COMPARISON OF EMISSIONS FROM DIFFERENT BRICK KILN TECHNOLOGIES IN PUNJAB PAKISTAN

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ABSTRACT: This study investigates the environmental emissions from different brick kiln technologies, including Fixed Chimney Bull's Trench Kiln (FCBTK), Zigzag (High Draught), Natural Draught Zigzag, and Improper Zigzag Technology. The results show significant variations in particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) emissions, as well as emission loads of multiple pollutants. The Zigzag is identified as an environmentally friendly and low emission technology as compared to FCBTK and improper Zigzag technologies.

Key Words: Zig Zag, Brick Kilns, emissions, Iso Kinetic

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INTRODUCTION

Different brick kiln technologies contribute to air pollution at varying levels due to differences in combustion efficiency, fuel use, and design. Fixed Chimney Bull's Trench Kilns (FCBTKs) emit significant amounts of pollutants such as PM2.5, sulfur dioxide (SO_2), and carbon dioxide (CO_2), primarily due to inefficient fuel combustion. Studies highlight that adopting Induced Draught Zigzag Kilns (IDZKs) can reduce PM2.5 emissions by 20-40% and black carbon emissions by around 30-55% compared to FCBTKs (Raza et al., 2023; MDPI, 2019).

Additionally, Vertical Shaft Brick Kilns (VSBKs) are among the cleanest technologies, producing the least amount of atmospheric pollutants. These kilns consume less energy and emit significantly lower amounts of PM10, CO, and NO_x compared to conventional kilns. Tunnel kilns, which are often more energy-efficient due to continuous firing processes, rank slightly below VSBKs in emission reduction potential but still outperform older FCBTKs and clamp kilns (Longdom, 2023).

Transitioning from older technologies like FCBTKs to more efficient designs, such as zigzag and VSBKs, plays a crucial role in mitigating the environmental impact of brick manufacturing. Such shifts also align with sustainable development goals by reducing fuel consumption and greenhouse gas emissions (MDPI, 2019; Longdom, 2023).

Brick kilns are significant sources of air pollution, emitting various harmful pollutants depending on the technology and fuel used. Traditional technologies like Fixed Chimney Bull's Trench Kilns (FCBTK) are prevalent in many developing countries, including Pakistan. These kilns typically burn low-grade coal, bagasse, or wood, resulting in emissions of particulate matter (PM2.5), black carbon, sulfur dioxide (SO_2), and carbon monoxide (CO). The inefficient combustion in these setups leads to significant environmental degradation and health impacts in nearby communities.

Recent research suggests that switching to more modern technologies, such as Induced Draught Zigzag Kilns (IDZK), can reduce pollution significantly. IDZKs improve combustion efficiency by altering the airflow within the kiln, resulting in approximately 30% lower CO_2 emissions and up to 35% reductions in PM2.5 emissions compared to FCBTKs. Additionally, emissions of black carbon, a potent climate forcer, can be reduced by 80% with this technology. Cleaner kilns also contribute to a decline in acidification and photochemical pollutants, reducing local environmental impacts such as smog formation and soil degradation.

A study conducted in Nepal and Pakistan found that the adoption of zigzag technology also enhances energy efficiency, demanding 30% less fuel for the same production output. These improvements not only reduce operational costs for kiln owners but also align with global climate mitigation goals by cutting greenhouse gas emissions (Raza et al., 2023; Zavala et al., 2018). Brick kiln technologies emit varying amounts of pollutants based on design and fuel efficiency. Conventional Fixed Chimney Bull's Trench Kilns (FCBTKs) release high levels of PM2.5, black carbon, CO, and SO_2 due to inefficient combustion. However, transitioning to Induced Draught Zigzag Kilns (IDZKs) can reduce PM2.5 emissions by approximately 40% and black carbon emissions by 55% through improved airflow and combustion (Raza et al., 2023). Another study highlights that Hoffman kilns are more energy-efficient, producing fewer CO_2 emissions than traditional kilns (Zavala et al., 2018; MDPI, 2019).

In the year 2017, EPA Punjab with the collaboration of ICIMODE introduced a zigzag methodology which is not only environment friendly but also feasible for brick kiln industry due to its low consumption of coal and relative high yield of quality bricks. EPA Punjab adopted the ZigZag Methodology in its policy and old technology brick Kilns had been banned and multiple legal and technicals steps were taken to promote zigzag methodology. However, majority brick kilns have been converted into zigzag methodology. The purpose of this study is to study the comparison of different brick kiln technologies operating in Punjab.

