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Review

A Systematic Review of Drivers of Sustainable Wastewater Treatment Technology Adoption

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Abstract: In this systematic review we explore the forces that encourage or hinder the adoption of wastewater treatment and/or management technology. Our literature search uncovered 37 sources that discuss these issues. Retrieved sources were then subjected to qualitative synthesis. We adopted a systems-theory perspective in analyzing the qualitative data and provide insights into the interaction between the political environment and societal and organizational systems. Our findings indicate that sustainable change can best be achieved through understanding the interaction between systems and their actual capability to meet the needs of related systems. Societal-level systems emerge as having the possibility to influence the political environment as well as organizations.

Keywords: wastewater; technology adoption; organizations; policy; society; systems theory

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1. Introduction

The textile industry is water-consumption intensive. Specifically, it is estimated that approximately 93 trillion liters of water is consumed yearly for the needs of the global textile industry [1]. Intense water resource usage contributes to social and environmental issues, one of them being resource overconsumption leading to resource scarcity [2]. To reduce water usage, textile industries could adopt innovative wastewater treatment technologies [3], for example, closed-loop systems [4]. Such systems enable sustainability issues caused by the textile industry to be addressed. Namely, they allow freshwater uptake to be minimized because they rely on recycled water and significantly reduce contamination of the environment because they nearly eliminate water discharge from the system.

Despite the environmental benefits of the closed-loop wastewater treatment systems textile companies might not necessarily readily accept and adopt them. This is because of a variety of factors and mixture of these factors plays a role in this process. First, depending on the governmental initiatives such as adoption policies and financial measures, could facilitate or hinder willingness to adopt closed-loop technologies [5]. Second, social pressure of local communities or consumers affects the extent to which organizational performance practices are socially responsible [6]. Third, organizational factors such as perceived usefulness of technology and perceived ease of use might affect intentions to adopt the system [7]. Fourth, the costliness of the technology might also determine the willingness to adopt it [8]. Fifth, depending on whether other organizations in the same field have already adopted such technologies can influence the adoption decision in a competing organization [9].

In this systematic review we adopt a systems-theory approach [10] toward the interaction of the political, societal, and organizational components of sustainable wastewater treatment technology adoption [11]. We view the political system as a supersystem in which both communities and organizations operate and interact, receiving inputs from the political supersystem and providing feedback to it. As is common in the systems-theory approach and we consider various outcomes, not as a result from one singular system or agent, but as a result of the interaction of various systems and subsystems within them [12], thus we view the adoption of novel and sustainable wastewater treatment and disposal technologies as a result of communities, organizations, and the political environments adapting to one another through continuous interaction [13].

This approach enables a holistic understanding of the interplay between various forces affecting each stakeholder in the pursuit of sustainable wastewater treatment technology adoption, not focusing separately on regulation, policy, incentives, social action, economic viability, or other factors [14]. Each of these forces act in an open and interacting environment, where neither can be fully effective if the whole system does not change in the same direction. In essence, to achieve sustainable and effective change, an equilibrium position needs to be reached within interacting systems, where all systems both produce desired outputs and are able to receive desired inputs [15]. In other words, simply legislating change would not have a desired effect if the regulated system were incapable of producing the outputs required from it, nor would social pressure have any effect if the required infrastructure was simply not present [13]. Thus, a systems-theory approach is capable of illustrating of how all interacting parts of a system rely on each other and how through mutual change and adaptation they achieve homeostasis and effective functioning.

A multitude of factors might explain acceptance and adoption of technologies which can also can depend on the specifics of the technology itself; there might be complex interactions among various drivers of technology acceptance and a multitude of criteria may need to be met in order for change to occur [16]. Therefore, we conducted a systematic review to find out which factors are particularly relevant in explaining the adoption of locally novel wastewater treatment systems and what type of interaction between political, social, and organizational systems is likely to lead to positive, sustainable results in this regard.

2. Method

Here we describe all decisions we made in searching for sources and the procedures of carrying out the search and filtering out eligible sources.

2.1. Eligibility Criteria

Studies that met the following criteria were included in the review: (a) the study explored the topic of wastewater; (b) the study dealt with acceptance of sustainable wastewater treatment or disposal technology on any level (political, societal, or organizational); (c) the study could be theoretical or empirical; and (d) the study was written in English.

