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DRY SORBENT INJECTION OF SODIUM SORBENTS FOR SO_2, HCl AND MERCURY MITIGATION

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ABSTRACT

Solid waste incinerators emit air pollutants such as SO_2, HCl, and mercury. Dry sorbent injection of sodium sorbents has emerged as an important SO_2, HCl, and mercury mitigation technology due to its (a) low capital cost; (b) small installation foot print; (c) ease of operation; and (d) flexibility to fuel changes.

In a dry sorbent injection system, trona or sodium bicarbonate is injected directly into hot flue gas. After injection, the sorbent is calcined into porous sodium carbonate that reacts with acid gases (SO_2, HCl and SO_3). This technology is able to achieve high removal rates for HCl (>99%) and SO_2 (>90%), and has been implemented at many waste incinerators in Europe and coal-fired power plants in the United States. With the promulgation of MACT rules, this technology will be a low-cost and easy-to-use option for waste-to-energy boiler owners.

INTRODUCTION

Solid waste incinerators emit air pollutants such as SO_2, HCl, and mercury. The wet scrubbers used at the utility power plants are too large and costly for waste-to-energy applications. As a result, dry sorbent injection of sodium sorbents has emerged as an important SO_2, HCl, and mercury mitigation technology due to its (a) low capital cost; (b) small installation foot print; (c) ease of operation; and (d) flexibility to fuel changes. As a matter of fact, many waste-to-energy facilities in Europe have adopted this technology to remove over 99% of HCl and over 90% of SO_2 with sodium bicarbonate.

TECHNOLOGY DESCRIPTION

In a dry sorbent injection system, trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) or sodium bicarbonate ($NaHCO_3$) is injected directly into hot flue gas (> 275 ^oF). After injection, the sorbent is calcined into porous sodium carbonate (Na_2CO_3), as shown in Figure 1 and 2. Its high surface area enables fast gas-solid reactions between acid gases (SO_2, HCl and SO_3) and Na_2CO_3 to form Na_2SO_4 and NaCl which are collected by either electrostatic precipitators or fabric filters.

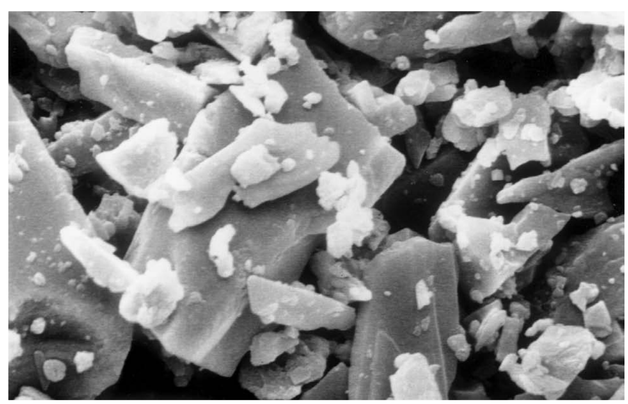

Figure 1: Raw Trona under Microscope

The chemical reactions between the porous sodium carbonate (Na_2CO_3) and acid gases are:

$$Na_2CO_3 + SO_2 \rightarrow Na_2SO_3 + CO_2$$

$$Na_2SO_3 + \frac{1}{2} O_2 \rightarrow Na_2SO_4$$

$$Na_2CO_3 + SO_3 \rightarrow Na_2SO_4 + CO_2$$

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

$$Na_2CO_3 + 2HF \rightarrow 2NaF + H_2O + CO_2$$

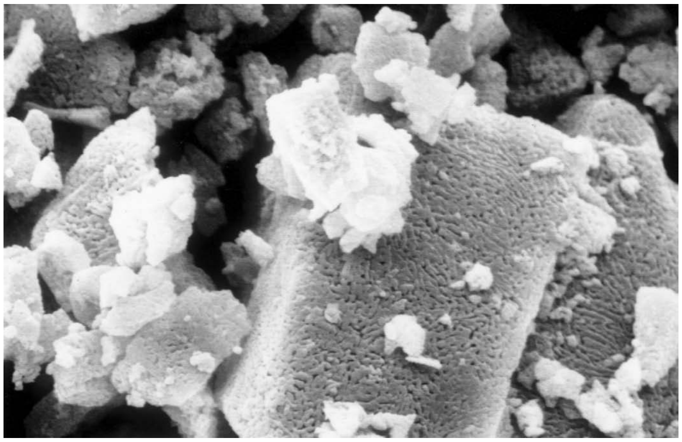

Figure 2: Calcined Trona under Microscope

Since SO_3 competes with mercury for adsorption sites on fly ash particles or injected activated carbon, even SO_3 at concentrations as low as a few parts per million is able to adversely affect mercury removal. By removing SO_3 with trona, the fly ash with high unburned carbon alone is able to remove over 90% of mercury.

