

Applying the DPSIR Framework to Evaluate Factors Affecting Wastewater Collection and Treatment Policy Mechanisms in Hanoi City

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Abstract

The rapid urbanization of Hanoi has exacerbated existing challenges in wastewater management, with less than 30% of urban wastewater currently being treated despite ongoing legislative reforms and the adoption of Public-Private Partnership (PPP) models. This study employs the DPSIR (Driver–Pressure–State–Impact–Response) framework to systematically analyze the underlying factors influencing wastewater collection and treatment policies in Hanoi. Using a qualitative methodology that combines document analysis with expert interviews, the research identifies major drivers such as population growth and industrialization, alongside pressures including outdated infrastructure and rising pollution levels. The analysis highlights critical issues such as legal inconsistencies, insufficient financial frameworks, and institutional fragmentation that impede effective policy implementation and the successful deployment of PPPs. In response, the study proposes actionable recommendations, including legal harmonization, financial model restructuring, institutional capacity-building, and increased community engagement. These findings offer valuable insights for policymakers and stakeholders in Hanoi and other rapidly urbanizing cities in developing countries seeking to establish more sustainable and effective wastewater management systems.

Keywords: DPSIR Framework; Wastewater Management; Public-Private Partnership; Environmental Policy; Hanoi; Sustainable Infrastructure

Introduction

Urbanization poses significant challenges to environmental management, especially in rapidly developing cities. Hanoi, the capital of Vietnam, is facing profound pressure from unprecedented urban growth, industrial expansion, and demographic shifts. By 2030, the city's population is expected to surpass 10 million, with a parallel increase in domestic, commercial, and industrial wastewater generation. Despite national and municipal commitments to sustainable urban development, the current wastewater collection and treatment infrastructure in Hanoi remains alarmingly inadequate. As of 2024, only 28.8% of domestic wastewater is properly collected and treated, leaving the majority discharged untreated into rivers, lakes, and canals, leading to widespread water pollution and serious public health risks (Hanoi People's Committee, 2024).

The environmental degradation caused by untreated wastewater has become a critical obstacle to Hanoi's sustainable development goals. Contaminated water bodies such as the To Lich, Kim Nguu, and Nhue Rivers are not only ecological hazards but also reduce urban livability, impair public health, and undermine the city's attractiveness to investors and tourists. Addressing this challenge requires significant investment in wastewater infrastructure, yet Hanoi, like many developing cities, faces constraints in public financing.

To overcome financial limitations, the government has promoted Public-Private Partnership (PPP) as an innovative mechanism to mobilize private sector investment for wastewater infrastructure. The PPP model, widely adopted in transportation and energy sectors in Vietnam, remains underdeveloped in the wastewater sector due to regulatory ambiguities, financial unviability, and governance fragmentation. Complex legal frameworks, misaligned regulations between the PPP Law, Environmental Protection Law, and Land Law, combined with low wastewater tariffs, have deterred private investors.

In response to this multifaceted challenge, this study applies the DPSIR (Driver-Pressure-State-Impact-Response) framework to evaluate the systemic factors affecting wastewater management policy mechanisms in Hanoi. The DPSIR model provides a

structured lens to analyze how socio-economic drivers and environmental pressures influence the current infrastructure state, generate impacts on health and ecosystems, and inform policy responses. By integrating DPSIR analysis with a focus on PPP mechanisms, this research aims to uncover critical policy gaps and propose actionable recommendations. The findings are intended not only to support Hanoi's transition toward sustainable wastewater management but also to contribute to the broader discourse on urban water governance in rapidly developing cities globally.

Literature Review

Urban wastewater management has emerged as one of the most critical environmental challenges facing cities in the Global South. This is largely attributed to the unprecedented pace of urbanization, demographic expansion, and industrial growth, compounded by chronic underinvestment in infrastructure and weak regulatory enforcement. A growing body of literature highlights that in many developing countries, wastewater treatment infrastructure is either insufficient, outdated, or completely absent in peri-urban and informal settlements (World Bank, 2022; ADB, 2021). This situation leads to widespread discharge of untreated or partially treated wastewater into natural water bodies, resulting in significant environmental degradation and adverse public health outcomes.