2.2. Search Strategy and Data Sources

One of the authors of the present study carried out the initial literature search using this search string: (accept* OR adopt*) AND (technolog*) AND (environment* OR sustainab*) AND (wastewater OR waste-water) NOT (education OR healthcare). The timeframe was set from 2010 onwards, the search was carried out on 7 January 2021. The search yielded 1766 results (duplicates were removed by the search engine). The number of articles in each specific database is presented in parentheses:

- Academic Search Complete (1126);
- GreenFILE (468);
- Business Source Complete (146);
- MasterFILE Premier (21);
- SocINDEX with Full Text (5).

2.3. Article Selection

One rater screened the 1766 sources for potential inclusion in the review and a total of 89 articles were identified as potentially eligible. Two raters separately evaluated each of the identified articles for eligibility and a total of 37 articles were included in the review after this step. Initial rater agreement was 82%, with a Cohen's κ of 0.65, which is considered as indicative of good interrater agreement [17]. After a group discussion of the sources all disagreements were resolved. See Table 1 for all included studies and see Figure 1 for a step-by-step description of the article inclusion process.

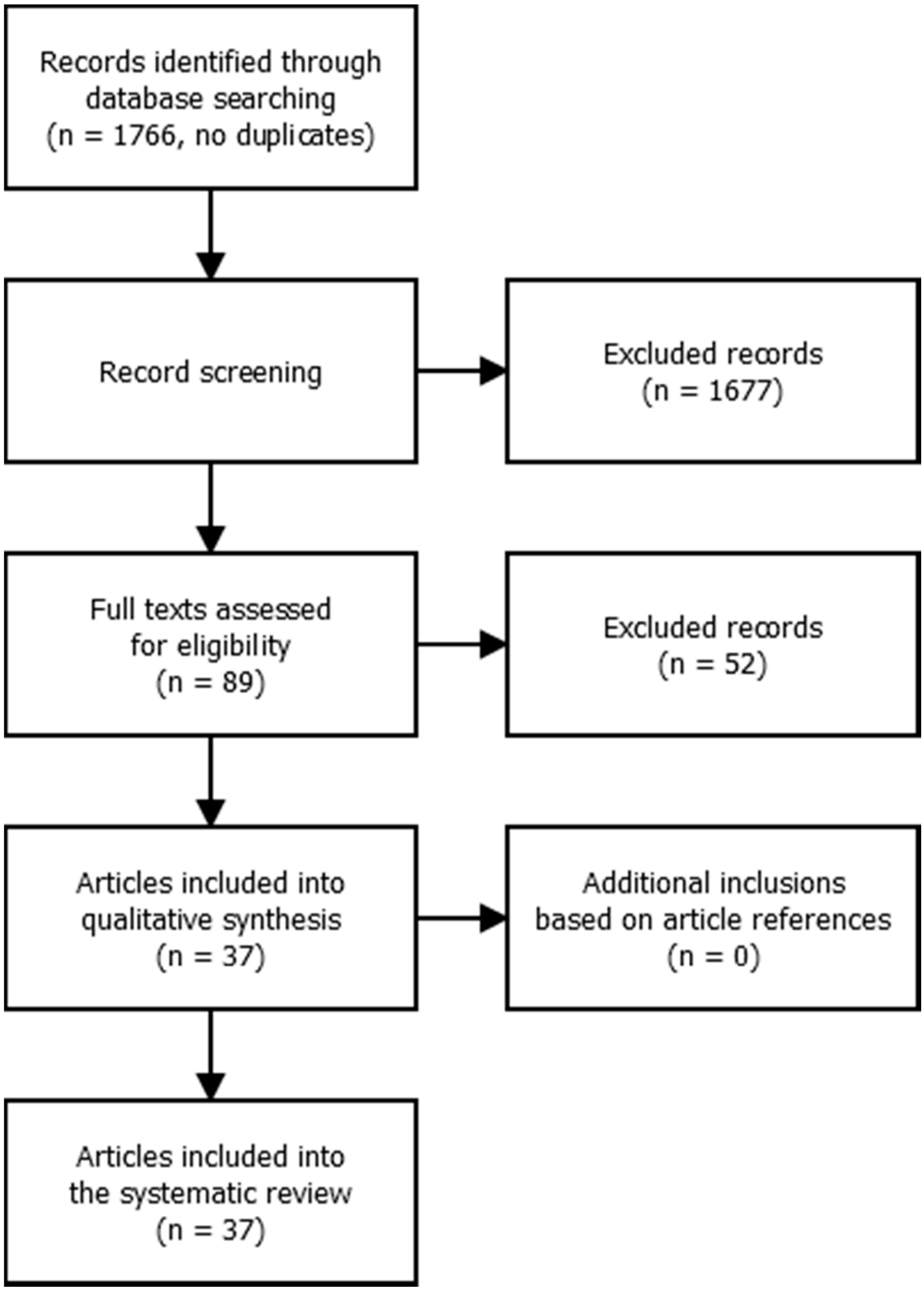

Figure 1. The process of article inclusion in the systematic review following the PRISMA methodology.

Table 1. Summary of analyzed articles.

Ref.	System Level	Main Findings
[18]	Societal	Legitimacy is one of the key factors in explaining the adoption of a particular innovation. Legitimacy framework for potable water reuse: (1) pragmatic (exchange, influence, and dispositional); (2) moral (consequential, procedural, structural, and personal); and (3) cognitive (comprehensibility and taken-for-grantedness).
[19]	Societal	The importance of the person-oriented approach in graywater treatment technology adoption in households. Controlling bad smells and eliminating potential diseases were found to be the most significant factors in graywater treatment technology adoption. The cost was also a significant factor.
[20]	Societal, political, organizational	Seven criteria including, value added, job creation, implementation costs, development of social and environmental issues, lack of public acceptance, quality of the products, and food security were considered for the evaluation of wastewater reuse application alternatives and four main criteria, i.e., economic, technological, environmental, and sociological/cultural and their respective sub-criteria (a total of 33 sub-criteria) were used to evaluate tertiary treatment technologies.