METHODOLOGY

In this study EPA Punjab selected four brick kilns on the basis of technology and fuel.

FIXED CHIMNEY BULL'S TRENCH KILN (FCBTK- Old Technology), High draught zigzag Methodology, Natural draught zigzag technology, Biomass Fired Improper Zigzag Methodology are the major technologies which are being considered in this study.

The sampling and monitoring have been conducted by complying reference methods such as US-EPA Method 3A, 7E, 6C, 10 & European Standards EN15267-1 (2009), EN15267-2(2009), EN15267-4(2017), EN14793(2017), EN14181(2014) for continuous and short term emissions measurement for SO2, NO, NO2, CO, O2, CO2, etc. In case of particulate Matter (PM) sampling / measurement, An Iso-kinetic Stack assembly has been used which compiles Japanese Industrial Standards (JIS) ZIS-8808.

The sample of stack emissions was taken from 10-15 feet above the graybrick surface. During sampling the calculated quantity of fuel was fed as prior calculated on the basis of total coal used for bricks baking in complete brick baking cycle.

The feeding interval was inspected on different scenarios. It was inspected that the feeding interval and the interval was of 45 minutes for FCBTK while in case of zigzag the feeding of fuel was continuous or semi-continuous. On fuel feeding in FCBTK, it was observed that it took approximately 5 minutes for smoke to reach the top of the stack and started to show black smoke and then upon stopping the feeding of fuel, it took around 12-15 minutes to turn the black smoke into white color. It was observed that in the interval of 45 minutes the black smoke emission time is approximately 12-15 minutes and for white smoke emission interval is ranging between 30-32 minutes.

The portable multi-gas Analyzer (PG-350, Horiba Japan) is used for measuring concentration of flue gases. The used analyzer is reliable equipment which is TUV & MCERTS Certified product. Iso-Kinetic Sampling Apparatus is used to collect sample for Particulate Matter (PM). Iso- Kinetic Sampling Technique refers to collecting airborne particulate matter in which the collector is so designed that the airstream entering the collector it has a velocity equal to that of the air passing around and outside the collector. The advantage of isokinetic sampling lies in its accuracy and freedom from the uncertainties due to selective collection of only the larger, less easily deflected particulates. In principle, an isokinetic sampling device can efficiently collect all sizes of particulates in the sampled air.

RESULTS

The results elaborated in Table 1 show that the M/S Union Bricks, a High Draught Zigzag kiln, had relatively lower SO2 and CO emissions compared to the other kilns. However, the M/S BTK Bricks, an FCBTK kiln, exhibited the highest CO emissions, indicating potential issues with incomplete combustion. The M/S Sultan Bricks, an Improper Zigzag kiln, showed the highest SO2 emissions, likely due to its inefficient design and operation.

Regarding coal consumption, the M/S BTK Bricks consumed the most coal per baking cycle, suggesting lower efficiency. The M/S Saddique Bricks, a Natural Draught Zigzag kiln, had the lowest coal consumption among the four kilns.

The Figure 1 shows CO2 emissions from different technologies of brick kilns. The Natural Draught Zigzag showed 15.47% decline and blower Zigzag Brick Kiln Showed 14.72% decline in GHG (CO2) as compared to FCBTK. Some Indian studies are indicating CO2 emissions 105g/kg (per kg Brick) or less. Zigzag brick kilns showed CO2 emission close to base value (i.e.105g/kg) Zigzag (Biomass) showed and FCBTK showed very high increase of GHG as compared to base value. The emission pattern of CO2 found against 1 million brick baking also showed low emission for Zigzag Brick Kilns.

Scientifically, the excess air 15% to 30% is recommended for kilns / furnaces. The efficient coal burning in Cement mill kilns, power plants kilns is achieved at this base value of excess air. The fire into brick kiln is also a type of kiln / furnace and ICIMODE recommends 300% excess air for zigzag methodology which is too much high. As shown in Figure 2, and Table 2too much excess air causes loss of fuel, emissions at higher side and even manipulation in blackness of smoke can be easily achieved by addition of excess air. Brick kilns operators have not defined guidelines to maintain constant level of excess air and it is maintained by hit & trial method. This study observed 5% extra fuel consumption due to too much excess air and the same may be saved by limiting values of excess air into zigzag & other methodologies.

