Let a sewage plant running smart

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Abstract. Out-dated technical equipment, occlusive information communication, inadequate sanitation, low management level and some irrational distribution structures in the existing sewage plants bring about lower sewage treatment efficiency and poorer water quality, thereby permanently harming human health and severely damaging the environment. With the rapid development of scientific-technological progress and the vigorous support of the entire international community, the existing sewage plants call for more and more intelligent operation and management in the future. This review for the first time proposes the novel concept of the “smart” sewage plant, and gives a through interpretation of its special functions and attributes. We envision that the future smart sewage plant will became an “ambient intelligence” in all aspects in the sewage plants.

1. Why Do We Need a Smart Sewage Plant?
Water resource is critical for sustainable development. With the acceleration in the urbanization process, the increasing generation of domestic and industrial wastewater has already attracted much more public attention and awareness in many countries in the world [1]. According to the United Nations World Water Development Report, by 2050, there will be at least one in four people live in a chronic or recurring freshwater shortage country [2]. Thus in the coming years, people are going to face more and more serious water resource challenges.

The United Nations has always been committed to water programs and planning, e.g. resolution A/RES/47/193 of 22 December 1992 (Observance of World Day for Water) [3], resolution A/RES/55/196 of 20 December 2000 (International Year of Freshwater, 2003) [4], resolution A/RES/58/217 of 23 December 2003 proclaimed the period 2005-2015 International Decade for Action “Water for Life” [2]. In the report of the Second Committee (resolution A/RES/65/154), General Assembly declared 2013 the International Year of Water Cooperation [5]. For the Year, the U.N. announced its strongest calling for “all Member States to take advantage of the Year to promote actions at all levels, including through international cooperation, as appropriate, aimed at the achievement of the internationally agreed water-related goals, as well as to increase awareness of their importance” [5]. How to solve the water resource problem, has become a vital challenge that each country in the world is now facing and in urgent of solving.

Water resource shortage problems that are particularly challenging in China, have already become an important factor restricting China's social and economic development [6]. On 19 April 2012, the General Office of the Chinese State Council issued a notice of 12th Five-Year Plan on “The Urban
Sewage Treatment and Recycling Facility Construction Plan” [7]. The “Notice” stressed that during the 12th Five-Year Plan, the government’s total investment on construction of sewage treatment and recycling facilities will amount to CNY 430 billion (U.S. $ 70.24 billion), which increased by 22.79% of total investment compared with that in the 11th Five-Year Plan (U.S. $ 54.32 billion).

Although Chinese government ramped up the capital investments, this “Notice” focuses mainly on facilities construction and sewage treatment capacity, still not sufficient. According to the latest report from China’s water network (available at http://www.h2o-china.com/), there are about 32% of the existing sewage plants were built and put into operation before 2006, in which the sewage treatment capacity is account for 50% of the total capacity today. Among all of these sewage plants, there are only 12% can meet class A Integrated Wastewater Discharge Standard (GB8978-1996), however, these plants only occupied less than 7% of the total sewage treatment capacity. While the number of sewage plants meeting class B (GB8978-1996) accounted for 54%, and still 34% of the sewage plants discharge is below class B (GB8978-1996). The fundamental reasons for lower sewage treatment capability and quality in traditional sewage treatment plants may due to outdated technical equipment, irrational industrial structure, occlusive information communication network, high energy consumption, as well as low level of management. With more and more ambient intelligence improved our daily life [8], it is strongly needed to make our sewage plants more smart and intelligent.

As the 12th Five-Year Plan proposed that the development of sewage plants in China is entering the “Upgrading and Reconstruction Time”, the traditional sewage plants will arouse increasing intelligent operation and management [9]. The technologically innovation with intelligence, automation, digitalization, flexibility, resilience, and sustainability operation and management will be strongly recommended in the future. The construction and extension of the new-generation sewage plants, which entitles “smart sewage plant”, will forward new challenges to create a completely intelligent environment in the future sewage plants in China.

2. What is a Smart Sewage Plant?
The realization of “smart” for a future sewage plant needs four essentials (Figure 1):

![Figure 1](image)

**Figure 1.** The messages transmitted in the smart sewage plant are based on typical Ethernet 5-layer protocol architecture. The communication between the field equipment and SCADA can be realized through Wi-Fi and fixed optical fiber.

**Intelligent and picturesque supervisory control and data acquisition (SCADA).** Intelligent and picturesque SCADA could provide deeper understanding of the overall sewage plant
performances. All the intelligent decisions are automatically made by SCADA, and subsequently sent to the various control terminals. Via a local or remote control operations, the network communication platform will expand to the SCADA to make the collected data readily and conveniently available.

✓ **Advanced and intelligent control equipment.** Advanced and intelligent control equipment are the key essential in determining the behavior of the smart sewage plant. With the participation of more advanced and intelligent control equipment, a smart sewage plant is expected to detect, analyze and respond smartly to the changes (or the shocks) in the operation or to predict the possibility of failures at the earliest without human intervention.

✓ **Automatic sensing and monitoring devices.** Automatic sensing and monitoring devices embedded in the control equipment efficiently guarantee the intelligent decision-making strategy. These devices in the smart sewage plant play the fundamental role in enabling the transformation of data into straightforward information. With the introduction of advanced sensing and monitoring devices, the smart sewage plant can evaluate the health of the sewage plant operation in real time, enabling a rapid smart diagnosis and supporting the optimized control strategy.

