PARTICULATE MATTER REDUCTION FROM STEEL FURNACES AND COAL FIRED BOILERS THROUGH INSTALLATION OF EMISSION CONTROL SYSTEMS (ECS) IN LAHORE PUNJAB, PAKISTAN

M. Nadeem[1], I. H. Sheikh[2], N. Naz[3], R. Haider[4*], M. F. Alam[5] and F. Hussain[6]

[1]Assistant Director (Research), Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
[2]Imran Hamid Sheikh, Director General Environmental Protection Agency, Govt. of Punjab, Lahore (Pakistan)
[3]Director (ML&I), Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
[4]Assistant Director (Research), Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
[5]Deputy Director (Lab), Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
Corresponding Author Email: rizwanchemist@gmail.com

ABSTRACT: This study investigated the impact of Emission Control Systems (ECS) on Particulate Matter (PM) emissions from two major industrial sectors in Lahore i.e boilers and steel induction furnaces. Data was collected from 2020 to 2024 to assess the effectiveness of the Environmental Protection Agency's (EPA) efforts in promoting and enforcing ECS installation. PM emissions were monitored using isokinetic sampling methods for both units equipped with ECS (Wet Scrubbers for boilers and predominantly Dry Scrubbers for steel furnaces) and those operating without ECS. The data demonstrated a significant reduction in PM emissions from both sources. The steel industry with 71 units in Lahore, the number of units operating without ECS decreased dramatically from 69 in 2021 to just 1 in 2024, leading to a 49% drop in emissions. Similarly, in the boiler sector, the installation of Wet Scrubbers on 540 out of 600 boilers resulted in a 25% reduction in PM emissions between 2021 and 2024. The study highlighted the effectiveness EPA mitigation measures to control pollution and ensuring cleaner air for the region.

Key words: Emission Control System, Boiler, Steel Furnaces, Scrubber, Lahore

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INTRODUCTION

Particulate matter (PM) pollution from industrial sources, particularly boilers and steel furnaces, represents a significant environmental and public health challenge in Punjab Pakistan. These industrial processes, essential for various manufacturing activities, are major emitters of PM, a complex mixture of solid and liquid particles suspended in the air (Pope et al., 2002, Cohen et al., 2017).). Boilers, used for generating steam or hot water for industrial processes and power generation, often rely on the combustion of fossil fuels such as coal, oil, or natural gas (USEPA, 1998, IEA, 2021). This combustion process releases PM, including fly ash, soot, and other combustion byproducts, into the atmosphere. The composition and size distribution of PM emitted from boilers vary depending on the fuel type, combustion technology, and emission control devices employed (VDI, 2018, Harrison et al., 2021). Steel furnaces, crucial for steel production, also generate substantial amounts of PM during various stages of the steelmaking process, including melting, refining, and casting (International Iron and Steel Institute, 2011). These emissions consist of metallic particles, dust, and fumes, which can contain hazardous substances such as heavy metals.

The health consequences of PM pollution from boilers and steel furnaces are well-established. Inhalation of PM, especially fine particles (PM2.5), can penetrate deep into the respiratory tract, leading to a range of adverse health effects, including respiratory diseases (asthma, chronic bronchitis, lung cancer), cardiovascular problems (heart attacks, strokes), and increased mortality (Burnett et al., 2018). The extent of health risks is determined by factors such as particle size, chemical composition, concentration, and duration of exposure. fine particles (PM2.5), can penetrate deep into the respiratory system, causing a range of adverse health effects, including respiratory illnesses such as asthma, bronchitis, and lung cancer, as well as cardiovascular diseases, and premature mortality (WHO, 2021).

The environmental impacts of PM pollution from these sources extend beyond direct health effects to include reduced visibility, acid rain, and contributions to climate change (IPCC, 2021). The deposition of PM on vegetation and soil can also disrupt ecosystems and affect agricultural productivity.

Controlling PM emissions from boilers and steel furnaces is crucial for mitigating their environmental and health impacts. Various emission control technologies are available, including:

- **Electrostatic precipitators (ESPs):** Remove particulate matter from exhaust gases using electrostatic forces.
- **Fabric filters (baghouses):** Filter particulate matter from exhaust gases using fabric bags.
- **Wet scrubbers:** Remove particulate matter by contacting the exhaust gases with a liquid.
- **Cyclones:** Use centrifugal force to separate particulate matter from exhaust gases.

Particulate Matter (PM) emissions from uncontrolled coal-fired boilers and steel induction furnaces have been a significant contributor to air pollution in Lahore, Pakistan. These industrial sources emit substantial amounts of PM, posing a significant threat to public health and environmental quality. To address this challenge, the Environmental Protection Agency (EPA) has implemented a series of measures to promote and enforce the installation of Emission Control Systems (ECS) in these industries. According to urban unit recent survey of 2024, around 96% of industry in Lahore have installed ECS. This study aims to evaluate the effectiveness of these interventions in reducing PM emissions from these key industrial sources in Lahore.

