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Comparative Analysis of Gas Emissions from Ecokiln and Artisanal Brick Kiln during the Artisanal Firing of Bricks

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Abstract: This article focuses on the research of gas emissions in two types of brick kilns located in the Maule Region, Chile. One of them is an artisanal brick kiln known as a "chonchón" (AKC), while the other is a semi-artisanal brick kiln with an improved design. The latter is referred to as the Ecokiln. This study focuses on the assessment of the emission profiles of key pollutants such as particulate matter (PM), CO, CO_2, SO_2, and NOx. The emission measurements of gasses, temperature, and flow were conducted during the operation of the kilns. These measurements were carried out following the protocol established by Chilean standards. The Ecokiln's design facilitates optimal fluid dynamics. In direct comparison to the AKC, it exhibits reduced fuel consumption, shorter operation periods, an increased brick processing capacity, decreased burnt brick losses, and notably lower emissions, with a concentration of SO_2 that is 83% less than that of the AKC, NOx emissions, 58% lower than the AKC, and a remarkable 74.3% reduction in PM10 emissions. Moreover, the Ecokiln reduces pollutant emissions, improving the well-being of brickmakers and their communities. These results offer insights into the environmental impact of local brick production and support sustainable manufacturing practices.

Keywords: brick kiln; brickmakers; eco-design; environmental impact; gas emissions

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1. Introduction

Currently, clay brick is an essential construction material due to its physical and chemical properties acquired during the firing process. Various authors [1–4] propose that bricks should have the following characteristics: (1) it should be well-molded, meaning flat faces, parallel sides, and sharp edges and angles; (2) uniform, compact, with a glossy geometry free of impurities; (3) porous but not in excess to ensure good mortar adhesion; (4) devoid of soluble salts to prevent efflorescence; (5) it should produce a metallic sound when struck with a hammer or similar object, as this sound indicates that the brick is well-fired and free of defects like cracks; (6) it should have low thermal conductivity to function as a thermal insulator; (7) and it should not be overfired, as this could result in a purplish or blackish color, a vitrified and glossy structure, deformations, and cracks. While the brick may become very hard, its strength is compromised by the presence of cracks, and (8) it should not be underfired or too soft, as it could easily crumble and produce a dull sound. In summary, the characteristics of the brick depend on proper firing, resulting in a brick with a uniform color and a "clear and dry sound" when struck.

The firing of the brick is a physicochemical process because the physical and chemical properties of the clay interact, enhancing characteristics such as strength and water absorption. During this process, typically conducted in brick or ceramic kilns, the clay hardens and transforms into a solid and durable material due to its exposure to high temperatures (~1000 °C). Furthermore, the firing process influences the color and texture of the brick, allowing for the attainment of various tones and finishes for aesthetic purposes. Therefore, an inadequate firing process results in a brick with (1) low mechanical strength (<15 MPa), (2) high water absorption (>14%), and (3) abnormal color and texture [5]. This implies that it is necessary to carry out an efficient firing process in the brick kiln to obtain a brick with the desired characteristics.

Brick kilns vary in size and design, but they generally operate through the following stages: (1) the loading of raw materials (bricks), (2) loading of fuel, (3) initiation of firing, (4) brick firing, (5) cooling, and (6) brick extraction. Stage (4) is subdivided into the following six phases [6]: evaporation (20–150 °C), dehydration (149–650 °C), oxidation (300–982 °C), vitrification (900–1316 °C), flashing (1150–1316 °C) and cooling (1316–20 °C). In artisanal brick kilns that use wood byproducts as an energy source, the most significant emission of toxic gasses occurs during stage (3). This is because the combustion is not yet complete, and in its initial phase, the surface of the fuel, which contains adhered organic residues, is burned [7–9]. The primary purpose of brick kilns is to produce bricks with optimal characteristics for use in the construction industry. However, to achieve this goal, brick kilns often exhibit inefficient energy usage and emit toxic substances and greenhouse gasses into the atmosphere [6,10,11]. This is because traditional brick kilns, used in many countries, often lack adequate emission control technologies.