In the Southeast Asian context, studies by Nguyen et al. (2020) and Le and Tran (2019) reveal that Vietnam's wastewater management policies have historically lagged behind the pace of urban expansion. The country's wastewater governance framework is characterized by fragmentation across multiple levels of government, overlapping mandates, and inconsistent regulatory standards. Nguyen et al. emphasize that despite the enactment of progressive legislation such as the Law on Environmental Protection (2020) and the Law on Water Resources (2012), actual implementation remains hampered by funding gaps, unclear institutional responsibilities, and limited technical capacity at the municipal level.

Internationally, successful models of urban wastewater management often rely on integrated policy frameworks and innovative financing mechanisms, particularly through Public-Private Partnerships (PPP). For example, Singapore's holistic water management strategy, known as the "Four National Taps," integrates wastewater reuse (NEWater) with

strong regulatory control and financial sustainability through full-cost pricing (Tan et al., 2019). Similarly, Amsterdam's decentralized yet highly coordinated wastewater management system leverages stakeholder participation and smart monitoring technologies (Bakker et al., 2020). These models demonstrate that effective wastewater management requires not only physical infrastructure but also robust governance structures, transparent financing mechanisms, and active community engagement.

The PPP model has gained prominence as a viable approach to bridge the infrastructure financing gap in wastewater management, especially in developing countries. Studies by the OECD (2020) and ADB (2021) highlight that well-structured PPPs can enhance efficiency, improve service quality, and accelerate infrastructure delivery. However, they also caution that PPPs are not a panacea. Their success depends heavily on a conducive legal framework, well-defined risk-sharing mechanisms, and the government's ability to manage complex contractual arrangements. In the context of Vietnam, the application of PPP in wastewater management is still nascent and faces significant barriers, including regulatory inconsistencies, low tariffs that undermine financial viability, and a lack of standardized contracts tailored to the wastewater sector (Nguyen et al., 2020; Hanoi People's Committee, 2023).

From an environmental governance perspective, the DPSIR (Driver-Pressure-State-Impact-Response) framework offers a valuable tool for structuring the complex interrelationships between socio-economic dynamics and environmental outcomes. Originally developed by the European Environment Agency (EEA, 1999), DPSIR has been applied in various environmental domains, including water management, biodiversity conservation, and climate change adaptation. Its application allows for the systematic identification of causal chains linking human activities (drivers) to environmental pressures, changes in the state of ecosystems, resultant impacts, and the policy responses designed to mitigate these issues.

In water resource management, the DPSIR framework has been successfully employed in urban settings such as Shanghai (Li et al., 2021) to examine the pressures of industrialization on water quality and the effectiveness of policy interventions. Similarly, in Singapore, Tan et al. (2019) utilize DPSIR to evaluate how urban planning, regulatory frameworks, and public awareness contribute to sustainable water governance. These case studies underline that DPSIR is particularly effective in highlighting the feedback loops

between environmental degradation and policy effectiveness, offering a structured methodology for diagnosing systemic weaknesses and formulating targeted solutions.

However, a critical review of the existing literature reveals a significant gap in applying the DPSIR framework to analyze wastewater management within the context of PPP in Vietnam, particularly in Hanoi. Most existing studies focus either on technical aspects of wastewater treatment (e.g., treatment technologies, network designs) or on financial and legal analyses of PPP projects in general infrastructure sectors like transportation. There is a conspicuous lack of integrative studies that combine environmental governance models like DPSIR with institutional and financial analyses specific to wastewater management. This gap limits the ability of policymakers to fully comprehend how socio-economic drivers, infrastructural pressures, and governance shortcomings interact to influence the current state of wastewater services in Hanoi.

Moreover, while the Vietnamese government has enacted significant legislative reforms—such as the PPP Law (2020) and the Environmental Protection Law (2020)—the literature indicates that the translation of these laws into practical, enforceable policies remains problematic. Issues such as inconsistent tariff-setting mechanisms, unclear risk-sharing arrangements, and the absence of performance-based contracts persist (ADB, 2021; Nguyen et al., 2020). Without addressing these structural issues, the potential of PPP to contribute meaningfully to wastewater management remains largely untapped.