Table 1: Emissions and coal usage in different technologies of Brick Kilns

Sr. No	Name of Brick Kilns	M/S Union Bricks, Raiwind, Lahore (High Draught Zigzag)				M/S Saddique Bricks, Kot Radha Kishen, District (Natural Draught Zigzag)				M/S BTK Bricks, Kot Radha Kishen, District Kasur (FCBTK)				M/S Sultan Bricks, Jalapur Pirwala, Multan (Improper Zigzag)			
-	Monitoring Date	26.06.24				27.06.2024				27.6.24				04.07.24			
-	Parameters	with Excess Air		Without Excess air	Load	with Excess Air	Without Excess air	Load	with Excess Air	with Excess Air		Without Excess air	Load	with Excess Air		Without Excess air	Load
-	Measuring Units	ppm	mg /NM^3	mg /NM^3	kg/hr	Ppm	mg /NM^3	mg /NM^3	kg/hr	ppm	mg /NM^3	mg /NM^3	kg/hr	ppm	mg /NM^3	mg /NM^3	kg/hr
1	Oxygen (O2)	16.53%	16.53%	-	-	18.137%	18.13%	-		11.073%	11.073%	-		15.47%	15.47%	-	
2	Carbon Dioxide (CO2) / GHG	3.38%	3.38%	-	480.04	1.839%	1.839%	-	486.5530	8.415%	8.415%	-	475.4689	4.3%	4.3%	-	438.6174
3	Carbon Monoxide (CO)	561.6	702.00	2487.691	4.2800	131.15	163.94	1154.90	1.7002	2961.3	3701.63	7584.46	8.0827	2193.67	2742.09	9907.29	12.5011
4	Sulfur Dioxide (SO2)	283.8	810.86	2873.450	4.9437	103	294.29	2073.18	3.0520	2145.64	6130.40	12560.92	13.3860	21.067	60.19	217.47	0.2744
5	Oxides Of Nitrogen (NOx)	4.9	10.06	35.659	0.0613	3.73	7.66	53.96	0.0794	7.4	15.20	31.14	0.0332	19.57	40.19	145.20	0.1832
6	Particulate Matter (PM)		171.5	820.2159	1.0456		93.0	703.474	0.9645	-	954.3	2028.980	2.0838		342.9	1319.818	1.5633
7	Excess Air (%)	378.26				656.42				112.67				700			
8	Flow Rate with Excess Air (NM^3/Hr)	6098.87				10370.72				2185.918388				4558.97			
9	Baking Cycle (Days)	39				33				45				35			
10	Coal consumption in baking cycle (Tons)	231				210				264				213.6			
11	Average weight of baked brick (Kg)	3.4145				3.4303				3.425				2.52875			
12	Bricks Baked per Baking Cycle (M)	1.2				1.2				1.0				1.0			
13	Average Coal Burning Rate:	246.79				265.15				244.44				254.2857143			

Studies reports that the yield for first class bricks is about 85% and the same yield for BTK is about 55%. But is present study it has been observed that none of zigzag is achieving its desired limit. However, the BTK surprisingly is yielding bricks of good quality than the base vales.

The PEQS for PM is 500mg/Nm3. While interpreting level of PM without excess Air, none of the brick Kiln Technology complies with PEQS. However, the natural draught Zigzag, Zigzag (Induced), showed decline in PM as compared to BTK. Improper Zigzag showed increase of PM.

