

Within the technological factor, the lack of large-scale implementation, despite the existence of various technological advances for nutrient recovery was stressed (McConville et al., 2023). McConville et al. (2017a) reported the limited availability of urine-diversion flush toilets in Sweden, coupled with a low diversity of applied treatment methods for urine, resulting in a weak rating for urine-diversion systems. Additionally, Wald (2022) identified the importance of improving the design of urine-diverting toilets to simplify urine treatment to convert it into valuable products.

Within the environmental factor, the potential risks associated with human excreta recycling, which may harbour numerous pathogens, pharmaceuticals, and organic micro-pollutants were mentioned as a weaknesses of source separation sector (Došek et al., 2014; McConville et al., 2017b). The importance of safety in the recycling process was stressed, highlighting that fresh urine can be a source of various pathogens. For example, Tidåker et al. (2007) reported that the season that fertiliser derived from human urine is applied has an influence on its environmental benefits.

Within the legal factor, the EU organic farming restriction was reported as the primary obstacle hindering development of source separation sector in Sweden (Spångberg et al., 2014). EU directives on organic production prohibit the use of human excreta as fertilisers in organic farming (Spångberg et al., 2014). Additionally, the lack of national vision and strategy, weak national advocacy coalitions, and a lack of national incentives were reported as barriers (Lennartsson et al., 2019).

The literature review revealed a notable gap in the threat category. The articles only emphasised economic, technological, and environmental factors (Appendix B, Figure B. 4). However, it is noteworthy that each of these factors was supported by only a single reference. This reveals a potential limitation in the existing body of literature, as a comprehensive exploration of threat factors across a broader range of references would contribute to a more nuanced understanding of the subject.

Within the economic and environmental factors, McConville et al. (2017a) discussed that economic recessions and environmental disasters reduce funding for pro-environmental projects such as advancing the source separation sector, as resources are diverted to address other urgent needs). Within the technological factor, Lennartsson et al. (2019) reported that separate collection and treatment of blackwater and greywater leads to increased vulnerability during power outages.

In summary, the studies analysed identified weaknesses in Sweden's source separation approach, including a lack of common vision and cross-sectoral collaboration, limited financial resources, safety concerns regarding fertiliser use, and the absence of clear international and national strategies.

3.3. RQ 3: how can actors leverage opportunities to devise strategies for scaling up and diffusing solutions to overcome existing barriers?

Overall, the analysis identified 25 PESTEL subfactors as opportunities (Appendix B, Figure B.3).

Within the political factor, the most referenced subfactors focus on a paradigm shift towards circularity (Burgman and Wallsten, 2021; Lennartsson et al., 2019; McConville et al., 2017b). Aliahmad et al. (2023) and Guest et al. (2009) emphasised the necessity for a paradigm shift in current sanitation systems to consolidate circularity as it is essential to meet SDGs and achieve food and fertiliser security. The identification of critical raw materials, such as P, is seen as a potential opportunity for developing the source separation sector (Akram et al., 2019). The EU has classified P as a critical raw material, indicating a willingness to explore management strategies that can reduce the food system's vulnerability to disruptions in the availability or price of synthetic P fertilisers. This recognition opens the door to alternative approaches, like source separation, to help ensure a stable P supply. Additionally, Barquet et al. (2020) reported that countries with clear policy measures promoting circular systems, such as the legislation introduced by Germany in 2017, have experienced increased business interest and investment in green technologies, such as source separation.

Within the economic factor, the transition into the mass market was repeatedly mentioned (Akram et al., 2019; Aliahmad et al., 2023; Lennartsson et al., 2019). Aliahmad et al. (2023) reported the readiness for human urine recycling to move from small grassroots initiatives to broader mainstream market acceptance. The ongoing decentralisation of organisational structures in Sweden was identified a key opportunity for such mainstreaming (McConville et al., 2017b). Additionally, tax incentives for circular businesses were prominently reported as an opportunity for scaling up of source separation (Heshmati and Rashidghalam, 2021; McConville et al., 2017a). For instance, Heshmati and Rashidghalam (2021) stressed the importance of lowering taxes for the labour force engaged in the remanufacture, repair, and reuse sector in Sweden.

Within the social factor, improved knowledge dissemination (Heshmati and Rashidghalam, 2021; McConville et al., 2017a, 2017b, 2023) and the engaging with relevant stakeholders (Aliahmad et al., 2023; Bisschops et al., 2019; McConville et al., 2017b) were most mentioned. Heshmati and Rashidghalam (2021) advocated for government promotion of investments in public education through circular economy information campaigns. McConville et al. (2017a) reported the crucial role of knowledge dissemination channels, such as formal media and other outlets. In addition, the authors noted that the importance of targeted information campaigns towards identified stakeholders to increase their willingness to expand sustainability strategies, particularly in nutrient recycling (McConville et al., 2023). The change to a vegetarian diet is viewed positively for the source separation sector in Sweden (Lennartsson et al., 2019; McConville et al., 2023). For example, Wu et al. (2016) argued that adopting a vegetarian diet is a crucial upstream measure for reducing the total P budget with a growing population.

Within the technological factor, the need for technological innovation (McConville et al., 2017a, 2023) and technical research and development (Bisschops et al., 2019; McConville et al., 2017a) were repeatedly mentioned. Ongoing advancements in technology play a crucial role in enhancing the effectiveness and efficiency of nutrient recycling methods. Additionally, increased support for research and development in this domain promises to further refine recycling techniques and systems.

Within the environmental factor, the importance of consideration of human and environmental health were mentioned as the dominant value in policies related to municipal water and wastewater documents in Sweden, creating an opportunity for the growth of source separation systems (McConville et al., 2017b). Additionally, the need to address regional differences to avoid over or under-fertilising while recycling human excreta was identified (Akram et al., 2019).

Within the legal factor, mandatory double piping in all new buildings in existing urban areas was identified as an opportunity for source separation development in Sweden as it should facilitate connections to an extra sewer for blackwater when available (Drangert and Kjerstadius, 2023). Lennartsson et al. (2019) reported enhanced municipal-utility cooperation, stressing that successfully implementing source separation requires increased cooperation between municipalities and water, waste, and energy utilities. Stricter pollution and climate legislation addressing reduced emissions of pharmaceuticals and pathogens are further notable factors that could support the sector (McConville et al., 2017a).

In summary, the analysed studies identified opportunities in Sweden's source separation approach, including a paradigm shift toward circular practices and sustainable development, as well as emerging market opportunities for human excreta-derived fertilisers driven by system decentralisation, incentives, and mandatory guidelines.

4. Discussion

The PESTEL-SWOT framework analysis results allow us to suggest twelve strategies addressing local challenges hindering sustainable food systems through converting urban sanitary waste to safe bio-based fertilisers for agricultural production in Sweden (Table 2). These strategies aim to promote the use of human urine derived fertilisers as part of a broader shift towards sustainable food systems, which could optimise strengths, seize opportunities, and overcome weaknesses and threats.

