Urban Sewage Pollution Dynamics: Reviewing Deposition, Attenuation Patterns, and Environmental Implications

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Abstract. Domestic sewage is prone to deposit in the sewer system due to its complex composition and lengthy collection and transportation route. The migration and transformation of pollutants between deposits and sewage during the deposition process play a vital role in the sound and stable operation of the sewer system, the enhancement of the centralized collection rate of domestic sewage, and the safeguarding of urban water environments. Built on research findings worldwide, this paper summarizes the generation pattern and composition characteristics of the deposition and attenuation of pollutants in domestic sewage within the sewer system. The leading factors influencing sewage pollutant deposition are explored, and the harm engendered by the migration and transformation of pollutants between deposits and sewage is analyzed. Finally, we express hopes for addressing the issue of sewage pollutant deposition and attenuation, aiming to enhance the quality and efficiency of sewage treatment and foster the green and healthy development of sewer systems.

1 Introduction

Domestic sewage pollutants have complex chemical compositions and relatively lengthy collection and transportation routes. The occurrence of sewage deposition is twofold. On the one hand, differences in the physicochemical properties of particulate matters among sewage pollutant components contribute to their deposition characteristics [1]; on the other hand, the sustained residence time during the collection and transportation routes, extending from residential buildings, community sewer networks, septic tanks, municipal sewer networks, to sewage treatment plants, creates favorable conditions for the deposition of sewage pollutants. This process mainly encompasses the physical deposition of solid particles such as sediment and gravel, biodegradation of microbial flora, and chemical transformation among nitrogen, phosphorus, and organic matter [2]. The functioning mechanisms of these effects in the composition variations of sewage pollutants and the impacts of such changes on the sewer system, sewage treatment, and urban water environment safety have aroused widespread concern [3]. In response, this paper summarizes the deposition and attenuation pattern and composition characteristics of pollutants in domestic sewage, delves into the main factors affecting the deposition of sewage pollutants, and analyzes the harm engendered by the migration and transformation of pollutants between deposits and sewage. Based on the above analysis, we express hopes for addressing the issue of sewage pollutant deposition and attenuation.

2 Methodology

In general, this study adopts a systematic approach to gather and analyze information on pollutant deposition and attenuation in domestic sewage within sewer systems. To ensure a comprehensive review, a selected database closely linked to global research on this topic is utilized. Databases, including Web of Science, Google Scholar, and Scopus, are systematically searched, resulting in the identification of a number of papers. These papers undergo meticulous screening based on predefined keywords, content check and publication process quality check refining the dataset to articles listed in reference list that represent the most relevant and impactful studies in the field. This approach aligns with the systematic and rigorous methodology employed by various researchers [i.e., 4-5], ensuring a robust analysis of pollutant deposition and attenuation in domestic sewage.

In particular, methodology employed in this study comprises a thorough examination of global research on pollutant deposition and attenuation in domestic sewage within sewer systems. The study builds upon the intricate composition and extensive journey of domestic sewage, leading to its deposition, as a foundational aspect. The focus of the analysis is on comprehending the patterns and characteristics of pollutant deposition and attenuation, with a systematic exploration of key influencing factors sourced from diverse global research. Employing a synthesis approach, the study summarizes the identified patterns and characteristics, and further investigates the adverse effects arising from the
migration and transformation of pollutants between deposits and sewage. The study concludes by expressing aspirations to address pollutant deposition and attenuation issues, aiming for improved sewage treatment quality and efficiency with the ultimate goal of contributing to the sustainable development of sewer systems in urban environments.

3 Research progress on the deposition and attenuation of domestic sewage pollutants

The discharge and transportation of domestic sewage from residential buildings to sewage treatment plants typically commence from the community sewer networks, passing through septic tanks, and then proceeding to the municipal sewer networks. The deposition and attenuation of sewage pollutants may occur at any stage of the transmission process.

