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Mercury mass flow in iron and steel production process and its implications for mercury emission control

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ABSTRACT

The iron and steel production process is one of the predominant anthropogenic sources of atmospheric mercury emissions worldwide. In this study, field tests were conducted to study mercury emission characteristics and mass flows at two iron and steel plants in China. It was found that low-sulfur flue gas from sintering machines could contribute up to 41% of the total atmospheric mercury emissions, and desulfurization devices could remarkably help reduce the emissions. Coal gas burning accounted for 17%–49% of the total mercury emissions, and therefore the mercury control of coal gas burning, specifically for the power plant burning coal gas to generate electricity, was significantly important. The emissions from limestone and dolomite production and electric furnaces can contribute 29.3% and 4.2% of the total mercury emissions from iron and steel production. More attention should be paid to mercury emissions from these two processes. Blast furnace dust accounted for 27%–36% of the total mercury output for the whole iron and steel production process. The recycling of blast furnace dust could greatly increase the atmospheric mercury emissions and should not be conducted. The mercury emission factors for the coke oven, sintering machine and blast furnace were 0.039–0.047 g Hg/ton steel, and for the electric furnace it was 0.021 g Hg/ton steel. The predominant emission species was oxidized mercury, accounting for 59%–73% of total mercury emissions to air.

Introduction

Iron and steel production is considered to be one of the predominant anthropogenic sources of atmospheric mercury (Hg) (UNEP, 2008, 2013a). Mercury emissions from iron and steel plants have been confirmed to cause mercury exposure to not only the workers in the plant but also the residents in surrounding areas (Pervez et al., 2010). The global mercury emissions from iron and steel production were estimated to be 46 tons in 2010 (UNEP, 2013a). The mercury emissions from Chinese iron and steel plants were about 9 tons in 2003 (Pirrone and Mason, 2009; Streets et al., 2005; Wu et al., 2006). China's iron and steel production has been increasing at an average annual growth rate of approximately 15% since 2000. As the largest iron and steel producer in the world, China made 780 million tons of crude steel in 2013. Therefore, it is important to study and control the mercury emissions from iron and steel production in China (Wang et al., 2014c).

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In the complicated process of iron and steel production, mercury comes from a variety of raw materials at different stages and is emitted by dozens of stacks. Due to lack of information on the mercury emission characteristics of iron and steel plants, a single emission factor of 0.04 g Hg/ton steel has long been adopted for the emission estimate in previous emission inventories for the world and China (Feng et al., 2009; Pacyna and Pacyna, 2002; Pacyna et al., 2006, 2010; Pirrone et al., 2010; UNEP, 2013a; Wong et al., 2006). The above-mentioned single emission factor, neglecting the variations of Hg content in raw materials and the detailed production process, results in high uncertainty in emission estimates. The recently released report by the United Nations Environment Program (UNEP) employed a method based on the unabated emission factor and the mercury removal of the air pollution control devices (APCDs) (UNEP, 2013b). In this report, only the emissions from the coke oven, sintering machine and blast furnace were considered. However, other studies indicated that the mercury concentration in the flue gas of the electric furnace was comparable to that of the above three processes (Kim et al., 2010; Park et al., 2008). Knowledge on the emission characteristics and mercury mass flow in iron and steel production is imperative to improve the mercury emission inventory and useful in the development of a mercury emission control strategy.

In this study, we conducted field tests to study the mercury emission characteristics of two typical iron and steel plants in China. The mercury concentrations in the flue gas and solid samples were analyzed. Based on the test results, a mercury mass flow analysis of the production process was conducted. The mercury emissions from different stages of the iron and steel production were assessed. The implications of these results for mercury emission control were also discussed.

1. Experimental

1.1. Iron and steel smelting plants studied

The conventional iron and steel production process can be divided into four consecutive stages, that is, raw material preparation, sintering machine, blast furnace and convertor (as shown in Fig. 1). In the raw material preparation stage, coke used in the sintering machine and blast furnace is produced from coal in a coke oven. The limestone and dolomite ores are roasted in rotary kilns, though in some cases, the production of limestone and dolomite is not included in iron and steel plants. The prepared iron ores, coke, limestone (dolomite), and other recycled materials, including some collected dust from the sintering machine or blast furnace, are sintered in the sintering machine. Since the sintering machine is the first thermal treating process for most raw materials, the composition of its flue gas is very complicated. Generally speaking, the flue gas from the sintering machine includes three parts, the high-sulfur flue gas and low-sulfur flue gas from the machine head, and the flue gas from the machine tail. Electrostatic precipitators (ESP) and desulfurization devices are used to remove dust and SO_2 in the flue gas of the sintering machine. The sinter, coke and limestone are smelted in the blast furnace to produce pig iron, which is further smelted with limestone in the convertor to produce steel. Besides the above stages related to the production of steel, coal gas produced by the coke oven, blast furnace and convertor is eventually burned and emitted. In some plants, the coal gas is burned to generate electricity in a power plant. Additionally, the flue gases emerging from the production of pig iron, iron scrap and crude steel are collected and de-dusted before being emitted into the atmosphere. Besides the above conventional iron and steel production process, there is an individual process in some

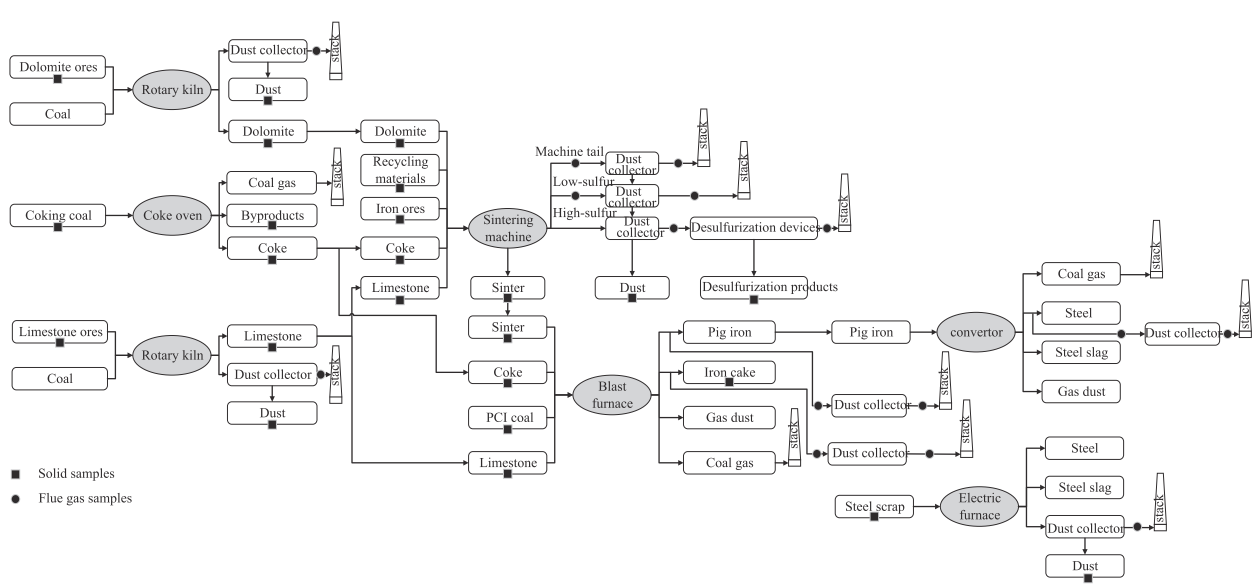

Fig. 1 – Schematic diagram of iron and steel smelting process and sampling sites. PCI coal: pulverized coal injection of the blast furnace.