✓ **Intelligent communication networking.** Sophisticated wired and wireless communication networking allow a “plug-and-play” environment, which these can ensure the high-speed and high-reliable transmission of controlling and sensing information from intelligence terminal devices to smart control center [10]. We can envision that in the future, some portable interfaces, for instance, iPad, iPhone, and Android mobile phones can be exploit by the operators to carry out simple and convenient check, to control the operation state of the sewage plant in a wireless way.

3. **What Makes a Smart Sewage Plant Smart?**

Exactly what is a smart sewage plant? Actually, the smart sewage plant is not defined by how advanced equipment it integrates but rather by what it can smartly cooperate. The running for a future smart sewage plant is to provide the means to implement scientific decision-making by smart control algorithms. It can provide an optimal sewage treatment strategy smartly itself.

3.1. **Real-Time Modelling**

For the future smart sewage plant, real-time modelling is a novel concept. Through the collection of the real-time information and real-time monitoring data from the whole sewage treatment plant, real-time modelling gives the accurate analysis and evaluation of its present operating state and builds the corresponding regulation and control model. Real-time modelling, as one of the core functions, could give a variety of strategies to optimize the sewage treatment process.

3.2. **Intelligent Decision-Making**

The new generation smart sewage plant will reduce the number of workforce and require highly educated and well-trained managers who can keep skills fresh and up-to-date in response to the growing requirement of the smart sewage plant. The future sewage plant is expected to automatically detect the possible changes and faults, continuously check and report the operating state of a sewage plant, and give the intelligent decision-making and self-healing based on real-time modelling.

3.3. **Stable and Fast Security Analysis**

Stability and Security are the critical issues in the future smart sewage plant. An intelligent and strong smart sewage plant must guarantee a stable and fast security analysis for the sewage plant operation. The future smart sewage plant will rely extensively on the use of the safe and stable online monitoring and real-time analysis technologies. The application of real-time analysis in the future smart sewage plant would provide more scientific protection on human, production, operation, fire, environment security and safety.

3.4. **Self-Healing/Self-Correction System**
Self-healing/self-correction system is a high performance system which is integrated into the future smart sewage plant. It is expected that the smart sewage plant will detect, analyze and respond automatically to provide a set of optimal self-healing and self-correction control strategies according to the real-time information feedback without human intervention.

3.5. Wireless Communication Networking
Advancement in communication networking technology is another significant aspect in realizing a smart sewage plant. In the future smart sewage plant, wide application of the wireless communication networking would enable us to transfer the collected information over both short-range and long-range communications. We can envision that in the future, some portable interfaces, for instance, iPhone, and Android mobile phones can be exploit by the operators to carry out simple and convenient check.

3.6. Superior Effluent Quality
Effluent quality is another significant element to evaluate the operation performance of a sewage plant, as any changes (e.g. influent quality fluctuation, temperature variation, mechanical fault and etc.) can in turn do harm to the environment. Unlike the existing sewage plants, the future smart sewage plant provides many intelligent and powerful functions and allows for the visualization, flexibility, interoperability, resilience, and sustainability of operation [9]. Superior effluent quality is hence confident, and helps enhance the environment protection.

3.7. Humanized and Visualized Interoperability platform
A humanized and graphical visualization interoperability platform will offer more convenient and simpler operation to the sewage plant operators. As it can display the function keys and modules on the SCADA, it is more friendly and useful for this interoperability platform to provide simple, well defined, humanized, and graphical operation. Thus the operators could promptly give operation instructions and actionable commands.

4. What Are the Perspectives for a Smart Sewage Plant?
Above all, a future smart sewage plant can intelligently provide the corresponding control decision; implementation program and emergency solution. As the smart sewage plant is featured by automated information, we depict the blueprint of a future smart sewage plant here (Figure 2).

![Figure 2. The scope of a smart sewage plant extends over all the aspects of the sewage treatment processes.](image-url)
5. What Are the Main Roadblocks for a Smart Sewage Plant?
Implementation of the smart sewage plant involves many formidable obstacles and anticipative challenges. One critical challenge of replacing the existing sewage plant with a smart sewage plant is the demand for a unified communication protocol. As is mentioned above, the realization of “smart” for sewage treatment plant needs advanced and intelligent control equipment and automatic sensing and monitoring devices. Different equipment and devices purchase directly from different manufacturers have their own communication protocols; a common understanding is the ability to access any data from anywhere. However, an unify communication protocol standard plays an important role in a smart sewage plant by providing an unified way of accessing and exchanging data related to equipment and devices. For a long-term hard task, the need for a unified communication protocol is therefore obvious and imperative for the efforts of researchers.

Another challenge for the future smart sewage plant is to set a unified operational platform in the smart control centre. With the introduction of unified operational platform and standardized operation manual, a future smart sewage plant will not only realize the resources sharing between different sewage plants, but also can achieve a wide range of centralized monitoring and management.

6. Conclusion
Even as we confront the obstacles and challenges before us, overcoming the obstacles and challenges are inevitable and technical-enabled. In this review, we have defined a future smart sewage plant, its further development is indispensable for human quality living and long-term development. When looking beyond the horizon, we envision a brilliant and better future for a smart sewage plant.

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