[21]	Societal	Key steps are to incorporate water-chain management into holistic urban planning and thus produce a cradle-to-cradle approach that society will find acceptable. Social acceptance can be obtained by good documentation, communication, and interaction, although direct reuse could pose some psychological difficulties, especially in regions that are not under heavy water stress. Public acceptance is pivotal when designing the cities of the future according to the ZeroWasteWater concept. Sanitation remains taboo for many cultures and religions and in some cases even for science. We should not underestimate the force of particular views that are non-compatible with the paradigm of sanitation by implementing the cradle-to-cradle concept, especially for potable purposes. It will take decades of education and demonstration to convince people that recycling and health can go together as part of a sustainable bio-economy. In this respect, there might be a need to give thorough consideration to the question of whether a novel technology or scheme can be acceptable, taking into account not only our Western lines of thinking, but the global cultural boundaries in terms of sanitation.
[22]	Political, organizational	Results indicated that regulation is an important factor for utility managers considering new technologies but were ambiguous as to whether regulation is a net incentive or a net barrier. Of the wastewater utility managers, 76% indicated that concerns about regulatory noncompliance are a strong or very strong influence on their willingness to consider new technologies.
[23]	Societal, political	Public acceptance as a relevant topic in water reclamation and reuse
[24]	Societal, political, and organizational	Wastewater reclamation and reuse in China face challenges such as the slow adoption of urban wastewater reuse programs, the lack of integrated water resources management framework and guidelines for wastewater reuse programs, incoherent water quality requirements, the limited commercial development of reclaimed water, and the strengthening of public awareness and cooperation among stakeholders. Society must participate in development process of standards, regulations, and policies targeted at wastewater reuse.
[25]	Societal and political	Water reuse is hindered by negative attitudes towards the health effects of recycled water. Societal approval needs to be gained before any legislation regarding recycled water can be proposed.
[26]	Societal	Consumers are, in general, unwilling to consume crops fertilized with human urine and their willingness to do so does not depend on their environmental attitudes, nor is it linked to their health concerns, meaning that highly subjective beliefs play a prominent role in customer choices.
[27]	Societal, political	Wastewater treatment largely depends on its cost to the communities that are in need of such infrastructure and, consequently, there are occasions when voluntary engagement in adopting these systems might depend on the community's willingness to cooperate.