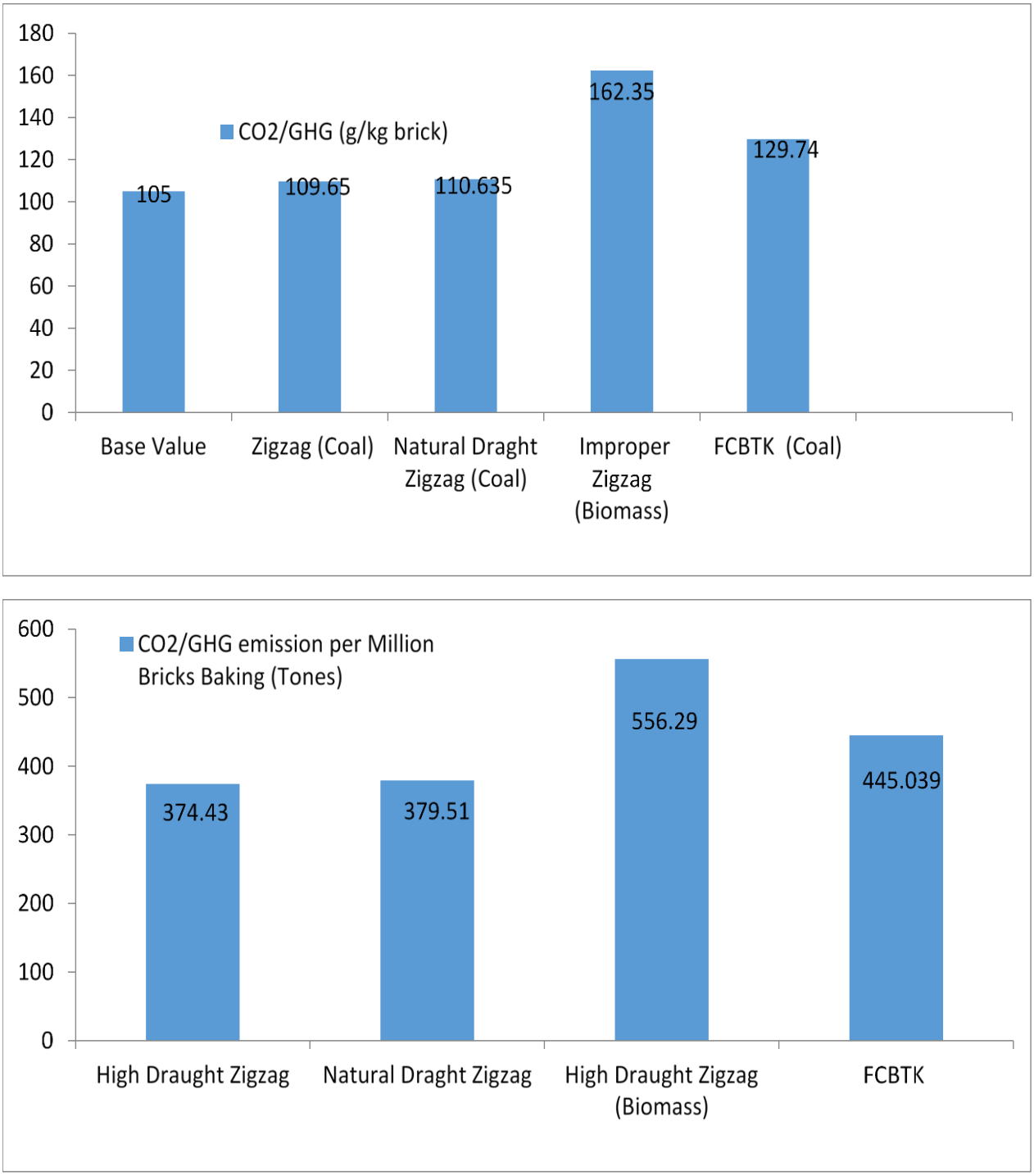

Figure 1: CO2 emissions from different technologies of brick kilns

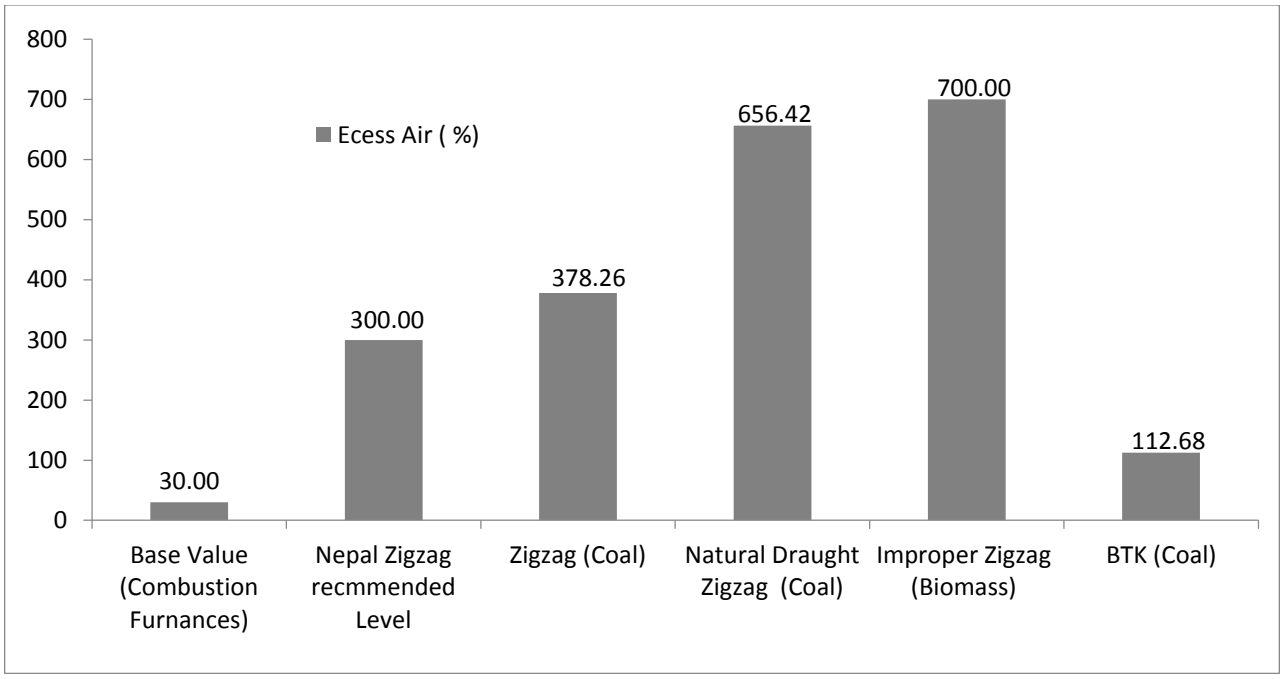

Figure 2: Recommended and observed excess air

Table 2: Heat loss and extra coal usage due to too high excess air

Brick Kiln Technology	Required Coal Amount Equivalent to Heat Loss due to excess Air (say calorific value 4300Kcal)	% age of extra Coal Consumption due to Heat loss due to of excess Air (for Complete baking Cycle)
Zigzag (Coal)	6.274271 Tons	2.716135 %
Natural Draught Zigzag	9.908428 Tons	4.718299%
BTK	0.754498 Tons	0.285795%

