Taking Hong Kong as an Example to Introduce Sustainable Drainage Systems and Wastewater Treatment Technologies

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Abstract: Due to the rapid development of recent society, the amount of pollutants has become larger and larger, especially the amount of wastewater, which has become a crucial challenge around the world. It is significant to understand the paramount importance of efficient sewage drainage and wastewater treatment systems in safeguarding human health and ecological balance. This study mainly focuses on the progress in sewage drainage and wastewater treatment infrastructure and then shifts to emphasize the strategic implementation of sustainable solutions. This paper explores the design and operational aspects of advanced systems, including Sustainable Drainage Systems (SuDS) and innovative technologies like green roofs and membrane bioreactors (MBRs), used in Hong Kong as a model. Apart from acknowledging the challenges behind such systems, such as knowledge gaps, financial barriers, and technical complexities, this study proposes solutions like educational initiatives and financial support. With the integration of innovative technologies, including Artificial Intelligence (AI) and the Internet of Things (IoT), these systems can effectively enhance their efficiency and sustainability. This futuristic approach aims to build urban resilience and guarantee effective sewage management, thereby mitigating environmental pollution and fostering a healthier, sustainable urban landscape.

1 INTRODUCTION

In recent decades, with the high development of industrialization and urbanization, there has an increasing environmental pollution, particularly in the form of sewage. Such wastewater without proper management may contribute to terrible effects on both human health and the entire ecosystem. It is important to realize that sewage drainage and wastewater treatment are significant nowadays. Firstly, as long as the wastewater without treatment is left in rivers, lakes, and oceans, those drinking water sources may be contaminated. Polluted water sources may also harm aquatic life and even disrupt the ecosystem. For human activities, polluted water sources will have an effect on the human body, agriculture, and so on. What is also worth noticing is that there are several chemicals and pathogens that may cause diseases in humans and animals. The pollutants in sewage, such as chemicals, heavy metals, pathogens and so on, need fastidious treatment to avoid contaminating water bodies, soil, and air quality.

In China, wastewater treatment has received attention: the number of wastewater treatment plants is continuously increasing from 481 in 2000-3717 in 2014, and the treatment capacity achieves 1.57 million $m^3 d^{-1}$ (Ben et al., 2018). The focus of sustainable development is to balance economic growth with environmental protection and social well-being. Recently, sustainable development has been the main cornerstone to reduce pollution and protect the environment. For wastewater, including drainage systems and sewage treatment, sustainable development is also the main concentration. Researchers and the government are increasingly focusing on innovative and sustainable methods for sewage identification, purification, and drainage, which is crucial for achieving long-term environmental sustainability. Through improving wastewater treatment methods and processes, it is possible to reduce carbon footprint and pollution.

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Proper sewage drainage and purification can prevent illness from spreading. Also, it is extremely effective to reuse the energy and nutrients in wastewater during the process of management and purification. For instance, treated wastewater can be reused for irrigation, industrial processes, and even as potable water in some cases, thus reducing the demand for fresh water and promoting resource efficiency. With the continuous advancement of the entire world, it is imperative to deal with the environmental challenges they bring, particularly in the aspect of wastewater drainage and treatment.

The article will briefly introduce the design of drainage systems, the technology of wastewater treatment and the sustainability of them. At the same time, taking Hong Kong, a harbor city, is an example to explain the methods and process of wastewater treatment. What is more, is that some innovative technologies which can be used in drainage systems and wastewater treatment will be mentioned to further achieve sustainable development.

2 INTRODUCTION OF DRAINAGE SYSTEM AND WASTEWATER TREATMENT TECHNOLOGY

2.1 the Design and Operation of Drainage Systems and Wastewater Treatment Technologies

The design and operation of the drainage system and wastewater treatment technologies are extremely important for water resources management, public health improvement, and environmental protection. The relationship between drainage systems and wastewater treatment technologies is integral and symbiotic. While the drainage system is responsible for collection and conveyance, the wastewater treatment plants will remove contaminants before the wastewater is discharged or reused. It is significant to understand and further improve the strategies of design and operation of drainage systems and wastewater treatment technologies.