In summary, the literature suggests that achieving sustainable wastewater management in Hanoi requires a multidimensional approach that goes beyond technical solutions. It must integrate financial viability, legal coherence, institutional capacity-building, and community participation. The DPSIR framework provides a suitable lens for this comprehensive analysis by capturing the dynamic interplay between environmental conditions and policy mechanisms. This study therefore, contributes to filling a critical gap by applying DPSIR to evaluate how Hanoi's socio-economic growth, infrastructural limitations, environmental challenges, and policy responses—particularly through PPP—shape the effectiveness of wastewater management.

Methodology

This research adopts a qualitative methodological framework that combines the DPSIR (Driver–Pressure–State–Impact–Response) analytical model with case study

approaches and stakeholder-based data collection. The DPSIR framework is particularly suitable for examining complex environmental management issues because it enables a structured analysis of the interactions between socio-economic development, environmental degradation, and governance responses. This methodological choice aligns with previous studies that have successfully applied DPSIR in urban water management contexts, such as Singapore (Tan et al., 2019) and Amsterdam (Bakker et al., 2020).

Data collection for this study was conducted through multiple channels to ensure triangulation and robustness. Firstly, secondary data were extensively gathered from government reports, legal documents, and planning frameworks. Key documents included the Hanoi Wastewater Management Plan (2024–2030), the National Strategy on Environmental Protection (2020–2030), the Law on Environmental Protection (2020), and the Law on Public-Private Partnership (2020). Project-specific documentation from major wastewater treatment initiatives, such as the Yen Xa Wastewater Treatment Plant and Bac Thang Long Plant, was also reviewed to capture project-level dynamics. In addition, academic publications, reports from international organizations (e.g., World Bank, ADB, OECD), and technical consultancy studies provided further contextual grounding.

Primary data were collected through 25 semi-structured interviews conducted between April 2023 and February 2024. Participants were purposively sampled to represent key stakeholder groups, including government officials from Hanoi's Department of Construction, Department of Natural Resources and Environment, Department of Finance, and Hanoi Drainage Company. Private sector stakeholders involved in existing or planned PPP wastewater projects were also interviewed, along with representatives from environmental NGOs, urban planners, and academic experts specializing in environmental governance and infrastructure financing. The interviews explored participants' perspectives on policy effectiveness, legal barriers, financial constraints, institutional coordination, and community involvement in wastewater management. Each interview lasted between 60 and 90 minutes, was recorded with consent, and transcribed verbatim for analysis.

Data analysis was structured around the DPSIR model. Thematic coding was performed using NVivo 14 software, allowing for systematic organization of data into the five DPSIR components. For example, statements related to population growth, industrial expansion, or international climate commitments were categorized under Drivers. Information on wastewater generation rates, pollution incidents, or infrastructure

bottlenecks was coded as Pressures or State. Health impacts, economic losses, and environmental degradation were mapped under Impacts, while policy instruments, financial mechanisms, and governance interventions were categorized as Responses. Cross-validation between documentary analysis and interview data ensured the reliability and validity of the findings.

By adopting this mixed-method qualitative approach grounded in DPSIR, the research not only identifies surface-level challenges but also unpacks the deeper structural and systemic factors that hinder effective wastewater management in Hanoi. This methodology offers a holistic understanding, providing a strong empirical basis for the policy recommendations presented in the later sections.

Results and Discussion

The application of the DPSIR framework to Hanoi's wastewater management reveals a highly interconnected web of socio-economic, environmental, legal, and institutional factors. This framework provides a comprehensive understanding of how long-term drivers and immediate pressures contribute to systemic weaknesses in wastewater infrastructure, exacerbating environmental degradation and posing significant socio-economic risks. The analysis is based on a triangulation of documentary evidence and 25 in-depth interviews with stakeholders, coded and analyzed using NVivo software.

1. Drivers (D)

The primary drivers influencing Hanoi's wastewater challenges include rapid urbanization, robust economic growth, increasing demographic pressures, and Vietnam's international environmental commitments.