The emission of gasses from the brick kiln leads to the following least five problems: (1) the combustion of solids such as wood, coal, or agricultural residues can release fine particles (PM2.5 and PM10) and toxic gasses such as carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and volatile organic compounds (VOCs), which are harmful to human health and contribute to poor air quality [12–14]; (2) the contamination of nearby soil and water due to the release of ashes and combustion residues containing harmful chemicals [15–17]; (3) deforestation to obtain wood for fuel, negatively impacting local ecosystems and biodiversity [18–20]; (4) Greenhouse gas emissions, such as carbon dioxide (CO_2) and methane (CH_4), from the burning of fuels in brick kilns contribute to climate change and global warming, which has adverse effects worldwide [21–23]; and (5) brick kiln workers are at risk of experiencing respiratory problems, dermatitis, and other occupational health disorders due to their exposure to the inhalation of toxic fumes and contact with hazardous materials [24–26]. In recent years, there has been growing interest in developing strategies and technologies to reduce gas emissions in brick kilns with the aim of improving the environmental sustainability of this industry [27–29]. The study of emission sources, the types of pollutants released, and potential solutions to mitigate these impacts have become a priority for researchers. These investigations have led governments in various countries to establish stricter environmental regulations and best practices in the brick industry to reduce emissions and mitigate their environmental and health impact.

In several countries, control over pollutant emissions has been enshrined in regulations that seek to prevent or restrict the level of gas emissions generated during brick firing, primarily CO_2, CO, SO_2, NOx, and particulate matter (PM). For example, China is one of the largest producers of ceramic bricks in the world and has the GB 29620-2013 regulation, which applies to the entire ceramic tile and brick industry. This regulation governs the emissions of PM, SO_2, NOx, and fluorine (F) [30]. On the other hand, in Chile, emissions of pollutant gasses from brick kilns are regulated, albeit not directly and specifically, by the General Bases for the Environment Law, Law 19,300 [31], through the primary air quality standards for PM10, PM2.5, SO_2, NO_2, CO, Pb, and O_3, and the secondary air quality standard for SO_2 (see Table 1). These standards establish concentration limits in the ambient air around the source and conditions for the use of emission sources, such as brick kilns.

Table 1. Standards applied in Chile and their concentration limits in the air surrounding the source.

Standard	Pollutant	Limit	Reference
D.S. N° 12/2021	PM10	50 μg/Nm^3 annual 130 μg/Nm^3 24 h	[32]
D.S. N° 12/2011	PM2.5	20 μg/m^3 annual 50 μg/m^3 24 h	[33]
D.S. N° 104/2018	SO_2	500–649 μg/Nm^3 hourly: alert 650–949 μg/Nm^3 hourly: pre-emergency >950 μg/Nm^3 hourly: emergency	[34]
D.S. N° 22/2009	SO_2	northern zone: 80 μg/Nm^3 annual southern zone: 60 μg/Nm^3 annual	[35]
D.S. N° 114/2003	NO_2	100 μg/Nm^3 annual 400 μg/Nm^3 hourly	[36]
D.S. N° 115/2002	CO	10 mg/Nm^3 in 8 h 30 mg/Nm^3 hourly	[37]
D.S. N° 136/2000	Pb	0.5 μg/Nm^3 annual	[38]
D.S. N° 112/2002	O_3	120 μg/Nm^3 in 8 h	[39]

Specifically in the Maule Region (the location of the case study in this research), there are Air Pollution Prevention and Control Plans, such as Decree 49/2016 [40]. These plans are environmental management instruments that, through the implementation of specific measures and actions in areas considered to be saturated (where emissions exceed imposed limits), aim to reduce air pollution levels to safeguard public health. Additionally, Decree 29/2013 [41] is one of the regulations applied to emissions from brick kilns as it establishes emission limits for processes that involve fuel combustion (see Table 2). The limit values in Table 2 are based on gas flow containing 11% O_2. Therefore, if the O_2 percentage differs from this value, the measured pollutant concentration can be corrected according to Equation (1).

$$PC = MPC \cdot \left(\frac{21 - 11}{21 - MO} \right) \quad (1)$$

where PC is the concentration (mg/Nm^3) of the pollutant corrected to the standardized oxygen percentage (11%), MPC is the measured concentration (mg/Nm^3) of the pollutant, and MO is the measured oxygen percentage (%). Twenty-one is the concentration of oxygen in the air.

