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Environmental effect of current desulfurization technology on fly dust emission in China

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ABSTRACT

The heavy haze over China has recently become a persistent global environmental issue. Although the Chinese government has invested immense manpower, materials, and financial resources, efforts at controlling the said haze remain relatively ineffective. However, in the last few years, sulfur dioxide (SO_2) emissions have been effectively controlled because of the strict desulfurization policy. In this study, we show that the current desulfurization technology of wet limestone flue gas desulfurization, which has more than 90% of the market share in China, significantly contributes to fly ash emissions that cause the haze. Heavy amounts of carbon dioxide (CO_2) and energy are additionally emitted and consumed, respectively. These undesired effects are mainly attributable to secondary pollutants (e.g., gypsum particles) and energy consumption during the flue gas desulfurization process. To assess the transfer of pollutants and generation of secondary pollutants, we conduct a life cycle environmental assessment of typical implementations of flue gas desulfurization technologies that are commonly used in China. Approximately 64%, 99%, 91%, and 44% of the total environmental benefit for the climate change, human toxicity, particulate matter formation, and fossil energy depletion respectively can be obtained by systematically updating current desulfurization technologies.

1. Introduction

Heavy haze weather over China has recently gone from bad to worse and has become a global environmental issue that needs to be addressed because pollutants from East Asia may deteriorate the air quality of the Pacific, Arctic, and North American regions [1,2]. In the last decade, PM_{10} (i.e., particulates smaller than 10 μm in aerodynamic diameter) has been used as a general indicator for measuring haze pollution in China [3] because both PM_{10} and haze pollution are mainly attributable to primary particulate emission and secondary aerosol. The latter is largely derived from sulfur dioxide (SO_2) emissions [4,5]. To promote national air quality and reduce the precursor of microscopic sulfate particles, the Chinese government implemented limits, the strictest in China's history, on SO_2 for thermal power plants on July 1, 2014 [6]. The required upper limits of SO_2 for new buildings and existing power plants are 100 and 200 mg/m^3, respectively, which is close to the European and American emission limit for SO_2. Complying with this restriction [6] is a huge technical and economic challenge because the previous limit on SO_2 emissions was 400 mg/m^3 [7]. Wet limestone flue gas desulfurization technology (FGD), the most mature desulfurization technology used worldwide with approximately 86% of the market share rate [8], is extensively adopted in China [9]. However, wet limestone-based FGD technology can generate secondary gypsum particle pollution [10,11]. More than 50% of gypsum particles contribute to the dust emitted from desulfurized flue gas [10,11] and is mostly less than 2.5 μm [11].

We estimate the effect of the SO_2 removal rate on dust emitted from a wet limestone-based FGD system theoretically. Statistical data of national and provincial SO_2 removal rates, industrial dust emissions, and industrial coal consumption are regressed to verify the theoretical estimate. The effect of SO_2 removal rates on gypsum emitted from a wet limestone-based FGD system is also forecasted. To effectively reduce the primary particulate emissions in China and to assess the transfer of pollutants and generation of secondary pollutants, the current desulfurization technology is also systematically re-examined by a life cycle assessment (LCA) [12,13].

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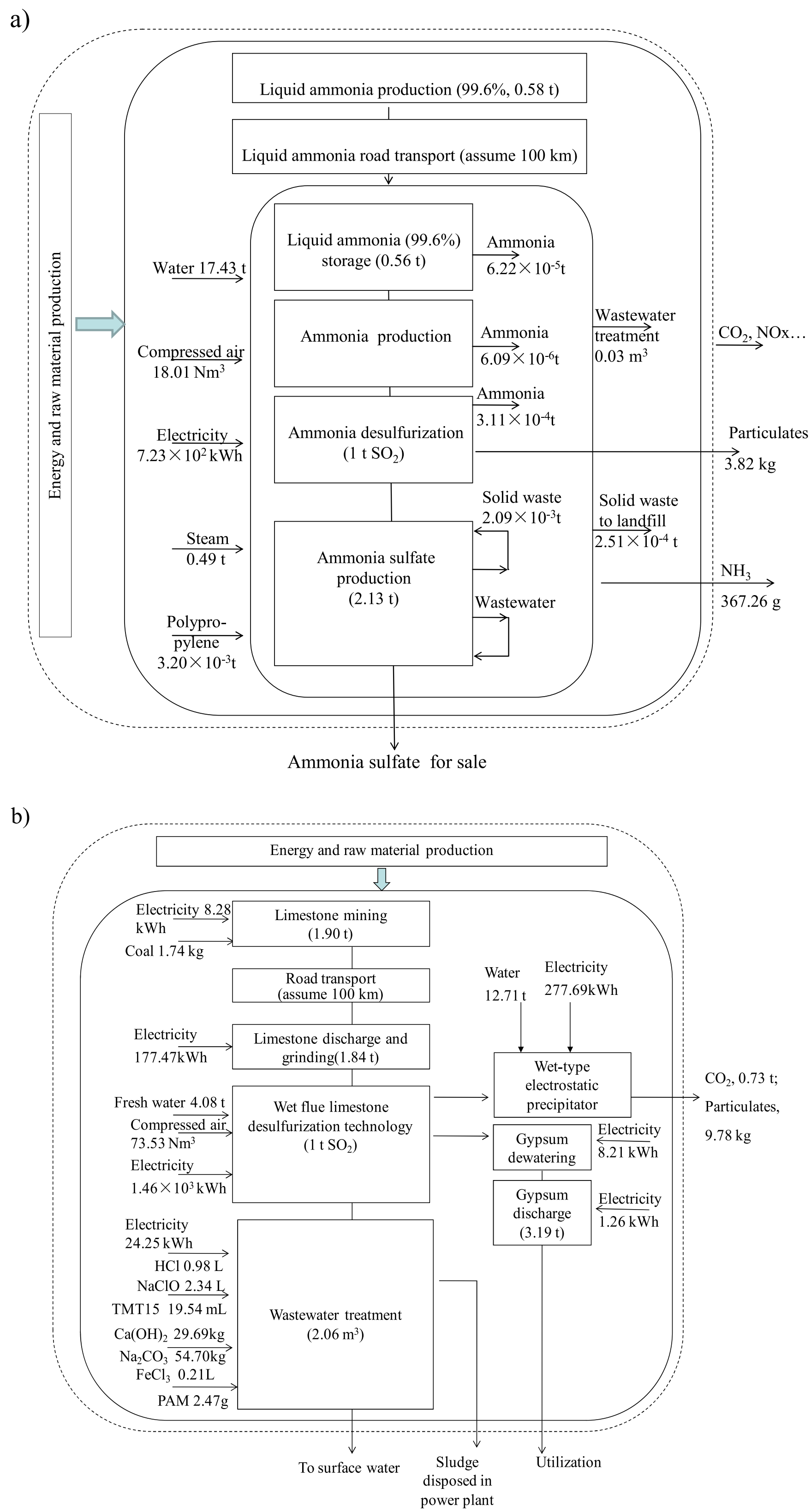

Fig. 1. System boundary and mass flow a) Ammonia b) Limestone c) Active coke.

2. Literature review

National SO_2 and dust emissions have significantly decreased since 2005 because of the strict desulfurization and dedusting demands of the Chinese government [3]. National nitrogen oxides (NO_x) emissions have decreased since 2011 [3,14], after the release of the newly and strictly revised emission standards of NOx for thermal power plants [6]. However, the national average environmental concentration of PM_{10} remained stable from 2007 to 2012 and suddenly increased in 2013 [3], the worst air pollution year in China in the last 52 years