A novel silica--titania (SiO$_2$–TiO$_2$) nanocomposite has been developed to effectively capture elemental mercury (Hg$^0$) under UV irradiation. Previous studies under room conditions showed over 99% Hg$^0$ removal efficiency using this nanocomposite. In this work, the performance of the nanocomposite on Hg$^0$ removal was tested in simulated coal-fired power plant flue gas, where water vapor concentration is much higher and various acid gases, such as HCl, SO$_2$, and NO$_x$, are present. Experiments were carried out in a fix-bed reactor operated at 135 °C with a baseline gas mixture containing 4% O$_2$, 12% CO$_2$, and 8% H$_2$O balanced with N$_2$. Results of Hg speciation data at the reactor outlet demonstrated that Hg$^0$ was photocatalytically oxidized and captured on the nanocomposite. The removal efficiency of Hg$^0$ was found to be significantly affected by the flue gas components. Increased water vapor concentration inhibited Hg$^0$ capture, due to the competitive adsorption of water vapor. Both HCl and SO$_2$ promoted the oxidation of Hg$^0$ to Hg(II), resulting in higher removal efficiencies. NO was found to have a dramatic inhibitory effect on Hg$^0$ removal, very likely due to the scavenging of hydroxyl radicals by NO. The effect of NO$_2$ was found to be insignificant. Hg removal in flue gases simulating low rank coal combustion products was found to be less than that from high rank coals, possibly due to the higher H$_2$O concentration and lower HCl and SO$_2$ concentrations of the low rank coals. It is essential, however, to minimize the adverse effect of NO to improve the overall performance of the SiO$_2$–TiO$_2$ nanocomposite.
pollution control devices (APCDs) such as SO2 scrubbers. Thus, the need exists for a low cost Hg oxidation/capturing process that can be applied for flue gas treatment.

A novel methodology using titanium dioxide (TiO2) nanoparticles as a photocatalyst has been recently developed to effectively remove Hg0 [4–10]. Under ultraviolet (UV) irradiation, hydroxyl (OH) radicals can be generated on the surface of TiO2 and then oxidize Hg0 into mercury oxide (HgO), which is retained on the particle surface due to its low vapor pressure [9]. The reaction mechanism is described as follows [5,6]:

\[
\begin{align*}
\text{TiO}_2 + \text{hv} & \rightarrow e^- + h^+ \\
\text{H}_2\text{O} & \rightarrow \text{H}^+ + \text{OH}^- \\
h^+ + \text{OH}^- & \rightarrow \cdot \text{OH} \\
h^+ + \text{H}_2\text{O} & \rightarrow \cdot \text{OH} + \text{H}^+ \\
\text{OH}^- + \text{Hg}_0 & \rightarrow \text{HgO} 
\end{align*}
\]

Removal of Hg0 has been achieved using photocatalysts in the form of either in-situ generated TiO2 particles [4,9] or a high surface area silica gel doped with TiO2 nanoparticles (SiO2–TiO2 nanocomposite) [5–8]. The SiO2–TiO2 nanocomposite is advantageous due to its high surface area and open structure, which allows effective irradiation by UV light and thus minimizes the mass-transfer resistance for Hg0 [7].

The efficiency of Hg0 removal using a SiO2–TiO2 nanocomposite was able to reach 99% at low relative humidity at room temperature [7]. However, studies conducted at room temperature but higher water vapor concentrations (up to 23,000 ppmv) demonstrated that Hg0 capturing on the nanocomposite was hindered by the competitive adsorption of water vapor on the active sites, and the extent of decrease in Hg0 removal was proportional to the water vapor concentration [5,6]. It should be noted that in coal-fired boiler flue gas, the concentration of water vapor typically accounts for 6 to 12% in volume, much higher than that at normal room conditions. Thus, it is expected that water vapor may have a greater inhibitory effect on Hg0 removal in flue gas. One the other hand, the catalyst developed in this work was designed for application at the cold-end of the boiler convective pass (e.g. between the electrostatic precipitator and the wet scrubber), where the typical flue gas temperature is in the range of 120 to 150 °C. Because adsorption of water vapor is favored at lower temperature, it is expected that the inhibitory effect of a certain concentration of water vapor would be less significant at flue gas temperature than at room temperature. These two counteracting effects warrant further investigation on the performance of the SiO2–TiO2 nanocomposite for Hg0 removal in flue gas at higher water vapor concentrations and process temperature.