2.1.1 Drainage Systems

The main purpose of a drainage system is to convey sewage to wastewater treatment plants. The drainage can be divided into three types: stormwater drainage, sanitary drainage, and combined systems. The stormwater drainage manages the runoff from rainfall to prevent flooding and erosion, while the sanitary drainage transports wastewater from bathrooms, sinks, kitchens, and other plumbing components to treatment facilities (Greater Lansing Regional Committee, 2024). The combined systems are the systems to handle both sewage at the same time. It is available in normal situations; however, during extreme weather such as heavy rainfall, water quantity in the systems will exceed the maximum amount, which results in overflow. As a result, such systems are less commonly used.

The design of the drainage system should concentrate on several aspects. Firstly, the hydraulic design, such as pipe diameter, roughness, and flow rate, can ensure pipes and channels can handle peak flow rates without causing backups or overflows. Also, the gravity flow can effectively minimize the utilization of pumping stations. At the same time, proper slope and elevation can enhance flow efficiency and stagnation prevention. Apart from these, choosing different materials based on the type of waste and environmental conditions is also significant. The last point is to establish manholes and cleanouts for maintenance and inspection.

2.1.2 Wastewater Treatment Technologies

In order to remove contaminants from wastewater so that wastewater can be discharged or reused, wastewater treatment technologies have been introduced. The process of wastewater treatment can be divided into several steps: preliminary treatment, primary treatment, secondary treatment, tertiary treatment, and sludge treatment. The initial treatment mainly focuses on the removal of large objects or debris from raw sewage, which can effectively neutralize the smell and protect the purification machines from breakdown. Also, the purpose of primary treatment is to separate solid macrobiotic matter from wastewater with a grit chamber and sedimentation tank. Then, the secondary treatment, also known as the activated sludge process, will remove the organic compounds by introducing oxygen into the wastewater. At the tertiary treatment stage, due to chlorination, ozone treatment, disinfection with ultraviolet light, and nitrogen reduction, wastewater will be further purified and achieve the level of drinking water. Finally, the sludge from primary and secondary treatments will be divided into water and sludge. The remaining water will discharge to the large aeration tank, while the sludge will be used for agriculture (Wastewater Treatment Process, 2023).

During the process of sewage treatment, it is significant to monitor and control the flow rates, pollutant levels, and system performance. Data monitoring can effectively identify potential problems in a timely manner and guide subsequent maintenance. At the same time, regular maintenance of mechanical and electrical components of drainage systems is effective to prevent erosion and failure of machines. Apart from ensuring effective monitoring and maintenance of sewage treatment systems, the standard of effluent quality and techniques should also comply with local and national regulations.

2.2 Sustainability of Drainage Systems and Wastewater Treatment Technologies

In order to improve water quality and achieve the goal of sustainable development, sustainable drainage systems (SuDS) and sustainable wastewater treatment technologies are invited, thus protecting the environment, conserving resources, and ensuring public health.

2.2.1 SuDS

During the late 2000s, the tendency for researchers and governments was to take action to protect, manage and restore ecosystems. The natural-based solution (NBS) emerged to devise management strategies that synergize with ecosystems, aiming to tackle escalating urban sustainability issues while simultaneously fostering economic prosperity and employment opportunities within the framework of a green economy. In such a situation, improvement of the water environment can effectively affect the social economy and public health, which results in the development of SuDS. The SuDS are structured as a series of interconnected stormwater management practices and technologies. The comprehensive management training they consist can efficiently store, attenuate, and treat surface runoff, thereby mitigating the risk of flooding and reducing the overall volume of runoff. The main principle for sustainable drainage systems is to mimic natural horological processes which utilize vegetated land surfaces for drainage (Cotterill & Bracken, 2020).