Sweden has been an early pioneer in implementing source separation practices, with significant political awareness of alternative sanitation solutions. However, the adoption rates for these practices have been slow despite the continuous expansion of centralised aspects of the Swedish sanitation system (Söderholm et al., 2023). Conducting a PESTEL-SWOT analysis of the source separation market in Sweden identified strategies for promoting the use of human excreta-derived fertiliser for agricultural production as part of a broader shift towards sustainable food systems by leveraging SWOT opportunities. It is crucial to consider local weaknesses within the PESTEL factors when framing implementation strategies for overcoming the challenges associated with converting urban sanitary waste to safe bio-based fertilisers. Twelve key strategies were identified to advance the source separation sector in Sweden.

Overall, the strategic framework offers recommendations for advancing the source separation sector in Sweden by capitalising on external opportunities identified within the PESTEL-SWOT analysis to overcome major challenges.

Under the political factor, to counteract the existing system resistance and slow transition (Bisschops et al., 2019; McConville et al., 2017a), the suggestion is to implement clear policies incentivising circular businesses while addressing inconsistencies in policy implementation. For example, by adding aspects of water separation systems in procurements and tenders for retrofitting, restauration and new constructions could help accelerate some changes in this market, while also helping create a common vision and cross-sectoral cooperation helping tackle the existing goal divergence and poor communication among some cities and regions (McConville et al., 2017a). We align with Moons et al. (2024), that political ambitions need to be clarified and aligned with industry needs. Therefore, an increased dialog between

Table 2
Strategic framework for advancing the source separation sector in Sweden.

Factor	Exemplary weaknesses and threats	Strategies
Political	• System resistance and slow transition (Bisschops et al., 2019; McConville et al., 2017a). • Lack of common vision and cross-sectoral cooperation: for example, local municipalities such as Kullön and Tanum show weak cooperation due to goal divergence and poor communication (McConville et al., 2017a).	• Implement clear policy measures to incentivise circular practices – water separation systems to be included in procurement processes. • Advocate for tax incentives and subsidies for circular businesses.
Economic	• High logistics costs: transporting human excreta-derived fertilizers incurs significantly higher costs than the market value of synthetic fertilizers (Akram et al., 2019). • High investment needs: large-scale infrastructure lock-in and long-term investment horizons (McConville et al., 2017b).	• Support the transition of sustainable practices into the mass market. • Foster technological innovation for circularity.
Social	• Low social acceptance: social and cultural taboos, particularly concerns over safety and contamination of fertilizers derived from human excreta (McConville et al., 2023). • Risk aversion among stakeholders: reluctance from farmers and politicians to adopt new technologies due to safety concerns and lack of trust (McConville et al., 2017b).	• Build societal support through stakeholder engagement and increased communication and collaboration. • Encourage a shift to a vegetarian diet.
Technological	• Limited large-scale implementation despite technological advances in nutrient recovery (McConville et al., 2023). • Unimproved toilet design (Wald, 2022).	• Foster technological innovation for circularity. • Invest in technical research & development.
Environmental	• Pathogen] derived from human urine vary depending on the season of application (Tidåker et al., 2007).	• Address regional differences to ensure sustainable resource use. • Make double piping mandatory in all new buildings.
Legal	• EU Organic farming restriction: EU directives prohibit the use of human excreta in organic farming (Spångberg et al., 2014). • Lack of national vision: weak national advocacy (Lennartsson et al., 2019).	• Advocate for stricter pollution and climate legislation. • Enhance municipal-utility cooperation for sustainable services.

policymakers and industry groups is one way to heighten clarity.

Another opportunity touching both the political and economic aspects which can have an impact in overcoming the high logistics costs (Akram et al., 2019) and initial high investments (McConville et al., 2017b) lies in initial tax incentives (such as the strategies used for the energy sector with the market change and adoption of electric cars from 2017 until 2022) and subsidies as effective tools to lower the economic barriers of high front-end investment costs and lack of consumer demand (Riksdagen, 2017). Ekdahl et al. (2024) identified this policy instrument as the most supported by senior experts in the circular economy field. Upscaling and transitioning to the mass market is crucial to tackling the economic challenges of high logistics costs and organisational barriers.

Building support through stakeholder engagement and communication aims to address social factor challenges such as low social acceptance and weaknesses in knowledge dissemination. To achieve such support and change both the current social and cultural taboos, particularly concerns over safety and contamination of fertilizers derived from human excreta (McConville et al., 2023) and the risk aversion among stakeholders (McConville et al., 2017b), a combination of communication and awareness campaigns strategy needs to be deployed. Such campaigns need to demonstrate the advantages of such separation technologies while also highlighting how people's experience of their own waste will not be affected by such changes (as their toilet visits experience remain the same).

Another social factor to overcome deals with current unsustainable food systems, where encouraging a shift to a more vegetarian diet is recommended. Several studies argue that weaning from animal protein is a crucial upstream measure to reduce the total phosphorus budget and the resources expended in food production (Lennartsson et al., 2019; McConville et al., 2023; Wu et al., 2016). Such change in diet requires a wider agro-food strategy, as it is connected to a greater set of stakeholders and to deeply ingrained cultural perceptions and individual habits. Nevertheless, such change could have a wider impact on both overall food systems, making it more circular and sustainable, while also reducing emissions (Withers et al., 2020).

Supporting innovation and investing in research and development aims to overcome technological factor challenges of limited scale implementation (McConville et al., 2023) and unimproved designs (Wald, 2022), as the existing policy framework tends to prioritise product innovation over other aspects (Moons et al., 2024). Such investment in research and development could benefit from public-private partnerships within the agro-food sector for the development of a variety of crops using the resources from source separation, lowering the investment burden in the public sector. The investment in R&D in this field, would also help address the aspects dealing with pathogen and pollutant risks (Došek et al., 2014), and overcome some of the seasonal inefficiencies (Tidåker et al., 2007). For the advancements in such research field, the public sector needs to develop and enforce strategies to overcome environmental challenges, focusing on addressing regional differences to ensure sustainable resource use. Aligning with political and economic factors, such approach could be deployed through changes in procurement, making double piping mandatory in new buildings to mitigate pathogen and micro-pollutant challenges.

The legal factors are highly intertwined with political, technological and market aspects. As technologies advance, resources can be separated and safely applied to fertilize crops (Akram et al., 2019). However, legislations tend to lag behind technology advancements due to a lack of access, standardization and control. Currently EU directives prohibiting the use of human excreta in organic farming (Spångberg et al., 2014), development and testing of technologies could help towards a revision of this legislation. Another legal aspect to be tackled deals with a lack of national vision (Lennartsson et al., 2019). Advocating for stricter legislation and enhancing municipal-utility cooperation could minimise such inconsistencies between national laws and lack of inter-municipal coordination.

