IMPACT OF EPA ENFORCEMENT ACTIVITIES ON EMISSION REDUCTION OF BRICK KILNS IN PUNJAB

M. Nadeem[1], I. H. Sheikh[2], N. Naz[3], R. Haider[4*,] M. F. Alam[5], M. Arshad[6] and T. Mahmood[7]

[1] Environmental Protection Agency, Govt. of the Punjab, Lahore Pakistan)
[2]Director General Environmental Protection Agency, Govt. of Punjab, Lahore (Pakistan)
[3]Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
Director Research, Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
[5]Deputy Director (Lab), Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
[6] Assistant Director (Research), Environmental Protection Agency, Govt. of the Punjab, Lahore Pakistan)
[7]Research Assistant, Environmental Protection Agency, Govt. of the Punjab, Lahore (Pakistan)
Corresponding Author Email: rizwanchemist@gmail.com

ABSTRACT: This study aimed to quantify the reduction in greenhouse gas (GHG) and particulate matter (PM) emissions from the brick manufacturing sector in Punjab, Pakistan, following the increased adoption of Zigzag technology. Utilizing emission factors from our previous research by Sheikh I.H. *et al*. (2024), the study estimated emissions from brick kilns in 2019, assuming all kilns were traditional BTK type. Subsequently, considering the increased adoption of Zigzag kilns after June 2024 due to enhanced enforcement by the Punjab Environmental Protection Agency, emissions were recalculated based on the technology intervention in brick kilns. The results demonstrated a significant reduction, with a 16.08% decrease in GHG emissions and a 29.32% decrease in PM emissions from 2019 to December 2024. These findings highlight the positive environmental impact of the transition to Zigzag technology and emphasize the importance of continued policy enforcement and technological advancements in mitigating emissions from the brick industry.

Key words: Zig Zag, Bull Trench Brick Kiln, Coal, PM emissions.

(Received 20.09.2024 Accepted 02.12.2024)

INTRODUCTION

Brick kilns are one of the significant contributors to air pollution in South Asia, particularly in countries like Pakistan, India, and Bangladesh. Traditional brick kilns emit large quantities of pollutants, including Particulate Matter (PM2.5 and PM10), Black Carbon, Sulfur Dioxide (SO_2), Nitrogen Oxides (NO_x), and Carbon Monoxide (CO). Studies show that the combustion of coal, wood, and agricultural residues in outdated Fixed Chimney Bull's Trench Kilns (FCBTKs) contributes heavily to air pollution, especially during winter months when meteorological conditions favor pollutant accumulation (Guttikunda *et al*., 2021).

PM2.5 emissions from brick kilns exacerbate smog in urban centers like Lahore and New Delhi. A single traditional brick kiln is estimated to emit around 200–400 mg/m³ of PM2.5, far exceeding permissible limits (UNEP, 2022). These emissions lead to respiratory diseases, reduced visibility, and environmental degradation. Graphical trends indicate that brick kiln emissions peak during winter months due to increased demand for bricks and temperature inversions trapping pollutants at ground level (Ahmed *et al*., 2023).

The transition to cleaner technologies, such as Zig-Zag kilns and Vertical Shaft Brick Kilns (VSBKs), has demonstrated a reduction in PM emissions by 40–60%. However, the adoption rate remains slow due to financial and technical barriers.

Brick kilns are a significant source of air pollution, particularly in developing countries like Pakistan, India, Nepal, and Bangladesh, where outdated kiln technologies dominate the industry. Traditional Fixed Chimney Bull's Trench Kilns (FCBTKs), which make up over 70% of operational kilns, emit large quantities of Particulate Matter (PM2.5 and PM10), Carbon Dioxide (CO_2), Black Carbon, Sulfur Dioxide (SO_2), and Nitrogen Oxides (NO_x). These pollutants contribute to smog formation, global warming, and severe health risks, including respiratory illnesses and cardiovascular diseases (Gautam *et al*., 2022).

In South Asia, brick kilns operate intensively during the dry winter months, coinciding with the season of temperature inversions, which trap pollutants near the ground. Estimates suggest that brick kilns contribute to 10-15% of total PM2.5 concentrations in cities like Lahore, Dhaka, and Kathmandu during peak smog periods (Rashid *et al*., 2023). A single traditional kiln can release up to 30 tons of CO_2 annually, with a cumulative impact on regional air quality and climate.

