Comprehensive Evaluation of the Environmental and Socio-Economic Impacts of Adopting Advanced Technologies for Treatment of Sewage Sludge in Beijing

（北京市における先進的汚泥処理技術の導入による環境と社会経済への影響の総合評価）

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ABSTRACT

With the rapid development of urbanization and industrialization process, a sharp increase in urban population and the expansion of urban areas, the volume of industrial wastewater and municipal sewage has increased significantly. In order to improve water quality, the Chinese government has invested heavily in the construction of sewage treatment plants. At the same time, as the byproduct of sewage treatment, the amount of sewage sludge has also increased year by year. However, the government has ignored sewage sludge treatment. In term of current sewage sludge treatment, landfill, aerobic fermentation, natural drying, sludge burning and without any treatment account for 65%, 15% , 3%, 2% ,15%, respectively. About 80% of sewage sludge is not treated and disposed in a safe and effective manner. These untreated or improperly treated sewage sludge has polluted the water environment. Beijing is a typical case in this regard in China.

Due to its rapid economic and population growth, Beijing’s municipal sewage emissions are increasing every year. In 2010, the city discharged more than 1.4 billion

tons of sewage. Many sewage treatment plants that have been constructed by the Beijing municipal government have adopted advanced technologies, and the sewage treatment rate increased to 80% in 2010. However, the amount of sewage sludge has also increased. Sewage sludge is the byproduct of sewage treatment, and these byproducts pollute the water environment. If this sewage sludge cannot be treated properly, 50% of the water pollutants not removed by sewage treatment will return to the environment. However, the need for sewage sludge treatment has not been addressed by the government. The rate of sewage sludge treatment was less than 50% in 2010. More than 20,000 tons of total nitrogen is discharged by untreated sewage sludge every year, which accounts for approximately 30% of the total nitrogen load in Beijing.

Recently, the government has realized the importance of environmental protection. Accordingly, The Twelfth Five-Year Plan of Economic and Social Development requires that all sewage sludge be treated by 2015 and load of chemical oxygen demand (COD) be reduced by 8.7% in 2015 compared with 2010. Therefore, the government has adopted an integrated policy that promotes water conservation, reduction of working capital and the introduction of advanced sewage and sewage sludge treatment technologies. In order to determine the optimal development plan for Beijing, it is beneficial to use a simulation method to evaluate the regional environmental and economic impacts of adopting advanced technologies for the treatment of sewage sludge.

In this study, firstly, an experimental simulation was undertaken to simulate the impact of integrated policy on sewage treatment with advanced technology to achieve the Beijing government plan as well as effectively improve water quality while keeping economic development. The experimental results prove the dynamic simulation method is reliable and the model is accurate in estimating the future economic development of the local area. This initial simulation also suggests that COD should be selected as a limiting factor when advanced sewage sludge technology is adopted. This finding differs from other studies, which only considered sewage treatment.

And then, based on the positive simulation results, a comprehensive optimization

simulation model was constructed to simulate socio-economic and environmental development in Beijing city. The simulation period is from 2010 to 2020. The Simulation model for this comprehensive analysis was performed using Lingo software.

Based on the comprehensive simulation results, we found out that the integrated policy emphasis on sewage sludge treatment with advanced technology is effective to reduce environmental pollutants and achieve economic development. Specifically, in the optimal scenario (Scenario 4), the total GRP for 2010-2020 reaches 24,151 billion CNY and the average rate of economic growth from 2010 to 2020 is 8.03%. Moreover, the total net load of T-P, T-N and COD is 49 thousand tons, 449 thousand tons, and 1,933 thousand tons, respectively. The reduction rate of T-P, T-N and COD is 46%, 40% and 25%, respectively, in 2020 compared with 2010 while keeping the target of 8% GRP growth.

If the reduction rate of COD is 25% in 2020 compared with 2010, the reduction rate of energy consumption intensity and GHG emission intensity reaches 39% and 36%, respectively, both of which can achieve the government's plan. Moreover, GHG emission reduction potential by proper treatment of sewage and sewage sludge is 19 million tons for the study period. Additionally the model generates 724 thousands TCE as byproduct.

The optimal budget expenditures for the policy are 3.19 billion CNY for new sewage plant construction and 6.81 billion CNY for new sewage sludge plant construction for the study period. Specifically, the optimal subsidy for sewage and sewage sludge plants construction of every sub-region is: 7,120 million CNY, 484 million CNY, 453 million CNY, 404 million CNY, 429 million CNY, 176 million CNY, 206 million CNY, 245 million CNY, 240 million CNY, 146 million CNY, 97 million CNY for Central City, Fangshan, Tongzhou, Shunyi, Changping, Daxing, Mentougou, Huairou, Pinggu, Miyun, Yanqing, respectively.

The optimal sewage and sewage sludge plants construction plan involves eleven new sewage plants featuring the MBR technology and fourteen plants featuring the EMBR technology; nine sewage sludge plants with the A-D-F-I technology, fifteen

sewage sludge plants with the A-D- F-II technology and one sewage sludge plant with the F-C-II technology.

In this study, we also confirm that uniform policies do not always lead to identical sub-regional impacts. There are regional gaps regarding sustainable development. By comparing the simulation results, Central City (zone 1) plays a key point of sustainable development of Beijing city. The size of GRP will be about 75% of total GRP of Beijing City in the next eleven years while water pollutants intensity is lower than the average level of the other sub-regions.

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