Table 1. *Cont.*

Ref.	System Level	Main Findings
[28]	Societal	Consumers are willing to adopt novel, more convenient sanitation technologies but their acceptance can be increased even more through reliable information from trusted sources.
[29]	Political, organizational	Economic disincentives of inefficient wastewater treatment infrastructure increase adoption of more efficient approaches.
[30]	Societal, political	Solutions for wastewater treatment need to be tailored to their particular circumstances to both increase community acceptance and the political will to invest in infrastructure.
[31]	Political, organizational	While water reuse can be a reliable source of nutrients, robust technical solutions need to be put in place and regulated to make it economically viable and safe.
[32]	Societal, political, organizational	Regulations related to water supply infrastructure may negatively affect businesses which would in turn put a burden on the consumers, thus all stakeholders, including governments, businesses that supply water, and consumers should look for a mutually acceptable solution that ensures reasonable cost as well as high environmental standards.
[33]	Societal, political, organizational	Wastewater treatment is a crucial part of infrastructure, yet in some cases communities are faced with the need to have both cheap and environmentally friendly solutions to these issues, especially in developing areas. Lack of available expertise and technical information as well as a governmental focus on more developed areas might hinder the development of wastewater infrastructure.
[34]	Societal	Communities can be encouraged to adopt water reuse technologies if appropriate societal factors are met, including available information, encouraging individuals to hear more diverse opinions on the matter and to transcend their social circle, reducing their risk perception and increasing their attitudes toward the benefits of such technologies.
[35]	Societal	Individuals' attitudes toward reclaimed water consumption tend to change depending on how reclaimed water is branded, meaning that subjective beliefs and emotions associated with reclaimed water might shift with more attractive representations of such water.
[36]	political, organizational	Disincentivizing water waste and improper disposal of wastewater through precise and measured taxation can encourage stakeholders to adopt more environmentally friendly practices that both lead to cost reduction for stakeholders, and save water. This is mostly effective for large companies that produce wastewater.
[37]	Political, organizational	Increased societal pressure on and stricter legal control of public wastewater treatment facilities nudges voluntary adoption of environmentally friendly initiatives by these organizations.
[38]	Societal, political, organizational	Reducing pollution in water generated by industry is determined by the economic feasibility, incentives/disincentives of various treatment options, as well as the political and social climate affecting the organization.
[39]	Political, organizational	New technologies for wastewater treatment are developed as a response to legal requirements as well as a means of saving costs for their users. Government funding for research for these technologies takes away the financial burden of R&D from organizations, thus incentivizing them to create technologies that comply more readily with ever-stricter regulations.
[40]	Political, organizational	Public wastewater treatment facilities work in a context of ever-stricter legal requirements for quality and sustainability, yet these organizations still need to be profitable to continue their operation. This requires wastewater treatment facilities to make decisions based on market research and projected waste input in order to conserve capital and operate optimally.