The SuDS includes green infrastructure, natural waterways, retention and detention basins, swales and bioswales, and rainwater harvesting systems. There are three working concepts for SuDS. Initially, the systems should encourage rainwater to infiltrate into ground. Also, preventing runoff from contamination is also important. Finally, the flow rate of runoff for SuDS should not exceed the undeveloped area (Hamilton, 2014).

2.2.2 Sustainable Wastewater Treatment Technologies

Currently, the sustainable development goals (SDGs) becomes the main concentration around the world. Wastewater management plays an important role in achieving 11 out of 17 SDGs. For example, mitigating the impact of wastewater, providing income sources, increasing water availability, improving public health, reusing waste to generate energy, and so on (Obaideen et al., 2022).

Thus, utilizing sustainable technologies and strategies for wastewater treatment is significant. Firstly, reducing the energy consumption of wastewater treatment plants by using energy efficient pumps, blowers, and other equipment. Also, reusing the resources during the treatment process, such as nitrogen and phosphorus. Decentralizing treatment is also effective to mitigate the burden on centralized facilities and minimize the need for extensive sewer networks. Apart from these, it is efficient for wetlands, lagoons, and other natural systems to treat wastewater with minimal energy input. At the same time, enhancing the wastewater treatment level can reuse water in agriculture, industry, or even potable water supplies. The last one, which is also the most effective and needs further development, is to utilize innovative technologies such as ultrasound technique, hydrodynamic cavitation technology, advanced oxidation processes (AOP), advanced green technologies, and membrane bioreactors (MBRs) (Obaideen et al., 2022). Firstly, the ultrasound technique can be utilized in pre-treatment, sludge disintegration, and enhanced chemical reactions to breakdown the pollutants through the high temperature and pressures created by collaption of bubbles. With the same working principles, hydrodynamic cavitation technology is widely used in pollutant degradation, disinfection, and pre-treatment process. At the same time, it is effective to utilize AOP to degrade recalcitrant compounds, remove color, and disinfection with the generation and oxidation of highly reactive species. Furthermore, advanced green technologies apply natural processes and materials to treat wastewater in phytoremediation, constructed wetlands, and biofiltration. The MBRs can combine biological treatment with membrane filtration to allow wastewater to pass through membranes to filter out suspended solids, bacteria, and other contaminants in municipal wastewater treatment, industrial wastewater treatment, and water reuse aspects (Kumar et al., 2022). Apart from high efficiency, hydrodynamic cavitation technology is cost-effective and scalability, while advanced green technologies are sustainable with the reduction of carbon footprint and recovery of resources.

3 TAKING HONG KONG AS AN EXAMPLE TO INTRODUCE SUDS

3.1 Introduction of the Current Wastewater Situation in Hong Kong

Due to the large amount of sewage, Hong Kong generates by population and factories every day, sewage treatment becomes a serious challenge for the Hong Kong government. As a harbour city with a large population, Hong Kong has devoted efforts to sewage treatment for several years to provide residents a safe and healthy environment. Managing sewage in Hong Kong is a significant challenge, requiring both efficiency and cost-effectiveness. Over 93% of the population is connected to the public sewerage system, which includes a network of approximately 1900 kilometers of sewers and around 300 sewage pumping stations and treatment plants. This system handles and processes 2.8 million cubic meters of sewage daily. At the same time, harbour area treatment scheme (HATS) was applied in 2001 to upgraded the harbour area sewage treatment at a strategic level (GovHK, 2023). Besides these, Hong Kong government also implement several practical solutions. For example, for constructional sewage, applying water pollution control ordinance (WPCO) license from the EPD before it is discharged; constructing wastewater treatment facilities to ensure that the quality of discharge water meets WPCO standards; separating domestic sewage from construction wastewater and surface runoff to separate treatment for different wastewater; conducting regular inspection and maintenance to make sure the effluent discharged meets the required standards.