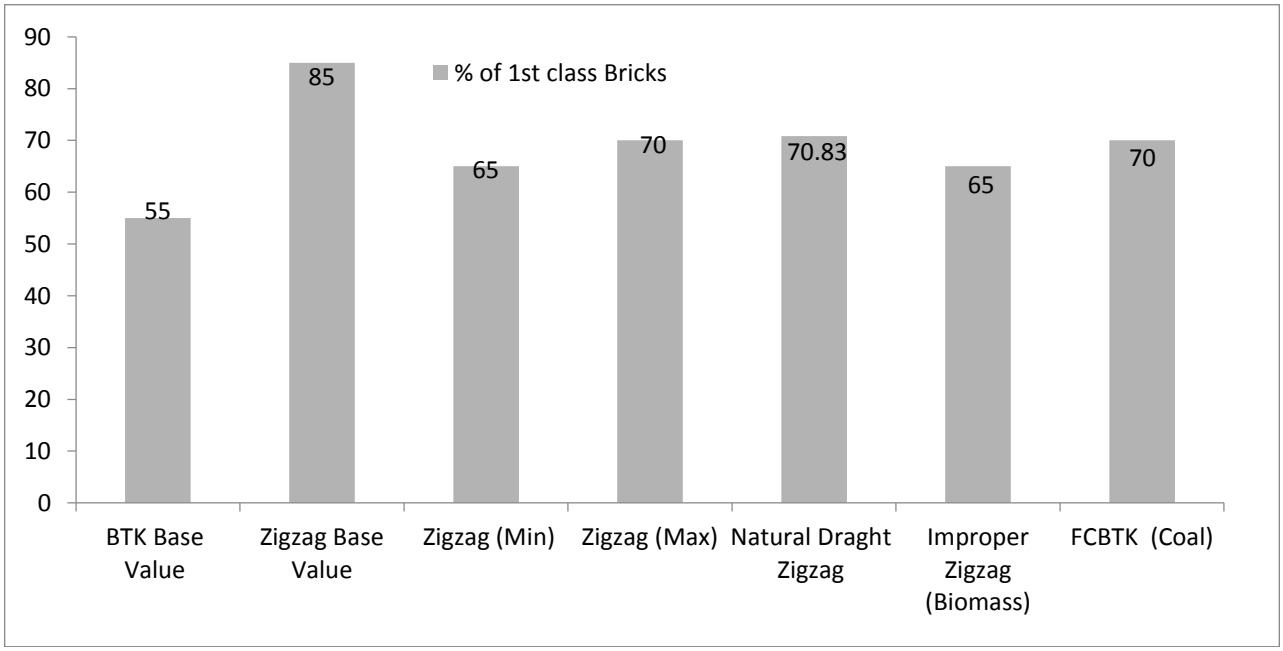

Figure 3: First Class bricks produced by different technologies of brick kilns

Figure 4: PM emissions per Kg of brick kilns

Carbon monoxide (CO) is very important pollutants which come out as a result of inefficient burning in combustion zone. At present, the entire monitored bricks kiln does not comply with PEQS (i.e. legal limits). However, some of High drought Zigzag showed remarkable design in CO emissions as compared to

FCBTK. Over Natural Draught Zigzag found at lowest level in term of CO emissions if counted on pollution load terminology.