Considering all of the above, the objective of this research is to compare the quality of gas emissions from two brick kilns, one of which is a traditional artisanal kiln (AKC), and the other is an improved version of the artisanal kiln, known as Ecokiln. The purpose of the contribution of this study is to provide the rural community of the Maule Region with an efficient semi-artisanal brick kiln characterized by reduced emissions and lower energy consumption. This contribution translates into significant improvements in the health of the residents in this area. Additionally, the study aims to identify the technological solutions integrated into the Ecokiln that enable a reduction in emissions and an improvement in energy efficiency in these firing systems. The originality of this article lies in the results obtained from a full-scale brick kiln (Ecokiln) designed and built by the authors of the study. This kiln was created in accordance with the specific requirements of operators in rural areas, ensuring its operational simplicity and aligning with the characteristics of artisanal brick kilns. Among the main findings of this research are that the Ecokiln's design allows for proper fluid dynamics, and, when compared to firing in the AKC, it consumes less fuel, operates for shorter durations, processes more bricks, and experiences fewer losses of burnt bricks. Furthermore, the Ecokiln emits fewer polluting gases, thereby enhancing the quality of life for brickmakers and their neighboring communities.

Table 2. Emission limits for processes that incinerate fuel [41].

Pollutant	Emission Limit (mg/Nm^3)
PM	30
SO_2	50
NOx	300
CO	50
Total organic carbon	20
Cadmium and its compounds	0.1
Mercury and its compounds	0.1
Beryllium and its compounds	0.1
Lead + Zinc and their compounds	1
Arsenic + Cobalt + Nickel + Selenium + Tellurium and their compounds	1
Antimony + Chromium + Manganese + Vanadium	5
Gaseous chlorinated inorganics	20
Gaseous fluorinated inorganics	2
Benzene	5
Dioxins and furans	0.2×10^{-6}

2. Materials and Methods

Figure 1 depicts the Ecokiln and the AKC during the brick-firing process. The Ecokiln is a down-draft brick kiln, while the AKC is an open kiln without fixed walls (rectangular) [6]. The Ecokiln's dimensions are as follows: 4.8 m (width), 8.8 m (length), and 3.8 m (height), with a chimney height of 15.5 m. In contrast, the AKC has a square base with a side length of 5 m, an upper square face with a side length of 4 m, and a height of 2.4 m [6,42]. The Ecokiln and the AKC operate for 16 h (producing 28,000 fired bricks) and 36 h (producing 18,000 fired bricks), respectively. The Ecokiln is a device for brick production that optimizes the use of energy resources. It includes a preheating zone, a cooking zone with a combustion chamber, and a cooling zone with a third means for air supply and means of an air outlet, allowing the generation of a third form of airflow. The three zones are successively connected by a transport path that facilitates the movement of bricks. Additionally, the device features the first means for air supply and means for air outlet in the preheating zone, generating the first form of airflow; fuel supply means in the combustion chamber, in communication with the second means for air supply, generating a second form of airflow; and control means to regulate the supply of air and fuel to control heat generation, as well as the direction and circulation of the first, second, and third airflows within the device [42].

The brick used in the firing process is prepared by manually mixing clay, and this mixture is then fed into the extruder's feeding hopper (30 hp, MC-23, Maquinas MAN, Marília, Brazil), which produces a brick designed by the authors of this study [43].

Both kilns use sheets of Pinus radiata bark, locally known as "lampazo", as fuel (see Figure 2). This type of fuel, characterized by a moisture content of 16.8 ± 0.5%, is manually and intermittently added to the kilns.