3.1. Research progress of sewage deposition and attenuation within septic tanks

A septic tank typically adopts either a two-chamber or three-chamber design, determining that the residence time of sewage within septic tanks is longer than that within sewers of identical length, and the deposition effect of sewage in septic tanks is more prominent. Zhang et al. [6] monitored and analyzed the influent and effluent water quality of septic tanks in four typical residential communities in the main urban areas of Chongqing. The results showed varying decreases in the sewage flowed through septic tanks, with COD and BOD5 experiencing the largest decreases, reaching 39.83% and 24.06%, respectively. Meanwhile, BOD5/TN and BOD5/TP ratios were reduced by 23.43% and 34.27%, respectively, after the sewage ran through septic tanks, indicating that septic tanks have the capacity to consume carbon sources in sewage to a certain degree. In another study, Yang [7] monitored the influent and effluent water quality of septic tanks in a residential community in Chongqing, and the results showed that COD and BOD5 of sewage lowered by 41.1% and 31.9%, respectively, after passing through septic tanks. Similarly, Wang et al. [8] investigated the factors influencing the spatial variation in both quantity and quality of rural domestic sewage discharge in China. The research aims to uncover key determinants shaping sewage pollution patterns across different regions in the country. The findings contribute valuable insights for understanding and managing rural sewage dynamics. Additionally, Wei et al. [9] monitored the influent and effluent water of septic tanks in a residential community in Beijing, the results of which revealed a decline of 67.24% and 67.64% for COD and BOD5. Furthermore, Song et al. [10] conducted a control experiment with or without septic tanks. It was found that the COD and BOD5 of sewage decreased considerably by 51.0% and 65.0% with the adoption of septic tanks. When septic tanks were removed, no evident deposition was observed in the community sewers, and the concentration of sewage flowing into the municipal sewers increased.

A mass of studies has demonstrated that septic tanks are a force to be reckoned with in the attenuation of sewage pollutants [11-12]. However, some scholars contend that septic tanks may not serve as the main driver of sewage pollutant attenuation. In normal cases, the septic tank is the source "sedimentation tank" of domestic sewage, with its attenuation effect on sewage hinging on sewage’s residence time in it. Septic tanks that are newly operational or cleaned regularly have a relatively prolonged residence time for sewage, contributing to higher efficiency in removing pollutants. Restricted by ownership issues and poor management, however, most septic tanks in China are rarely cleared on time, which leads to the long-term deposition of deposits. This renders septic tanks the conventional discharge channels of sewage, with a fairly pronounced reduction in the pollutant removal effect. In this regard, the evaluation of the deposition and attenuation effects of sewage pollutants in septic tanks should factor in the operation and maintenance, as well as the cleaning status of septic tanks [13]. A summarized data on sewage deposition attenuation is presented in Table 1.

Table 1. Summarization of literature on sewage deposition and attenuation.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Focus/Metho dology</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>[7]</td>
<td>Monitored septic tank in a residential community in Chongqing</td>
<td>- COD and BOD5 of sewage lowered significantly after passing through septic tanks</td>
</tr>
<tr>
<td>[8]</td>
<td>Investigated factors influencing spatial variation in rural sewage discharge in China</td>
<td>- Contributed insights into factors shaping sewage discharge patterns across regions in China</td>
</tr>
<tr>
<td>[9]</td>
<td>Monitored septic tanks in a residential community in Beijing</td>
<td>- Decline of COD and BOD5 after passing through septic tanks</td>
</tr>
<tr>
<td>[10]</td>
<td>Conducted control experiment with or without septic tanks</td>
<td>- COD and BOD5 of sewage decreased considerably with the adoption of septic tanks. - Removal of septic tanks led to no evident deposition in community sewers and increased</td>
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</table>
Deposition in sewer networks significantly influences scarcity challenges. This suggests that sediment to understand interrelationships among contaminants, challenges posed by contaminant resuspension in wet plants and microbial communities. It highlighted pollutants tend to be adsorbed by particles with larger of sewage pollutants in sewers indicate that organic pollutants. Monitoring results of particle size distribution accompanied by the synchronous settling of sewage during the sewage transport process. This deposition is diversion, representing the primary physical change separate sewers with incomplete rain and sewage simulations. 

3.2. Research progress of sewage deposition and attenuation in sewer networks

Domestic sewage exhibits deposition characteristics due to the varied density and physicochemical properties of pollutants. Gao et al. [14] elucidated the natural deposition traits of sewage pollutants through static tests on sewage from residential buildings. It was observed that after ten hours of natural deposition, the concentration of particulate organic matter in sewage significantly decreased, with suspended solid (SS) and COD decreasing by 61.1% and 18.1%, respectively. Conversely, the concentration of soluble NH3-N increased slightly, while COD/TN and COD/TP ratios decreased by 20.1% and 9.9%, respectively. These findings indicate the notable deposition and migration of sewage pollutants in the static deposition state. Similarly Ref [15] explores the development of a cutting-edge 1D-2D dynamic bidirectional coupling model utilizing an advanced acceleration techniques for high-resolution simulations of urban water environments. This study aims to enhance the precision of urban water system simulations.