Technological upgrades, such as the Zig-Zag Kiln design, have shown promising results in reducing

emissions by 60% for PM2.5 and 20% for CO_2 compared to traditional kilns. Despite the environmental benefits, only 30% of kilns in South Asia have transitioned to cleaner technologies due to limited financial resources and inadequate enforcement of environmental regulations (UNEP, 2022).

Seasonal patterns of emissions further reveal that PM2.5 levels from brick kilns peak in December and January, with urban centers reporting a 20–30% increase in PM2.5 concentrations during these months. Policy measures such as stricter emission controls, subsidies for cleaner kiln technologies, and regional collaboration are critical for reducing the environmental footprint of this sector (Hossain *et al*., 2023).

Brick kilns in Punjab have historically been a significant source of air pollution, characterized by the emission of thick black smoke due to the inefficient combustion of coal. This not only contributed to severe air pollution in the region but also posed serious health hazards to nearby communities and the environment. To address this critical issue, the Punjab Environmental Protection Agency (EPA) has taken a proactive approach by enforcing the conversion of traditional brick kilns to more environmentally friendly Zigzag technology. The Punjab EPA has played a crucial role in driving the transition by implementing regulations that either mandate the conversion of existing kilns to Zigzag technology or prohibit the operation of traditional kilns.

MATERIAL AND METHODOLOGY

The first source for this study is the survey data of Urban Unit, Govt of Punjab for ten district of Punjab namely Lahore, Kasur, Sheikhupura, Sahiwal, Okara, Pakpatten, Layyah & Minwalai, Bhakar & Bahawalnager to assess population of Zigzag & non Zigzag brick kilns. Urban Unit conducted survey of 3339 brick kilns for ten districts and population of percentages of functional Zigzag Brick Kiln, functional Non Zigzag Brick Kiln & abandoned / non functional Brick Kilns were reported as 40.73%, 20.275%, 38.99% respectively. This percentage is applied on 10,000.00 brick kilns operating in Punjab to assess actual population of Zigzag & Non Zigzag Brick Kilns.

The second source for this study is the data of coal consumption taken reported by Economic Survey of Pakistan 2024 in its report as 3429000.68 ton for brick Sector for year 2024. The set percentage of Urban Unit data has been applied for functional brick kilns in Punjab which comes as 312.26 ton per functional brick kiln for year 2024.

The third source of data of emission factors for one million brick baking for present study has been taken from our previous study (Sheikh I.H. *et al*., 2024). In instant study the said emission factors have been applied for all functional brick kilns in Punjab.