The emission measurements of gasses, temperature, and flow are conducted during the operation of the kilns. The measurement of gas emissions was conducted between the end of the dehydration stage and the beginning of the oxidation stage. These measurements were carried out following the protocol established in the Exempt Resolution N°2051 [44], where the sampling operational conditions were specified according to the emission source. For the AKC, the protocol suggests the use of a provisional chimney to contain gas emissions, and this recommendation was followed. This protocol sets a sampling time of 4 h for brick kilns. Additionally, the protocol recommends equipment, instruments, and accessories for the measurements. Table 3 shows the equipment used in both kilns for measuring the parameters of the brick-firing process. In this research, emission measurements were recorded every 30 s.

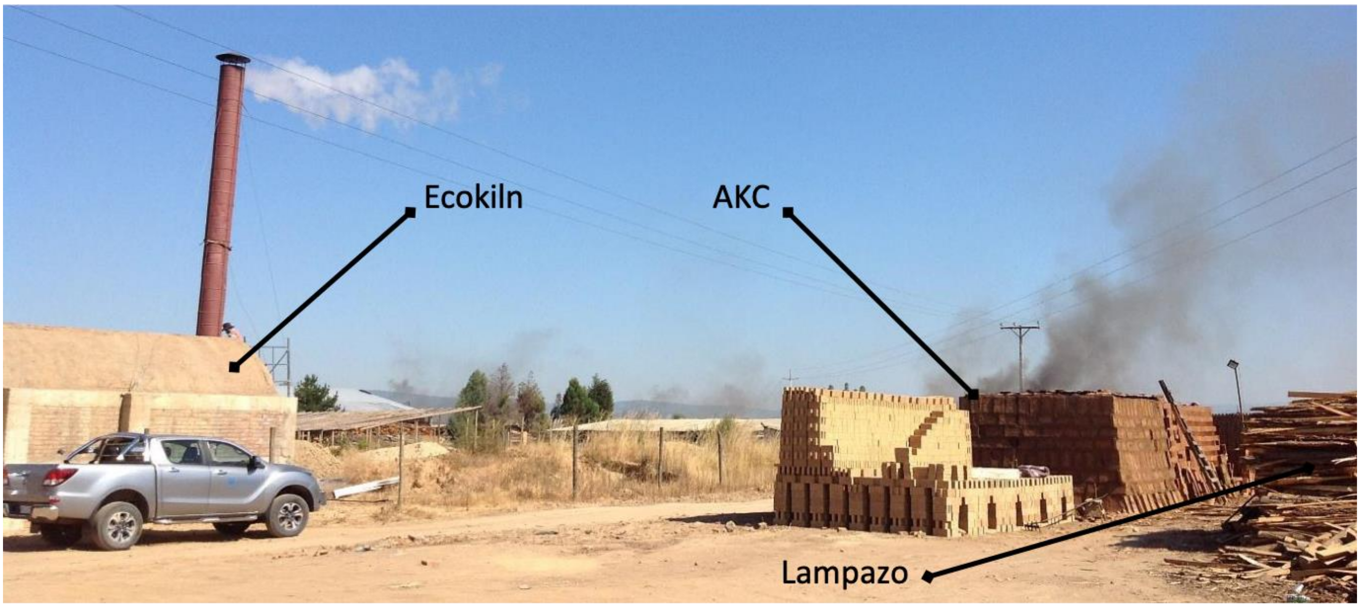

Figure 1. Photograph of the brick kilns: Ecokiln and AKC.

Figure 2. Photograph of the "lampazo".

Table 3. List of equipment or instruments for measuring the parameters of the brick-firing process in both kilns.

Parameter	Equipment or Instrument	Characteristics
NOx	Gas analyzer: NOxMAT 600 (Siemens ®, Munich, Germany)	Measures from 10 ppb to 3000 ppm full scale (NO/NOx) [45].
CO	Gas analyzer: Gassboard-3000 Plus (Cubic-Ruiyi Instrument Co., Wuhan, China)	Measures from 0 to 9999 ppm [46].
CO_2	Gas analyzer: Gassboard-3000 Plus (Cubic-Ruiyi Instrument Co.)	Measures from 0 to 25% [46].
SO_2	Gas analyzer: Gassboard-3000 Plus (Cubic-Ruiyi Instrument Co.)	Measures from 0 to 9999 ppm [46].
O_2	Gas analyzer: Gassboard-3000 Plus (Cubic-Ruiyi Instrument Co.)	Measures from 0 to 25% [46].