The strategic framework proposed in the following is built on external opportunities and internal strengths identified to scale up the expansion of source separation in Sweden. The strategies are designed to tackle internal weaknesses and external threats, while leveraging existing growth potential within the circular system.

5. Conclusions, limitations, and future work

This study contributed an overview of Sweden's source separation sector, synthesising the existing literature within PESTEL-SWOT framework to highlight key market patterns.

Findings from the literature show clear strengths in Sweden's approach to source separation and nutrient circularity through its diversity of national organisations and research institutes supporting experimentation and learning in this domain. This underscores the critical role of bolstering capacity to recycle human excreta to enhance water security. Reduction of eutrophication and greenhouse gas emissions is also a notable outcome of Sweden's approach.

While human excreta recycling shows significant potential for enhancing food and fertiliser security and has been in existence since the early 1990s, it has not yet been widely implemented. The primary weaknesses and obstacles hindering the diffusion and expansion of source separation in Sweden are social and cultural taboos towards the recycling of human excreta, disbelief in its quality as fertiliser, concerns about hazardous substances like pharmaceuticals, and a preference for using it to grow non-food crops. Our research identified twelve key theory-derived upscaling strategies aimed at fostering resource circularity within the source separation sector for Sweden. These strategies may, facilitate increased sustainable and resilient water management practices.

The strategic framework derived from our PESTEL-SWOT analysis of internal and external barriers and opportunities in the source separation market in Sweden enhance the theoretical understanding of source separation systems and real-world implementation. This framework offers guidance to stakeholders considering adopting human excreta recycling systems, drawing insights from Sweden's experience. While the study focused on Sweden, many findings are likely generalisable for other EU countries, particularly since many findings from the review are supported by the broader literature on resource recovery and circular sanitation For example, a recent experimental study on recycling initiatives in Spain demonstrated that fertilizers derived from human excreta are viable alternatives to commercial fertilizers, yielding marketable crop production (Häfner et al., 2023). Similarly, a study on decentralized source-separating sanitation systems in France highlighted their growing adoption through initiatives such as the Saint-Vincent-de-Paul project in Paris, which integrates urine separation and treatment with municipal green space management (Larsen et al., 2021). Additionally, a recent survey conducted in the Southeastern United States suggests that public acceptance of recovered nutrients can be strengthened by fostering institutional trust and evolving social norms, as only 8 % of respondents expressed willingness to use recycled water for drinking (Pathiranage et al., 2024). These findings underscore the importance of suggested long-term strategies to address persistent challenges in source separation across the EU and beyond. Our analysis serves as a valuable reference point for further research, contributing to the broader discussion on scaling circular sanitation solutions and enhancing resource recovery practices.

The primary limitation of this study is the relatively sparse prior research on human excreta recycling in Sweden which resulted in the inclusion of 24 studies in the analysis. Additionally, the reliance on a single database may have constrained the diversity of journals and study types, as different databases offer distinct coverage and strengths. However, the objective of this review was not to provide an exhaustive survey of all studies in the field but rather to efficiently identify key themes and trends. The variation in research design makes it challenging to go beyond identifying general patterns to make quantitative claims about the significance of strengths and weaknesses. However, the thematic structure of the review allows for comparisons across study outcomes. The study may have benefited from narrowing its scope to one industry sector following Ekdahl et al. (2024). However, its comprehensive perspective produced results helpful to policymakers and broader policy discussions.

Our study contributes to the growing literature on circular wastewater management by conducting a novel market assessment of source-separating sanitation systems in Sweden that integrates internal and external factors. The findings underscore the untapped potential of source-separating systems in enhancing nutrient recovery, mitigating eutrophication, and reducing greenhouse gas emissions, thereby advancing sustainability goals. From a practical perspective, by applying the PESTEL framework, we propose 12 structured upscaling strategies for circular sanitation solutions. These strategies address critical barriers such as cultural perceptions, regulatory fragmentation, and scepticism regarding the quality of fertilizers derived from human excreta. Our study contributes to research on the broader shift towards sustainable food systems by leveraging internal strengths and external opportunities. While grounded in Sweden's context, our study provides valuable foundation for future research on the untapped potential of circular wastewater systems globally and within Europe. Further research is needed to provide more specific insights into the challenges and opportunities at the EU-wide level. This would be particularly relevant considering the high levels of current interest and research activity within human excreta recycling, the associated public debate in the EU and globally, and current circular economy policy development.

CRediT authorship contribution statement

Albina Dioba: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Anna Schmid:** Writing – review & editing, Writing – original draft, Visualization, Data curation, Conceptualization. **Abdulhamid Aliahmad:** Writing – review & editing, Writing – original draft, Conceptualization. **David Struthers:** Writing – review & editing. **Isabel Fróes:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A.1
PICOS Framework

Inclusion/exclusion criteria:		
	Inclusion	Exclusion
Population	All wastewater fractions or source separated fractions: urine, blackwater, greywater. Studies focused on human excreta-derived fertilizers in the agricultural sector.	Other wastewater fractions like combined sewage sludge, industrial wastewater, or non-source-separated municipal wastewater. Excreta from non-human sources (e.g., animal urine, manure).
Intervention	Converting urban sanitary waste to safe bio-based fertilizers for agricultural production in Sweden; The use of human excreta derived fertilizer in agricultural sector.	
Comparison	Source separation wastewater sector in Sweden; Converting urban sanitary waste to safe bio-based fertilizers for agricultural production in Sweden.	
Outcomes	PESTEL/SWOT characteristics of source-separation wastewater sector in Sweden.	
Study design	Qualitative Quantitative Experimental Quasi-experimental	Review
Time	Since 2003	Pre 2003
Type of publication	Academic publications	Gray Literature (Gov. reports, NGO reports, third-party consultant reports, theses, etc.). Anything else, i.e. media, blogs. If full text not available through CBS
		Non-English language
Search strategy:		
Electronic databases	Electronic databases accessible at CBS: Web of Science	
Compiling	Results will be compiled in Mendeley, and search strings compiled in Excel	
Review methods:		
Reviewers	One researcher conducted the review. Two rounds of sifting enabled greater rigour within this process.	
Sifting	First sift: application of inclusion/exclusion criteria to title and abstract. Second sift: application of inclusion/exclusion criteria to full paper.	
Data extraction	Data from included studies will be extracted in Excel.	
	The data extraction framework developed iteratively based on key paper analysis, and focused on outcomes and study design.	
Synthesis:		
Main synthesis areas	1. Synthesis of the studies with rest of the literature around on the challenges and opportunities associated with converting urban sanitary waste to safe bio-based fertilizers for agricultural production in Sweden. 2. Policy and research recommendations (strategies) for advancing the source separation sector in Sweden as part of a broader shift towards sustainable food systems. To overcome the challenges associated with converting urban sanitary waste to safe bio-based fertilizers for agricultural production.	