METHODOLOGY

This study analyzed the impact of Emission Control Systems (ECS) on PM emissions from two major industrial sectors in Lahore: 600 boilers and 71 steel induction furnaces. Data was collected from 2020-21 to 2023-24 to assess the impact of the EPA's efforts in promoting and enforcing ECS installation.

For boilers, PM emissions were calculated based on the average PM concentration, flow rate (derived from coal consumption data), and emission factors. This onsite testing data-driven approach for boilers provides valuable insights into the effectiveness of the EPA's interventions in reducing PM emissions from key industrial sources in Lahore

For steel furnaces, PM emissions collection efficiency was estimated based on zinc ash collection data. The study tracked the number of units operating without ECS and those equipped with ECS, predominantly Dry Scrubbers for steel furnaces. The impact of ECS was assessed by comparing PM emissions from units with and without these systems, with a (25-79%) ave. 60%, collection efficiency for ECS in steel furnaces. The 25% efficiency is for wet scrubbers and upto 79% for dry scrubbers. As mostly dry scrubbers are installed on steel induction furnaces, the average collection efficiency is around 60%.

Data Collection and Analysis:

- **PM Emission Monitoring in Boilers:** PM emissions were measured using **isokinetic sampling methods** to ensure accurate and representative data collection.
  - Samples were collected from both units equipped with ECS and units operating without any ECS.
- **Emission Factors calculation for Steel Furnaces:** PM emission factors were determined steel furnaces based on Zinc Ash dust recovered per unit ton of coal used in steel furnaces.
- **Data Analysis:**
  - The study tracked the number of units operating without ECS and those equipped with ECS over the study period.
  - PM emissions from units without ECS were calculated and compared to those equipped with ECS.
  - The impact of ECS was assessed by comparing PM emissions from units with and without these systems, considering the collection efficiency of the installed ECS.

RESULTS

This study investigated the impact of Emission Control Systems (ECS) on Particulate Matter (PM) emissions from two major industrial sectors in Lahore: 600 boilers and 71 steel induction furnaces. Data was collected between 2020-21 and 2023-24 to assess the effectiveness of the Environmental Protection Agency's (EPA) efforts in promoting and enforcing ECS installation.

PM emissions from Steel Induction Furnaces: The Table 1 shows a significant decrease in total PM emissions from steel induction furnaces from 2021 to 2024, calculated based on zinc ash generation. Here's a breakdown of the contributing factors:

- Zinc ash is a byproduct of the steelmaking process in induction furnaces, and it's used as a basis for estimating PM emissions. The variation in zinc ash production from year to year (2218.32 tons in 2021, peaking at 2972.26 in 2022, then decreasing) indicates changes in overall steel production volume.
- Decreasing Number of Units Without ECS: The most significant factor is the dramatic reduction in the number of steel induction furnace units operating without Emission Control Systems (ECS). In 2021, 69 units operated without ECS, contributing 2155.83 tons of PM. By 2024, this number has dropped to just 1 unit, contributing only 25.842 tons of PM. This demonstrates the successful implementation of ECS across the steel industry.

- No. of Units With ECS: This shows the number of units equipped with ECS. The number increases from 2 in 2021 to 70 in 2023 and remains stable in 2024.
- Respective Emissions (25-79%) ave. (@60% collection efficiency due to ECS installation) (Tons per Year): This row calculates the total PM emitted by the units with ECS. It's calculated as follows:
- First, the PM emissions *without* ECS for these units are calculated (just like in row 4, but for the units *with* ECS).
- Then, this value is multiplied by (1 - collection efficiency). Since the collection efficiency is (25-79%) ave. 60%, the multiplication factor is (1 - 0.60) = 0.40. This means that only 40% of the potential emissions are actually released because 60% are captured by the ECS.
- Increasing Number of Units With ECS: Correspondingly, the number of units *with* ECS has increased significantly. In 2021, only 2 units had ECS installed. By 2024, this number has risen to 70 units.

The combined effect of these factors resulted in a substantial decrease in total PM emissions from all steel induction furnace units. From 2193.33 tons in 2021, total emissions decreased to 1111.21 tons in 2024, representing a 49.34% reduction.

PM emissions from Boilers: The Table 2 presents data on particulate matter (PM) emissions from 600 boilers between 2020-21 and 2023-24. In 2020-21, with an average PM concentration of 601.9 mg/m³ and a combined flow rate of 1,940,876.9 m³/hr from 600 boilers, the annual PM emissions were 4056.365 tons. However, by 2023-24, the average PM concentration decreased to 451.425 mg/m³. Despite the same flow rate, this reduction in PM concentration resulted in lower annual emissions of 3042.273756 tons in 2023-24. This represents a 25% reduction in PM emissions from the 600 boilers over this period.

