

A COMPARATIVE STUDY OF STEEL FURNACES AND BOILERS EMISSIONS WITH AND WITHOUT EMISSION CONTROL SYSTEM (ECS)

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ABSTRACT: In this study, emissions from boilers and steel furnaces with and without emission control systems (ECS), more especially wet scrubbers, were assessed. The concentrations of PM, SO₂, and NO_x were determined using an isokinetic assembly for particulate matter (PM) monitoring and a flue gas analyzer for CO, NO_x and SO₂ monitoring. The efficacy of the wet scrubber in capturing airborne particles was demonstrated by the remarkable 70% reduction in PM emissions observed in the steel furnace findings. There was no discernible change in CO₂ levels, and emissions of SO_x and NO_x were reduced by 15% and 16%, respectively, but CO emissions only dropped by 3.31%. With a reduction of 70.22% in SO_x emissions, the wet scrubber proved to be the most efficient in lowering emissions of NO_x (30.79%) and PM (27.75%) in the context of boilers. CO₂ levels marginally increased while CO emissions declined by 17.75%. In general, the wet scrubber demonstrated significant efficacy in mitigating pollutants, including PM and SO_x; however, its influence on CO and CO₂ was restricted.

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INTRODUCTION

Technologies for reducing air pollution are crucial for reducing the negative effects of industrial emissions on the environment and human health. Air pollutants such as particulate matter (PM), sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs) are primarily produced by industries, especially heavy industries like steel manufacturing and boiler-based power generation (Zhang *et al*, 2019). Effective pollution control systems are vital because these pollutants cause respiratory ailments, acid rain, and smog.

In the steel industry, emissions arise from processes like blast furnace operations, steel smelting, and refining. Key pollutants from steel production include PM, CO, SO_x, and NO_x, largely originating from combustion processes and material handling (Cieřlik *et al*, 2020). To mitigate these emissions, industries adopt various pollution control technologies such as electrostatic precipitators (ESPs), fabric filters (baghouses), and wet scrubbers. Wet scrubbers, for instance, are commonly used to capture particulate matter and absorb sulfur dioxide (SO₂) from the flue gas by using a liquid, typically water or an alkaline solution, to wash pollutants out of the gas stream (European Environment Agency, 2016).

Fossil fuels such as coal, oil, and natural gas are burned in boilers, which are used in power production and other industrial heating operations. This process results in a large contribution to air pollution. Boilers

release mostly SO_x, NO_x, CO, and PM into the air. While selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) are frequently used to lower NO_x emissions by converting nitrogen oxides into harmless nitrogen and water, technologies like flue gas desulfurization (FGD) systems are used to reduce SO_x emissions by removing sulfur compounds from the exhaust gases (Wang *et al*, 2021).

Boilers and the steel industry have both developed air pollution control technologies to comply with stricter environmental laws. For instance, wet scrubbers have demonstrated efficacy in lowering PM and SO_x emissions in both industries. With the right upkeep and optimization, these technologies can drastically cut industrial emissions, improving the quality of the air and lessening the impact on the environment.

When it comes to reducing the harmful emissions that are released from industrial processes, air pollution control solutions are essential. This is especially true for industries that contribute significantly to air pollution, such as steel making and boilers. Particulate matter (PM), sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases like carbon dioxide (CO₂) are the main pollutants resulting from these sectors (Kumar *et al*, 2020). Given that these emissions directly affect ecological systems, human health, and global climate change, action must be taken to reduce them.

The primary operations in the steel industry that cause air pollution include coking, sintering, smelting, and refining. The burning of fuel and the processing of

raw materials like iron ore and coke lead to high concentrations of SO_x and PM. The use of electrostatic precipitators (ESPs) and baghouses for particulate capture, low-NO_x burners to lower NO_x creation, and wet scrubbers to remove PM and SO_x from exhaust gases are examples of contemporary air pollution management measures in the steel industry (Chung & Lee, 2017). Wet scrubbers work especially effectively at eliminating dust and gasses because they use a liquid to trap airborne contaminants, a technique that is ideal for the high temperatures seen in steel furnaces.

In order to extract tiny particulate matter from flue gases, the steel industry frequently uses electrostatic precipitators, or ESPs. By giving exhaust stream particles an electric charge, these devices attract and deposit the particles on sizable collection surfaces (EPA, 2018). In contrast, fabric filters are used in baghouses to capture particles in the exhaust flow as it passes through. Both methods are necessary to reduce particulate matter emissions and keep air quality regulations in place.