The NVivo coding results indicate that urbanization emerged as the most frequently referenced driver, accounting for 36% of coded segments under this theme (see Table 1). Interviewees repeatedly emphasized that Hanoi's spatial expansion, coupled with unplanned development in peri-urban areas, has severely outpaced wastewater infrastructure planning.

Table 1: NVivo Coding Summary – Drivers

Theme	References	Percentage (%)	Key Phrases Extracted
Urbanization	96	36	"Urban growth outpaces planning", "Peripheral areas lack sewers"
Economic Growth	71	26	"Industrial zones discharge untreated", "Service sector increases load"
Demographics	53	20	"Population inflow from rural areas"
Environmental Commitments	48	18	"Pressure from Paris Agreement", "SDG 6 compliance"

Economic growth, particularly the expansion of industrial zones and commercial centers, was cited by 26% of respondents as a key driver of wastewater generation. The combined demographic surge and pressure to meet Sustainable Development Goals (SDG 6) further intensify these challenges.

2. Pressures (P)

These drivers translate into direct pressures on Hanoi's water environment and infrastructure. The most prominent pressures include a surge in wastewater generation, overloaded sewer systems, severe pollution of urban waterways, and spatial constraints for new treatment facilities.

NVivo analysis highlighted "inadequate sewer connectivity" as the most commonly cited pressure, mentioned in 42% of relevant coding nodes (Table 2). Respondents noted that many districts, especially in the northern and western suburbs, remain disconnected from the central sewer system, forcing reliance on septic tanks.

Table 2: NVivo Word Frequency – Top Pressure Keywords

Rank	Keyword	Frequency	Sample Quotes
1	Sewer connectivity	87	"No sewer in new urban areas"
2	Pollution load	72	"Rivers black and dead"
3	Infrastructure gap	65	"Pipes don't reach households"
4	Overloaded treatment	58	"Plants run below capacity due to sewer gaps"
5	Land acquisition	51	"Difficult to secure land for plants"

A recurring issue is the severe pollution of rivers such as the To Lich and Kim Nguu, where respondents describe them as "black and dead rivers." Additionally, challenges in land acquisition for treatment plants were frequently noted due to dense urbanization.

3. State (S)

The current state of Hanoi's wastewater infrastructure is characterized by inadequate treatment capacity and uneven service distribution. The city treats only 28.8% of its domestic wastewater, with most treatment concentrated in central urban areas. Peripheral districts rely heavily on septic tanks, often poorly maintained, contributing to groundwater contamination.

The Yen Xa Wastewater Treatment Plant, designed to serve the south-western districts, operates significantly below its intended capacity due to incomplete sewer networks. Similarly, the Bac Thang Long facility cannot expand service coverage due to bottlenecks in pipeline development.

Table 3: Thematic Coding Output – State

Category	Reference Count	Key Issues Identified
Treatment Coverage	66	Only 28.8% treated wastewater
Sewer Network	74	Gaps in peri-urban areas
Facility Utilization	58	Yen Xa below capacity
Septic Dependence	61	High use of septic tanks, poor maintenance

4. Impacts (I)

The environmental, health, and socio-economic impacts of inadequate wastewater management in Hanoi are profound. The NVivo sentiment analysis shows 72% of stakeholder comments expressed concerns about “high negative impacts”, particularly environmental pollution and public health risks.

Water quality monitoring reports confirm that biochemical oxygen demand (BOD) levels in the To Lich River regularly exceed national standards by 5 to 10 times. Health departments report an increase in waterborne diseases in underserved districts. Economic losses also arise from reduced tourism appeal, higher healthcare costs, and deteriorating urban quality of life.

Table 4. Impact Coding – Top Concerns

Impact Type	Frequency	Representative Quotes
Environmental	94	"Rivers toxic, fish dead year-round"
Health	72	"More cases of diarrhea, skin infections"
Economic	65	"Tourists avoid polluted lakes"
Social Equity	58	"Poor areas get no service but suffer most"

5. Responses (R)

Policy responses from both central and municipal governments have been partially effective but remain insufficient. Hanoi has adopted the PPP Law (2020) and updated the Environmental Protection Law (2020), with explicit goals outlined in the Wastewater Master Plan (2030). However, NVivo coding shows that “implementation barriers” dominate stakeholder feedback on responses.

