Effect of Flue Gas Purification Facilities of Coal-Fired Power Plants on Mercury Emission

Bing Li*, Qi-Long ZHANG, Can ZHOU
Shandong Branch of Huadian Electric Power Research Institute, No.14508, Jingshi Road, Jinan 250014, Shandong Province, China
13869187893@163.com
*Corresponding author

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Abstract. Mercury emission of 38 coal-fired power plants in China from published literatures has been summarized and analyzed. The results show that clean flue gas of coal-fired power plant is mainly composed of gaseous mercury and mercury emission concentration in different units has very large difference. The selective catalytic reduction catalyst promotes oxidation of Hg\(^0\) to Hg\(^{2+}\) and the oxidation of Hg\(^0\) is greatly affected by chlorine content in coal. The dust removal facilities affect mercury emission by removal of Hg\(^P\), and the mercury removal efficiency of fabric filter is higher than that of electrostatic precipitator. Wet flue gas desulfurization affects mercury by removal of gaseous mercury, depending on Hg\(^{2+}\). Mercury removal efficiency from the coal-fired power plants equipped with selective catalytic reduction denitration, dust removal facilities and wet flue gas desulfurization is higher.

Introduction

Coal is the largest source of anthropogenic mercury emission source. Mercury pollution has been focused all over the world, which is strictly controlled following dust, SO\(_2\) and NO\(_x\) and mercury concentration has been included into obligatory target of coal-fired power plants in China.

Coal-fired flue gas mercury exists in three forms, namely element mercury (Hg\(^0\)), oxidation mercury (Hg\(^{2+}\)) and particle mercury (Hg\(^P\)). Sum of the three forms is regarded as total mercury (Hg\(^T\)). Hg\(^0\) is main existence form of gaseous mercury in flue gas, which is hardly soluble in water and can be adsorbed under certain condition. It can not be easily removed by existing conventional flue gas purification facilities. Hg\(^{2+}\) is soluble in water, which can be easily captured in wet flue gas desulfurization system (WFGD), and absorbed on the surface of solids. Hg\(^P\) can be removed by dust removal facilities [1-7].

Coal-fired power plants are equipped with selective catalytic reduction (SCR) denitration, efficient dust removal facilities, and WFGD. The conventional pollution control facilities have important effect on mercury emission characteristics in flue gas, and Hg removal by conventional pollutants control facilities has become a competitive method in coal-fired flue gas.

In the paper, the field test data of mercury emission from 38 cola-fired power plants in China has been summarized and analyzed, and the effect of the conventional pollution control devices on mercury emission is investigated.
Mercury Emission of Coal-Fired Power Plants

The net flue gas mercury emission concentration of different capacities and different coal types has great differences. Net flue gas mercury content is in the range from 0.64 to 23.35µg/m³, mainly composed of gaseous mercury [2,3]. Hg⁰ and Hg²⁺ account for different proportions, which depend on coal category, combustion mode, flue gas composition, pollutant control devices passed by flue gas, and other factors.

Since conventional flue gas pollutant purification facilities can achieve collaborative removal of mercury, mercury in flue gas is transferred to desulfurization gypsum, fly ash, desulfurization waste-water and other coal-fired by-products. Mercury influence on solid products, mercury stability and secondary pollution problem are worth of attention.

Influence of SCR Denitration Facilities on Mercury Emission

Mercury speciation and concentration changes before and after SCR denitration facilities are shown in Fig. 1 [2,3]. When different coals are burned, total mercury concentration of flue gas before and after SCR is basically consistent. When flue gas passes through SCR denitration

![Graph showing mercury speciation and concentration changes before and after SCR denitration](image-url)
facilities, deduction effect of SCR on total mercury in flue gas is not prominent. Particle 
mercury concentration is not greatly changed in front of and behind SCR. Element mercury 
concentration in flue gas is reduced after it passes through SCR. Concentration of oxidized 
mercury is increased at varying degrees. SCR denitration catalyst has certain catalytic oxidation 
effect on element mercury. Meanwhile, test and analysis result of Fig. 1 shows that catalytic 
oxidation of element mercury by SCR catalyst depends on content of chlorine in coal. When 
chlorine content in coal is high, SCR catalysts has more prominent oxidation effect on element 
mercury. SCR catalyst oxidizes Hg$^0$ into Hg$^{2+}$ soluble in water, which is beneficial for being 
washed and removed in downstream wet flue gas desulfurization facilities.

**Influence of Dust Removal Facilities on Mercury Emission**

Fly ash particles in flue gas have certain adsorption effect on gaseous mercury in flue gas. Therefore, dust removal facilities have the effect of synergistic removal of mercury, thereby 
affecting mercury emission characteristics. Dust removal facilities have different removal 
effect on mercury of different forms in flue gas. It has low influence on concentration of 
element mercury and oxidized mercury. Influence on total mercury in flue gas is mainly 
embodied on removal of particle mercury. The mercury removal efficiency is from 2.68% to 
80.6% [2,3], depending on coal category, combustion mode, flue gas composition, pollutant 
control measures passed by flue gas. The coal in China has higher ash content. A lot of specific 
surface capable of absorbing mercury is provided by fly ash in flue gas, thereby leading to Hg$^p$ 
concentration increase in flue gas. The dust removal facilities have higher synergistic mercury 
removal ability.