Table 3. *Cont.*

Parameter	Equipment or Instrument	Characteristics
Particulate material	Isokinetic: Method 5 Isokinetic Control Console (CleanAir Engineering, Palatine, IL, USA)	Parts: pump, dry gas meter, manometer, timer, umbilical power output connection, auxiliary power output connection, Pitot inlet connections, sample inlet connection, pumpless, temperature controllers and thermocouple connections [47].
Gas flow	Flowmeter: Pitot tube type S (CleanAir Engineering)	Digital caliper: 0–150 mm (±0.01 mm) Protractor: 0–360° (±5′) [48].
Gas temperature (chimney)	Thermocouple type K (Walfront LLC, Lewes, DE, USA)	Measures from 0 to 400 °C, 200 mm [49].
Gas temperature (kiln)	Thermocouple type K, data logger 175T3 (Testo SE & Co. KGaA, Alta Selva Negra, Germany)	Measures from −50 to 1000 °C (±0.5 °C) [50].
Gas humidity	Gas hygrometer: Wet gas meter W-NKoDa-10A-ST (Shinagawa Co., Tokyo, Japan)	Operating pressure limits: 0 to 10 kPa; operating temperature limits: 0 to 50 °C [51].
Fuel humidity	Wood hygrometer: Mini-Master H, HT (HTC) (Lignomat USA Ltd., Portland, OR, USA)	Measures from 6 to 75% [52].

During the brick-firing process, it was observed that the kiln reached its steady state after 4 h of ignition. Therefore, at that moment, the measurements of the process parameters were initiated.

3. Results and Discussion

The AKC used by the rural community in the Maule Region exhibits the typical issues of non-industrial brick kilns, namely, the inefficient use of energy resources, emission of polluting gases, and overfiring of bricks. This is why the Ecokiln was created to address the problems caused by the AKC in the brick-firing process. For instance, in this study, the AKC and Ecokiln used 70 and 20 m^3 of "lampazo" as fuel for firing 28,000 and 18,000 bricks, respectively, and the loss of bricks due to overfiring for the AKC and Ecokiln are 15% and 5%, respectively.

The kiln operators, relying on their on-site experience, refrained from adding fuel, leading to maximum temperatures of 823 °C and 982 °C in the firing chambers of the AKC and Ecokiln, respectively. Weyant et al. [53] argued that the vitrification temperature is contingent upon the composition of minerals within the clay, with particular emphasis on fluxing oxides such as ferrous oxide, lime, magnesia, and potash. Fluxing oxides play a pivotal role in reducing the vitrification temperature. This phenomenon accounts for a significant variation in firing temperatures observed across different locations, which can span a range between 800 °C and 1100 °C. Therefore, both kilns surpass the oxidation or carbonate decomposition stage, reaching the vitrification stage [6,53]. However, given that the maximum temperature in the Ecokiln is higher, it can be assured that it easily achieves the vitrification stage, allowing the bricks to attain the desired mechanical characteristics.

The measurements taken in the chimneys (see Table 4) of both kilns show some similarity in the results, with significant differences noted in humidity, flow, temperature, and pressure drop. These differences are attributed to the better fluid dynamics within the firing chamber of the Ecokiln, resulting in a higher flow rate, higher humidity, lower temperature, and greater pressure drop in the Ecokiln chimney compared to the AKC. This higher humidity is a result of the forced airflow displacing the water produced by wood dehydration and combustion. The lower temperature is due to Ecokiln's design, which enables the efficient utilization of thermal energy, allowing the combustion gasses to exit the chimney at the lowest possible temperature.

Table 4. Average values of the main process variables measured in the chimney.