Table A.2
List of articles included

Code	Title	Reference
1	Urea stabilisation and concentration for urine-diverting dry toilets: Urinedehydration in ash	Senecal, J., & Vinnerås, B. (2017). Urea stabilisation and concentration for urine-diverting dry toilets: Urine dehydration in ash. Science of the Total Environment, 586, 650–657.
2	Factors influencing the recovery of organic nitrogen from fresh human urinedosed with organic/inorganic acids and concentrated by evaporation inambient conditions	Simha, P., Vasiljev, A., Randall, D. G., & Vinnerås, B. (2023). Factors influencing the recovery of organic nitrogen from fresh human urine dosed with organic/inorganic acids and concentrated by evaporation in ambient conditions. Science of the Total Environment, 879, 163,053.
3	Enhancing nutrient recycling from excreta to meet crop nutrient needs in Sweden – a spatial analysis	Akram, U., Quttineh, N. H., Wennergren, U., Tonderski, K., & Metson, G. S. (2019). Enhancing nutrient recycling from excreta to meet crop nutrient needs in Sweden–a spatial analysis. Scientific Reports, 9(1), 10,264.
4	Assessment of the urban circular economy in Sweden	Heshmati, A., & Rashidghalam, M. (2021). Assessment of the urban circular economy in Sweden. Journal of Cleaner Production, 310, 127,475.
5	Integrated nutrient recovery from source-separated domestic wastewaters for application as fertilisers	Bisschops, I., Kjerstadius, H., Meulman, B., & van Eekert, M. (2019). Integrated nutrient recovery from source-separated domestic wastewaters for application as fertilisers. Current Opinion in Environmental Sustainability, 40, 7–13.
6	Recycling Nutrients and Reducing Carbon Emissions in the Baltic Sea Region —Sustainable or Economically Infeasible?	Callesen, G. M., Pedersen, S. M., Carolus, J., Johannesdottir, S., López, J. M., Kärrman, E., Hjerppe T., Barquet, K. (2022). Recycling Nutrients and Reducing Carbon Emissions in the Baltic Sea Region—Sustainable or Economically Infeasible? Environmental Management, 69(1), 213–225.
7	Use of urine for recycling of phosphorus in the form of soil conditioner	Došek et al., 2014. Use of urine for recycling of phosphorus in the form of soil conditioner. *Conference MendelNet 2014,* 537–541.
8	Recycling – The future urban sink for wastewater and organic waste	Drangert, J. O., & Kjerstadius, H. (2023). Recycling–The future urban sink for wastewater and organic waste. City and Environment Interactions, 19, 100,104.

(*continued on next page*)

Table A.2 (*continued*)

Code	Title	Reference
9	Should the Sludge Hit the Farm? – How Chemo-Social Relations Affect Policy Efforts to Circulate Phosphorus in Sweden	Burgman and Wallsten (2021). Should the sludge hit the farm? –How chemo-social relations affect policy efforts to circulate phosphorus in Sweden. Sustainable Production and Consumption, 27, 1488–1497.
10	Human-Water Dynamics and their Role for Seasonal Water Scarcity – a Case Study	Lindqvist, A. N., Fornell, R., Prade, T., Tufvesson, L., Khalil, S., & Kopainsky, B. (2021). Human-water dynamics and their role for seasonal water scarcity–a case study. Water Resources Management, 35, 3043–3061.
11	Carbon footprint of urban source separation for nutrient recovery	Kjerstadius, H., Saraiva, A. B., Spångberg, J., & Davidsson, Å. (2017). Carbon footprint of urban source separation for nutrient recovery. Journal of Environmental Management, 197, 250–257.
12	Carbon and nutrient recycling ecotechnologies in three Baltic Sea river basins – the effectiveness in nutrient load reduction	Koskiaho, J., Okruszko, T., Piniewski, M., Marcinkowski, P., Tattari, S., Johannesdottir, S., Karman, E.,Kämäri, M. (2020). Carbon and nutrient recycling ecotechnologies in three Baltic Sea River basins–the effectiveness in nutrient load reduction. Ecohydrology & Hydrobiology, 20(3), 313–322.
13	The potential contribution of urine sourceseparation to the SDG agenda – a review of theprogress so far and future development options	Larsen, T. A., Gruendl, H., & Binz, C. (2021). The potential contribution of urine source separation to the SDG agenda–a review of the progress so far and future development options. Environmental Science: Water Research & Technology, 7(7), 1161–1176.
14	Life cycle assessment of phosphorus alternatives for Swedish agriculture	Linderholm, K., Tillman, A. M., & Mattsson, J. E. (2012). Life cycle assessment of phosphorus alternatives for Swedish agriculture. Resources, Conservation and Recycling, 66, 27–39.
15	A Circular Economy for Phosphorus in Sweden—Is it Possible?	Lorick, D., Harder, R., & Svanström, M. (2021). A Circular Economy for Phosphorus in Sweden—Is it Possible? Sustainability, 13(7), 3733.
16	Acceptance of human excreta derived fertilizers in Swedish grocery stores	McConville, J. R., Metson, G. S., & Persson, H. (2023). Acceptance of human excreta derived fertilizers in Swedish grocery stores. City and environment interactions, 17, 100, 096.
17	Is the Swedish wastewater sector ready for a transition to source separation?	McConville, J. R., Kvarnström, E., Jönsson, H., Kärrman, E., & Johansson, M. (2017b). Is the Swedish wastewater sector ready for a transition to source separation? Desalination and Water Treatment, 1–9.
18	Source separation: Challenges & opportunities for transition in the Swedish wastewater sector	McConville, J. R., Kvarnström, E., Jönsson, H., Kärrman, E., & Johansson, M. (2017a). Source separation: Challenges & opportunities for transition in the Swedish wastewater sector. Resources, Conservation and Recycling, 120, 144–156.
19	Environmental impact of recycling nutrients in human excreta to agriculture compared with enhanced wastewater treatment	Spångberg, J., Tidåker, P., & Jönsson, H. (2014). Environmental impact of recycling nutrients in human excreta to agriculture compared with enhanced wastewater treatment. Science of the Total Environment, 493, 209–219.
20	The urine revolution: how recycling urine could help save the world?	Wald, C. (2022). The urine revolution: how recycling pee could help to save the world. nature, 602.
21	Environmental impact of wheat production using human urine and mineral fertilisers - a scenario study	Tidåker, P., Mattsson, B., & Jönsson, H. (2007). Environmental impact of wheat production using human urine and mineral fertilisers–a scenario study. Journal of Cleaner Production, 15(1), 52–62.
22	Anthropogenic phosphorus flows under different scenarios for the city of Stockholm, Sweden	Wu, J., Franzén, D., & Malmström, M. E. (2016). Anthropogenic phosphorus flows under different scenarios for the city of Stockholm, Sweden. Science of the Total Environment, 542, 1094–1105.
23	Investments in Innovative Urban Sanitation – Decision-Making Processes in Sweden	Lennartsson, M., McConville, J., Kvarnström, E., Hagman, M., & Kjerstadius, H. (2019). Investments in innovative urban sanitation–decision-making processes in Sweden. Water Alternatives, 12(2), 588–608.
24	Urine recycling - Diffusion barriers and upscaling potential; case studies from Sweden and Switzerland	Aliahmad, A., Kanda, W., & McConville, J. (2023). Urine recycling-Diffusion barriers and upscaling potential; case studies from Sweden and Switzerland. Journal of Cleaner Production, 414, 137,583.