Typical coal-derived flue gas consists of various trace gas components such as HCl, SO2, and NOx. Their concentrations are dependent on the type of coal burned, coal firing systems, boiler operating conditions, and/or NOx control processes. It has been reported that these trace gases are important to the heterogeneous adsorption and/or oxidation of Hg0 on activated carbons or fly ash under flue gas conditions [11,12]. Carey et al. [11] reported that the adsorption capacity for both Hg0 and HgCl2 by Darco FGD carbon dramatically increases as HCl concentration increases from 0 to 50 ppmv but decreases as the SO2 concentration increases from 0 to 500 ppmv. Norton et al. [12] reported that in the presence of fly ash, NO2, HCl, and

![Fig 1 – Schematic diagram of the experimental system.](image-url)
SO2 result in greater levels of Hg oxidation, while NO inhibits Hg oxidation. It is expected that the nature of Hg capture on the SiO2–TiO2 nanocomposite would be different under flue gas conditions from that reported under room conditions in our previous studies [5,6].

In this work, a photocatalytic reactor packed with SiO2–TiO2 nanocomposite was installed. The goal of this research was to investigate the oxidation and capture of Hg0 by the SiO2–TiO2 nanocomposite under flue gas conditions and to identify the effects of individual flue gas components on Hg0 removal. An improved understanding of the role of the flue gas components on Hg0 oxidation can help evaluate the potential of applying this novel material as an effective Hg emission control strategy for coal-fired power plants.

2. Experimental methods


The SiO2–TiO2 nanocomposite was made by a sol–gel method using deionized water, ethanol and tetraethyl orthosilicate (TEOS). Nitric acid (HNO3) and hydrogen fluoride (HF) were used as catalysts to increase the hydrolysis and condensation rates. A detailed procedure has been described in our previous study [6]. The nanocomposite was prepared in the form of cylindrical pellets approximately 5 mm in length and 3 mm in diameter. The weight fraction of TiO2 in the prepared SiO2–TiO2 pellets was approximately 12%, which corresponded to the optimum performance of Hg0 removal at room conditions [7]. The average BET (Brunauer, Emmett, and Teller equation) surface area of the nanocomposite was measured to be 280 m2 g−1 using a Quantachrome NOVA 1200 Gas Sorption Analyzer (Boynton Beach, FL).

2.2. Experimental setup and procedure

A schematic diagram of the experimental setup is shown in Fig. 1. The simulated flue gas consisted of three major gases: O2, CO2, and N2. The N2 flow was divided into three branches. One of the N2 streams converged with the O2 and CO2 to form the main gas flow, which was allowed to pass through a heated water bubbler to introduce water vapor into the system. The second stream of N2 served to dilute the main flow so as to adjust the humidity of the total gas stream. The third stream of N2 passed through a Dynacal® Hg2+ permeation tube (VICI Metronics) and introduced the saturated Hg2+ vapor into the system. The permeation tube was placed in a U-shape glass tube which was immersed in a constant-temperature (90 ± 0.2 °C) water bath to ensure a constant Hg2+ permeation rate. Hg2+ concentration in the system was controlled in the range of 75–80 μg m⁻³. Minor gases including HCl, SO2, NO, and NO2 were introduced into the main flow individually or in combination. Mass flow controllers (MFCs) were used to control each of the gas flows, with a total gas flow rate controlled at 2.0 L/min. The gas concentrations were designed to be within the range of typical coal-fired flue gas composition [13]: 4% O2, 12% CO2, 4–16% H2O, 10–50 ppm, HCl, 400–1200 ppm, SO2, 50–300 ppm, NO, 10–30 ppm, NO2, and balanced with N2. The experimental conditions for investigation of the flue gas effects are listed in Table 1.

Downstream of all the gas flows is the packed-bed photocatalytic reactor placed horizontally. The SiO2–TiO2 pellets were packed in a U-shape quartz tube with an inner diameter of 13 cm. A heating cord was wrapped around the U-tube so that the flue gas temperature can be controlled at around 135 °C, which was monitored by a Teflon thermocouple (Type K, Omega). A UV lamp wavelength of 365 nm with an intensity of 4 mW/cm² measured by a UVX radiometer (with a UVX-36 sensor probe). A stream of cooling air was continuously purged through the UV lamp to lower the lamp temperature to around 60 °C. The entire reactor was placed inside an aluminum cylinder so that the UV light could be reflected back to the pellets and a maximum utilization of the UV energy could be achieved.