Variable	Unit	AKC	Ecokiln
Humidity	%	7.26 ± 1.47	17.13 ± 1.90
Velocity	m/s	2.37 ± 0.03	2.43 ± 0.00
Flow	Nm^3/h	1192 ± 22	1680 ± 28
Temperature	K	554.77 ± 9.19	352.09 ± 1.64
Pressure	mmHg	753.00 ± 0.00	737.00 ± 0.01
Pressure drop (ΔP)	mmH_2O	0.25 ± 0.00	0.40 ± 0.00
Dry molecular weight	g/mol	29.54 ± 0.16	29.43 ± 0.16
Wet molecular weight	g/mol	28.70 ± 0.32	27.47 ± 0.24
Cross-section area	m^2	0.28	0.28

Figure 3 depicts the behavior of gas emissions (O_2, CO, CO_2, SO_2, and NOx) during combustion in both kilns, while the first column in Table 5 shows the average concentration of these emissions. In the graphs, the first 60 min are considered as the initial adjustment of the measurement equipment. The peaks correspond to the adaptation of the brick kiln following the moment when the operators add fuel to the combustion chamber. Additionally, considering that the Ecokiln operates for 66% less time than the AKC, Table 5 provides an estimation of the mass flow and total gas emissions, where the Ecokiln has between 50% and 89% less total gas emissions than the AKC. Therefore, the Ecokiln features a brick-firing process with fewer emissions of polluting gasses, and the higher O_2 flow is due to the Ecokiln operating with fans that enhance combustion. Furthermore, considering that the Ecokiln consumes 71% less fuel compared to the AKC, the total emitted mass/fuel volume indicator favors the Ecokiln, as it demonstrates a higher transformation of wood (*lampazo*) into direct combustion gasses, the lower emission of polluting gasses, and higher emission of O_2. This is because the Ecokiln features a design that enhances the gas fluid dynamics in the combustion chamber and inside the kiln. The results of emissions are more varied for the AKC, and higher peaks are observed compared to the Ecokiln, which is why the average emission value for the AKC is higher than the Ecokiln.

Table 5. Concentration, flowrate, and total emitted mass of carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NOx), and oxygen (O_2) for AKC and Ecokiln.

	Concentration (mg/Nm^3 for CO, SO_2 and NOx) (% for CO_2 and O_2)		**Flowrate (g/h)**		**Total Emitted Mass (kg)**		**Total Emitted Mass (g)/Fuel Mass (kg)**	
Type of Gas	**AKC**	**Ecokiln**	**AKC**	**Ecokiln**	**AKC**	**Ecokiln**	**AKC**	**Ecokiln**
CO	905.9 ± 352.1	678.6 ± 305.9	1079.9	1140.0	38.9	18.2	1.12	1.82
CO_2	5.9 ± 1.2	4.9 ± 3.4	68,205.9	79,241.5	2455.4	1267.9	70.16	126.78
SO_2	41.2 ± 21.9	7.1 ± 4.9	49.1	12.0	1.8	0.2	0.06	0.02
NOx	69.7 ± 21.2	29.6 ± 18.3	83.1	49.7	3.0	0.8	0.08	0.08
O_2	14.5 ± 1.0	15.9 ± 1.4	245,390.7	276,149.2	8834.1	4418.4	252.40	441.84

CO is a gas that results from incomplete combustion. This gas is very harmful to humans, as CO binds to the oxygen-carrying site on hemoglobin, reducing the transport of O_2 in the body. At high concentrations, CO is highly toxic, causing headaches, nausea, reduced cognitive ability, and even death [54–56]. Furthermore, this gas harms the environment as CO oxidizes in the atmosphere to become CO_2, a greenhouse gas, and can combine with other gasses to form O_3 [57,58]. In both kilns, CO emissions exceed the allowable limits according to regulations, but the Ecokiln emits CO at a concentration 25% lower than the AKC. On the other hand, SO_2 emissions from the AKC exceed the allowable limits by 63%, while the Ecokiln emits 14% less emissions than the limits established by Chilean regulations. In other words, the Ecokiln emits SO_2 at a concentration 83% lower than the AKC. The reduction in emissions of this gas is crucial, as SO_2 causes respiratory irritation, exacerbates pre-existing respiratory illnesses, such as triggering asthma attacks in asthmatic individuals, increases respiratory symptoms in adults, such as coughing, and alters lung function in children [56,59,60]. Furthermore, SO_2 oxidizes in the atmosphere to become sulfuric acid, which is a significant component of acid rain [61,62]. In the case of NOx, in both kilns, emissions are below the allowable limits set by regulations, but the Ecokiln emits NOx at a concentration 58% lower than that of the AKC. The reduction in this gas is crucial for the population since NO_2 causes respiratory irritation, exacerbates existing respiratory diseases, triggers bronchial hyperresponsiveness, and reduces lung function in asthmatic individuals [56,63]. NOx oxidizes in the atmosphere to become nitric acid, a major component of acid rain and combines with volatile organic compounds to form O_3 [64,65].