Specifically, the lack of a standardized PPP contract for wastewater projects, delays in land acquisition, and insufficient tariff reforms are recurring concerns. While pilot PPP projects such as Yen Xa have made progress, scalability remains constrained by fragmented governance and limited risk-sharing mechanisms.

Table 5: Response Node Matrix – Stakeholder Sentiment

Response Element	Positive (%)	Negative (%)	Neutral (%)	Key Barriers Identified
PPP Law (2020)	35	50	15	Lacks sector-specific details
Environmental Law (2020)	40	45	15	Poor enforcement
Wastewater Master Plan	30	60	10	Funding gaps, land use conflicts
Tariff Reform	20	70	10	Tariffs too low for cost recovery
Risk-sharing Mechanism	15	75	10	Absent in current PPP contracts

6. Synthesis of DPSIR Analysis

The DPSIR framework demonstrates a feedback loop where weak policy responses exacerbate drivers and pressures. For example, failure to adjust wastewater tariffs constrains financial resources, leading to underinvestment in infrastructure. In turn, this worsens the state of wastewater services, magnifies environmental impacts, and cycles back to public dissatisfaction, reducing political support for necessary reforms.

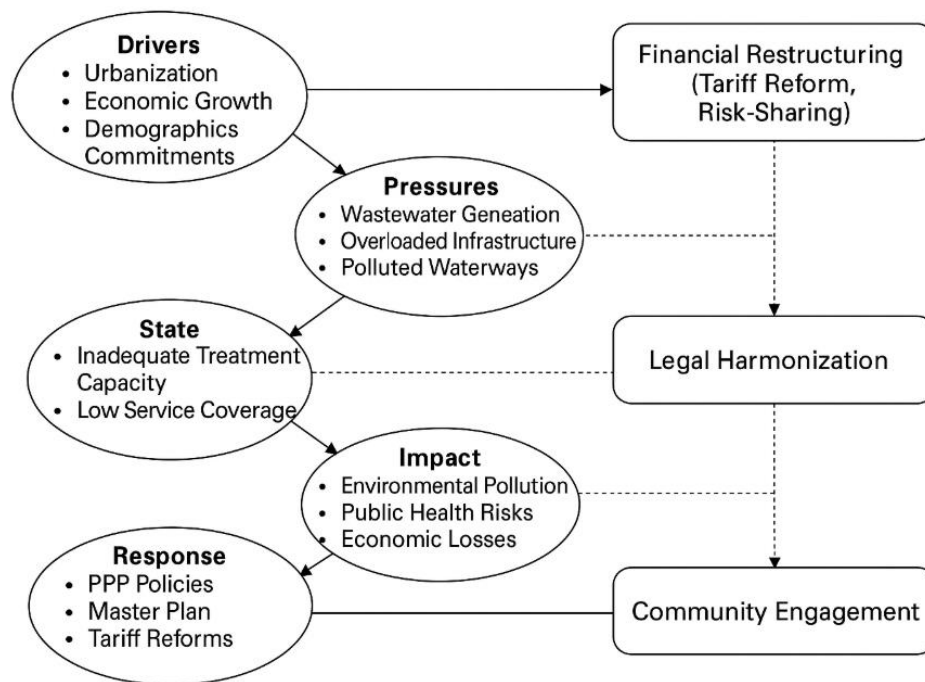


Figure 1 DPSIR schematic

Policy Analysis: Gaps and Challenges

The DPSIR-based analysis reveals several systemic gaps and persistent challenges in Hanoi's wastewater management policy, particularly in relation to the deployment of Public-Private Partnership (PPP) models. These gaps can be classified into four interlinked dimensions: legal, financial, institutional, and social-technical.