Table A.3
PESTEL-SWOT matrix

PESTEL factors	SWOT factors			
	Internal factors		External factors	
	Strengths	Weaknesses	Opportunities	Threats
Political	Strength within the source separation sector concerning political institutions and government policies.	Weakness within the source separation sector concerning political institutions and government policies.	Opportunities stemming from political institutions and government policies.	Pressure stemming from political institutions and government policies.
Economic	Strength within the source separation sector concerning economic structures and the degree to which economic factors influence decisions.	Weaknesses within the source separation sector concerning economic structures and the degree to which economic factors influence decisions.	Opportunities stemming from economic structures.	Threats caused by economic structures.
Social	Strength within the source separation sector through cultural aspects, attitudes, beliefs.	Weaknesses within the source separation sector through cultural aspects, attitudes, beliefs.	Opportunities rooted in cultural aspects, attitudes, and beliefs.	Threats, caused by cultural aspects, attitudes, and beliefs.
Technological	Strength within the source separation sector through technological aspects, innovations, incentives.	Weaknesses within the source separation sector through technological aspects, innovations, incentives.	Opportunities rooted in technological development, innovations, incentives.	Threads caused by technological aspects.
Environmental	Strength within the source separation sector through environmental and ecological developments.	Weaknesses within the source separation sector through environmental and ecological developments.	Opportunities rooted in environmental and ecological developments.	Threats rooted in environmental and ecological developments.
Legal	Strength within the source separation sector through laws, regulations, and legislation.	Weaknesses within the source separation sector through laws, regulations, and legislation.	Opportunities rooted in legal developments.	Threats rooted in legal developments.

Appendix B

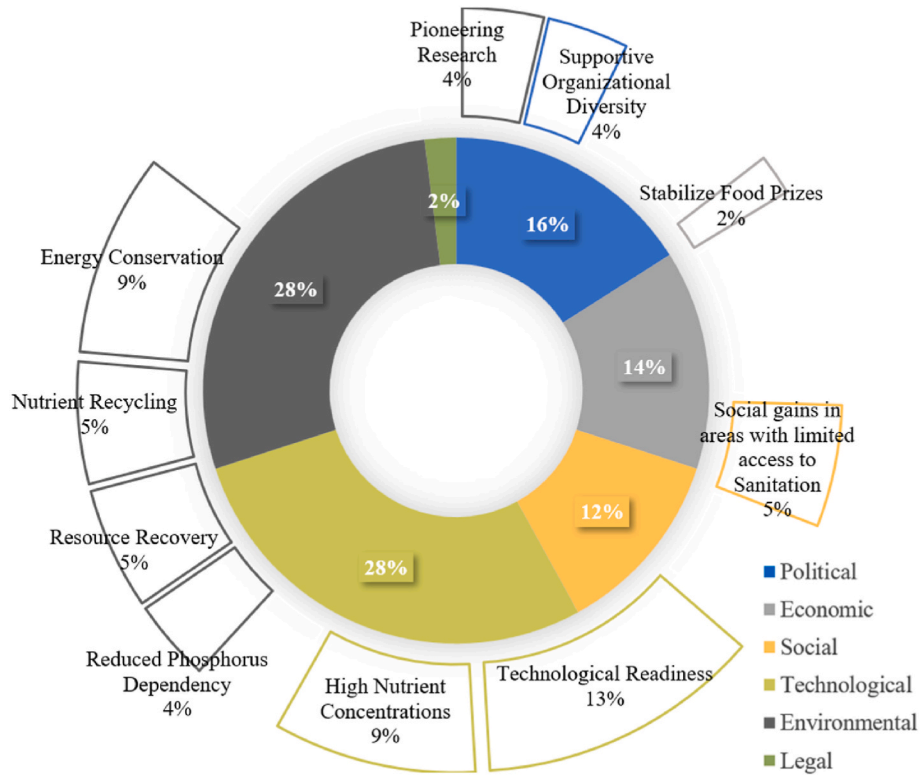

Fig. B.1. SWOT (Strength) and PESTEL Factors.

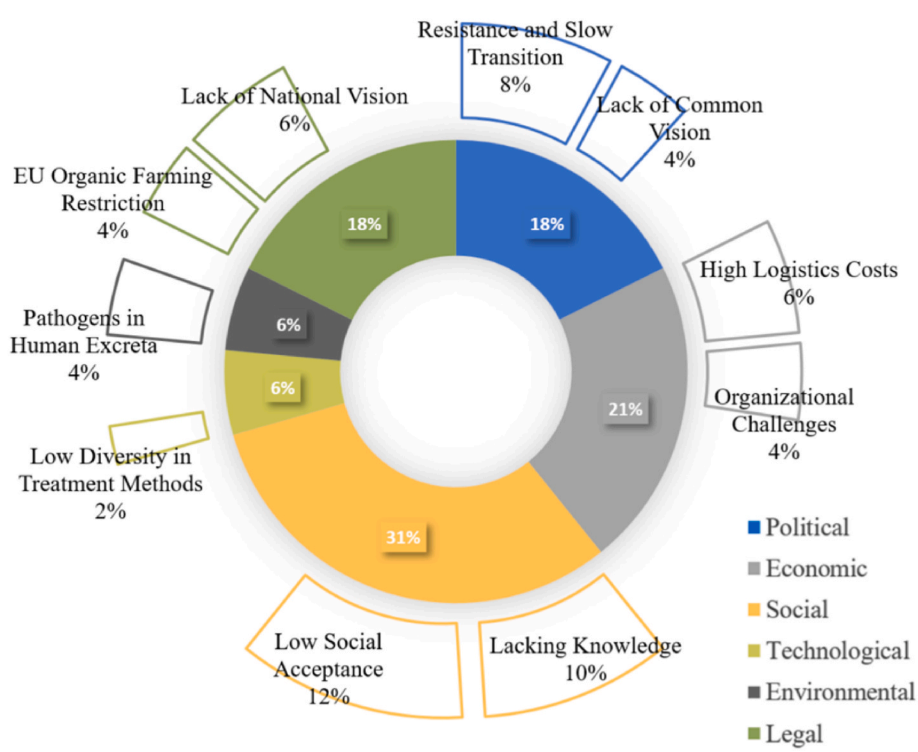

Fig. B.2. SWOT (Weaknesses) and PESTEL Factors.

