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Technological approaches and policy analysis of integrated water pollution prevention and control for the coal-to-methanol industry based on Best Available Technology

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ABSTRACT

Coal-to-Methanol (CTM) production is an energy- and water-intensive industry that creates considerable industrial pollutants and wastewater. We developed a bottom-up model to analyze reduction potential of industrial pollutants, based on Best Available Technologies (BATs), and to analyze and estimate targets for total pollution control. This paper explores the total pollution control and emission standard approaches of environmental management based on the analysis of water pollution in China's CTM industry. A set of pollution prevention and control systems are built and incorporated into the bottom-up model. In order to project future water pollution emission trends, we designed three scenarios: Baseline scenario (S1), process planning scenario (S2), and technology promotion scenario (S3). Results show that the emission reductions of water pollution via structural adjustments during processing are better than those from upgrading existing technology in China. So best available gasification processes like advanced cleaner production of entrained flow pressurized continuous gasification, and coke-oven gas for methanol should be promoted and systematically installed in new enterprises. A technological upgrade is needed of existing CTM enterprises that use old processes. According to the ranking of water pollution emission reduction potentials, wastewater zero discharge in the ammonia and methanol integrated production and emission reduction of water pollutants in coal-water slurry gasification both have significant and comprehensive mitigation effects on wastewater, chemical oxygen demand (COD) and Ammonia-N. Recommended BATs for reducing industrial pollutants and wastewater can be determined based on emission reduction cost per unit of pollutant required to achieve the emission target for water pollution.

1. Introduction

In recent years, pollution control efforts have moved away from end-of-pipe approaches to integrated prevention. Cleaner production concepts have been widely accepted by both government and industrial sectors (Coleman and Peng, 2003; Hicks and Dietmar, 2007).

The main policies to promote pollution reduction include technical standards for cleaner production, industrial pollutant emission standards, elimination of backward production capacity, and promotion of new technologies etc. China has implemented strict energy-saving and pollution reduction policies, especially for high energy consumption and pollution-intensive industries. In 2006, China's first formal pollution reduction goal was a 10% reduction in COD stipulated in the 11th Five-Year Plan (State-Council, 2006). *The* 12th *Five-Year Plan Guidelines in the Chinese State Economic and Social Development* section added a 10% reduction target to the total amount of ammonia-N (State-Council, 2011). To ensure the goal of reducing pollutants are to be met, the Chinese government developed a comprehensive working program (State-Council, 2007) and established an industrial environmental management system to enact its control policy (Zhang and Wen, 2008). Promoting technology advancement in pollution intensive industries as well as eliminating outdated production capacities and techniques were essential parts of these critical approaches. From historical observations and current policy efforts, we can conclude that technological advancement plays an increasingly important role in achieving major pollution reduction goals.

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However, due to a lack of systematic and comprehensive understanding of pollution reduction, energy saving and economic effectiveness, a consistent assessment of resource efficiency and environmental protection using BAT (Best Available Technology), is needed (Liu and Wen, 2012; Schollenberger et al., 2008). China's current practice of technology assessment to determine BAT primarily relies on personal experience and subjective judgment, with little consideration given to optimizing the balance between operational and environmental performance (Zhang et al., 2009). Because environmental emissions standards for BAT and total control policies are set by different administrative departments, they operate separately from one another. Two lists of cleaner production technologies in key industries were released, aimed at communicating technical information and helping enterprises adopt the highlighted technologies in China (SETC, 2000, 2003). In 2006, a BAT determination system was established by China's Ministry of Environmental Protection, in which BATs are defined as technologies and organizational measures expected to minimize overall environmental harm at acceptable costs (CMEP, 2007; Liu and Wen, 2012).

Coal-to-methanol (CTM) production is an energy and water intensive industry that creates considerable environmental pollution. Annual average production of methanol in China's CTM plants is only 100,000 tons, much lower than foreign countries' average of 600,000–1,000,000 tons per year. In China, the old fixed-bed gasification process is still commonly used. The energy consumption per ton of methanol (75 GJ/t) in this process is more than twice that of the advanced foreign natural gas to methanol process (29 GJ/t). Its fresh water consumption is 1–50 t/t methanol. Also, high levels of industrial water pollutants and wastewater are produced in the CTM production process. Rough estimates suggest that total wastewater emissions from the whole CTM industry are about 72–80 million tons per year (Yu, 2010). Under the highest pollution reduction standards, emissions of COD would be 3600 tons per year. However, not all pollutants can achieve this kind of removal, especially for organic contaminants and Ammonia-N, which will surpass safety standards. Therefore, there is great potential for pollutant emission reduction via BAT in the CTM industry. In light of the problems in status quo, our research explored the total pollutant control and emission standards related to the CTM industry, and built a correlation between BATs and primary environmental management measures.