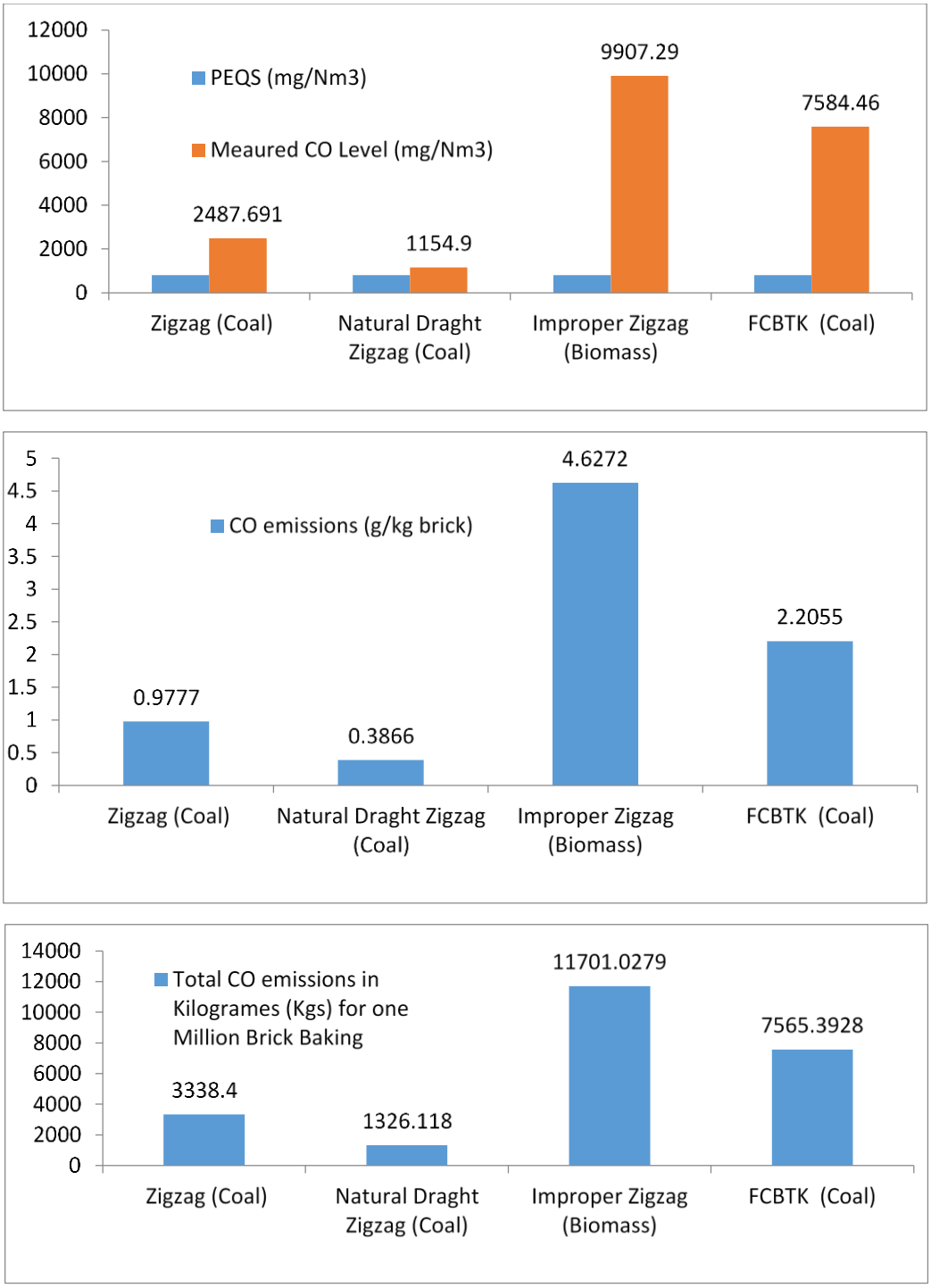

Figure 5: CO emissions from different brick kilns

Sulphur Dioxide (SO2) comes in flue gases of brick kilns due presence of Sulphur on Fuel Contents. The coal used in brick kilns is usually high in sulfur contents. Biomass has very low sulfur contents and its SO2 emissions are also at lowest than other technologies. The soil of gray bricks is usually alkaline in nature and