Sediment deposition occurs in combined sewers and separate sewers with incomplete rain and sewage diversion, representing the primary physical change during the sewage transport process. This deposition is accompanied by the synchronous settling of sewage pollutants. Monitoring results of particle size distribution of sewage pollutants in sewers indicate that organic pollutants tend to be adsorbed by particles with larger sizes, while nitrogen and phosphorus pollutants are more likely to be adsorbed by particles with smaller sizes [16].

Gao et al. [17] investigated in-sewer physio-biochemical processes impacting wastewater quality, emphasizing their influence on wastewater treatment plants and microbial communities. It highlighted challenges posed by contaminant resuspension in wet weather, underscoring the need for systematic research to understand interrelationships among contaminants, microorganisms, and sewage components for effective sewer management amid climate change and water scarcity challenges. This suggests that sediment deposition in sewer networks significantly influences organic pollutants. Liu et al. [18] argued that sewer design should incorporate a threshold flow velocity to prevent sediment entrainment in sewage from depositing in the sewer, ensuring the hydraulic performance and drainage capacity of the design remain uncompromised. Additionally, based on model test results on sediment deposition patterns of diffusers at drain outlets, they analyzed sediment transport formulas for typical sewers and proposed recommended formulas for the critical flow velocity of sediment motion in sewers with different diameters.

During the transport of sewage in sewers, various factors can contribute to the deposition of sewage pollutants and the formation of sewage deposits. These factors include a gentle slope and a slow flow velocity [19]. The complex composition of sewage pollutants results in the intricate composition of deposits. Ahyerre et al. [20] classified sewage deposits into three categories based on their physicochemical properties: gross bed sediment (GBS), organic layer (OL), and biofilm. Among these, GBS consists mainly of inorganic solids such as sediment and macromolecular organic matter (COD or BOD₅), which deposit in sewers in large quantities during the dry season. Conversely, NH₃-N, phosphate, and other substances generally do not deposit. Furthermore, nitrogen salts and phosphate salts concentrated in sewer deposits for an extended period may undergo hydrolysis, releasing soluble substances such as NH₃-N and phosphate into the sewage [21].

The research findings on the pattern of deposition-scouring effects on sewage pollutants demonstrate that flow velocity is the key factor influencing the contribution rate of the deposition effect. Sang et al. [10] delved into the changing pattern of organic matter, nitrogen, and phosphorus pollutant content, as well as particle size distribution in sewage under varying flow velocities by devising an experimental device for sewer deposition simulation. The results revealed that when the flow velocity was less than 0.6 m/s, the deposition effect of particulate pollutants in sewage was more prominent than the scouring effect, and deposits would form. When the flow velocity surpassed 0.6 m/s, sediment would be washed away by the sewage, resulting in elevated concentrations of organic matter, nitrogen, and phosphorus, with a notable increase in organic matter. Jin et al. [22] studied the release mechanism of pollutants in the deposits under different flow velocities by designing an experimental device for sewer deposition-scouring simulation and developed calculation models for sewage pollutant deposition and release. The results revealed the contribution rate of deposition, scouring, and biodegradation effects to the removal of sewage organic matter under different flow velocities. Specifically, when the velocity was 0.32 m/s, the variation in sewage pollutants was mainly due to deposition and attenuation effects. When the velocity rose to 0.6 m/s, the scouring force of sewage flow strengthened, and the deposition effect weakened. When the velocity increased to 0.9 m/s, the scouring effect played a major role. Additionally, Jin et al. [22] proposed constructing a mathematical model by integrating the characteristics of pollutants in the
deposits and flow monitoring data of different drain areas. The proposed model can predict sewage quality and the distribution and transport of deposits in the sewer network, facilitating the operation and maintenance of the municipal sewer network.