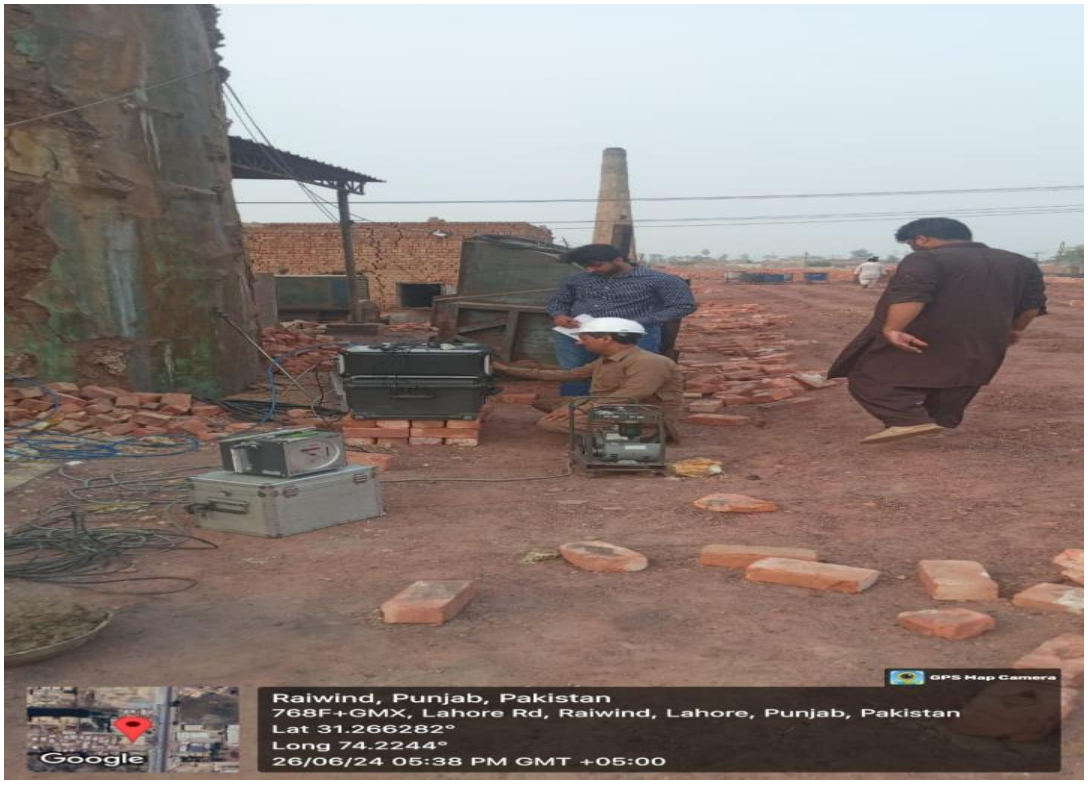

Figure 1: Exhaust emissions monitoring from a Brick Kiln in Raiwind Lahore

RESULT AND DISCUSSIONS

The Table 1 provides a snapshot of the brick kiln industry in Punjab, likely as of the end of 2024. Description is provided on the basis of Urban unit Survey data.

- **Total Brick Kilns:** The total number of brick kilns in Punjab is estimated to be 10,000.
- **Kiln Types:**
  - **Functional Non-Zigzag:** 2028 kilns are currently operating using traditional, non-Zigzag methods.
  - **Abandoned/Dis-functional:** 3899 kilns are no longer in operation.
  - **Functional Zigzag:** 4073 kilns have been converted to the more environmentally friendly Zigzag technology.
- **Coal Consumption:** The total coal consumption across all functional brick kilns in 2024 is estimated to be 3,429,000.68 tons.
- **Coal Consumption per Kiln:** On average, each functional brick kiln consumes approximately 312.62 tons of coal annually.

Table 1: Data of Brick Kilns and Coal consumption in Punjab, during 2024 (Urban Unit, 2024).

Sr. No	Total Brick Kiln In Punjab	Functional Non Zig Zag	Abondouned / Dis-Functional	Functional Zigzag	Total Coal Consumption Year 2024 (Tons)	Coal Consumption per Functional Brick Kiln (Tons)
%age	-	20.275%	38.993%	40.73%	3,429,000.68	312.62
Brick Kiln in Punjab	10,000*	2028	3899	4073		

Table 2: Reduction of CO2 and PM emissions from Brick Kilns during 2024.

Parameter Description	Kiln Type	Emission Factors	Emissions from Brick kiln in year 2019 (KTons)	Emissions from functional Brick kiln till June 2024 (KTons)	Emissions for functional brick kiln after June 2024 (KTons)	Total Reduction
CO2/GHG Per Million Brick Baking(Tons)	BTK	374.43	462.447243 (all BTK)	153.7195556	-	-
CO2/GHG Per Million Brick Baking(Tons)	Zig Zag	445.039	-	259.7455683	330.7149 to 350.1687	-
Total			**462.447243**	**413.4651239**	330.7149 to 350.1687	**-**
Reduction percentage				**-10.59%**	**-5.33 to -5.64%**	**-15.92 to -16.23**
PM emission per Million Baking of Bricks (Tons)	ZigZag	0.81557	-	5657.685	7616.2735	
PM emission per Million Baking of Bricks (Tons)	BTK	1.46322	10571.22	3513.923	-	
Total			10571.22	9171.607	7616.2735	
Reduction percentage				**-13.24%**	**-15.92 to -16.23% =Ave. 16.08%**	**Ave. -29.32**

According to EP Aprevious study, coal consumption per functional brick kiln is used to calculate annual brick production per functional brick kiln and it is estimated as 1.70319 million bricks for Zigzag & 1.46322 million bricks for BTK (Sheikh I.H. *et al*., 2024). The previous articles also reports about emission factors of Particulate Matter (PM) and GHG gases against per million brick production. These emission factors have been applied to estimate PM & GHG reduction in brick sector of Punjab since 2019 to end of December 2024.