Mercury removal efficiency of fabric filter (FF) is from 16.3% to 78.2%, which is superior to 
mercury removal efficiency of electrostatic precipitator (ESP) [2,3]. In FF, contact surface and 
time between gaseous mercury and fly ash is increasing, thereby promoting absorption of 
gaseous mercury on the surface of fly ash. Meanwhile, since FF shows relatively higher 
efficiency in removing sub-micron fly ash particles, mercury is easily concentrated on 
sub-micron fly ash; therefore FF has higher mercury removal efficiency compared with ESP.

When the power plant is equipped with SCR denitrification, the mercury removal efficiency of 
ESP is high to 80.6% [2,3]. SCR catalyst promotes Hg$^0$ catalytic oxidation into Hg$^{2+}$, easily 
adsorbed on the surface of fly ash particles, and the mercury is collaborative removed in ESP.

For circulating fluidized bed boiler (CFB), the mercury removal efficiency of ESP is from 
66.0% to 99.1% [2,3], which is higher than mercury removal efficiency of pulverized coal 
boiler (PC). CFB mostly burns lean coal, anthracite and low reactivity fuels such as coal gangue 
and the combustion temperature in CFB is lower, so, the carbon content of fly ash is generally 
higher that in PC. Studies have shown that [8], there is a positive correlation between the 
adsorption of mercury on fly ash and its carbon content, and the fly ash carbon content 
increases, the increase of its adsorption capacity of mercury.

**Influence of Wet Desulfurization Facilities on Mercury Emission**

Flue gas at the inlet of WFGD is mainly composed of gaseous mercury. After the flue gas 
passed through WFGD, mercury contents of various forms in flue gas are decreased at varying 
degrees. Total mercury removal efficiency in flue gas by WFGD is from 8.8% to 72.9% [2,3], 
which shows great difference. Studies shows that influence of WFGD on mercury
concentration in flue gas is mainly depended on removal of Hg\textsuperscript{2+} \cite{6,7}. The mercury removal efficiency mainly depended on Hg\textsuperscript{2+} proportion in flue gas at the inlet of WFGD.

After flue gas passes through wet desulfurization facilities, Hg\textsuperscript{T} is mainly composed of gaseous mercury. However, proportion changes of Hg\textsuperscript{2+} and Hg\textsuperscript{0} in total mercury of flue gas do not show consistency trend.

Mercury removal efficiency by WFGD increases gradually with the increase of the L/G, pH \cite{3}. The mercury removal can be improved by adjusting WFGD running parameters.

**Influence of Flue Gas Purification Facilities on Mercury Emission**

Different combustion modes and flue gas purification facilities present different mercury removal efficiency, total mercury removal efficiency are from 3.2\% to 99.1\% \cite{2-3}. When PC is equipped with ESP+WFGD, mercury removal efficiency of flue gas purification facilities is from 14.1\% to 81.4\% \cite{2-3}. When PC is equipped with SCR+ESP+WFGD, mercury removal efficiency of flue gas purification facilities reaches from 36.4\% to 89.9\% \cite{2-3}. SCR catalysts have no direct function on removal of Hg\textsuperscript{T}, but it can promote transformation of Hg\textsuperscript{0} to Hg\textsuperscript{2+}, which is beneficial for mercury removal by downstream ESP and WFGD. When CFB+ESP is adopted, mercury removal efficiency is increased to 99.1\% compared with PC+ESP \cite{2-3}. Since carbon contents in CFB fly is relatively high, and calcium is sprayed for desulfurization inside the furnace, Hg\textsuperscript{P} proportion in flue gas is relatively high \cite{8}.

**Conclusion**

The mercury emission concentrations in net flue gas of coal-fired power plants with different capacities and coal types are greatly different and mainly composed of gaseous mercury, depending on coal type, combustion mode, pollutant control facilities passed by flue gas. SCR denitration facilities have insignificant emission reduction effect on mercury. However, element mercury is catalyzed and oxidized into oxidized mercury by SCR catalyst. The catalytic oxidation effect is positively correlated with chlorine content in coal. SCR denitration facilities have significant impact on mercury emission characteristics. Influence of dust removal facilities on mercury emission is reflected on synergistic removal of particle mercury. Mercury removal efficiency by FF is higher than that of ESP. Influence of WFGD on mercury emission is embodied on synergistic removal of gaseous mercury, mainly Hg\textsuperscript{2+}.

When PC is equipped with SCR+ESP+WFGD, mercury removal efficiency of flue gas purification facilities reached 89.9\%. Mercury in flue gas is transferred to desulfurization gypsum, fly ash, and desulfurization waste-water. Mercury influence on solid products, mercury stability and secondary pollution problem are worth of attention.

**References**