Sewage pollutant deposition is always accompanied by the biodegradation of sewage pollutants by microorganisms, which is instrumental in the change of sewage quality in sewer networks [23-25]. Shi et al. [26] simulated the operational state of sewer network systems under different confluence conditions by regulating the velocity of the main sewer and branch sewer. The study investigated the distribution characteristics of organic matter, nitrogen, and sulfur pollutants and the distribution pattern of microbial population structure in sewer deposits under varied confluence conditions. The results showed that the concentrations of COD, TN, NH₃-N, NO₃-N, and sulfate in sewer deposits gradually decreased, while that of sulfide gradually increased along the vertical direction. Furthermore, the increase in flow velocity would result in an enlargement of the vertical concentration gradient. With increasing flow velocity, the concentrations of dissolved oxygen (DO) and oxidation reduction potential (ORP) in deposits changed along the vertical direction under different scouring intensities. This change affected the distribution of microbial population structure, with the relative abundance of predominant bacterial genera Methanoseta in methanogenic archaea (MA), Desulfomicrobium in sulfate-reducing bacteria (SRB), and Caldisericum in hydrolytic fermentative bacteria (FB) decreasing gradually, whereas that of Thiobacillus in sulfur-oxidizing bacteria (SOB) increased. Table 2 provide summarization of literature on sewage deposition and attenuation in sewer networks.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Focus</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>[14]</td>
<td>Natural deposition traits of sewage pollutants in residential building sewage</td>
<td>Significant decreases in particulate organic matter, SS, and COD after ten hours of natural deposition. Soluble NH3-N increased slightly, and COD/TN and COD/TP ratios decreased.</td>
</tr>
<tr>
<td>[16]</td>
<td>Sediment deposition in combined and separate sewers</td>
<td>Influence of flow velocity on particle size distribution of sewage pollutants. Organic pollutants tended to be adsorbed by larger particles, while nitrogen and phosphorus pollutants favored smaller particles.</td>
</tr>
<tr>
<td>[17]</td>
<td>In-sewer physio-biochemical processes affecting wastewater quality and microbial communities</td>
<td>Challenges posed by contaminant resuspension in wet weather and the need for systematic research for effective sewer management amid climate change.</td>
</tr>
<tr>
<td>[18]</td>
<td>Sewer design considerations to prevent sediment entrainment</td>
<td>Argument for sewer design incorporating a threshold flow velocity to prevent sediment entrainment, ensuring hydraulic performance and drainage capacity.</td>
</tr>
<tr>
<td>[19-21]</td>
<td>Classification of sewage deposits and composition analysis</td>
<td>Classification into GBS, OL, and biofilm. Inorganic solids in GBS deposit in large quantities during the dry season. Release of soluble substances from nitrogen and phosphate salts.</td>
</tr>
<tr>
<td>[10]</td>
<td>Pattern of deposition-scouring effects on sewage pollutants</td>
<td>Flow velocity as a key factor. More prominent deposition effect at velocities &lt;0.6 m/s, scouring dominated at velocities &gt;0.6 m/s, leading to increased concentrations of organic matter, nitrogen, and phosphorus.</td>
</tr>
<tr>
<td>[22]</td>
<td>Release mechanism of pollutants and mathematical model development</td>
<td>Proposed a mathematical model to predict sewage quality and deposit distribution in the sewer network, aiding in municipal sewer network operation and maintenance.</td>
</tr>
<tr>
<td>[23-25]</td>
<td>Simulation of sewer network systems under various confluence conditions</td>
<td>Decreasing concentrations of COD, TN, NH₃-N, NO₃-N, and sulfate. Increasing sulfide along the vertical direction. Changes in microbial population structure influenced by flow velocity.</td>
</tr>
</tbody>
</table>

### 4 Research progress on the influence of pollutant deposition and attenuation in domestic sewage

#### 4.1. Deposition and blockage of sewer networks

Sewer networks are crucial transport facilities for urban domestic sewage and rainwater, and their operational conditions significantly impact urban safety [27]. However, over the long term, they often face challenges with the accumulation of deposits due to historical issues, management oversights, and imperfect operation and maintenance measures [28]. This accumulation ultimately leads to deposition and, in some cases, blockage of the sewer network [29-30]. Li [31] conducted an investigation in urban areas of Beijing and found widespread deposition in sewers. According to the report, nearly 80% of sewers were affected by deposits, with the degree of deposition related to the diameter and material of the sewers. In separate research, Zhang et al. [32] examined the deposition status of some sewer networks in the urban areas of Guangzhou, and the results indicated that over 50% of the sewer networks within the investigation scope experienced varying
degrees of deposition. Globally, Chebbi et al. [33] reported that more than 8 km of French sewers with a diameter greater than 1.25 m had a deposit thickness exceeding 30 cm. In Europe, the deposition rate of sewers was measured between 30 and 50 g/(m·d) [34]. To prevent deposition and blockage in the sewer network, the urban management department must invest a significant amount of labor and financial resources in sewer cleaning and dredging each year.