Results of the current study are shown in Table 2. In this present study, it has been assumed that in year 2019, most of the brick kilns were operating on BTK and hence emissions have been assessed for this year

accordingly. After 2019 to June 2024, both type of Zigzag and non Zigzag brick kilns practically exist. After report of Urban Unit, EPA expedited its stringent enforcement activities for conversion of BTK to Zigzag technology. According to initial survey 85-90% of the total brick kilns have been converted to Zigzag technology for which the emission reduction has been calculated.

This conversion of zigzag brick kiln showed 16.08% in reduction of Green House gases and 29.32 % reduction in PM since 2019 to December 2024. The substantial emission reduction was achieved by EPA enforcement activities as indicated in the Table 2.

Key Findings:

- The conversion of BTKs to Zigzag technology has indicated substantial emission reduction.
- The vigilant enforcement activities by the EPA Punjab have played a crucial role in the adoption of Zigzag technology.

Conclusion: This study aimed to analyze the emission reductions achieved through the conversion of traditional brick kilns (BTK) to Zigzag technology by EPA enforcement activities in Punjab, Pakistan from 2019 to 2024. During 2019, almost all brick kilns were operating on conventional BTK technology. By gradual EPA interventions 85-90%of conventional BTK have been converted to Zigzag technology by the end of year 2024 leading to 29.32% reduction of PM and 16.08% reduction of CO_2.

Recommendations

- **Continued Enforcement:** Maintain and strengthen the enforcement of regulations promoting the adoption of Zigzag technology and discouraging the operation of traditional BTKs.
- **Incentivization:** Explore incentives for brick kiln owners to support transition from BTK to Zigzag technology, such as subsidies, financial assistance, or access to credit.
- **Research and Development:** Invest in research and development to further improve the efficiency and environmental performance of Zigzag and other modern brick kiln technologies.

REFERENCES

Ahmad, F., Shah, G. M., Pradhan, B. B., & Dixit, R. (2022). *Towards an environment-and-worker-friendly brick kiln sector in Punjab*. Pakistan. Working Paper, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Ahmed, N., Raza, S., & Khan, F. (2023). *Impact of Traditional Brick Kilns on PM2.5 Levels in Urban Environments*. Environmental Monitoring and Assessment, 195(5), 405-412.

Economic Survey of Pakistan, (2024).

Gautam, S., Shrestha, P., &Aryal, R. (2022). *Environmental and Health Impacts of Brick Kilns in South Asia*. Atmospheric Pollution Research, 13(3), 245-258.

Guttikunda, S. K., Begum, B. A., &Wadud, Z. (2021). *Air Pollution from Brick Kilns in South Asia: A Review*. Atmospheric Environment, 246, 118131.

Hossain, A., Begum, M., & Chowdhury, S. (2023). *Mitigating Air Pollution from Brick Kilns: Policy Interventions in Bangladesh*. Journal of Cleaner Production, 385, 135-145.

Rashid, T., Ahmed, R., & Khan, F. (2023). *Brick Kiln Emissions and Their Role in PM2.5 Pollution: A Case Study of Lahore*. Journal of Environmental Management, 325, 115431.

Sheikh, I. H., Naz, N., Nadeem, M., Hussain, F., Alam, M. F., Haider, R., ...& Malik, S. A. (2024). COMPARISON OF EMISSIONS FROM DIFFERENT BRICK KILN TECHNOLOGIES IN PUNJAB PAKISTAN. Pakistan Journal of Science, 76(3), 363.

UNEP. (2022). *Cleaner Brick Production in South Asia: Challenges and Opportunities*. United Nations Environment Programme.

UNEP. (2022). *Mitigating Air Pollution from Brick Kilns in South Asia*. United Nations Environment Programme.

Urban Unit (2024). Brick Kiln Survey Data.