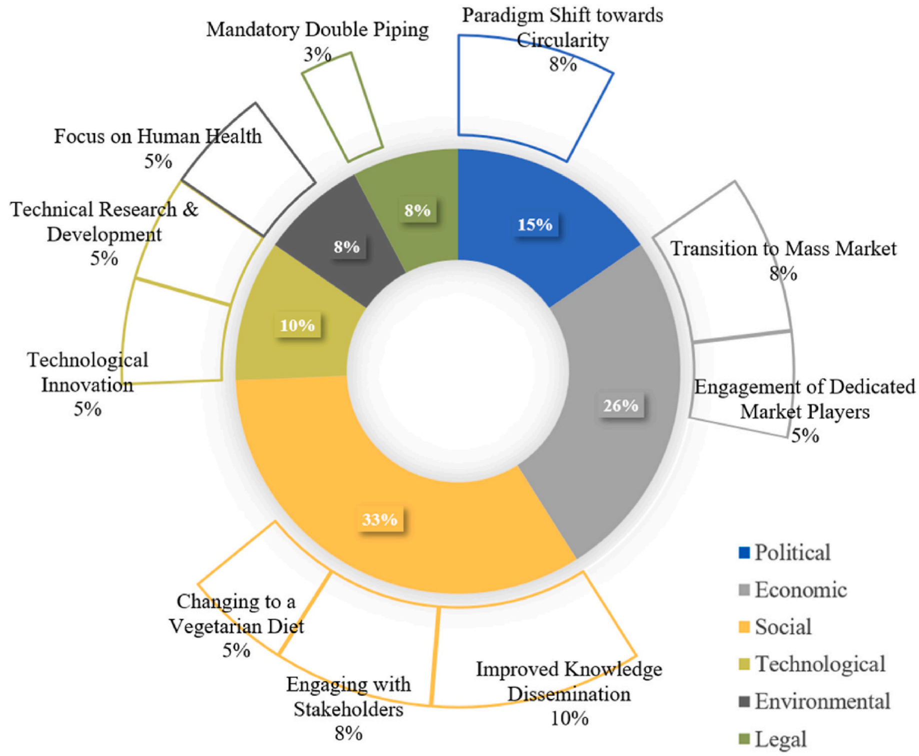

Fig. B.3. SWOT (Opportunities) and PESTEL Factors.

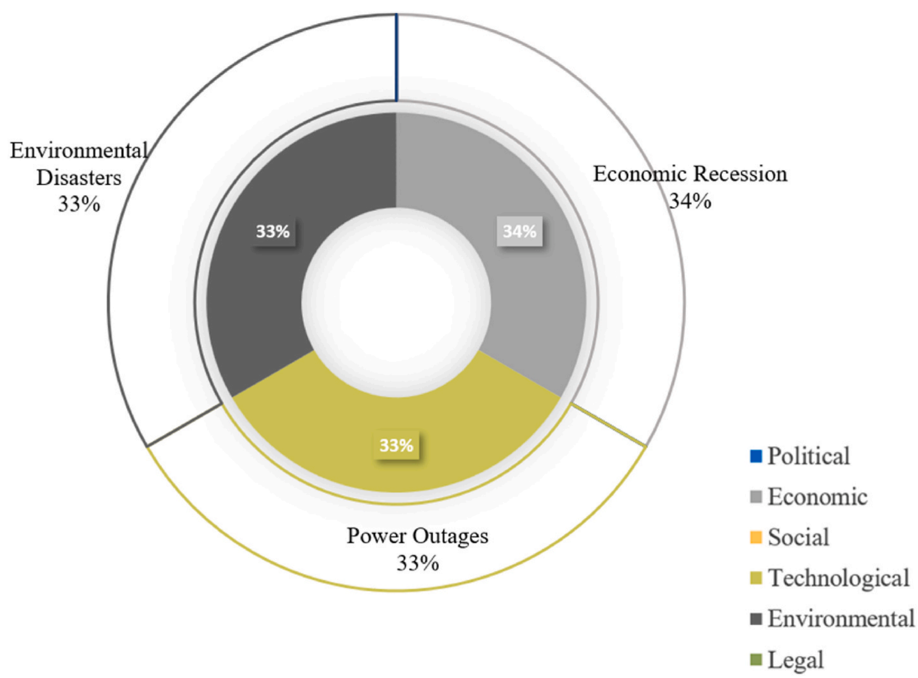

Fig. B.4. SWOT (Threats) and PESTEL Factors.

Data availability

Data will be made available on request.

References

Akram, U., Quttineh, N.H., Wennergren, U., Tonderski, K., Metson, G.S., 2019. Enhancing nutrient recycling from excreta to meet crop nutrient needs in Sweden – a spatial analysis. Sci. Rep. 9 (1). https://doi.org/10.1038/s41598-019-46706-7.

Aliahmad, A., Harder, R., Simha, P., Vinnerås, B., McConville, J., 2022. Knowledge evolution within human urine recycling technological innovation system (TIS): Focus on technologies for recovering plant-essential nutrients. J. Clean. Prod. 379, 134786. https://doi.org/10.1016/j.jclepro.2022.134786.

Aliahmad, A., Kanda, W., McConville, J., 2023. Urine recycling - diffusion barriers and upscaling potential; case studies from Sweden and Switzerland. J. Clean. Prod. 414. https://doi.org/10.1016/j.jclepro.2023.137583.

Barquet, K., Järnberg, L., Rosemarin, A., Macura, B., 2020. Identifying barriers and opportunities for a circular phosphorus economy in the Baltic sea region. Water Res. 171, 115433. https://doi.org/10.1016/j.watres.2019.115433.

Birkle, C., Pendlebury, D.A., Schnell, J., Adams, J., 2020. Web of science as a data source for research on scientific and scholarly activity. Quantitative Science Studies 1 (1), 363–376. https://doi.org/10.1162/qss_a_00018.

Bisschops, I., Kjerstadius, H., Meulman, B., van Eekert, M., 2019. Integrated nutrient recovery from source-separated domestic wastewaters for application as fertilisers. Curr. Opin. Environ. Sustain. 40, 7–13. https://doi.org/10.1016/j.cosust.2019.06.010. Elsevier B.V.

Burgman, L., Wallsten, B., 2021. Should the sludge hit the farm? – how chemo-social relations affect policy efforts to circulate phosphorus in Sweden. Sustain. Prod. Consum. 27, 1488–1497. https://doi.org/10.1016/j.spc.2021.03.011.

Callesen, G.M., Pedersen, S.M., Carolus, J., Johannesdottir, S., López, J.M., Kärrman, E., Hjerppe, T., Barquet, K., 2022. Recycling nutrients and reducing carbon emissions in the Baltic sea region—Sustainable or economically infeasible? Environ. Manag. 69 (1), 213–225. https://doi.org/10.1007/s00267-021-01537-z.

