Meeting Minamata: A Cost-Effective Compliance Roadmap for Mercury Pollution Control in China's Non-Ferrous Metal (Zinc, Lead and Copper) Smelters

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SCHOOL OF THE ENVIRONMENT, NANJING UNIVERSITY

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ABOUT SCHOOL OF THE ENVIRONMENT, NANJING UNIVERSITY

As one of the pioneering institutions dedicated to environmental education and research in China, the School of Environmental Studies, Nanjing University, started in 1978 and remains a leading institution in environmental research in China. The school is ranked No.3 of all the university environmental science and engineering programs in China proper, according to the 2012 review of the Ministry of Education (MOE).

ABOUT NATURAL RESOURCES DEFENSE COUNCIL

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Executive Summary

In this study, a technology-based probabilistic emission factor model was used to estimate Hg emissions in the non-ferrous metal smelting (NFMS) industry in China by province. Monte Carlo simulation was adopted to assess the uncertainties of the emission inventories. Parameters for emission factors were collected based on previous onsite measurements and additional investigation contacted in this study. The activity level data, including the amounts of metal production, the application rates of smelting techniques, the installation rates of air pollution control devices (APCDs), etc. were obtained through public available resources. Before emission inventory development, we identified the policies that have the most significant impacts on the mitigation of Hg emission, including the *Three-Year Action Plan for the Blue Sky Defense Battle* (Guofa [2018] No. 22), the *Announcement on the Implementation of the Special Emission Thresholds for Air Pollutants in Beijing-Tianjin-Hebei Air Pollution Transport Channel Cities* (Announcement No. 9 of 2018), the *Emission Standard of Pollutants for Lead, Zinc and Copper Industry* (GB 25466-2010 and GB 25467-2010), and so on.

The atmospheric Hg emissions from the zinc, lead and copper smelting in China in 2010 were estimated to be 76.8 t, 30.3 t and 7.5 t, respectively. In 2015, the atmospheric Hg emissions from zinc, lead and copper smelting in China were 57.5 t, 10.5 t and 7.5 t, respectively. The total Hg emission from the NFMS sector in 2015 was 75.6 t, 34% lower than in 2010. The reduction of Hg emission from 2010 to 2015 was achieved by phasing out outdated production capacity and the widespread application of the double contact and double absorption (DCDA) acid plants. The APCDs applied at the roasting/smelting stage, including dust collector (DC), flue gas scrubber (FGS), electrostatic demister (ESD), mercury reclaiming tower (MRT), acid plant, and flue gas desulfurization (FGD), were more advanced in 2015 compared to 2010.

In addition, the Hg flow in the treatment processes for by-products from non-ferrous metal smelters was evaluated. In 2015, during the processing of smelting by-products, the amounts of Hg entering the atmosphere, the water and the soil were 24.7 t, 89.2 t and 22.1 t, respectively. Most of the Hg in metal concentrates ended up in waste acid and sulfuric acid. The atmospheric Hg emitted during the process of waste acid treatment was the highest, reaching 10.2 t. Sulfuric acid was mainly sold to fertilizer plants, and consequently a large amount of Hg was transferred to the soil.

Combining the primary smelting processes and the by-product treatment processes, the overall Hg flow in the NFMS industry in 2015 was calculated. The distributions of ultimate Hg outputs in the zinc, lead and copper smelting industry were similar, mainly entering hazardous waste (~50%) and solid waste (~30%). Hazardous waste, such as waste acid sludge, contains a large amount of Hg and has not been fully and harmlessly treated, which will pose great risks to the environment. Solid waste is mainly the various slags produced by smelting. The final atmosphere Hg emission accounted for ~10% of the total Hg input.

Future scenarios for 2020 and 2030 were established based on existing control policies and possible additional measures, including two energy scenarios and three pollution control scenarios. By 2020, the total atmospheric Hg emission from the NFMS industry is projected to be reduced by approximately 19% compared to the 2015 inventory, among which zinc, lead, and copper smelting will reduced Hg emissions by 19%, 22%, and 13%, respectively (average of various pollution control and energy consumption scenarios). By 2030, higher Hg emission reductions are expected to be achieved, which are 21%, 38%, and 12%, respectively, for zinc, lead, and copper smelting. The maximum Hg emission reduction potential could be as high as 64% by 2030.

This study has summarized the currently available co-benefit and dedicated Hg control technologies in the NFMS industry, and performed a cost-effectiveness analysis at the both the smelter and the national level. We developed a pollutant equivalent apportionment (PEA) method to calculate the costs apportioned to Hg in the NFMS industry. The combination of DC+FGS+ESD+DCDA (+DC) has the lowest annualized cost (1,404 CNY/kg Hg removal). In the case of FGD adding to the refining stage, the overall Hg removal efficiency reaches 98.4%, while the annualized cost is only 10,660 CNY/kg Hg. The addition of FGD at the refining stage not only brings higher Hg removal efficiency, but also lowers the cost compared to installation at the roasting/smelting stage. Therefore, the reinforced Hg emission control at the refining stage will bring greater cost-effectiveness. The APCD combination with the highest Hg removal efficiency is DC+FGS+ESD+MRT+DCDA+FGD (+DC+FGD). The overall Hg removal efficiency reaches 98.6%, but the cost is also extremely high. At the national level in 2015, 113.3 million CNY was spent in the NFMS industry for Hg removal. By 2020 and 2030, the total costs could reach 216.7 and 573.4 million CNY, respectively. The most strict scenario with high concentrate consumption in 2030 has the highest costs (1,426 million CNY), and also brings 223 t Hg emission reduction compared to 2015.

As part of this study, we identify the most significant operational aspects leading to mercury emissions and releases. Based on this analysis, we provide four key sets of recommendations to further reduce mercury pollution from this sector: (1) control Hg input at the pre-smelting stage with selection, import, and blending of metal concentrates; (2) enhance the use of co-benefit Hg control technologies, especially the application of FGDs at different stages; (3) adopt dedicated Hg control technologies to produce low-Hg sulfuric acid while taking into account Hg waste disposal; and (4) strengthen the control of Hg emissions and release from the smelting by-product treatment processes to reduce cross-media effects. Chapter 8 of the report discusses these recommendations in greater detail.

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