4.2. Overflow Pollution in Combined Sewer Networks

As one of the design and construction modes for urban sewer networks, combined sewer systems have found widespread application both domestically and globally. Overflow pollution in combined sewer networks has emerged as a universally recognized leading engineering and technical problem [35]. While transporting rainwater and sewage in a combined sewer network, inorganic sediment in rainwater and organic matter in sewage easily deposit under low flow velocity in dry weather, leading to the enrichment of pollutants at the bottom of the sewer network and the formation of a deposit layer. This further blocks sewage flow and increases its residence time. During wet-weather periods, a large amount of rainwater flows into the sewer, scouring and carrying sedimentary pollutants at the bottom into the water body, resulting in malodorous black rivers in urban areas and other environmental pollution incidents [36-37]. Zhao et al. [38] tested the quantity and quality of influent and effluent water in typical communities adopting combined sewer systems in Kunming on rainy days. The results suggested that the release of pollutants from sewer deposits could drastically alter the sewage pollution load. Pollutants released from sewer deposits accounted for more than 30% of total pollutants on rainy days, and with the increase in rainfall intensity, the proportion could even exceed 50%. In another study, Li et al. [39] researched the characteristics and pollution contribution rates of pollutants from different sources in the combined sewer system in urban areas of Beijing during three rainfall periods. It was found that overflow water exhibited a higher average concentration of pollutants and poorer water quality compared to dry-weather flows in the sewer system. The pollution contribution rates of sewer deposits to overflow water during rainfalls are as follows: TN: 20.9% to 44.6%, TP: 35.76% to 47.3%, COD: 46.2% to 48.8%, and SS: 35.7%.

4.3. Imbalance of Influent C/N and C/P Ratios in Sewage Treatment Plant

Anaerobic hydrolysis or micro-aerobic reactions typically occur during the deposition process of domestic sewage, wherein organic nitrogen and phosphorus are prone to ammoniation or phosphatation. This facilitates a transition from a sedimentary phase to an ionic state, re-entering the sewage and endowing the bottom sediment with high carbon and low nitrogen and phosphorus content [40]. In a survey by Sun et al. [41] in a northern Chinese city's sewage sewer network, the test results revealed COD/TN ratios typically ranging from (30 to 50):1, and COD/TP ratios reaching (80 to 100):1. According to the mass balance relationship of sewage pollutants, an increase in COD/TN and COD/TP ratios within deposits implies a reduction in the influent COD/TN and COD/TP ratios at the sewage treatment plant. This necessitates the addition of extra external carbon sources to eliminate nitrogen and phosphorus pollutants in sewage treatment plants, compromising the low-carbon operation of the sewer system. Zhou et al. [42] investigated influent water quality data from 191 sewage treatment plants across six provinces along the Yangtze River. It was observed that many old urban areas were equipped with sewers featuring minimal slopes or, in some cases, counter-slope configurations. This has resulted in low flow velocity or detention of sewage within the sewers, leading to the deposition of pollutants. Consequently, the sewage entering the sewage treatment plants is dominated by supernatant with low BOD₅ concentration. Table 3 presents summarized data on literature on the influence of pollutant deposition and attenuation in domestic sewage.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Focus</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>[32]</td>
<td>Deposition status in urban areas of Guangzhou</td>
<td>Over 50% of sewer networks experienced varying degrees of deposition.</td>
</tr>
<tr>
<td>[33]</td>
<td>French sewers with diameter &gt; 1.25 m</td>
<td>Deposit thickness exceeding 30 cm in more than 8 km of sewers.</td>
</tr>
<tr>
<td>[34-37]</td>
<td>Combined sewer systems globally</td>
<td>Recognized overflow pollution as a leading problem; deposition under low flow velocity in dry weather; wet-weather periods lead to scouring and pollutant release.</td>
</tr>
<tr>
<td>[38]</td>
<td>Influential study on rainy days in Kunming</td>
<td>Pollutants released from sewer deposits could alter sewage pollution load, accounting for over 30% of total pollutants on rainy days.</td>
</tr>
<tr>
<td>[39]</td>
<td>Characteristics and pollution contribution rates in Beijing</td>
<td>Overflow water exhibited higher pollutant concentration and poorer quality during rainfalls; pollution contribution rates during rainfalls: TN (20.9% to 44.6%), TP (35.76% to 47.3%), COD (46.2% to 48.8%), SS (35.7%).</td>
</tr>
<tr>
<td>[40]</td>
<td>Anaerobic hydrolysis or micro-aerobic reactions in deposition process</td>
<td>Occurrence of anaerobic hydrolysis or micro-aerobic reactions in sewage deposition process, influencing the composition of bottom sediment.</td>
</tr>
<tr>
<td>[41]</td>
<td>Survey in a northern</td>
<td>COD/TN ratios (30 to 50):1, COD/TP ratios (80 to 100):1,</td>
</tr>
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</table>
5 Conclusion and recommendations