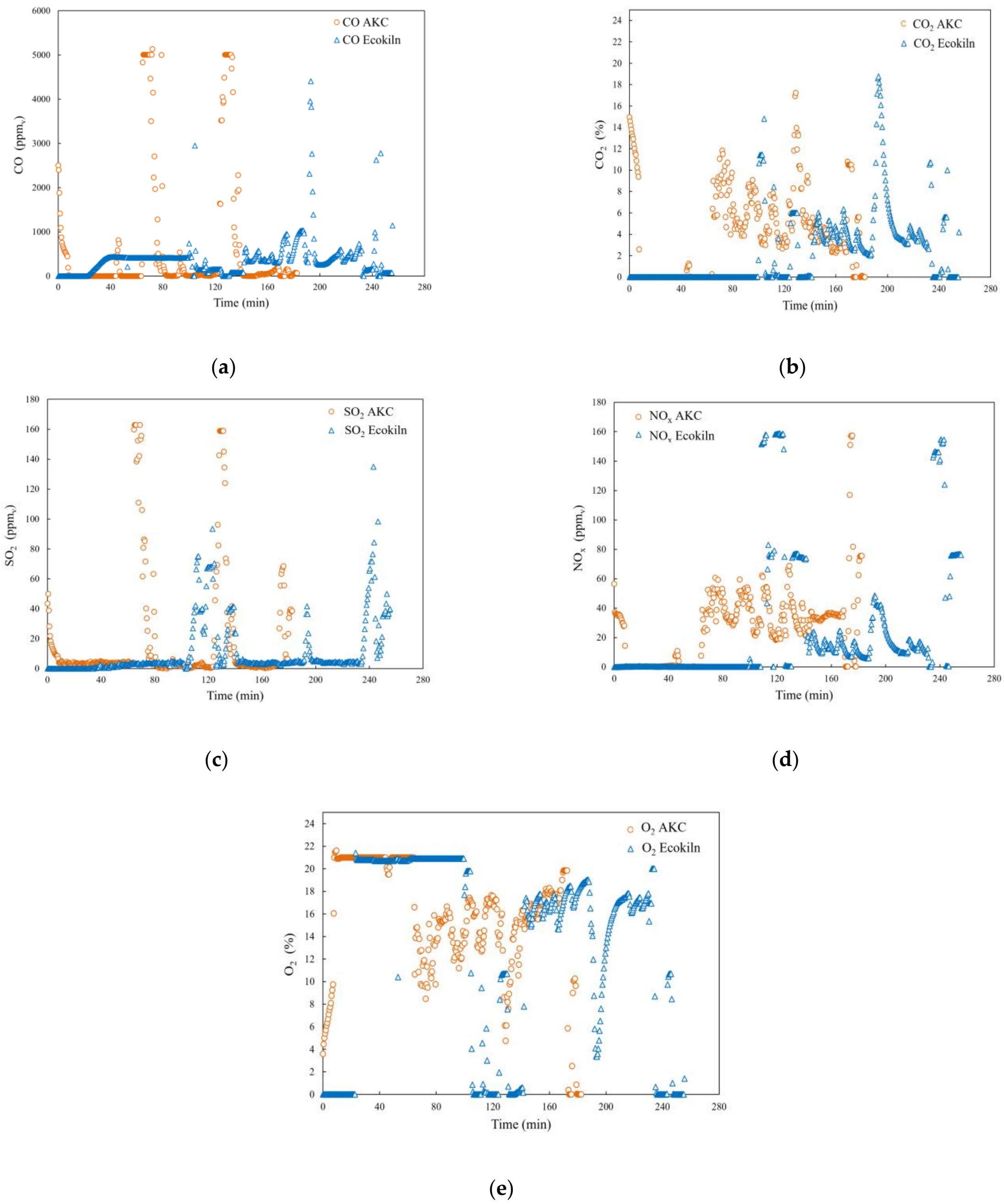

Figure 3. Time evolution graphs of gas emissions from both kilns: (**a**) CO, (**b**) CO_2, (**c**) SO_2, (**d**) NOx, (**e**) O_2.