Dioba, A., Kroker, V., Dewitte, S., Lange, F., 2024. Barriers to pro-environmental behavior change: a review of qualitative research. Sustainability 16 (20), 8776. https://doi.org/10.3390/su16208776.

Došek, M., Černý, M., Dostal, P., 2014. Use of urine for recycling of phosphorus in the form of soil conditioner. In: Proceedings of MendelNet 2014. Mendel University in Brno, pp. 537–544.

Drangert, J.O., Kjerstadius, H., 2023. Recycling – the future urban sink for wastewater and organic waste. City and Environment Interactions 19. https://doi.org/10.1016/j.cacint.2023.100104.

Ekdahl, M., Milios, L., Dalhammar, C., 2024. Industrial policy for a circular industrial transition in Sweden: an exploratory analysis. Sustain. Prod. Consum. 47, 190–207. https://doi.org/10.1016/j.spc.2024.03.031.

European Environment Agency, 2024. Europe's state of water 2024. The Need for Improved Water Resilience. Publications Office of the European Union, Luxembourg.

European Union, 1991. Council Directive 91/271/EEC of 21 May 1991 Concerning Urban waste-water Treatment. European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0271.

European Union, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy. European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32000L0060.

European Union, 2020. Farm to Fork Strategy. for a Fair, Healthy and environmentally-friendly Food System. European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0381.

Fertel, C., Bahn, O., Vaillancourt, K., Waaub, J.P., 2013. Canadian energy and climate policies: a SWOT analysis in search of federal/provincial coherence. Energy Policy 63, 1139–1150. https://doi.org/10.1016/j.enpol.2013.09.057.

Government Offices of Sweden, 2002. Sweden's climate strategy: Proposed climate policy bill. Ministry of Environment. https://www.government.se.

Guest, J.S., Skerlos, S.J., Barnard, J.L., Beck, M.B., Daigger, G.T., Hilger, H., Jackson, S. J., Karvazy, K., Kelly, L., Macpherson, L., Mihelicic, J., Pramanik, A., Raskin, L., van Loosdrecht, M.C.M., Yeh, D., Love, N.G., 2009. A new planning and design paradigmDesign paradigm to achieve sustainable resource recovery from wastewater. Environ. Sci. Technol. 43 (16), 6121–6125. https://doi.org/10.1021/es803001r.

Gwara, S., Wale, E., Odindo, A., Buckley, C., 2021. Attitudes and perceptions on the agricultural use of human excreta and human excreta derived materials: a scoping review. Agriculture (Switzerland) 11 (2), 1–30. https://doi.org/10.3390/agriculture11020153. MDPI AG.

Haby, M.M., Barreto, J.O.M., Kim, J.Y.H., Peiris, S., Mansilla, C., Torres, M., Guerrero-Magaña, D.E., Reveiz, L., 2023. What are the best methods for rapid reviews of the research evidence? A systematic review of reviews and primary studies. Res. Synth. Methods. https://doi.org/10.1002/jrsm.1664.

Harder, R., Wielemaker, R., Molander, S., Öberg, G., 2020. Reframing human excreta management as part of food and farming systems. In: Water Research, 175. Elsevier Ltd. https://doi.org/10.1016/j.watres.2020.115601.

Häfner, F., Monzon Diaz, O.R., Tietjen, S., Schröder, C., Krause, A., 2023. Recycling fertilizers from human excreta exhibit high nitrogen fertilizer value and result in low uptake of pharmaceutical compounds. Front. Environ. Sci. 10, 1038175. https://doi.org/10.3389/fenvs.2022.1038175.

HELCOM, 2018. State of the Baltic sea – second HELCOM holistic assessment 2011-2016. In: Baltic Sea Environment, Proceedings 155.

HELCOM, 2021. HELCOM Baltic sea action plan. https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf.

Heshmati, A., Rashidghalam, M., 2021. Assessment of the urban circular economy in Sweden. J. Clean. Prod. 310. https://doi.org/10.1016/j.jclepro.2021.127475.

Islam, F.R., Mamun, K.A., 2017. Possibilities and challenges of implementing renewable energy in the light of PESTLE & SWOT analyses for island countries. Green Energy and Technology 0. https://doi.org/10.1007/978-3-319-50197-0_1, 9783319501963.

Kirchmann, H., Börjesson, G., Kätterer, T., Cohen, Y., 2017. From agricultural use of sewage sludge to nutrient extraction: a soil science outlook. Ambio 46 (2), 143–154. https://doi.org/10.1007/s13280-016-0816-3.

Kjerstadius, H., Bernstad Saraiva, A., Spångberg, J., Davidsson, 2017. Carbon footprint of urban source separation for nutrient recovery. J. Environ. Manag. 197, 250–257. https://doi.org/10.1016/j.jenvman.2017.03.094.

Koskiaho, J., Okruszko, T., Piniewski, M., Marcinkowski, P., Tattari, S., Johannesdottir, S., Kärrman, E., Kämäri, M., 2020. Carbon and nutrient recycling ecotechnologies in three Baltic sea river basins – the effectiveness in nutrient load reduction. Ecohydrol. Hydrobiol. 20 (3), 313–322. https://doi.org/10.1016/j.ecohyd.2020.06.001.

Khangura, S., Polisena, J., Clifford, T.J., Farrah, K., Kamel, C., 2014. Rapid review: an emerging approach to evidence synthesis in health technology assessment. Int. J. Technol. Assess. Health Care 30 (1), 20–27. https://doi.org/10.1017/S0266462313000664.

Laitinen, J., Katko, T.S., Hukka, J.J., Juuti, P., Juuti, R., 2022. Governance and practices for achieving sustainable and resilient urban water services. Water (Switzerland) 14 (13). https://doi.org/10.3390/w14132009.

Lam, S., Nguyen-Viet, H., Tuyet-Hanh, T.T., Nguyen-Mai, H., Harper, S., 2015. Evidence for public health risks of wastewater and excreta management practices in southeast Asia: a scoping review. Int. J. Environ. Res. Publ. Health 12 (10), 12863–12885. https://doi.org/10.3390/ijerph121012863. MDPI.

Larsen, T.A., Gruendl, H., Binz, C., 2021. The potential contribution of urine source separation to the SDG agenda – a review of the progress so far and future development options. Environmental Science: Water Research and Technology 7 (7), 1161–1176. https://doi.org/10.1039/d0ew01064b. Royal Society of Chemistry.

Lennartsson, M., Mcconville, J., Kvarnström, E., Hagman, M., Kjerstadius, H., 2019. Investments in innovative, urban sanitation – decision-making processes in Sweden. Water Altern. (WaA) 12 (2), 588–608. www.water-alternatives.org.

Linderholm, K., Tillman, A.M., Mattsson, J.E., 2012. Life cycle assessment of phosphorus alternatives for Swedish agriculture. Resour. Conserv. Recycl. 66, 27–39. https://doi.org/10.1016/j.resconrec.2012.04.006.