Table 1: Comparison of PM emissions from Steel Furnaces in Lahore from 2021 to 2024.

		2021	2022	2023	2024	Improvement (2024 Vs 2021)
1.	Zick Ash Per Year in tons	2218.32	2972.26	1753.13	1834.78	
2.	Average PM emission Per Unit Per Year (Tons) if all units have working without ECS	31.2439	41.8629	24.692	25.842	
3.	No. of units without ECS	69	6	1	1	
	Respective emissions without ECS (Tons per year)	2155.83	251.177	24.692	25.842	
4.	No. of units with ECS	2	65	70	70	
	Respective emissions (25-79%) ave. 60% collection efficiency due to ECS installation) (Tons per Year)	37.4927	1632.65	1037.06	1085.36	
5.	Total PM emissions from all Steel induction units per year ECS (Tons) (with ECS + without ECS)	2193.33	1883.83	1061.76	1111.21	49.34%

Table 2: Calculation of emissions from boilers in Lahore during 2020-21 and 2023-24 based on 09 hours a days and 350 days a year.

		mg/m3	flow rate from all kind 600 Boilers m3/hr	Discharge mg/hr	Ton per hours	Ton per Day	Tons per Year	Reduction %
PM	2020-21	601.9	1940876.9	1168.21	1.28	11.58	4056.36	
PM	2023-24	451.4	1940876.9	876.16	0.96	8.69	3042.27	25%

The Table 3 demonstrates a significant reduction in particulate matter (PM) emissions from 600 boilers located in the District of Lahore between 2020-21 and 2023-24. This reduction is attributed to the continuous efforts of the Environmental Protection Agency (EPA) in promoting and enforcing the installation of Emission Control Systems (ECS), specifically Wet Scrubbers, on these boilers.

Table 3: Comparison of PM emissions from boilers in Lahore from 2020-21 to 2023-24.

Sr. No	Category of Industry		2020-21	2021-22	2022-23	2023-24	Reduction%
1	**Boilers** Total : 600 Boilers with ECS: 540	PM (Tons per Year)	4056.39	3934.69	3752.86	**3042.29**	25%

The data reveals a steady decline in annual PM emissions. In 2020-21, the total annual PM emissions from these boilers were 4056.39 tons. Through consistent interventions by the EPA, this figure decreased to 3934.69 tons in 2021-22, further reduced to 3752.86 tons in 2022-23, and ultimately reached 3042.29 tons in 2023-24. This represents a substantial 25% reduction in PM emissions over the four-year period.

This trend suggests that the EPA's initiatives to encourage and enforce the installation of Wet Scrubbers on boilers have been effective in mitigating PM emissions and improving air quality in the District of Lahore. These efforts are crucial for safeguarding public health and environmental sustainability in the region.

Conclusion: The data demonstrates a significant reduction in PM emissions from steel induction furnaces in the region between 2021 and 2024. This decline can be primarily attributed to the successful implementation of Emission Control Systems (ECS) in a large number of units.

In 2021, a substantial portion of PM emissions originated from units operating without any ECS. However, by 2024, a significant number of units (from 2 to 70) had installed ECS, leading to a dramatic decrease in emissions from these sources. This highlights the effectiveness of the policy interventions aimed at promoting and enforcing the installation of pollution control equipment.

Similarly, a significant reduction in Particulate Matter (PM) emissions from 600 boilers in the District of Lahore between 2020-21 and 2023-24. This positive trend can be attributed to the proactive efforts of the Environmental Protection Agency (EPA) in promoting and enforcing the installation of Emission Control Systems (ECS), specifically Wet Scrubbers, on these boilers. The observed 25% decrease in PM emissions over the four-year period highlights the effectiveness of these interventions in mitigating air pollution and improving air quality in the region.

This success underscores the importance of continued and sustained efforts by the EPA in monitoring, regulating, and enforcing environmental regulations within the industrial sector. By promoting cleaner technologies and incentivizing the adoption of pollution control measures, the EPA can play a crucial role in safeguarding public health and environmental sustainability in Lahore and beyond.

Recommendations:

- **Technological Upgrades:** Encourage and support research and development of more advanced and efficient ECS technologies, such as high-efficiency particulate air (HEPA) filters and advanced oxidation processes
- **Incentivize ECS Installation:** Explore and implement financial incentives, such as subsidies or tax breaks, to encourage ECS installation.
- **Regular Monitoring and Maintenance:** Establish a robust system for regular monitoring and maintenance of installed ECS to ensure their optimal performance and continued effectiveness.

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