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ScienceDirect

IFAC PapersOnLine 52-25 (2019) 421–423

Strategic innovative technologies as a tool to improve the control efficiency of water supply systems of a modern city

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Abstract: This paper presents a summary analysis of urban water supply problems faced by Chinese cities and global practices of using tech-driven solutions for reducing adverse environmental impacts and improving water and energy efficiency in water supply and sewage disposal systems. Urbanization has the potential to facilitate the modernization of urban water supply management systems, helping improve water quality for urban residents in China. Improving intelligent water supply management systems, in particular using alternative water sources, has the potential to ensure the sustainable management of water.

Keywords: urban water supply systems, water resources, urbanization, agent-oriented models, water security, climate change, smart city, strategy, BIM

1. INTRODUCTION

Urbanization can be viewed as a new challenge for existing urban water supply systems. As more and more people choose to move to urban areas, cities are increasingly coming under pressure to improve urban water supply both in quantitative and qualitative terms. The need for a complete overhaul of water supply systems is further emphasized by pollution concerns, excessive wear of water supply infrastructure and the fact that outdated and inefficient solutions are still used for managing the use of water, a critical resource for humankind.

2. KEY CHALLENGES IN TERMS OF WATER SUPPLY FOR CHINESE CITIES

Urban development inevitable entails the need to upgrade water supply. China's experience in promoting cross-border water supply projects date all the way back to the country's ancient history, exemplified by the construction of the Grand Canal that stretches for more than 2,000 km (UNESCO). Today, China continues to engage in monumental water supply projects (Xiong et al., 2018).

Although China ranks sixth in the world in total water resources (2.8 trillion m3), the annual per capita renewable freshwater availability is only 2,300 m3, or 25% of the world's average. With the world's largest population and the second-largest national economy, water shortages in China could shake world food security and threaten global prosperity (Cheng et al., 2009).

While the rapid pace of industrial development, urbanization and population growth create obvious advantages for the Chinese economy, these processes have also a downside, which includes pollution and the degradation of water ecosystems (Wu et al., 2019). Jinchuan River is a case in point. It is a major tributary of Yangtse River that runs entirely within Nanjing City, surrounded by residential and business neighborhoods (Fig.1). In China, environmental quality standards for surface water include five classes. Unfortunately, the analysis of water samples from Jinchuan River for bacterial pollution consistently showed that its water quality was below the fifth class. Rivers of this kind are regarded as having an elevated level of pollution, and are characterized by black or dark green water with a distinct unpleasant odor.

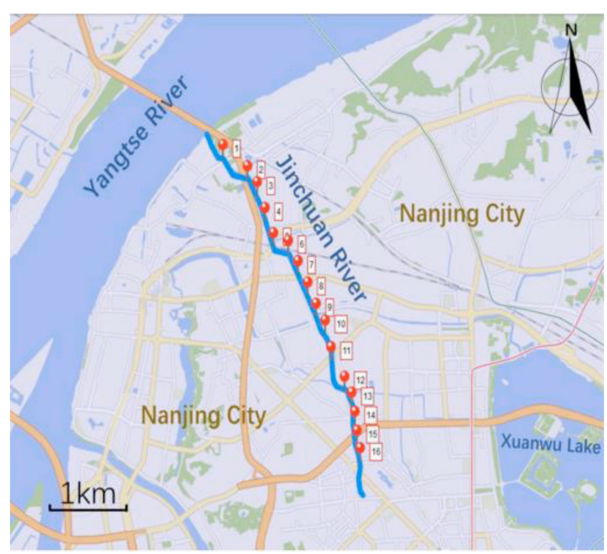

Fig.1. Distribution of sampling locations in the Jinchuan River.

The black water and odor coming from urban rivers result from an excessive anthropogenic burden, affecting human livelihoods and the cityscape in significant ways. The aquatic environment acts as a major pool for antibiotics and antibiotic resistant genes (ARGs). Antibiotics in the aquatic

10.1016/j.ifacol.2019.12.574

environment generally originate from effluents of wastewater treatment plants, industrial sites, hospitals and livestock farms. It was estimated that in 2013 the total usage of 36 antibiotics reached 92,700 tons in China, making it the world's largest producer and user of antibiotics (Zhang et al., 2015).

