Ideas for Building the Concept Wastewater Treatment Plants in China

Juhui QU, Kaijun WANG, Hongchen WANG, Gang YU, Bin KE, and Han-qing YU

Expert Committee for China's Concept WWTPs (EC^3 WWTPs)

Abstract:

In China, six local experts set up an Expert Committee for China's Concept WWTPs (EC^{3}WWTPs) which aims to build several concept wastewater treatment plants over the next five years. The concept wastewater treatment plants aim to achieve sustainable water quality, energy self-sufficiency, resources recovery and be environmentally friendly. As we know, activated sludge process (ASP) plays a leading role in pollutants removal from wastewater since its invention over a century ago. However, existing sewage treatment practices employing ASP can no longer satisfy the challenging demand arising from the promotion of Low Carbon, Green Growth strategy. Under the guideline of this strategy, sewage should be considered as a renewable resource capable of converting organic carbon into clean energy, while simultaneously recovering both nitrogenous and phosphorus nutrients. Critical and intellectual thinking is required to transform these cherished ideas into reality. As leading experts in water remediation technology, it is imperative for us to brainstorm the blueprints of conceptual WWTPs incorporating such renewable technology. The construction of demonstrative sewage treatment plants (STPs) is already underway and will be operational between fiscal years 2030 to 2040. These demonstrative STPs will validate novel functionalities and treatment capacity that are necessary to fulfill the rising demand of China wastewater industry in the future.

What is China Concept WWTPs ?

Currently, China is the second-largest economy and one of the largest water markets in the world. On one hand, wastewater treatment plants have rapidly developed in the past decades in China, which has significantly controlled water pollution and improved local water environment. By the end of 2013, there were 1999 large scale municipal WWTPs in China (excluding those in the rural and lower-tier towns) with a cumulative capacity of about 122 million cubic metres per day. On the other hands, the overall water environment in China is still fragile and facing heavy burdens. The operation issues of the WWTPs are drawing more and more attention, including high energy consumption, low efficiency.

To build the future WWTPs in China, four questions have to be answered:

- What changes should be made by current plants to improve their efficiency?
- What concept should be considered to achieve sustainability for water infrastructures?
- What technologies are most promising and attractive to improve water treatment process?
- What revisions should be made to national water standard to satisfy demand in future?

The idea for Building the Concept WWTPs in China is an ambitious attempt to answer the above questions and provide real examples for all the WWTPs to follow in future. The water professionals in China are very concerned about the challenges and opportunities which our infrastructures are facing. Protection of our water environment requires the expansion of WWTPs to meet the pressure of growing populations, increased water quality requirements, global resource shortage and energy crisis. We are very concerned about the detrimental effect that current high energy costs can have on the ability of local government to maintain and upgrade their water infrastructure. This in turn can have a detrimental effect on our ability to protect water environment. Therefore, we plan to act now to protect our water environment with Ideas of Building the Concept Wastewater Treatment Plants in China to ensure sustainable wastewater treatment.

Why does China need the Concept WWTPs ?

Opportunities in China

Since the first large-scale WWTP started in China in 1982, the municipal WWTPs in the country has developed significantly, especially in the past decades. Between 2000 and 2010, China's wastewater plant building got a great jump with treatment capacity doubled. China is the only country worldwide to have achieved this feat. The graph below shows the development of municipal WWTPs in China. Now, China municipal WWTPs have capacity of more than 122 million cubic metres per day.

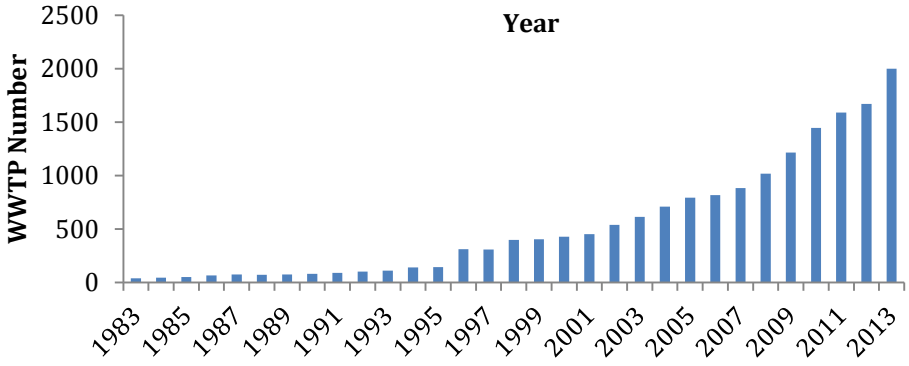

Figure.1 Development of WWTPs in China (1983-2013)