Trona supplied in this type of application is a fine powder and can be injected into a flue gas duct directly. On the other hand, sodium bicarbonate needs to be milled before injection. Their typical physical characteristics are shown in Table 1.

Table 1: Trona and Sodium Bicarbonate

	Trona	Sodium Bicarbonate
Formula	$Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$	$NaHCO_3$
Mean Diameter (d_{50})	30 µm	110 µm
Free–flowing bulk density	49 lb/ft^3	68 lb/ft^3
Purity	> 97%	> 99%

APPLICATION RESULTS

A test was conducted on a Stoker boiler with a heat generating capacity of 220 MMBTU/h. It burned a blended fuel of wood chips, coal, and Tire-Derived-Fuel (TDF) at a ratio of Wood/Coal/TDF: 35/35/30%. The sulfur content of the blended fuel was: 1.0 lb/MMBTU of SO_2. Trona was injected upstream of the bag house, as shown in Figure 3. The flue gas temperature at the injection point was around 330 ^oF.

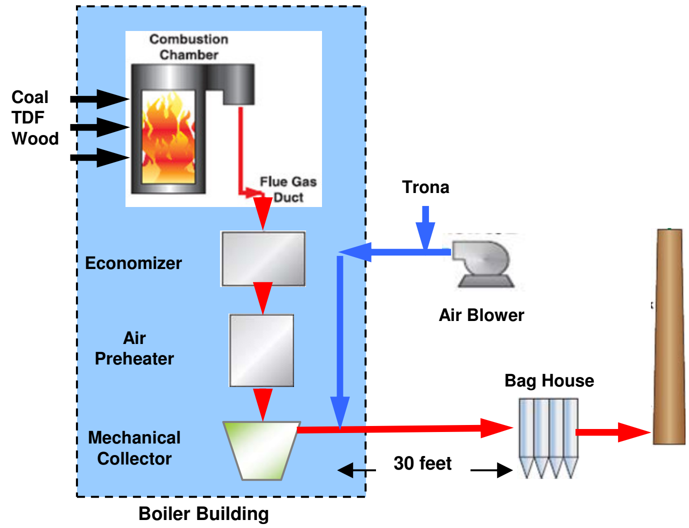

Figure 3: Trona Injection System

The SO_2 removal rates were satisfactory: the target of 65% was easily achieved with NSR > 2.5, as shown in Figure 4. Trona is not as reactive with NO_x. Figure 4 shows that around 10% of NO_x was removed by the trona injection, a nice bonus considering it was not a primary target of the treatment.

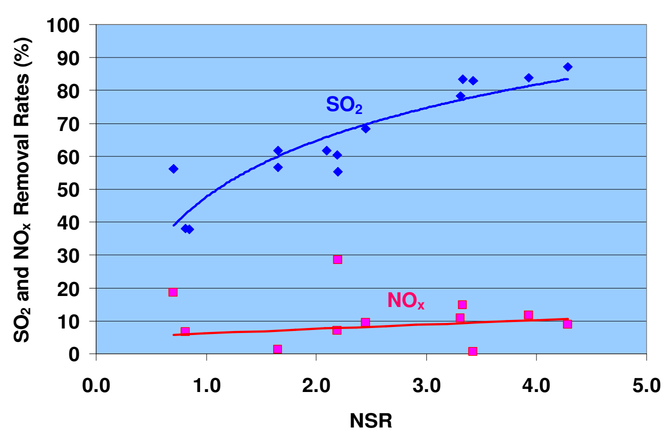

Figure 4: SO_2 and NOx Removal Rates with Trona Injection

NSR (Normalized Stoichioemetric Ratio) is calculated as follows:

$$NSR = \frac{\dfrac{\text{mass of sodium injected}}{\text{mass of acid gas entering system}}}{\dfrac{\text{mass of sodium theoretically needed}}{\text{to react with a unit mass of acid gas}}}$$

The removal rates of SO_3, HCl and HF were over 98% at all trona feedrates, which demonstrated trona's high reactivity with these acid gases.

The mercury readings before and after the trona injection were extremely low. Consequently, we were not able to determine if the trona injection had any impact on the mercury emissions.