In this paper, we assess the potential for industrial technology to improve pollution reduction policies. In doing so, we constructed an integrated bottom-up model to evaluate the potential for pollution reduction in China's CTM industry using BATs. In Section 2, we describe the technologies used in the CTM industry and the bottom-up technology model for policy assessment. Section 3 discusses the model's applications to support the total amount of pollution control under different scenarios and revisions of pollutant emission standards. The conclusion is presented in Section 4.

2. Methodology

2.1. Technologies in the CTM industry

There are three main processes for CTM production: direct coal gasification (DCG), coke-oven gas for methanol (COGM), and ammonia and methanol integrated production (AMIP). The DCG process directly gasifies coal into methanol; COGM uses coke oven gas as the raw material; and AMIP uses CO and CO_2 removed in the ammonia production and utilizes H_2 from the feed gas as raw materials. Of these three processes, DCG with fixed-bed gasification and AMIP processes are more conventional CTM production processes. Entrained-flow gasification with coal-water slurry and pulverized coal gasification is representative of the new CTM production processes. In all three processes, the devices used for methanol synthesis and rectification are basically the same. Fig. 1 shows the flow chart for the CTM production process. In this paper, the pollution prevention and control technologies used in the CTM industry were divided into production process control and end-of-pipe pollution treatment technologies.

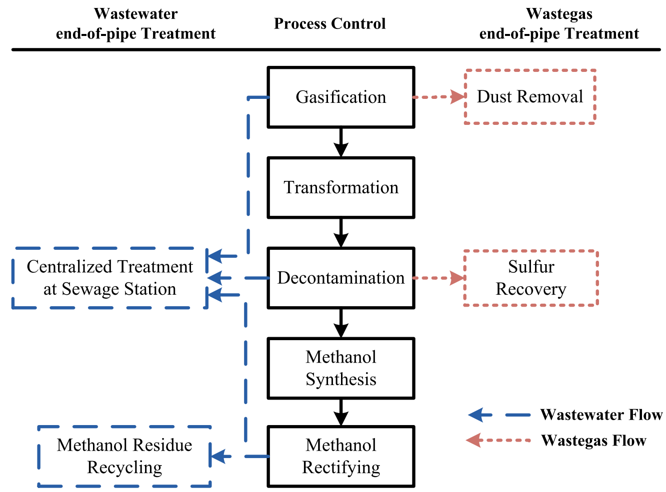

Fig. 1. Flow chart for the CTM and dimethyl ether production processes.

Table 1 shows environmental impacts to water from the CTM production process. The water pollutants are COD, Ammonia-N and cyanide, while air pollutants are dust and SO_2. Solid waste includes fly ash, boiler slag, and waste catalyst etc.

China's CTM industry is one of the newly developing coal chemical sectors. The coal chemical industry will play an important role in the sustainable development of China's energy resources over the next decades by mitigating environmental pollution caused by coal combustion, as well as reducing dependence on oil imports (Xie et al., 2010). Methanol is an important multipurpose chemical, which is used for fuel cells of automobiles, power generation, and portable equipment. Methanol is also an important clean fuel. In 2008 methanol production in China was 11.26 million tons, which was 28% of global output. In 2012, China's methanol production capacity and yield were 51.49 million tons and 31.29 million tons respectively, an increase of 10.2% and 18.6% over 2011. The main materials that methanol is produced from are: Coal, natural gas and coke-oven gas (COG). Methanol derived from coal is over two-thirds of the total production. Furthermore, in 2007, the Chinese government forbade any new projects or expansion of existing natural gas to methanol projects. Although COG for methanol has become an increasingly important direction in coking enterprises in recent years, CTM still occupies an important place in the long term.

Table 1
Environmental impacts from the CTM production process.

Process	Wastewater (m^3/t methanol)	COD (mg/m^3)	NH_3–N (mg/m^3)	CN^- (mg/m^3)
Gasification	0.2–1.5	300–800	200–300	6–10
Decontamination	0.02–0.05	900–1000	800–1350	700–1000
Methanol rectifying	0.25–0.35	3750–5300	0	0

Note: Data were collected from a field survey of the 16 coal-to-methanol enterprises in China carried out in 2012.