therefore it works as scrubber for acid SO2. The contact time of SO2 / flue gases with gray brick sin zigzag methodology is at higher side than BTK and hence scrubbering of SO2 in zigzag is at higher side. Due to higher moisture contents in Zigzag, the SO2 converts itself into other sulphure compounds such as SO3, CS2, Sulphur Acids mist. The market equipments used by researchers usually do not measure converted form of SO2 and hence researchers wrongly assumes reduction of SO2 for zigzag methodologies or such emission sources which have high moisture contents. The inaccurate data in such cases has not been noticed by reviewers and publications are usually published on inaccurate data. The standards moisture separation techniques for flue gases without making loss of SO2 are too expensive and sometimes its cost is higher than cost of flue gas analyzer and the researchers often have no standard moisture removal techniques and reads inaccurate reading of soluble gases such as SO2, SO3, NOx, H2S, HF. Such converted forms of SO2 in its converted forms alternatively are measured accurately by employing reference methods of wet chemistry. At present, the all monitored bricks kiln does not comply with PEQS (i.e. legal limits) except biomass fired Zigzag. However, some of Zigzag showed remarkable decline in SO2 emissions as compared to FCBTK.

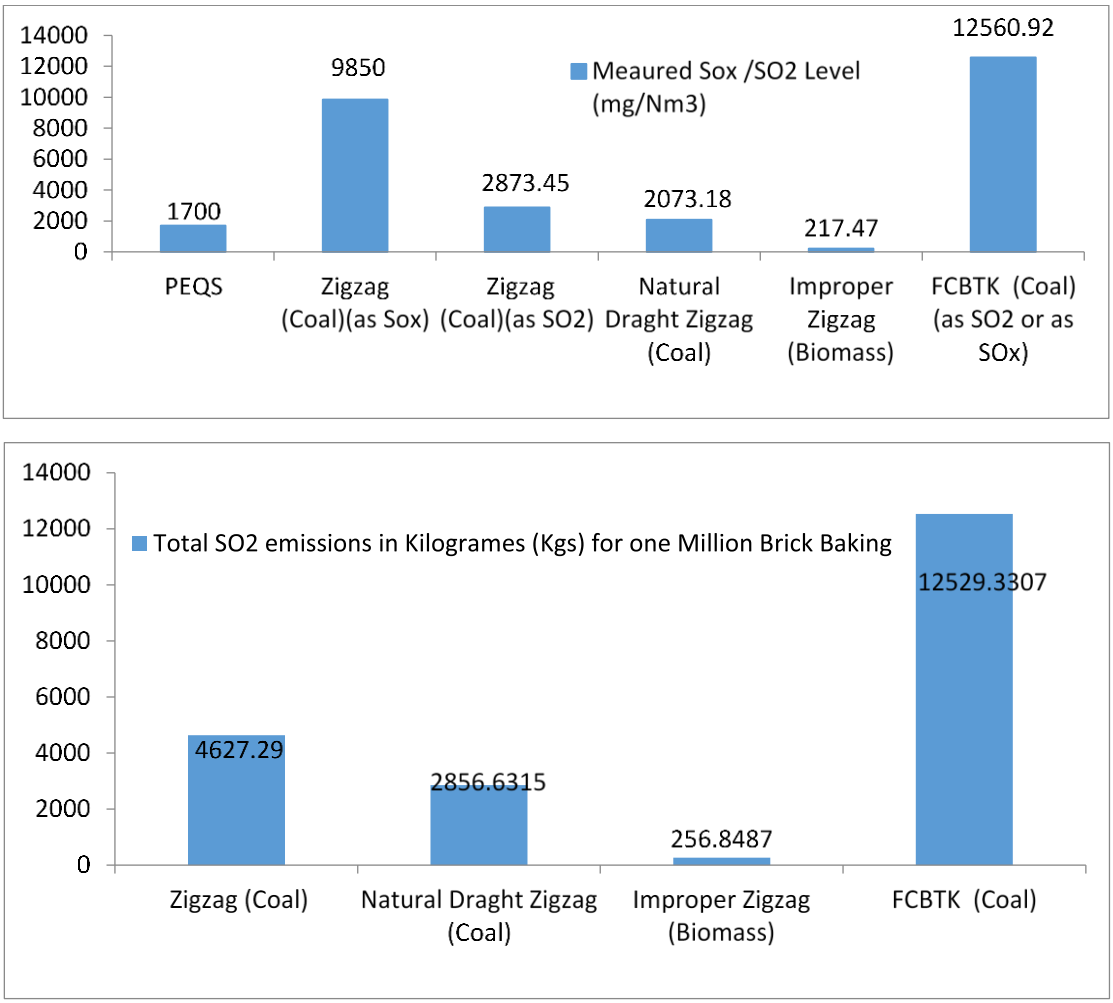

Figure 6: SO2 emissions from different Brick Kilns

Conclusion: The study concludes that the Natural Draught Zigzag technology is significantly more efficient and environmentally friendly compared to the traditional Fixed Chimney Bull's Trench Kiln (FCBTK). This is evident from the lower emissions of CO_2, Black Carbon, and Particulate Matter (PM), along with reduced fuel consumption. Despite the higher initial capital cost, the improved product quality and lower operational costs make the Natural Draught Zigzag technology a preferable choice for brick manufacturing.

The zigzag emissions vary greatly because majority of the Zigzag brick kilns are converted from FCBTK where no proper SOPs related to its Design

Manual has been followed and therefore such distorted / incomplete Zigzag Methodologies are causing greater emissions as compared to FCBTK.

In present study, no technology related to Vertical Shaft Brick Kiln (VSBK) has been identified so far within tutorial limits of Punjab. However, some regional studies and ongoing practices of National Pollution Control Board (NCPC), Government of India has recognized that VSBK is better & energy efficient than Zigzag and even brick community friendly due to its features such weather operations and highest yield for first class production (i.e. 90%).

Action Plan / Recommendations:

1. The Brick Kilns owners shall be directed to produce emission tests reports on quarterly basis and shall be directed to submit the same under provisions of SMART Rule, 2000.
2. The Design Manual & Operational Manual shall be formulated for zigzag Brick Kilns. The listed Zigzag brick Kilns in Punjab shall be verified as per proposed design & Operational manual to ascertain the compliance level with actual zigzag methodology.