Considering the urbanization process in current China, the increasing trend of WWTPs treatment capacity is expected to continue. For the first time in its thousands year long history, China is facing urbanization process moving forward at a great scale. The large cities with a population of over 1 million account for average 72% of the urban population all around the world, however the number is only 45% in China, which means the urbanization process will continue for the following years. The movement of farmers toward urban areas will be a long-term social phenomenon in the country. Thus, wastewater treatment will be an indispensable component of the resulting urbanization. More sewage treatment capacity and better water services are in urgent demands. Expectedly, China will continue to be one of the largest wastewater treatment markets in the world. These facts provide great opportunities for future WWTPs development.

Challenges for China

However, China's wastewater treatment plants continue to face severe challenges, as it did over the past 30 years. High development cost and poor output quality are the main problems. Lacks of long-term and clear development planning at the top and overemphasis on short-term profits significantly distort the development of wastewater treatment plants but also reduce wastewater treatment system effectiveness. From the macro development standpoint, development of China wastewater treatment industry is unsustainable given its high consumption of energy and resources. Nevertheless, there have been clear changes in wastewater treatment principles and technologies after the 21st century. Sustainable development and human–nature harmony have become the main themes of the times worldwide. However, China's wastewater treatment industry did not seize the opportunity to do so and, instead, adopted methods which have now been discarded in developed countries. From the micro perspective, lack of a water quality standard for sustainable development, scant consideration for wastewater potential energy, imperfect sludge disposal and odour control are concrete manifestations of the challenges facing the industry.

Why Concept WWTPs important？

Concept WWTPs keep up with the Global development trends

In the first half of the 20th century, the focus of wastewater treatment was on organic matter removal. In the second half of the 20th century, nutrient removal became the main challenge due to eutrophication. After a century of wastewater treatment plant development, many treatment plants which were initially built outside urban areas are now engulfed by residential areas. Consequently, plant expansion is problematic, and engineers are focusing on developing more compact treatment options. These efforts have yielded a whole range of new processes and devices such as moving bed biofilm reactors (MBBR) and biological aerated filters. After the 21st century, substantial population growth and rapid increase in the rate of urbanization worldwide have caused climate change, increased the rate of

biodiversity loss and affected nutrient cycles. Wastewater is becoming one of the world's greatest sustainable resources. Nutrient recovery has emerged as an attractive option for wastewater treatment plants planning or upgrade. Since the recovered products have valuable secondary uses, this process can potentially allow plants to generate alternative revenue streams which can offset operation and management costs. Phosphorus recovery has been achieved in some Europe- and US-based WWTPs. The energy contained in wastewater and solids is significantly higher than the energy required for treatment. Hence energy neutrality is an achievable goal and is being pursued successfully by implementing alternatives which include increased energy (methane gas) production and reduced energy consumption through the integration of emerging concepts such as anaerobic ammonia oxidation (ANAMMOX), high-efficiency digestion and optimized aeration control.