A wet-chemistry conversion system [14,15] and a RA-915+Hg analyzer (OhioLumex) were used to measure gas-phase Hg speciation (Hg0 and Hg(II)) downstream the reactor. The Hg analyzer is based on Zeeman Atomic Absorption Spectrometry (ZAAS), which is selective only for Hg0. In the conversion system, the sampling gas was divided into two streams, one for measuring Hg0 and the other for total Hg (Hg0). The solution used for Hg0 measurement consisted of 10% potassium chloride (KCl), which captures Hg(II) and allows only Hg0 to pass through. Hg0 measurement was accomplished using an acidic 10% stannous chloride (SnCl2) solution, which reduces Hg(II) to Hg0, thus producing Hg0. The concentration of Hg(II) can then be calculated by the difference between Hg0 and Hg0. The two streams converged to a 10% sodium hydroxide (NaOH) solution before entering the Hg analyzer. The NaOH solution captured acid gases, such as HCl and SO2, to prevent corrosion of the detecting cell in the Hg analyzer. In addition, as part of the conversion process, a NaOH solution was used to remove SO2 before the sampling gas entered the SnCl2 solution, as SO2 can interfere with the reduction of Hg(II) by SnCl2 [15]. A condenser was installed upstream of the Hg analyzer to remove excess moisture in the gas stream. This aided in avoiding condensation of water vapor inside the Hg detection cell and thus to minimize possible interference from water vapor. The Hg analyzer is capable of providing a real-time response every 1 s. The calibration of the Hg analyzer was conducted by the manufacturer using a Dynacal® permeation device. In this study, the high-concentration mode of the Hg analyzer was used (with a detection limit of 0.5 μg m⁻³ and an upper measurable concentration of 200 μg m⁻³). Finally, the gas stream was passed through a carbon trap before it was exhausted into the fume hood. The entire system was Teflon lined. To avoid condensation of the water vapor along the pathway, all the lines before the condenser were heated by heating tapes to above 90 °C.

Table 1 – Experimental conditions for investigation of the flue gas effects

<table>
<thead>
<tr>
<th>Condition</th>
<th>H2O (%)</th>
<th>HCl (ppm)</th>
<th>SO2 (ppm)</th>
<th>NO (ppm)</th>
<th>NO2 (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1 (baseline)</td>
<td>8</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Set 2</td>
<td>0, 4, 12, 16</td>
<td>30</td>
<td>1200</td>
<td>300</td>
<td>10</td>
</tr>
<tr>
<td>Set 3</td>
<td>8</td>
<td>10, 30, 50</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Set 4</td>
<td>8</td>
<td>–</td>
<td>400, 800, 1200</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Set 5</td>
<td>8</td>
<td>–</td>
<td>50, 100, 300</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Set 6</td>
<td>8</td>
<td>–</td>
<td>–</td>
<td>10, 20, 30</td>
<td>–</td>
</tr>
<tr>
<td>Set 7</td>
<td>8</td>
<td>30</td>
<td>1200</td>
<td>300</td>
<td>10</td>
</tr>
<tr>
<td>Set 8</td>
<td>12</td>
<td>10</td>
<td>400</td>
<td>300</td>
<td>10</td>
</tr>
</tbody>
</table>

* All the conditions contained 4% O2, 12% CO2, 75–80 μg m⁻³ Hg0 (inlet), and balanced with N2; the temperature was controlled at approximately 135 °C.
3. Results and discussion

3.1. Baseline test

Tests were first conducted to examine any possible interference caused by the flue gas components on the measurements by the Hg analyzer. Balanced with pure N\textsubscript{2}, 8% H\textsubscript{2}O\textsubscript{2}, 50 ppm\textsubscript{v} HCl, 1200 ppm\textsubscript{v} SO\textsubscript{2}, 300 ppm\textsubscript{v} NO, and 30 ppm\textsubscript{v} NO\textsubscript{2}, were individually introduced to the system without the presence of Hg. In all cases, no significant Hg readings were observed (i.e. the interference was less than the detection limit, 0.5 μg m\textsuperscript{-3}) with or without UV irradiation. This indicated negligible interference by the flue gas components in the concentration ranges studied in this paper. In addition, tests were performed by introducing 80 μg m\textsuperscript{-3} Hg\textsubscript{0} to an empty reactor (i.e. no catalyst) without UV irradiation for 2 h and subsequently with UV irradiation for another 2 h. Without UV, Hg\textsubscript{0} concentration remained constant with a small fluctuation (± 3%), which is probably associated with the errors of the Hg permeation device and the Hg analyzer. With UV, averagely less than 0.5% reduction in Hg\textsubscript{0} concentration was observed compared to without UV. These tests indicated that the loss of Hg\textsubscript{0} on the reactor wall was negligible either with or without UV irradiation.