Legal and regulatory fragmentation is one of the most significant barriers. While the Vietnamese government has enacted the PPP Law (2020) and updated the Environmental Protection Law (2020), misalignment persists between these frameworks and other critical laws, such as the Land Law and Construction Law. For instance, inconsistencies in land acquisition procedures create significant delays in PPP projects, as wastewater facilities often require large tracts of urban or peri-urban land that are difficult to secure under current regulations. Moreover, the lack of a standardized PPP contract specific to the wastewater sector generates uncertainty for private investors regarding risk allocation, revenue guarantees, and dispute resolution.

Financial unsustainability further exacerbates the issue. Wastewater tariffs in Hanoi are currently set at approximately 15% of the clean water tariff—insufficient to recover

operational costs, let alone capital expenditures or depreciation. The absence of a viability gap funding (VGF) mechanism forces private operators to shoulder disproportionate financial risks, reducing the attractiveness of the wastewater sector compared to other infrastructure investments like energy or transportation.

On the institutional front, governance remains highly fragmented. Responsibility for wastewater management is dispersed across several agencies, including the Department of Construction (DOC), the Department of Natural Resources and Environment (DONRE), and the Department of Finance (DOF). No dedicated PPP coordination unit exists within Hanoi's municipal government for the wastewater sector, leading to overlapping mandates, conflicting priorities, and accountability gaps. This fragmentation slows down project preparation, approval, and implementation phases.

Social and technical challenges further constrain progress. Public awareness of wastewater issues remains low, contributing to resistance against tariff increases and reluctance to host wastewater treatment facilities in local communities. Moreover, technological adoption is limited, especially in decentralized treatment systems that could serve rapidly urbanizing peri-urban areas. The lack of smart monitoring tools further hampers system efficiency and transparency.

Compounding these challenges is a weak risk-sharing framework. Current PPP contracts inadequately address how financial, operational, and environmental risks are distributed between public and private stakeholders. This deficiency undermines investor confidence, leading to project delays or outright cancellations.

In summary, Hanoi's wastewater PPP policy framework suffers from a structural misalignment between ambition and execution. Addressing these gaps requires a comprehensive approach that integrates legal reform, financial restructuring, institutional strengthening, and community engagement with technological modernization.

Recommendations

1. Legal and Regulatory Reform

Legal harmonization is an urgent priority to streamline wastewater PPP implementation in Hanoi. First, the PPP Law should be amended to include sector-specific guidelines for environmental infrastructure, particularly wastewater. This includes

developing standardized contract templates that clearly define risk-sharing mechanisms, performance benchmarks, tariff adjustment formulas, and dispute resolution procedures.

Second, inconsistencies between the PPP Law, Environmental Protection Law, Land Law, and Construction Law must be resolved. This can be achieved through inter-ministerial circulars or an omnibus amendment that explicitly addresses the overlaps. For example, land acquisition procedures should be expedited by introducing eminent domain provisions for essential environmental infrastructure, subject to fair compensation.

Third, environmental permitting processes should be simplified. Currently, PPP wastewater projects require multiple rounds of environmental impact assessments (EIAs), often duplicating requirements across different agencies. Establishing a one-stop permitting system would significantly reduce administrative burdens.

Finally, legal frameworks must incorporate sustainability and climate resilience criteria. Contracts should mandate compliance with international environmental standards, and project approvals should be contingent on climate risk assessments. Such provisions not only align Hanoi with global sustainability goals but also attract climate-aligned financing from international investors.

2. Financial Mechanisms

Reforming Hanoi's wastewater financial model is essential for PPP viability. The first step is adjusting wastewater tariffs towards full-cost recovery. A phased approach is recommended: gradually increasing tariffs over five to ten years while providing targeted subsidies for low-income households to maintain social equity.

Second, the establishment of a Viability Gap Funding (VGF) mechanism is critical. This fund would bridge the gap between commercially viable and socially necessary infrastructure, covering up to 40% of capital expenditures for PPP wastewater projects, similar to successful models in India and Indonesia.

Third, Hanoi should explore innovative financing mechanisms. Issuing municipal green bonds dedicated to wastewater infrastructure could attract ESG (Environmental, Social, Governance) investors. Blended finance models, combining public funds, development finance, and private capital, can also de-risk investments.