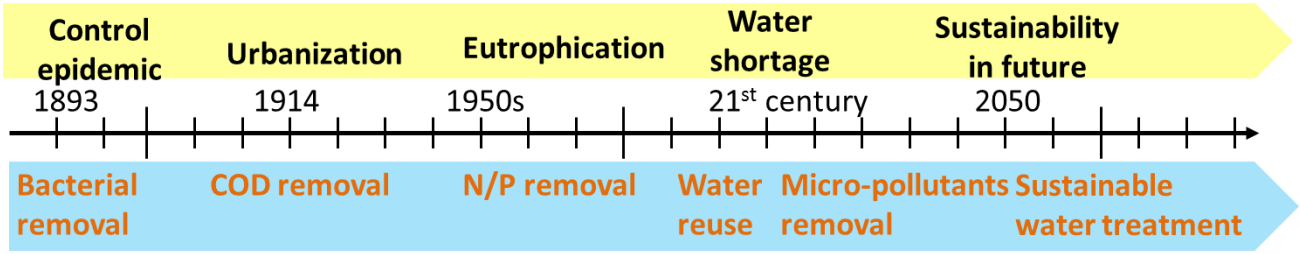

Figure.2 Brief history of water treatment requirements and goals

Meanwhile, water reuse is becoming increasingly important for modern societies, especially those based in arid regions. In fact, water reuse has been implemented in many famous plants such as Water Factory 21 in the *Orange County* Water District (OCWD) in California and NEWater project in Singapore. Scientists and engineers are more concerned about emerging contaminants in WWTP effluent. Endocrine disruptors and personal care products are typical emerging contaminants which pose great challenges for water reuse. As mentioned above, the China's Concept WWTPs, which stands for Nutrient, Energy and Water recovery (also mentioned as NEW concept composed by the three initial characters from Nutrient, Energy and Water), follows the Global development trends.

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Figure.3 Sustainable concepts for China's Concept WWTPs

How to building the Concept WWTPs?

Establishment of Committee for China's Concept WWTPs (EC³WWTPs)

In China, six local and recognized experts set up the China Concept wastewater treatment plant committee which aims to build several concept wastewater treatment plants over the next five years. The names of the committee members are listed below:

- Prof. Jiuhui Qu, Member of Chinese Academy of Engineering, Research Centre for Eco-Environmental Sciences
- Prof. Kaijun Wang, Tsinghua University
- Prof. Hongcheng Wang, Renmin University of China
- Prof. Gang Yu, Tsinghua University
- Mr. Bing Ke, The Administrative Centre for China's Agenda 21
- Prof. Hanqing Yu, University of Science and Technology of China

Figure.4 Expert Committee for China's Concept WWTPs (EC3WWTPs)

Considerations for Sustainable concepts

The Committee plans to build a series of Concept WWTPs within five years. These concept plants would practice low carbon ideas, intensively apply and demonstrate mature advanced technologies which are recognized internationally. Moreover, it can meet the strategic requirements of environmental development in Chinese cities and become a global benchmark for WWTPs. All of the above understanding will determine the construction concept wastewater treatment plant will be a long-term and a value-creating process. Although China has a lot of experience with wastewater treatment for many years, we do not think that the concept wastewater treatment plant can be realized simply through normal discussion. On the contrary, it requires systematic engineering which involves cooperation among multiple parties. Based on several discussions, the committee opines that the concept WWTPs should include the following four aspects:

- The water quality standard is one of the most important factors in concept WWTPs. The committee believes that the concept WWTPs should comply with a sustainable standard based on top-level design and long-term plan, and it needs to meet the requirements of local environment, while ensuring sustainable development of the society.
- The average energy demand of WWTPs in China is 0.27kWh/m3, which is below that of WWTPs in the US. There are several reasons for this. First, wastewater treatment systems in China are imperfect, especially from the sludge treatment viewpoint. Second, Chinese WWTPs handle low-quality influents, so energy consumption per cubic metre decreases naturally. However, wastewater treatment energy consumption will be increased via system optimization. As the consequences of climate change become more visible, the importance of wastewater energy recovery increases. The concept WWTP should achieve significant energy savings and even become energy-neutral. Based on the concept WWTP roadmap, Chinese WWTPs are expected to save 1% of the total energy consumption of the entire society.
- The products of a WWTP eventually need to move toward society or nature. The concept WWTP will select appropriate sludge disposal methods considering long-term urban development and will recover wastewater resources to the greatest possible extent. Meanwhile, the concept WWTPs will reduce the consumption of chemicals and decrease environment-related risks.

- Finally, the concept WWTPs will be very environmentally friendly. It will not only focus on odour control but also on achieving harmonious coexistence with the community. Land is the most valuable resource in China. However, the committee does not think that the goal of future WWTPs should be land conservation. Instead, said plants should not affect the functionality of the surrounding land, which is more important than its investments.