At a separate test where trona was injected upstream of the air pre-heater (APH) and electrostatic precipitator (ESP), the effect on mercury emissions was obvious. The 130 MW boiler burned low sulfur coal and had relatively low SO_3 concentration (~ 5 ppm). The high unburned carbon in the fly ash was able to remove 82% of mercury. The injected trona removed all SO_3, and consequently increased the mercury removal rate to 90% (Table 2). In order to increase the mercury removal rate further, powdered activated carbon (PAC) was injected downstream of the air pre-heater. As Figure 5 shows, the injection of PAC alone achieved only up to 80% of mercury removal. However, with trona injection (~1000 lb/h), the mercury removal rate went up to 98%.

Table 2: Effect of Trona on Mercury Removal

	No Trona No PAC	With Trona No PAC
SO_3 @ APH Inlet (ppm)	6.8	5.4
SO_3 @ Stack (ppm)	4.9	0
Mercury Reduction Rate (%)	82%	90%

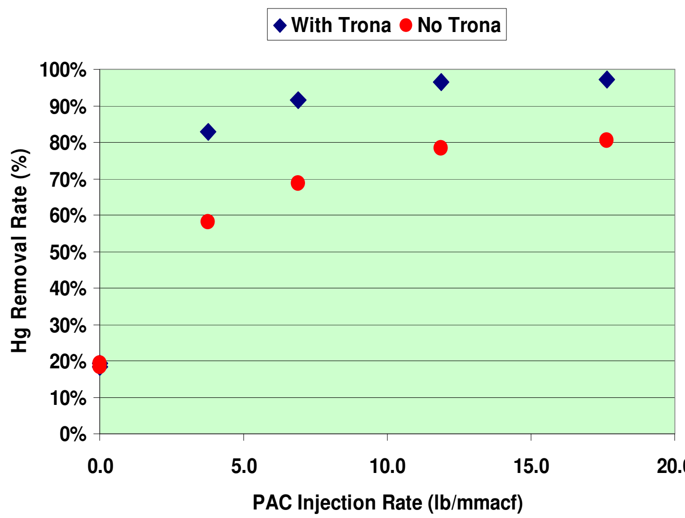

Figure 5: Positive Effect of Trona On Mercury Removal by PAC

Sodium bicarbonate was used to control HCl and SO_2 from a municipal waste incinerator in Germany. This waste incinerator burned about 6 tons/h of solid municipal waste to generate steam. The concentrations of HCl and SO_2 from the boiler were 581 ppm and 32 ppm, respectively. Table 3 shows that over 99% of HCl and 91% of SO_2 were removed with low sodium bicarbonate feedrates.

Table 3: Performance of Sodium Bicarbonate for HCl and SO_2 Removal from a Waste Incinerator

Test #	Solid Waste Feedrate (tons/h)	Sodium Bicarbonate Feedrate (kg/h)	HCl Removal Rate (%)	SO_2 Removal Rate (%)
1	5.1	130	99.2%	91.3%
2		148	99.3%	91.3%
3		202	99.2%	95.7%
4	5.5	192	99.3%	96.7%
5		99	99.3%	95.7%
6		110	99.3%	93.5%
7	5.5	107	99.3%	92.4%
8		127	99.3%	93.5%
9		103	99.3%	93.5%
10	5.2	139	99.3%	91.3%
11		149	99.3%	94.6%
12		126	99.3%	93.5%

This technology has been successfully applied at many waste incinerators in various countries. Table 4 shows a few examples.

Table 4: Dry Injection of Sodium Bicarbonate for HCl and SO_2 Removal at Various Waste Incinerators

Plant	Waste	Capacity (tons/y)	SO_2 Removal Rate (%)	HCl Removal Rate (%)
UVE Metz (France)	Municipal Solid Waste	90,000	98.6	98.3
Oshima (Japan)	Municipal Solid Waste	40,000	96.0	99.8
Sotrenor (France)	Special Industrial Waste	100,000	99.1	99.8
Burgo Mantova (Italy)	Special Industrial Waste	60,000	97.9	95.0

SUMMARY

Dry injection of sodium sorbents (trona and sodium bicarbonate) is able to achieve high removal rates for HCl (>99%) and SO_2 (>90%). This technology has been implemented at many waste incinerators in Europe and many coal-fired power plants in the United States. With the promulgation of MACT rules, this technology will be a low-cost and easy-to-use option for waste-to-energy boiler owners.