Research on this matter includes a study (Huang et al., 2019) in which researchers drew samples of water and sediments to analyze nine antibiotics (sulfonamides, tetracyclines, quinolones, and macrolides) and their corresponding ARGs in six urban rivers in Guangzhou, South China, in order to explore their spatial distribution and the influence of water remediation. All the samples had antibiotics in them.

Apart from chemical and biological pollution in cities, other factors to be taken into consideration are the engineering and technological capabilities of the existing systems. The high level of wear and tear and their low capability add to the negative factors related to urbanization.

3. TOWARD AN IMPROVEMENT IN WATER SUPPLY SYSTEMS

The problems with water supply and sewage disposal mentioned above have to be taken into consideration when upgrading China's urban water supply systems. In fact, urbanization raises the bar in terms of creating a people-friendly environment for local residents, since environment quality matters a great deal for them.

Digitalization tends to make cities smart (Dameri et al., 2019), however, all smart cities are unique in their own way, which is due to their specific characteristics, the challenges they face and concrete solutions they have to include in their strategies of improving (Kvint et al., 2010).

The improvement of water supply management systems can be broadly divided into four stages: *modeling, design, construction (technical and organizational measures) and operation.* Let's look at each of these four stages in more detail.

The modeling stage for new water supply systems consists of identifying the best mix of various water supply sources, including artificial recharge, wastewater reuse and brackish groundwater desalination, as well creating reservoirs. In a project to create a model for optimizing London's water supply, a water resource management simulator was linked to multi-objective search. The analysis showed that many-objective evolutionary optimization coupled with state-of-the art visual analytics can help planners discover more diverse water supply system designs and better understand their inherent trade-offs (Matrosov et al., 2015).

When *designing state*-of-the-art water supply systems, factors to be taken into consideration include the specific features of water sources, pollution levels, as well as the current and projected state of utilities networks and equipment. The Building Information Model (BIM) has proved its worth and effectiveness in the design of water supply and drainage systems (Wei et al., 2017). It can help reduce the risk of design flaws, minimize potential losses, and lower operational costs.

Tasked with producing and transporting water to end users, pumping stations are the most energy intensive elements in water supply systems. Their electricity consumption can account for as much as 95 to 98 percent of total power consumed by the whole water supply system. For example, the BIM model of water supply pumping station of Qingdao Guzhenkou water supply project (Miao et al., 2017) proved to be an effective solution. BIM seems to be best suited for designing advanced technological solutions.

When designing water supply systems, there are a number of important factors that have to be factored in the project model at the preceding stage, including high precipitation intensities caused by increasing urbanization and climate change (Hailegeorgis and Alfredsen, 2017).

Construction stage (technical and organizational measures)

After the design phase, projects move to the stage of construction and installation works, as well as technical and organizational measures. Models reflecting the possible changes in terms of urbanization, climate, environment and other factors have to be created during the modeling stage, and factored into the projects.

Apart from technical measures, a combination of engineering and biological techniques has to be used to remediate heavily polluted rivers (Sheng et al., 2013). Special attention must be paid to identifying and neutralizing antibiotics in water supply systems.

Operation

Beijing has a positive track record of using intellectual decision support subsystems for controling water supply. A leader-follower interactive solution algorithm based on satisfactory degree principle can be used to take strategic decisions regarding regional water resources management and ensure a high level of water security against the backdrop of multiple uncertainties (Chen et al., 2018).

Intellectual water supply contol systems proved their worth as part of smart city solutions, providing for water supply management automation and thereby reducing operational costs. Urban water supply infrastructure management subsystems have the capability to automatically collect water consumption data, enabling consumers to receive reliable information about the actual levels of water consumption, while utilities providers obtain data on the actual consumption and production. This provides an additional advantage of identifying unauthorized connections to water supply systems and detecting network sections affected by theft (Fomin et al., 2019).

Apart from the direct economic effect from enhancing the efficiency in water resources management, upgrading obsolete water supply systems provides an additional benefit of improving the quality of life and health of city residents who get to use cleaner water (Wang et al., 2019).

4. CONCLUSIONS

This summary analysis showed that upgrading water supply control systems in Chinese cities is an essential element of urbanization. Cutting-edge technology can help enhance water and energy efficiency in water supply and sewage disposal, while also ensuring that people living in Chinese cities benefit from better water. This can be achieved by upgrading sewage disposal systems, increasing the share of alternative water sources in the overall water supply, modernizing the existing water supply systems, as well as using state-of-the-art intellectual water supply management systems as part of an effort to create smart cities.

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