

Title: Impact of Ultra-Low Emission Technology on Mercury Speciation in Particulate Matter from Coal-Fired Power Plants

Coal-fired power plants (CFPPs) are significant contributors to atmospheric mercury (Hg), accounting for 32.7% of China's Hg emissions, impacting ecosystems and human health¹. Hg from CFPPs exists in different chemical forms: elemental, oxidized, and particulate-bound, each with unique properties and environmental behaviours⁷. For instance, elemental Hg is stable in the atmosphere and can travel long distances, while oxidized and particulate-bound forms are unstable and tend to deposit locally, which can be absorbed by soils and plants, affecting agriculture²⁻⁴. As Hg pollution from industrial activities increases worldwide, ultra-low emission (ULE) technology has been introduced in CFPPs to limit Hg emissions. This technology combines electrostatic precipitators, fabric filters, selective catalytic reduction, and wet flue gas desulfurization, focusing on capturing reactive and particulate-bound Hg before it enters the atmosphere. However, elemental Hg, which ULE technology struggles to capture, can still escape and contribute to long-range pollution.^{5,6}

While ULE retrofits effectively reduce oxidized and particulate-bound Hg (Hg^p) emissions, it is not well understood how they affect Hg speciation and bioavailability around CFPPs. Finer particulate matter (PM) is more dangerous since they are more readily inhaled and deposited on crops, potentially entering the food chain by depositing into crops like rice paddy fields². Although previous research highlights ULE's limitations^{2,5,6}, data on Hg distribution around ULE-equipped CFPPs remains

sparse. This study addresses this knowledge gap by investigating Hg speciation in size-fractionated particulate matter around a ULE-retrofitted CFPP in Southwest China, examining the potential environmental and health impacts of Hg emissions.

Zhang et al. conducted seasonal Hg sampling in particulate matter around a ULE-equipped CFPP in Guizhou Province, China. TSP (total suspended particles), PM₁₀ (aerodynamic particle diameter $\leq 10\ \mu\text{m}$), and PM_{2.5} (aerodynamic particle diameter $\leq 2.5\ \mu\text{m}$) samples were collected from five locations surrounding the plant, using a medium-volume sampler with quartz filters to capture Hg in particulate form. Seasonal sampling allowed for analysis of Hg variation across different weather conditions and heating demands. Samples underwent preparation steps involving chemical digestion, reduction, and purification before being analyzed using cold vapor atomic fluorescence spectrometry (CVAFS), which allows for highly accurate Hg detection. Speciation analysis was conducted by isolating different Hg types (exchangeable, HCl-soluble, elemental, and residual) through chemical treatments, including ultrasonic wave agitation and centrifugation, to separate Hg forms based on solubility and reactivity to determine the bioavailability and mobility of each type.

The study's results provided several insights into Hg distribution in particulate matter. Hg concentrations were highest in PM_{2.5}, the smallest particle fraction, which is of particular concern due to PM_{2.5}'s potential for inhalation or deposition on crops. Additionally, Hg concentrations peaked in autumn and winter, likely due to increased

coal use for heating, which suggests that local heating practices contribute to seasonal Hg pollution.

The analysis of Hg speciation offered deeper insight into the potential toxicity and bioavailability of Hg in the environment. Exchangeable and HCl-soluble Hg were the dominant forms of PM_{2.5}. These forms are highly bioavailable, meaning they can readily enter biological systems and transform into methylmercury, a toxic compound. The high concentration of these Hg types in fine particles presents immediate environmental and health risks, particularly in agricultural regions where Hg can accumulate in food crops, leading to bioaccumulation in the food chain. In contrast, residual Hg was relatively stable and less reactive, posing lower immediate risks. However, residual Hg contributes to long-term deposition, as it may transform into more bioavailable forms under certain conditions, although this mechanism is not well understood yet.

The study concludes that, although ULE technology reduces certain Hg emissions, fine PM near CFPPs still contains significant bioavailable Hg, particularly in PM_{2.5}, and should not be ignored. The persistence of bioavailable Hg^p near CFPPs highlights the need for targeted strategies to address both elemental and bioavailable Hg forms, which current ULE systems may not fully capture. This is particularly concerning for agricultural areas where fine Hg particles can settle on crops, potentially leading to increased methylmercury accumulation in the food chain.

Despite the findings, the study acknowledges several limitations. The CFPP's location close to major roadways may have influenced Hg levels due to vehicle emissions, which were not accounted for. Seasonal variations in temperature and atmospheric conditions could also impact Hg deposition and reactivity. Additionally, the study notes a limited understanding of residual Hg's behaviour, particularly its transformation processes. They suggest that residual Hg could be formed by humidity as humidity is beneficial when forming atmospheric aerosols and analyzing humidity levels at sites. Addressing these limitations in future studies could provide a better idea of Hg's environmental fate. The study suggests future research should focus on residual Hg's formation mechanisms and the development of methods to capture elemental Hg in ULE systems.

In conclusion, this study underscores the importance of mercury speciation in assessing CFPP emissions' environmental and health impacts. While ULE technology represents a milestone in emission reduction, the persistence of bioavailable mercury in fine particulate matter remains a concern. Addressing this issue requires continued research to increase the efficiency of ULEs and a better understanding of how mercury species interact with the environment will protect China's agriculture and food safety from mercury contamination, ensuring safe food consumption for its citizens.

References:

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