PM causes health damage to individuals based on their size; for instance, PM10 leads to irritation of the nose and throat, lung damage, bronchitis, risk of cardiac arrest, carcinogenic effects if carrying toxic compounds, and premature death [66,67], while PM2.5 is deposited throughout the human respiratory tract, causing lung diseases, heart diseases, and premature death [68,69]. The isokinetic measurement showed that PM10 emissions in the AKC and Ecokiln were 252.5 ± 23.1 mg/Nm^3 and 65.0 ± 5.0 mg/Nm^3, respectively. Therefore, the Ecokiln manages to reduce PM10 emissions by 74.3%. In other countries, brick kilns similar to the AKC emit PM at concentrations exceeding 500 mg/Nm^3 (soot presence) [70–72]; in fact, the AKC emits 50% less PM than similar technologies. Furthermore, the Ecokiln emits 10 to 26% of the PM emitted by down-draught brick kilns [6,29,73]; therefore, the incorporation of technology that improves the internal fluid dynamics of the kiln allows PM emissions to be similar to those of brick kilns recognized as the most efficient, such as zig-zag kilns and MK kilns [13,74].

The emission results show that the Ecokiln is less polluting than the AKC, but there is still room for improvement in the design to reduce CO and PM emissions, along with decreasing the excess oxygen observed in the chimney.

4. Conclusions

Brick production is a vital industry in construction and infrastructure development worldwide. However, this activity is also associated with the emission of gasses and atmospheric pollutants that can have adverse effects on air quality and human health. The Ecokiln serves as a semi-artisanal kiln designed for use by brickmakers in rural areas, offering improved efficiency compared to traditional brick kilns used in the Maule Region. The Ecokiln's design allows for proper fluid dynamics, and when compared to firing in the AKC, it consumes less fuel, operates for shorter durations, processes more bricks, and experiences fewer losses of burnt bricks. Furthermore, the Ecokiln emits fewer polluting gasses, thereby enhancing the quality of life for brickmakers and their neighboring communities. In this study, it was found that the Ecokiln exhibits significantly lower emissions when compared to the AKC: CO emissions are 25% lower, SO_2 emissions are reduced by an impressive 83%, NOx emissions are 58% lower, and PM10 emissions are reduced by a remarkable 74.3%.

The main limitation of this study lies in the measurement environment as it is not conducted in a controlled setting, such as a laboratory, resulting in a challenging degree of error management in field measurements. Therefore, it is recommended that future research minimize, to the greatest extent possible, the effects of the environment on these results.

5. Patents

Figueroa J., Vilches, J., Valdes, H., Diaz, L., Muñoz, P., Hormazabal, M., Jaque, J., Contreras, B., Roldan, R. Aparato para el procesamiento de ladrillos, que permite optimizar el uso de recursos energéticos. (Patent Chile, N°66.926. INAPI, Ministerio de Economía, Fomento y Turismo, 2023. In Spanish.

Figueroa, J., Vilches, J., Valdes, H., Diaz, L., Muñoz, P., Hormazabal, M., Jaque, J., Contreras, B., Roldan, R., Gallardo, F. Ladrillo de cuerpo paralelepipedo rectangular de aristas y vértices rectos dispuesto horizontal sobre una de sus caras mayores, con veinte y seis perforaciones que atraviesan verticalmente el cuerpo ordenadas en tres grupos uno central con diez perforaciones y los laterales un hexágono central mayor rodeado por siete perforaciones. (Patent Chile, N°10.091). INAPI, Ministerio de Economía, Fomento y Turismo, 2021. In Spanish.

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