Fourth, risk-sharing mechanisms must be formalized. Contracts should include minimum revenue guarantees, particularly in the early operational years. Additionally,

inflation-indexed tariff clauses and foreign exchange risk coverage for international investors can significantly improve bankability.

Finally, incentivizing performance is crucial. PPP contracts should incorporate output-based payments linked to water quality outcomes, treatment volume, and service reliability. Such mechanisms align public and private incentives, ensuring that financial sustainability goes hand in hand with environmental performance.

3. Institutional Strengthening

Institutional reform is as critical as legal and financial adjustments. Establishing a Dedicated PPP Unit for Water and Wastewater within the Hanoi People's Committee is a high priority. This unit would serve as the central coordinator, managing project pipelines, facilitating inter-agency collaboration, and providing technical support to both public entities and private investors.

Clear role delineation is necessary. The Department of Construction should focus on infrastructure standards and technical oversight; the Department of Natural Resources and Environment should handle environmental compliance; while the Department of Finance oversees fiscal management and tariff regulation. The PPP Unit would integrate these functions to ensure coherence.

Capacity building is also essential. Training programs on PPP contract management, financial modeling, and environmental compliance should be institutionalized for public officials. Partnerships with international organizations like the World Bank, ADB, and OECD can support this process.

Additionally, digitalization should be embraced. Implementing a centralized data management system for wastewater infrastructure—including real-time monitoring of treatment plants—would improve transparency, operational efficiency, and regulatory enforcement.

Finally, fostering public-private dialogue is vital. Regular stakeholder forums involving government agencies, private sector actors, NGOs, and community representatives can preempt conflicts and align expectations.

4. Community Engagement and Technology Adoption

Public acceptance is a cornerstone of sustainable wastewater management. First, Hanoi should launch city-wide public awareness campaigns emphasizing the health and

environmental benefits of proper wastewater treatment. Leveraging social media, schools, and community centers can foster behavioral change.

Second, participatory governance models should be adopted. Establishing local advisory committees for major PPP projects—comprising residents, NGOs, and technical experts—can improve transparency and accountability. These committees can participate in tariff discussions, site selection, and project monitoring.

On the technological front, Hanoi must diversify beyond centralized treatment. Deploying decentralized wastewater treatment systems (DEWATS), particularly in peri-urban and industrial zones, can offer cost-effective and scalable solutions. Technologies like modular membrane bioreactors (MBRs) or compact Johkasou units, proven in Tokyo and Singapore, are highly applicable.

Smart monitoring technologies should also be adopted. Installing IoT-based sensors for flow, quality, and operational metrics enables real-time oversight, reducing downtime and maintenance costs. These data can be integrated into the city's broader smart city framework, enhancing governance.

Finally, adopting circular economy principles—such as biogas recovery from sludge and nutrient recycling—can transform wastewater from a liability into a resource, aligning with Hanoi's green growth ambitions.

Conclusion

This study demonstrates that the DPSIR framework offers a robust and comprehensive tool for evaluating the multifaceted challenges facing wastewater policy in Hanoi. The analysis highlights that while Hanoi has made considerable strides in recognizing the importance of wastewater management—evidenced by the adoption of the PPP Law and updated wastewater master plans—substantial systemic gaps remain.

Legal fragmentation, financial unsustainability, institutional incoherence, and weak community engagement continue to impede the scalability of PPP models in the wastewater sector. The comparative analysis with global cities such as Singapore, Amsterdam, and Shanghai reinforces that successful wastewater PPP deployment requires a holistic framework combining legal certainty, sustainable financing, strong institutions, and active public participation.

The recommendations put forward in this study provide a clear roadmap for reform. Legal and regulatory harmonization, coupled with innovative financial mechanisms like VGF and green bonds, can enhance project bankability. Institutional strengthening through the establishment of a dedicated PPP unit ensures coherence, while community engagement and technological adoption address social acceptance and operational efficiency.

As Hanoi continues its trajectory toward becoming a modern, sustainable metropolis, transforming wastewater management from a persistent problem into a cornerstone of environmental resilience and public health is both an urgent necessity and an achievable goal. The lessons drawn from this research not only serve Hanoi but also contribute to the global discourse on sustainable urban water governance in the Global South.

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