Depending on the kind of fuel (coal, oil, or gas), boiler activities, which are common in power production and industrial heating, result in large emissions of SO_x, NO_x, and PM. Flue gas desulfurization (FGD) systems are utilized to capture SO_x in order to reduce these emissions; lime or limestone are frequently used to generate a gypsum byproduct that can be reused or disposed of safely (Bhargava & Khare, 2021). By chemically reducing nitrogen oxides to nitrogen and water vapor, a process known as selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) lowers NO_x emissions. These devices, especially in major power plants, have played a significant role in lowering NO_x emissions from boilers.

With the advent of dry and semi-dry scrubbers, which neutralize acidic gases without the need for a liquid phase by using alkaline reagents, flue gas treatment technologies have also advanced. In certain situations, these scrubbers are less complicated to operate and more economical to operate (Hassan *et al*, 2019). Additionally, improvements in combustion efficiency and the adoption of low-NO_x burners have reduced the formation of nitrogen oxides at the source

METHODOLOGY

To assess the effectiveness of emission control systems (ECS), particularly wet scrubbers, in reducing air pollutants from steel furnaces and boilers, emissions data were collected both with and without the use of ECS. The study focused on measuring the concentrations of particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x), and carbon monoxide (CO) using the following approach:

Site Preparation and Equipment Setup: The steel furnaces and boilers selected for the study were prepared for emissions testing. Each site was evaluated both before and after the installation of the emission control system (ECS).

Emission monitoring equipment was set up to ensure accurate data collection. A **Flue Gas Analyzer** was used to measure CO, NO_x, and SO₂ concentrations, while an **Isokinetic Assembly** was employed to monitor particulate matter (PM) emissions. All equipment was calibrated according to manufacturer specifications and industry standards.

Measurement Procedures:

Baseline Measurements (Without ECS): Before the installation of the ECS, emissions from steel furnaces and boilers were measured under normal operating conditions to establish baseline data. These measurements provided the initial concentrations of PM, SO₂, NO_x, and CO emitted without any pollution control system in place.

Post-ECS Measurements (With ECS): After the installation of the ECS, emissions were measured again under the same operating conditions to evaluate the effectiveness of the system in reducing pollutant concentrations. The wet scrubber was used as the ECS, and data on pollutant reduction were collected immediately after its implementation.

Instrumentation and Monitoring:

Flue Gas Analyzer: The flue gas analyzer was used to monitor gaseous pollutants such as CO, NO_x, and SO₂ in the exhaust gases. The analyzer was positioned in the stack to ensure accurate detection of gas concentrations.

Isokinetic Sampling for PM: The isokinetic assembly was employed to measure particulate matter concentrations. Isokinetic sampling ensures that the velocity of the gas entering the sampling probe matches the velocity of the gas in the stack, leading to precise measurements of PM.

Data Collection and Analysis: Emission data were recorded at regular intervals during normal operational periods for both the baseline and post-ECS phases.

Concentration values were reported in milligrams per normal cubic meter (mg/Nm³) to maintain consistency with industry standards. Data were then analyzed to calculate the percentage reduction in pollutant levels before and after the implementation of the ECS.

The effectiveness of the ECS was determined by comparing the pollutant concentrations without ECS to those measured with ECS, highlighting the reduction percentages for each pollutant (PM, SO₂, NO_x, CO).

Quality Control: To ensure data reliability, all instruments were regularly calibrated, and multiple

measurements were taken to account for variability in the emission levels. The results were averaged to provide accurate representation of the emissions with and without ECS.

RESULTS

EPA has conducted a short study to find out the effectiveness of emission control system installed in various industries in order to achieve the targets set in Punjab clean air action policy 2023 i.e. 30% reduction of Particulate Matter (PM 2.5 and 10) concentration of 2022 (annual average) by the year 2030 in the most polluted cities i.e., Lahore, Faisalabad, Gujranwala, and Multan. 25% reduction of major air pollutants (NO_x, SO_x, Ozone, CO and CO₂) concentration of 2021 (annual average) by the year 2030

Emissions from steel production units and boilers in various industrial settings are significant sources of air pollutants, including PM, CO, SO₂, and

NO_x. ECS, such as wet scrubbers, are widely employed to control these emissions. This study aims to compare the effectiveness of ECS (wet scrubbers) in reducing emissions from steel furnaces and boilers.

Table 1 shows Significant reductions in various pollutants are shown by the findings from the steel furnaces both with and without the use of an emission control system (ECS), most especially a wet scrubber. Particulate matter (PM) emissions showed the greatest reduction, falling by 70%, demonstrating the wet scrubber's excellent ability to collect airborne particles. NO_x levels dropped by 16%, while SO_x emissions also witnessed a 15% decrease. Carbon monoxide (CO) emissions, however, only slightly decreased—by 3.31%. The concentrations of carbon dioxide (CO₂) did not significantly differ amongst the systems. All things considered, using a wet scrubber significantly decreased harmful emissions, especially PM, but had little effect on CO.