Before examining the effect of individual flue gas components, a baseline test without the trace gases (Set 1) was first conducted. While a larger amount of SiO\textsubscript{2}-TiO\textsubscript{2} pellets could be used to achieve a Hg removal efficiency greater than 90%, only 8 g of pellets (~ 1 g TiO\textsubscript{2}) were used to better manifest possible enhancement by the minor gases in subsequent tests. As shown in Fig. 2, the inlet Hg concentration was measured within the first 10 min when the gas stream bypassed the reactor (Period A). Next, the gas stream was passed through the reactor without UV light for another 10 min (Period B) and then the UV light was turned on to activate the photocatalytic reaction (Period C). The concentrations of Hg\textsuperscript{T} and Hg\textsuperscript{0} at the outlet of the reactor were recorded in alternation and were averaged every 2 min for Periods A and B and every 10 min for Period C.

In Period A, the concentration of Hg\textsuperscript{T} was equal to that of Hg\textsuperscript{0}, confirming that the Hg source in this study was only Hg\textsuperscript{0}. In Period B when the gas passed through the reactor, the outlet Hg concentration first dropped by approximately 10%, probably due to the physical adsorption by the porous SiO\textsubscript{2}-TiO\textsubscript{2} pellets. However, it quickly recovered to the same level of the inlet concentration indicating the adsorption was saturated. A significant decrease in Hg concentration was detected only when the UV light was turned on in Period C. The concentration of Hg\textsuperscript{T} dropped to 59% of the inlet level during the first 10 min of UV irradiation and slowly decreased to 53% in the next 80 min. At 100 min, the rate of the decrease of Hg\textsubscript{T} was approaching zero, and thus it was assumed that the performance of the catalyst reached a relatively stable level at this point. At 100 min, the outlet concentration of Hg\textsubscript{0} decreased to 34% of the inlet Hg\textsubscript{0} level while Hg(II) slowly increased to 19%. The efficiency of Hg capture on the pellets can be expressed as:

\[
E_{cap}(\%) = \frac{Hg_{in}^0 - Hg_{out}^0}{Hg_{in}^0} \times 100\%
\]  

where Hg\textsubscript{in}\textsuperscript{0} and Hg\textsubscript{out}\textsuperscript{0} represent Hg\textsuperscript{0} at the inlet and outlet of the reactor, respectively. Since the inlet Hg source is 100% Hg\textsuperscript{0} and negligible Hg\textsuperscript{0} capture was observed without UV, it is reasonable to assume that the captured Hg species under UV irradiation was only Hg(II) due to the photocatalytic oxidation.

Hence, the efficiency of Hg\textsuperscript{0} oxidation can be expressed as:

\[
E_{oxi}(\%) = \frac{Hg_{in}^T - Hg_{out}^T}{Hg_{in}^T} \times 100\%
\]  

where Hg\textsubscript{in}\textsuperscript{T} and Hg\textsubscript{out}\textsuperscript{T} represent Hg\textsuperscript{T} at the inlet and outlet of the reactor, respectively. Since Hg(II) passed through the reactor.

3.2. Effects of individual flue gas components

The effects of individual flue gas components were examined and the results were compared with the baseline. At least two runs were performed at each of the experimental condition listed in Table 1. The average values of Hg capture (E\textsubscript{cap}) and oxidation (E\textsubscript{oxi}) efficiencies are calculated from Eqs. 1 and 2 and are illustrated in Fig. 3, where the error bars represent the envelope of minimum and maximum values.