3.2 Sustainable Technologies

3.2.1 SuDS in Hong Kong

Hong Kong has applied SuDS to manage storm water runoff and mitigate the impacts of urbanization and industrialization on the environment. Such systems aim to mimic natural hydrological processes, improve water quality, and reduce flood risks. SuDS typically include several components and techniques, such as green roofs, permeable pavements, swales, infiltration basins and trenches, rain gardens and bioretention ponds, detention basins, wetlands, and so on. As one of the techniques of SuDS, green roofs can manage rainfall in a sustainable way.

Firstly, the green roofs, which are vegetated spaces that are constructed on the top of buildings, are installed on several buildings in Hong Kong. There are two main types of green roofs: extensive green roofs and intensive green roofs. The extensive green roofs are designed with lightweight, thin soil, and lower maintenance cost. Also, they are suitable for large areas without irrigation. However, such green roofs cannot be accessed for recreation or other uses. At the same time, the plant species that can be used in extensive green roofs are limited. On the other hand, intensive green roofs contain deep soils, and a wide plant range, and can be used as recreational spaces by human beings. However, such green roof contains relatively higher cost and are not suitable for green roof retrofit projects. Also, energy, water, and materials are needed more than extensive green roofs. Both types of roofs have been applied, while the intensive green roofs are more widely used in Hong Kong. Despite the buildings in most old areas in Hong Kong being tall and finger-like, there are still some areas with green roofs. At the same time, other infrastructure buildings such as walkways, noise enclosures, ferry piers, pumping stations and vent buildings can also provide green areas. The application of green roofs effectively manages the peak flow of runoff during extreme weather and reduces the heat island effect in Hong Kong.

3.2.2 Sustainable Wastewater Treatment Technologies in Hong Kong

In order to keep sewage treatment more sustainable, it is significant to make the treatment process more efficient and cost-effective, which becomes a huge challenge for Hong Kong. In 2015, Hong Kong government set up a pilot compact sewage treatment plant with mechanical filter mesh and membrane bioreactors (MBRs) at Shatin Sewage Treatment Works (STSTW). With such technologies, the footprint required for a mechanical filter mesh is much less than the conventional primary sedimentation tank, which is 1/8th of the original. At the same time, the amount of removal suspended solid of mechanical filter mesh is comparable to the primary sedimentation tank and is capable of managing the diurnal peak and shock loads at the STSTW (Poon, 2016). Additionally, the installation of a deodorization unit effectively eliminates odour questions. The mechanical filter mesh also filters out hair and fibre, thereby protecting the downstream MBRs from fouling. In Hong Kong, such compacted sewage treatment plants with innovative technologies can provide high-quality effluent and clean water suitable for reuse, which complies with achieving sustainable development goals.

3.3 Challenges

3.3.1 Challenges for Green Roofs in Hong Kong

As one of the infrastructures of sustainable drainage systems, green roofs contain several constraints and barriers. There are five categories of green roof constraints. The first is the lack of knowledge and awareness. The design, installation, and maintenance of green roofs require specialized knowledge and skills, which may not be available for all regions. Additionally, the limited number of contractors and professionals with experience in green roof technology contributes to difficulty in finding qualified engineers and workers. The second constraint is the lack of an incentive mandate. For example, the building codes and zoning regulations in Hong Kong do not accommodate or encourage the installation of green roofs. Economic constraints are also worth noticing. The installation costs for green roofs can be significantly higher than those for traditional roofing systems due to the need for specialized materials, structural reinforcement, and professional expertise. At the same time, the maintenance cost for green roofs is also higher compared to the conventional ones. Besides these barriers, the lack of available roof areas is also a serious problem. The buildings in Hong Kong are always tall and finger-like, and the small total area of Hong Kong contributes to the less available area for green roofs. Finally, the technical issues and risks associated with uncertainty are also crucial. Potential leaks and water damage to the building structure can deter property owners from installing green roofs. Also, some stakeholders may be sceptical about the long-term benefits and cost-effectiveness of green roofs due to high setup costs.