3. The operational cost of Natural Zigzag Drought Brick Kilns is negligible as compared to High Drought Zigzag Brick Kilns which makes it long term sustainable. The Natural Zigzag Brick Kilns were included in design manual originally published by NEPAL & various Indian institutes. EPA Punjab previously assumed that the presence of blower / ID Fan is compulsory for Zigzag settings which is not technically suitable in the light of ground facts as well as the findings indentified under present study, where the emissions load of Natural Zigzag drought Brick kilns are found better than High drought Brick Kilns. Therefore, Natural draught Brick Kilns with Zigzag Pattern shall be included with policy of EPA Punjab.
4. Zigzag Brick Kiln Technology is not suitable for such brick kilns which have small capacity of brick production. India addressed this issue and it has introduced multiple brick baking technologies for brick kiln industry (i.e. Vertical Shaft Brick Kiln Technology-VSBK, Natural Zigzag Drought Technology, High Drought Zigzag Technology, use Piped Natural Gas as fuel in brick). The CPCB of Indian government has also notified industry specific permissible limits / standards for these brick kiln technologies. EPA Punjab confined itself into a shell of zigzag methodology and is hesitating to open for other technologies.
5. Vertical Shaft Brick Kiln Technology-VSBK is basically Chinese Technology which has been adopted by India & Bangladesh and currently, hundreds of brick Kilns are operating on the VSBK. It is also suitable for small enterprises also. The 1st class brick production is about 95% and it more energy efficient than Zigzag and even more environment friendly than Zigzag. The studies prove that PM emission for VSBK is 0.15g/kg which far better than High Drought Zigzag (0.24g/kg) and Natural Zigzag (0.22g/kg). EPA Punjab notified Smog Rules a couple of years before where brick technologies other than Zigzag have been locked which is not scientifically justified. These rules may be revised to give space for better technologies. EPA Punjab should focus on PEQS rather than technologies. The violation of PEQS under the umbrella of Zigzag Technology or any other technology is not permitted under Section 11 of Punjab Environment Protection Act-1997.
6. The study reveals that the considered zigzag brick kilns are not showing environment outcome as well as emission benefits as claimed for Zigzag Methodology (i.e. 30% coal reduction, 80-85% first class brick production) which is indicating that claimed zigzag are either improper or not fully compliant to zigzag methodology. Proper guidelines and check list may be formulated to evaluate the operation of zigzag after its conversion. The zigzag past efficiency of brick kiln may be evaluated on the basis of coal consumption and first class brick production. The saving of 30% fuel and production of 80-85% 1sts class bricks is good indicator to assess proper operation of brick kiln on zigzag methodology.

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