Table 1. *Cont.*

Ref.	System Level	Main Findings
[41]	Political, societal, organizational	Policies that are not based on real-life capabilities of all relevant stakeholders tend to be only declarative, while not achieving intended goals. In order for all stakeholders to benefit from an optimal water management system, water management needs to be efficient and financially and practically viable both for the consumer, and for those providing the services.
[42]	Societal, political, organizational	The need for stricter regulations for the reducing the graywater footprint in China is identified. Apart from the population density and industrial intensity of an area, the graywater footprint depends on whether water is treated in a sufficiently up-to-date and environmentally friendly manner.
[43]	Political, organizational	Contaminants from manure can pollute groundwater; thus proper treatment of manure is necessary for ensuring local groundwater quality. Stakeholders are mostly persuaded to engage in proper treatment of manure by governmental regulations, however the need for investing in treatment technologies as well as high treatment costs are identified as barriers to technology adoption.
[44]	Political, organizational	Treating wastewater can both help replenish water supplies as well as generate a profit through reclaimed nutrients in wastewater. Lack of holistic thinking on the side of policymakers leads to inefficient policy and hinders the establishment of a circular economy in water treatment.
[45]	Societal, political, organizational	Organizations more readily engage in more environmentally friendly practices if they perceive societal pressure and are confronted by relevant regulations on acceptable levels of pollution. Additionally, intending to have their products labeled with eco labels as a means of appealing to their customers, organizations are compelled to ensure that their practices are environmentally friendly, but this does not necessarily mean that organizations will engage in early adoption of technologies that go beyond what is required to have their products eco-labeled.
[46]	Societal	Wastewater generation in the urban environment has deep cultural roots which result in practices that may not be sustainable in the future, namely—flush toilets. An alternative to wastewater treatment is not generating wastewater altogether, in this case through composting toilets or other similar means. This is mainly an issue that is in direct contrast with societal norms, thus practical change will only follow after cultural changes.
[47]	Political	In many cases the lack of clear criteria and regulations on how wastewater can be reused is hindering the adoption of wastewater reuse practices.
[48]	Societal, political, organizational	Water scarcity is the main driving force behind wastewater reuse, which is translated both into policy, and into practical adoption of wastewater-reuse technologies by organizations and individuals. However, the increased complexity of wastewater use as well as societal attitudes toward wastewater use are among the forces that hinder the adoption of wastewater reuse practices.
[49]	Societal, political	There are a multitude of ways water can be gathered and/or reused and while society might be warming up to these means of conserving water, the lack of initiatives from the government leads to missed opportunities in adopting these technologies. A more bottom-up approach which is initiated at the level of the community might lead to more effective changes both in policy and in practice.
[50]	Political	While the technology to reuse graywater is readily available, its adoption might be hindered by the lack of regulation and official standards of using graywater.
[51]	Societal, political, organizational	The public can be reached through taxes/subsidies and through information, while on the political level work needs to be done to understand and regulate new technologies, making it easier for stakeholders to adopt and use novel technologies. Economic factors play a role in organizations; both the development and implementation of technology need to be financially viable.

Table 1. *Cont.*

Ref.	System Level	Main Findings
[52]	Societal	Early adopters, in terms of regions, adopt ecological innovations to a larger extend than late adopters, while late adopters tend to initially have faster adoption rates. Additionally, having proximal adopters increases the likelihood of adoption, meaning that social examples have a prominent role in the process of ecological innovation adoption.
[53]	Societal, political, organizational	Existing urine diversion technologies are slow to be adopted because of a lack of clear regulations and guidelines for such systems. It is suggested to provide working examples of the technology as both proof of its viability and to inform policy makers as well as the broader public, thus facilitating the adoption of this technology.
[54]	Societal	Graywater reuse is determined by one's environmental awareness, perceived cost (or reduction of cost), perceived risk (or lack of it), and one's experience with the system either working well, or having maintenance issues.

3. Results

The 37 studies included into the systematic review underwent qualitative analysis and synthesis and the main points of each source were briefly summarized alongside the relevant system levels discussed in each source (see Table 1). Overall, many of the included sources were relevant to all system levels—political, societal, and organizational, touching upon how the adoption of locally novel sustainable wastewater treatment and/or management technologies relies on the joint cooperation of all involved stakeholders.

The findings of the systematic review were further condensed into the main points of hindering technology adoption at each system level, providing a concise list of areas that need to be addressed in order to drive the acceptance of the wastewater treatment and/or management technologies (Table 2). Each system level has its own barriers that it needs to overcome, but tackling these barriers is not a localized action, it requires interaction between all systems participating in the process of change.

Table 2. A systems-theory approach to wastewater treatment technology adoption.