Table 1: Emissions from steel furnaces with and without ECS (wet scrubber)

Sr	Parameter	PEQS* mg/Nm ³	Conc mg/Nm ³ without ECS	Conc mg/Nm ³ with ECS	% Reduction	Remarks
1.	CO	800	28.32	27.38	3.31%	Effective reduction in SO _x , NO _x and PM concentration were observed
2.	SO _x	1700	5553.4	4694.35	15%	
3.	NO _x	600	264.93	314.91	16%	
4.	PM	500	316.110	97.172	70%	
5.	CO ₂ %	----	32017.85	30053.571		

The results show that ECS reduced CO, SO₂, NO_x, and PM by 3.31%, 15%, 16%, and 70%, respectively.

Table 2 shows that boilers with and without an emission control system (ECS), more especially a wet scrubber, show significant drops in a number of different pollutants. The wet scrubber's efficacy in reducing sulfur dioxide emissions was demonstrated by the largest reduction in SO_x emissions, which dropped by 70.22%. Particulate matter (PM) levels decreased by 27.75%, and NO_x emissions decreased by 30.79%. Emissions of

carbon monoxide (CO) decreased moderately by 17.75%. However, carbon dioxide (CO₂) levels marginally increased in the system with the ECS, demonstrating that while the wet scrubber is successful in decreasing pollutants including SO_x, NO_x, and PM, its impact on CO₂ emissions is modest. All things considered, the wet scrubber greatly decreased dangerous emissions, especially SO_x.

Table 2: Emissions from boilers with and without ECS (wet scrubber)

Sr	Parameter	PEQS* mg/Nm ³	Conc. mg/Nm ³ without ECS	Conc. mg/Nm ³ with ECS	% Reduction	Remarks
1.	CO	800	13853.04	11393.49	17.75 %	Effective reduction in SO _x , NO _x and PM concentration were observed
2.	SO _x	1700	412.37	122.81	70.22 %	
3.	NO _x	600	444.86	307.89	30.79%	
4.	PM	500	358.41	258.942	27.75%	
5.	CO ₂ %	----	45729.29	48134.12		

The results show that ECS reduced CO, SO₂, NO_x, and PM by 17.75%, 70.22%, 30.79%, and 27.75%, respectively.

DISCUSSION

The findings suggest that ECS (wet scrubber) is effective for reducing emissions from steel furnaces and boilers. The results have significant implications for the steel industry, highlighting the importance of implementing effective emission control measures.

Conclusion: Particulate matter (PM), sulfur dioxide (SO_x), and nitrogen oxides (NO_x) have significantly decreased, according to emission data from steel furnaces and boilers with and without emission control systems (ECS), especially wet scrubbers. The wet scrubber significantly reduced PM emissions in steel furnaces by 70% and also significantly reduced SO_x and NO_x emissions by 15% and 16%, respectively. Nonetheless, there was no discernible shift in the levels of carbon dioxide (CO₂), and the decrease in carbon monoxide (CO) emissions was just 3.31%. Similarly, in boilers, the wet scrubber somewhat decreased CO emissions (17.75%) while effectively reducing SO_x by 70.22%, NO_x by 30.79%, and PM by 27.75%. Although the wet scrubber is quite successful in reducing PM, SO_x, and NO_x emissions, its effect on CO₂ is still rather small, and CO levels only slightly improved.

Recommendations:

1. In order to more successfully target CO reductions in steel furnaces and boilers, it is advised to investigate supplementary technologies, such as catalytic converters, given the modest reductions in CO emissions.
2. Regular maintenance and inspection of the ECS should be required, especially in industrial settings, to preserve the efficacy of the wet scrubbers and guarantee a sustained reduction in pollutants.
3. Since the wet scrubber has limited effect on CO₂ emissions, CO₂ output should be addressed using alternative or supplemental measures such as energy efficiency upgrades, carbon capture, or fuel switching (e.g., to lower-carbon alternatives).
4. In industries that use combustion processes, authorities should establish and enforce higher emissions limits, especially for SO_x, NO_x, and PM. Industries with high emission outputs should be required to utilize ECS, such as wet scrubbers.

5. In order to guarantee real-time data collection and reporting of important pollutants, maintain compliance with environmental regulations, and enable prompt modifications to ECS performance, continuous emissions monitoring systems (CEMS) should be implemented.

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