An inhibitory effect of water vapor on Hg removal was observed as shown in Fig. 3a. Experiments were first conducted in a relatively dry condition (<0.1%) by bypassing the water bubbler and then in humid conditions, with increasing water vapor concentrations. The efficiencies of both Hg capture and oxidation reached over 99% in the relatively dry condition. In this case, the water vapor concentration, even though at a very low level, was still several orders of magnitude higher than Hg concentration, and thus enough OH radicals can be generated to oxidize Hg\textsuperscript{0} [5]. As the water vapor concentration increased from 4% to 16% (baseline was 8%), the Hg capture efficiency decreased from 73% to 18%, and the Hg oxidation efficiency decreased from 88% to 32%. The inhibitory effect of water vapor is due to its competitive adsorption with Hg\textsuperscript{0} on the active sites [5,6], and as shown in Fig. 3a, the extent of inhibition on Hg removal is proportional to the water vapor concentration.
to the concentration of water vapor. This trend agrees with the results obtained at room temperature and low water vapor concentrations (~2.3%) [5]. Since the concentration of water vapor (4–15%) was seven to eight orders of magnitude higher than that of Hg\(^0\), the inhibitory effect of water vapor could still be significant even at higher temperatures (135 °C in this work).

It should also be noted that penetration of oxidized Hg from the reactor (i.e. the difference between Hg oxidized and captured) occurred in humid conditions (4–16% H\(_2\)O) but not in the dry condition. This can be explained by the competitive adsorption of water vapor with the gas-phase oxidized Hg. It was reported in our previous study [5] that physically adsorbed Hg\(^0\) can be desorbed from the surface of SiO\(_2\)–TiO\(_2\) composite by water vapor at high concentrations, which suggested that Hg\(^0\) is only weakly adsorbed on the sorbent surface. Hence, it is very possible that a portion of the oxidized Hg, which is the product of the reaction between Hg\(^0\) and OH radicals, existed in the gas phase in the vicinities of the reaction sites. In the dry condition, the oxidized Hg in the gas phase was adsorbed and, thus, there was no penetration.

However, under humid conditions, water vapor competes with the oxidized Hg and consequently not all oxidized Hg in the gas phase can be adsorbed. The superhydrophilic surface of TiO\(_2\) after exposure to UV irradiation can further enhance the adsorption of water vapor [5,16–18] but reduce the capture of oxidized Hg. As a result, penetration of oxidized Hg was usually observed in humid conditions in this work.

The effect of HCl on Hg removal was found to be promotional (Fig. 3b). In the range of 10 to 50 ppm, HCl, Hg capture efficiency increased to approximately 75% and Hg oxidation efficiency increased to over 90%. However, the extent of promotion was not apparently related to the HCl concentration in the range studied. The promotional effect of HCl is consistent with reports in the literature that HCl promotes heterogeneous Hg oxidation [19]. It has been reported that in the presence of an appropriate catalyst (e.g. metal oxides), a Deacon process [20] could convert HCl in the flue gas to Cl\(_2\) at high temperatures (300–400 °C), thereby enhancing Hg\(^0\) oxidation (or chlorination). Niksa et al. [21,22] proposed that Hg oxidation occurs via an Eley-Rideal mechanism, where adsorbed HCl reacts with gas-phase (or weakly

Fig 3 - Effects of flue gas components on Hg capture and oxidation under various conditions of a) H\(_2\)O, b) HCl, c) SO\(_2\), d) NO, e) NO\(_2\), and f) simulated flue gases.
adsorbed) Hg\(^0\), however, the specific reaction pathway was not given. The mechanism was also consistent with the observation of enhanced Hg\(^2\) sorption to halogen-promoted sorbents and fly ashes in the literature [23,24]. In this work, the Deacon process was less likely to occur because of the relatively low flue gas temperature (135 °C). Instead, it is more likely to follow the Eley-Rideal mechanism, where HCl may first be adsorbed on the surface of SiO\(_2\)-TiO\(_2\) nanocomposite, and then react with gas-phase Hg\(^2\). Parfitt et al. [25] conducted an infra-red study of HCl adsorption on rutile TiO\(_2\) surface and found an increase in surface OH groups due to the introduction of HCl. The OH groups can further react with excess HCl to form Cl and H\(_2\)O. With the hypothesis that HCl adsorption on the SiO\(_2\)-TiO\(_2\) nanocomposite occurs following a similar pathway, the observed enhancing effect of HCl can be explained by the formation of additional Cl species on the surface which also contributes to Hg\(^0\) oxidation. Further investigation is needed to identify the exact reaction mechanism.

