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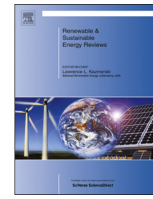

Influence of sewage treatment on China's energy consumption and economy and its performances

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ABSTRACT

The sewage treatment industry may affect China's energy-saving and economic growth related goals to some degree. This study investigated influence of sewage treatment on China's energy consumption and economic growth and its performances from 2008 to 2013. We adopted a set of indicator system based on energy, emergy and money to depict these interactions, including Energy use per unit emission reduction (*EUER*), Cost per unit emission reduction (*CUER*), Environmental benefit per unit investment (*EBUI*), Ratio of energy consumption from sewage treatment to national total energy consumption (*REST*), Ratio of cost of sewage treatment to the Gross Domestic Product (*RCSG*), Structural Coordination degree of sewage treatment (*SCDS*), and Scale harmony degree of sewage treatment (*SHDS*). Here emergy was used to quantify the environmental impact of water pollutants. The study results show that energy efficiency of sewage treatment keeps relatively stable, the economic cost of sewage treatment increases obviously, the environmental performance of sewage treatment investment slightly rises, and the sewage treatment has an increasing impact on the energy consumption and economic growth of this country. As far as the relationships between different indicators or factors are concerned, the structure of China's sewage treatment industry worsens obviously due to rising energy consumption and economic cost; meanwhile, the relationship between economic cost and energy consumption for sewage treatment, domestic water consumption, and discharged sewage's impact seriously deteriorated. Finally, some corresponding issues are discussed and the related policy implications are put forward.

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1. Introduction

China's economy has rapidly increased since the Reform and Opening, with annual rates 11.30% and 10.18% for its GDP and GDP per capita (Fig. 1). However, China's rapid economic growth has been bearing the cost of resource wastage and environmental deterioration [1]. Therein, the domestic water consumption has climbed from 5.75E10 m^3 in 2000 to 7.49E10 m^3 in 2013 [2,3]. The discharged volume of sewage has increased from 2.21E10 tons in 2000 to 4.63E10 tons in 2012, and the related discharged volume of NH_3-N and COD have risen from 8.70E05 tons and 7.83E06 tons in 2002 to 1.45E06 tons and 9.13E06 tons in 2012 [4].

As a result, the China's wastewater treatment industry is witnessing strong growth, driven by investments in upgrading the municipal wastewater treatment infrastructure and meeting the wastewater treatment needs of rapid industrialization and urbanization. And the Chinese government has made great efforts to expand and improve municipal wastewater treatment infrastructure in the last decade [5]. Steep increase has been seen in the number of wastewater treatment plants (WWTPs) and treatment capacity [6]. Nowadays, the related number of sewage treatment plants has also risen from 1521 in 2008 to 4136 in 2013, reaching the treatment ability of 1.61E08 m^3/d in 2013 [7].

The targets for sewage treatment in the 12th "Five-Year-Plan" (FYP) have been further emphasized, and the treatment rates for municipalities, county cities and organic towns are established as 85%, 70% and 30%, respectively in this FYP [8]. Therefore, the number of WWTP will continue to increase in the future.

Water and wastewater systems are significant energy consumers. In recent years, the high energy consumption in WWTPs has been paid wide attention to. For example, wastewater treatment used about one percent of the national electricity consumption in Swede [9], about 20% of energy consumption in municipal administration was used to treat sewage in German [10], and an estimated 3–4% of U.S. electricity consumption was used for the movement and treatment of water and wastewater [11,12]. The exact cost of energy use can vary widely from one utility to the next, with estimates ranging from 2–60% of total operating costs [13,14]. Therefore, energy represents a substantial cost to wastewater utilities, as it is typically required for all stages in the treatment process, from the collection of raw sewage to the discharge of treated effluent. And thus researches on energy-saving in WWTPs have been widely carried out. Therein, Zhang et al. [15] developed a new membrane bioreactor to treat municipal wastewater. They compared the energy consumption with a similar reactor and also carried out an energy consumption analysis in this system. Based on the OCP (Oxygen Consumption Potential) evaluation, Karlsson [16] thought that in comparison to conventional biological activated sludge treatment (with pre-settling), chemical treatment plants (primary precipitation) are cheaper in terms of cost per unit of OCP removed and that they require less energy per unit of OCP removed. According to the sustainability criteria consisted of energy balance, final sludge production, effluent quality, the use of chemicals and space requirement, Mels et al. [17] pointed out that physical–chemical pretreatment leads to energy saving when biological post treatment is applied. Besides, more energy can be generated through sludge digestion, due to an increased sludge production. However, the increased particle removal also leads to an increased final sludge production after digestion which will have to be disposed of and to a relatively high consumption of chemicals. The research of Sousa and Foresti [18] showed that a combined anaerobic–aerobic system, composed of an UASB reactor followed by sequencing batch aerobic reactors (SBR), compete favorably with conventional aerobic systems in three essential cost features, including energy consumption, excess sludge production and nutrient removal. However, fewer researches focus on the energy-saving related issues of sewage treatment at national or regional scale.

Municipal wastewater treatment has emerged as one of the largest resource consumers in the US. As a result, the goal of municipal wastewater systems has extended from protecting receiving water and human health to improving the system sustainability [19], i.e. municipal wastewater systems should both protect the local water body and reduce their energy intensity and other adverse impacts.

As one of environmental protection projects, the environmental impact of sewage treatment industry (including its contribution to the local water environment and its adverse impact due to nonrenewable resource consumption and pollutants discharge) should be firstly emphasized. Objectively quantifying this environmental performance can provide decision-makers with a clear picture. Therein, emergy can acts as one of useful quantifying tools. Emergy analysis, founded by Odum [20,21], can provide a holistic picture through considering environmental contribution to artificial systems and uniting different measure units into one single one (Solar emjoules). This method has also been used to evaluate the performance of sewage treatment systems by some researches. Nelson et al. [22] evaluated resource efficiency of a wetland wastewater treatment. An emergy analysis of municipal wastewater treatment and generation of electricity by digestion of sewage sludge was finished by Björklund et al. [23]. Vassallo et al. [24] researched the performance of a sewage treatment plant and the contribution of the receiving water body to purifying the discharged treated water using emergy approach. Furthermore, Zhang et al. [25] carried out an emergy evaluation of a municipal

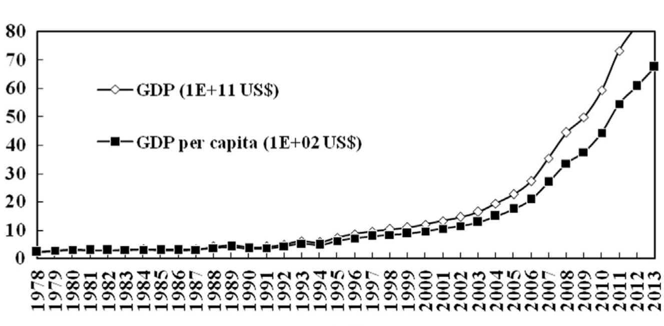

Fig. 1. Trends of GDP and GDP per capita of China from 1978 to 2013.