3.3.2 Challenges of Using Mechanical Filter Mesh and Membrane Bioreactor in Hong Kong

There are also several challenges to the utilization of mechanical filter mesh and membrane bioreactors in Hong Kong. The first challenge is complexity and expertise due to the special and complex knowledge to apply mechanical filter mesh and membrane bioreactor. Secondly, the capital and operational costs for initial investment and operational expenses, which include energy and chemicals for cleaning and membrane replacement due to the limited lifespan of the membrane, may be substantial. At the same time, the fouling problem is also crucial, which will reduce permeability, working efficiency, and operational costs.

4 FUTURE PROSPECTS AND RECOMMENDATIONS

With the highly developed society, several innovative technologies have emerged to improve the sustainability of the entire water cycle. For example, smart monitoring and control with the Internet of Things (loT) and artificial intelligence (AI). Integrating artificial intelligence and the Internet of Things in sustainable drainage systems and wastewater treatment can improve efficiency and sustainability.

Firstly, AI and loT can be used for sustainable drainage systems and for real-time monitoring and data collection. The application of loT sensors can effectively monitor parameters such as water levels, flow rates, rainfall quantity, soil moisture, and water quality in real-time and transmit the data to a central system for analysis. At the same time, AI models can be used to analyze historical and real-time data to predict potential flooding events and optimize drainage operations. The implementation of AI-driven decision support systems to take proactive measures, such as adjusting the operation of pumps and valves or diverting water flows to prevent flooding. Apart from these, AI are also beneficial for predictive maintenance. As long as the sensor data predicts that the systems should be maintenance, the sensor will inform system managers about the data, which can reduce the risk of system failures and optimize maintenance schedules.

Additionally, for wastewater treatment, AI and loT can also play significant role in optimizing the entire treatment process (Gupta et al., 2024).

Integrating loT sensors and AI control systems to monitor key parameters such as pH, turbidity, dissolved oxygen, and contaminant levels throughout the treatment process. Also, implementing AI algorithms to detect anomalies in water quality data, triggering automated responses to address potential issues. With the sensor of loT to monitor energy consumption and the analyzer of AI, it is easy to discover energy usage patterns and optimize energy-intensive processes, such as aeration and pumping, to reduce operational costs and carbon footprints. Besides such benefits. AI is able to control and optimize nutrient recovery systems and enhance the efficiency of extracting valuable resources like phosphorus and nitrogen.

By utilizing the combined AI and loT systems, the performance and sustainability of drainage systems and wastewater treatment infrastructure can be enhanced. Apart from AI and loT, there will be more and more technologies that can be used to create a more resilient and sustainable urban environment. With the effort of all residents around the world, sewage drainage and treatment can be more effective and sustainable.

5 CONCLUSIONS

In conclusion, in order to solve the questions of pollutants, especially sewage, generated from rapid industrialization and urbanization, proper management of wastewater is crucial to mitigate its detrimental effects on human health and ecosystems. Sustainable development, which balances economic growth with environmental protection and social well-being, is essential for addressing pollution and protecting the environment. Apart from properly handling the management processes, the SuDS and sustainable wastewater treatment technologies are also crucial to reducing the detrimental effects on human activities, agriculture, and public health.

This study takes Hong Kong as an example to introduce the significance of utilization of green roofs, which are the component of SuDS, and the application of mechanical filter mesh and membrane bioreactor, which are included in sustainable wastewater treatment technologies. However, challenges such as lack of knowledge, economic constraints, and technical issues must be addressed. The educational campaigns and financial support should be applied to deal with these challenges.

Future prospects, which are to construct a healthy, safe, and sustainable living environment for humans and creatures, include the integration of smart technologies like AI and IoT to enhance the efficiency and sustainability of drainage systems and wastewater treatment processes. By leveraging these advancements, we can create a more resilient and sustainable urban environment, ensuring effective and sustainable sewage drainage and treatment for the future.

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