During the transport process from residential buildings to sewage treatment plants, pollutants are prone to deposition and attenuation in various stages due to the long transportation distance. Generally, the deposition and attenuation effects of domestic sewage pollutants in well-maintained septic tanks are significant. After passing through septic tanks, the COD and BOD\(_5\) of sewage experience a marked decrease, and BOD\(_5\)/TN and BOD\(_5\)/TP ratios simultaneously decrease. However, for septic tanks that are not properly maintained, the residence time of sewage is greatly shortened, leading to the weakening or even disappearance of the sewage deposition effect. Therefore, when discussing the deposition and attenuation of sewage in septic tanks, the operation and maintenance, as well as the cleaning status of septic tanks, should be fully considered.

The deposition and attenuation of sewage pollutants in sewer networks are related to the deposition characteristics and sediment content of the sewage, the diameter, slope, and flow velocity of the sewer, as well as the distribution pattern of microbial population structure, among other factors. Among these, flow velocity is the key factor affecting the deposition and scouring effects of sewage pollutants, and the contribution rates of the three effects—deposition, scouring, and biodegradation—to sewage pollutant removal exhibit different characteristics under varied flow velocities. Therefore, integrating existing codes and standards with the actual operation status of sewer networks, designing and maintaining a scientifically determined flow velocity above the critical threshold for sediment motion, and weakening the deposition and attenuation effects of sewage pollutants have proven to be effective approaches for increasing the influent concentration of sewage treatment plants, improving the quality and efficiency of sewage collection and treatment facilities, and promoting the low-carbon operation of sewer networks.

The deposition and attenuation of sewage pollutants can lead to deposition and blockage of the sewer network, overflow pollution in the combined sewer network, an imbalance of influent C/N and C/P ratios at the sewage treatment plant, and other issues. These challenges pose substantial barriers to maintaining the sound and stable operation of the sewer system, safeguarding the urban water environment, and fostering low-carbon sewage treatment. Pollutant deposition in sewer networks during non-rainfall periods and loss induced by high-velocity scouring during rainfall periods are the primary causes of the low centralized sewage collection rate in many cities in China. Hence, sewage deposition control based on velocity maintenance in daily sewer network operations will become an important research focus for enhancing the quality and efficiency of sewage collection and treatment facilities.

Overall, addressing the challenges posed by the deposition and attenuation of sewage pollutants requires a multifaceted approach that spans individual behaviors, community engagement, technological innovations, and policy considerations. To enhance the resilience of urban sewer networks, it is imperative to establish clear guidelines for the regular maintenance of septic tanks, leveraging community awareness programs to instill a sense of responsibility among residents. Moreover, the integration of advanced technologies, such as real-time sensors, can revolutionize sewer network management by providing accurate data on flow velocities and sediment content. Standardizing flow velocity guidelines, backed by comprehensive studies on their effects, will further contribute to a scientific and effective approach. Policymakers must play a pivotal role in advocating for regulatory frameworks that specifically address deposition and attenuation challenges. Concurrently, fostering research collaborations, both domestically and internationally, will stimulate innovative solutions and ensure the adaptability of strategies to diverse urban contexts. By implementing these recommendations and suggestions, not only can the efficiency of sewage collection and treatment facilities be enhanced, but the broader goals of urban water environment preservation and low-carbon sewage treatment can be effectively pursued.

Acknowledgments

This work is one of the phased achievements of “Key Technologies for the Optimal Design and Simulated Dispatching of Sewer Networks” under the National Key Research and Development Program of China 3.3. It is also one of the phased achievements of “Z2022Q29” under the China Construction Technology Group Co., Ltd. Group Youth Fund.

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