System Level and Its Description	Main Factors Hindering Acceptance of Wastewater Treatment Technology
Political level: regulations and laws pertaining to wastewater treatment. This is the broadest system and can be considered the supersystem in which both the societal-level systems and the organizational-level systems work. While generally, political decisions impact smaller systems that operate in a given political environment, both societal systems (communities) and organizational systems can provide inputs to the supersystem to facilitate change that accommodates their needs.	Unwillingness to invest in infrastructure and R&D [39,43,51]. Lack of knowledge of state-of-the-art technologies that could inform policy decisions and regulation [32,42,44,47]. Lack of public support/pressure/approval to adopt new technologies [19,23,25].
Societal level: consumers, activists, affected parties. Societal-level systems are affected by both the political climate and the available services and goods they can be got from organizational systems. Systems on this level can provide inputs for the political system, facilitating change to suit their needs, and can influence organizational systems by exercising choice through market forces as well as through activism and collective action.	Lack of initiative/engagement/pressure [24,45,46]. Negative attitudes toward technologies, services, or products [25,35,48]. Lack of knowledge and understanding of possible technologies and solutions [28,34,51].
Organizational level: businesses, infrastructure owners, and service providers. Organizational-level systems need to balance being profitable while staying within the legal requirements for their goods and services and by staying competitive by appealing to their customers. However, by introducing new services and products and attractively branding them, these systems can influence their customers. Additionally, organizational systems can lobby to change their political supersystem.	Legal barriers: restrictive regulation or lack of clear regulation [24,50,53]. Financial barriers: requirements to invest in infrastructure and R&D [20,43,54]. Lack of societal and/or legal pressure to adopt novel technologies [29,37,45].

4. Discussion

As evidenced by the data presented in Table 1 and the obstacles identified in Table 2, there is an interdependence among all three system levels where one system cannot act in enabling adoption of new technology if it does not receive the needed inputs from the other systems. For example, the political system could propose novel regulations regarding wastewater treatment if it perceives a societal pressure to do so, yet communities cannot exert such pressure if they lack the knowledge and understanding needed regarding various solutions—an input that could reasonably come from the organizational level. This web of interdependence in moving forward with innovations illustrates the need for a more integrated dialogue between all stakeholders, so that businesses and organizations can provide the necessary information for both communities and lawmakers on what is infrastructurally possible and economically viable, helping communities develop an informed opinion regarding the matter and voice their opinion in such a way that it results in appropriate legal regulations and enabling.

When analyzing the way open systems interact, we must consider the concept of equifinality—the ability for a system to achieve desired results through a multitude of paths [10,12]. For wastewater treatment technology adoption this means that organizations can be persuaded to adopt novel practices and technologies through legal means and regulation, voluntarily, or based on the perceived pressure from the consumer, meaning that there is no universal one-best-way of achieving sustainable technology adoption and the process will be different under different interacting systems and the level of their openness [10].

Open systems interact by exchanging inputs and outputs, thus sustaining themselves in a state of equilibrium if the needs of the interacting systems are met. Any type of change in one system introduces disturbances in all related systems, thus there is a need for a balanced approach where none if the interacting systems requires more than other systems can provide. Regulation and social pressure might be a strong input for organizations providing services and goods, but if organizations are unable to accommodate the requirements posed to them—if there is a mismatch between their real outputs and the outputs expected by related systems—this results in neither system operating optimally. It follows that legal requirements and regulations, as well as societal pressure and expectations, should not exceed what is currently possible to achieve by organizations in terms of sustainable outcomes. Effective change, in this regard, needs to be gradual and evolutionary, building on existing capacities and introducing gradual changes that all stakeholders have agreed upon.

In order to achieve realistic and sustainable change, all interacting systems need to understand their interdependence and work together, through an informed and practical bottom-up perspective. This requires not only understanding what is possible technologically and financially, but understanding one's own goals and clearly communicating them to other stakeholders. If we take the interaction between the political environment, communities, and organizations as a singular organism, we cannot expect that one part of the whole can be improved at the expense of others.

5. Conclusions

The main barriers to novel (both locally and overall) wastewater treatment technology adoption are the lack of willingness to share the R&D cost the development of such technology by governments, the lack of a clear direction in which the industry should go, and the lack of clear and reasonable regulations regarding wastewater treatment.

Communities can be a strong force in promoting positive change in wastewater treatment technology adoption, however this requires their willingness to act, having relevant knowledge regarding possible technological solutions, and favorable attitudes toward such technology. Communities have the possibility to both affect change through collective action if they vocalize their needs to governing bodies and exert financial pressure on organizations by choosing to vote with their money and purchasing goods and services from those organizations that meet their expectations.

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