All of these actions constitute a new paradigm in wastewater treatment. As an important urban infrastructure element, WWTP development should involve not only technical experts and engineers but also planners, politician and members of the public.

Goals of China Concept WWTPs

The goals and outline of conceptual WWTP blueprints should contain:

1) implementing water sustainability;
2) improving energy self-sufficiency;
3) incorporating effective material cycle;
4) increasing eco-friendly performance.

Firstly, achieving efficient and safe sewage recycling is the core objective of conceptual WWPTs. Since water is the basic property of sewage and is a renewable resource, ensuring the effluent quality is vital for water reclamation as well as securing the ecological safety of the environment. Therefore, we need to optimize the water quality assessment system to accommodate the dynamic recycling targets and processes. This will minimize both ecological and health risk during sewage storage, utilization, and recycling steps, which are essential components to be incorporated into conceptual WWTPs.

Secondly, energy self-sufficiency has become a vital target of conceptual WWTPs. Studies have shown that the potential renewable energy that can be recovered from sewage is 10 times higher than the energy consumed by the STPs. However, the recovery of renewable energy from sewage remains largely unexplored. For instance,

the energy consumption of STPs accounts for about 3% of total energy consumption in the US. Similar phenomenon is also observed in China by which the annual energy consumption of STPs has exceeded 10 billion kWh. On the other hand, the potential energy that can be recovered from daily sewage production at global scale is equivalent to that produced by approximately 100 million tons of standard fuel oil. A few plants by which energy self-sufficiency can reach 60-100% have already demonstrated successful exploration of sewage energy. In this sense the construction of demonstrative STPs will significantly promote the sewage-to-energy practice in China, thus greatly benefiting the transition to a low-carbon society.

Thirdly, recycling nutrients from sewage is one of the important objectives for the development of conceptual WWTPs. Nutrients recovered (such as nitrogen and phosphorus) from the sewage can be recycled and reused through different approaches. We are currently exploring feasible options to incorporate highly efficient phosphorus recovery strategies into our blueprints of conceptual WWTPs to allow versatile utilization of recovered nutrients subsequently.

Finally, rational designing of conceptual WWTPs must ensure environment security. Community integration with minimal impact of the surrounding environments should be adequately pursued in both designing and operation of demonstrative STPs. In particular, the effluents must not induce any risk to the ecosystem of the receiving water bodies. In summary, the development of conceptual WWTPs in China is still in its infancy and requires momentum. The successful outcome of our demonstrative program will not only gain social acceptance of sewage as a viable renewable resource, but will also drive the advancement of wastewater treatment industry towards technological innovation, as well as promoting eco-friendly practice of sustainable sewage management. We will strive for this goal.

Schedule of China's Concept WWTPs

As it is introduced to the whole society, the ideas for Building the Concept Wastewater Treatment Plants in China has attract great attentions and supports from all aspects of water region including academic, industry and government. Some of people and institutions who are willing to contribute even become our cooperator and participator. Based on the former preparation, the building of China's Concept WWTPs is planned and scheduled as shown in Fig.5.

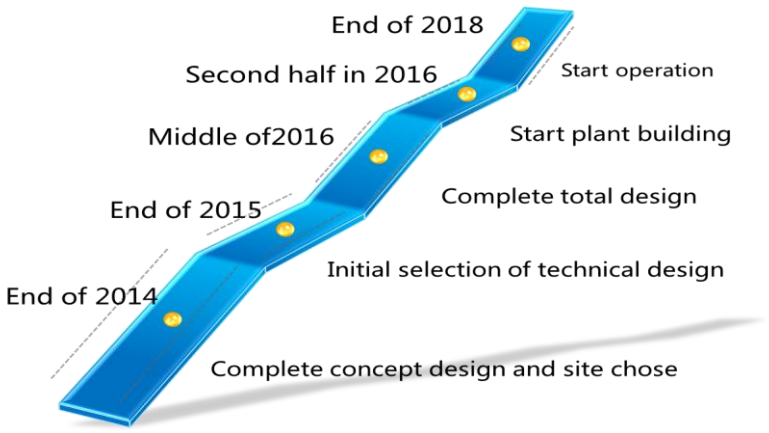

Figure.5 Time schedule for building Concept Wastewater Treatment Plants