As shown in Fig. 3c, SO\(_2\) was found to have a promotional effect on Hg capture and oxidation and the promotion was proportional to the concentration of SO\(_2\) in the range of 0–1200 ppmv. The Hg capture and oxidation efficiencies reached 73% and 91% respectively at 1200 ppmv SO\(_2\). The effect of SO\(_2\) on heterogeneous Hg oxidation is not conclusive in the literature. It has been reported that SO\(_2\) competes with NO to form NO\(_2\) and NO\(_3\) instead of HCl and H\(_2\)O. As shown in Fig. 3e, SO\(_2\) was found to have a promotional effect on heterogeneous Hg oxidation [12,28]. HCl adsorption on the surface of SiO\(_2\)-TiO\(_2\) nanocomposite has been synthesized for the removal of Hg\(^0\) from simulated coal-fired flue gas [26,27]. Carey et al. [11] reported that the adsorption capability of a Darco FGD carbon for both Hg\(^2\) and HgCl\(_2\) decreases as the concentration of SO\(_2\) in the range of 50–300 ppmv increases. However, in some cases, SO\(_2\) appears to enhance Hg\(^0\) oxidation [12,28]. Eswaran and Stenger reported a promotional effect of SO\(_2\) on Hg\(^0\) oxidation over a selective catalytic reduction (SCR) catalyst [28]. The mechanism was proposed as:

\[
\text{SO}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{SO}_3 \quad \text{(R6)}
\]

\[
\text{Hg} + \text{SO}_3 + \frac{1}{2} \text{O}_2 \rightarrow \text{HgSO}_4 \quad \text{(R7)}
\]

A similar mechanism can be used to explain the promotional effect of SO\(_2\) in this work, where SO\(_2\) could be formed through the oxidation of SO\(_2\) by OH radicals [29], which were generated on the SiO\(_2\)-TiO\(_2\) pellets under UV irradiation. The effect of NO on Hg removal was found to be inhibitory at a significant but relatively constant level in the concentration range of 50–300 ppmv, NO (Fig. 3d). The Hg capture and oxidation efficiencies both decreased to around 10% in the presence of NO. NO has been reported as an inhibitor for heterogeneous Hg\(^0\) oxidation on fly ash [12], but the mechanism is not clear. In this study, it is very likely that the scavenging of OH radicals by NO hindered the photocatalytic oxidation of Hg\(^0\). The inhibition may have occurred via [30]

\[
\text{OH} + \text{NO} + \text{M} \rightarrow \text{HONO} + \text{M} \quad \text{(R8)}
\]

In the presence of 10–30 ppmv NO\(_2\), the efficiencies of Hg capture and oxidation were slightly lower than those in the baseline (Fig. 3e). However, the effect of NO\(_2\) in this range can be considered as insignificant compared to the other flue gas components. It has been reported in the literature that NO\(_2\) can enhance heterogeneous oxidation of Hg\(^0\) in the presence of fly ash [12] or iron oxides [31,32], though this effect is often considered of minor importance compared to chlorination.

### 3.3. Hg removal in simulated flue gases

The performance of the SiO\(_2\)-TiO\(_2\) nanocomposite was finally tested in two simulated flue gases, the compositions of which were in line with those reported in literature [33]. Flue Gas 1 (Set 7) represents flue gas from high rank (bituminous) coals that contain higher chlorine and sulfur content. Flue Gas 2 (Set 8) represents flue gas from low rank (subbituminous and lignite) coals, which contain less chlorine and sulfur but more moisture. As shown in Fig. 3f, Hg removal in the Flue Gas 1 was close to that in the baseline, indicating that the prohibition effect of 300 ppmv NO counteracted the promotional effects of 30 ppmv HCl and 1200 ppmv SO\(_2\). Hg removal in the Flue Gas 2 was less than in the Flue Gas 1, very likely due to the higher concentration of H\(_2\)O and lower concentrations of HCl and SO\(_2\). Hence, high rank coals are preferable to low rank coals for the application of the SiO\(_2\)-TiO\(_2\) nanocomposite. Minimizing the adverse effect of NO so as to improve the overall performance of the catalyst would be an important task for future research.

### 4. Conclusions

A novel SiO\(_2\)-TiO\(_2\) nanocomposite has been synthesized for the removal of Hg\(^0\) from simulated coal-fired power plant flue gas. The flue gas components were found to have significant effects on Hg removal efficiency in a fixed bed study. HCl and SO\(_2\) promoted Hg oxidation and capture, while H\(_2\)O and NO inhibited Hg removal and the effect of NO\(_2\) was not significant. Experiments of Hg removal in simulated flue gases showed that high rank coals are preferable to low rank coals because of the lower moisture and higher HCl and SO\(_2\) concentrations in the flue gas. It is essential, however, to minimize the adverse effect of NO to improve the catalytic performance of the SiO\(_2\)-TiO\(_2\) nanocomposite.

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### References