Lindqvist, A.N., Fornell, R., Prade, T., Tufvesson, L., Khalil, S., Kopainsky, B., 2021. Human-water dynamics and their role for seasonal water scarcity – a case study. Water Resour. Manag. 35 (10), 3043–3061. https://doi.org/10.1007/s11269-021-02819-1.

Lorick, D., Harder, R., Svanström, M., 2021. A circular economy for phosphorus in sweden-is it possible? Sustainability 13 (7). https://doi.org/10.3390/su13073733.

McConville, J.R., Kvarnström, E., Jönsson, H., Kärrman, E., Johansson, M., 2017a. Is the Swedish wastewater sector ready for a transition to source separation? Desalination Water Treat. 91, 320–328. https://doi.org/10.5004/dwt.2017.20881.

McConville, J.R., Kvarnström, E., Jönsson, H., Kärrman, E., Johansson, M., 2017b. Source separation: challenges & opportunities for transition in the Swedish wastewater sector. Resour. Conserv. Recycl. 120, 144–156. https://doi.org/10.1016/j.resconrec.2016.12.004.

McConville, J.R., Metson, G.S., Persson, H., 2023. Acceptance of human excreta derived fertilizers in Swedish grocery stores. City and Environment Interactions 17. https://doi.org/10.1016/j.cacint.2022.100096.

McCrackin, M.L., Gustafsson, B.G., Hong, B., et al., 2018. Opportunities to reduce nutrient inputs to the Baltic sea by improving manure use efficiency in agriculture. Reg. Environ. Change 18, 1843–1854. https://doi.org/10.1007/s10113-018-1308-8.

Miles, M.B., Huberman, M.A., Saldaña, J., 2019. Qualitative Data Analysis: a Methods Sourcebook, fourth ed. Sage Publications, Inc., Thousand Oaks, California.

Moons, P., Goossens, E., Thompson, D.R., 2021. Rapid reviews: the pros and cons of an accelerated review process. Eur. J. Cardiovasc. Nurs. 20 (5), 515–519. https://doi.org/10.1093/eurjcn/zvab041. Oxford University Press.

Pathiranage, W.B., Bray, L., Jones, K., Redwine, N., Saralvarez, J., D'Alessio, M., 2024. Perception and acceptance towards water reuse in the Southeast United States: a public survey. Sci. Total Environ. 908, 168224. https://doi.org/10.1016/j.scitotenv.2023.168224.

Perez-Mercado, L.F., Perez-Mercado, C.A., Vinnerås, B., Simha, P., 2022. Nutrient stocks, flows and balances for the Bolivian agri-food system: can recycling human excreta close the nutrient circularity gap? Front. Environ. Sci. 10. https://doi.org/10.3389/fenvs.2022.956325.

Riksdagen (Swedish Parliament), 2017. *Regulation on climate bonus cars* (SFS 2017:1334). Retrieved from. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/forordning-20171334-om-klimatbonusbilar_sfs-2017-1334/.

Savchuk, O.P., 2018. Large-scale nutrient dynamics in the Baltic Sea, 1970-2016. Front. Mar. Sci. 5 (MAR). https://doi.org/10.3389/fmars.2018.00095.

Senecal, J., Vinnerås, B., 2017. Urea stabilisation and concentration for urine-diverting dry toilets: urine dehydration in ash. Sci. Total Environ. 586, 650–657. https://doi.org/10.1016/j.scitotenv.2017.02.038.

Senecal, J., Nordin, A., Simha, P., Vinnerås, B., 2018. Hygiene aspect of treating human urine by alkaline dehydration. Water Res. 144, 474–481. https://doi.org/10.1016/j.watres.2018.07.030.

Simha, P., Vasiljev, A., Randall, D.G., Vinnerås, B., 2023. Factors influencing the recovery of organic nitrogen from fresh human urine dosed with organic/inorganic acids and concentrated by evaporation in ambient conditions. Sci. Total Environ. 879. https://doi.org/10.1016/j.scitotenv.2023.163053.

Smela, B., Toumi, M., Świerk, K., Francois, C., Biernikiewicz, M., Clay, E., Boyer, L., 2023. Rapid literature review: definition and methodology. J. Mark. Access Health Policy 11, 2241234.

Söderholm, K., Vidal, B., Hedström, A., Herrmann, I., 2023. Flexible and resource-recovery sanitation solutions: what hindered their implementation? A 40-Year Swedish perspective. J. Urban Technol. 30 (1), 23–45. https://doi.org/10.1080/10630732.2022.2100212.

Spångberg, J., Tidåker, P., Jönsson, H., 2014. Environmental impact of recycling nutrients in human excreta to agriculture compared with enhanced wastewater treatment. Sci. Total Environ. 493, 209–219. https://doi.org/10.1016/j.scitotenv.2014.05.123.

Srdjevic, Z., Bajcetic, R., Srdjevic, B., 2012. Identifying the criteria set for multicriteria decision making based on SWOT/PESTLE analysis: a case study of reconstructing A water intake structure. Water Resour. Manag. 26 (12), 3379–3393. https://doi.org/10.1007/s11269-012-0077-2.

Tidåker, P., Mattsson, B., Jönsson, H., 2007. Environmental impact of wheat production using human urine and mineral fertilisers - a scenario study. J. Clean. Prod. 15 (1), 52–62. https://doi.org/10.1016/j.jclepro.2005.04.019.

Tsangas, M., Jeguirim, M., Limousy, L., Zorpas, A., 2019. The application of analytical hierarchy process in combination with Pestel-SWOT analysis to assess the hydrocarbons sector in Cyprus. Energies 12 (5). https://doi.org/10.3390/en12050791.

Tricco, A.C., Langlois, E.V., Straus, S.E. (Eds.), 2017. Rapid Reviews to Strengthen Health Policy and Systems: a Practical Guide. World Health Organization.

Vinnerås, B., Palmquist, H., Balmér, P., Jönsson, H., 2006. The characteristics of household wastewater and biodegradable solid waste - a proposal for new Swedish design values. Urban Water J. 3 (1), 3–11. https://doi.org/10.1080/15730620600578629.

Wald, C., 2022. The urine revolution: How recycling pee could help to save the world. Nature 602 (7896), 202–206. https://doi.org/10.1038/d41586-022-00338-6.

Withers, P.J., Forber, K.G., Lyon, C., Rothwell, S., Doody, D.G., Jarvie, H.P., et al., 2020. Towards resolving the phosphorus chaos created by food systems. Ambio 49, 1076–1089. https://doi.org/10.1007/s13280-019-01255-1.

Wu, J., Franzén, D., Malmström, M.E., 2016. Anthropogenic phosphorus flows under different scenarios for the city of Stockholm, Sweden. Sci. Total Environ. 542, 1094–1105. https://doi.org/10.1016/j.scitotenv.2015.09.127.