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RESEARCH ARTICLE

# EFFECT OF RED BRICK KILNS EMISSIONS ON AMBIENT CARBON MONOXIDE CONCENTRATION: A METROLOGIC STUDY IN ALKAMLEEN AREA, SUDAN

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## Abstract

**Background:** Red brick's kilns are known to be a source of environmental pollution by producing carbon particulates and gases like CO due to incomplete combustion of biomass used burning bricks. The objective of this study is to assess the effect of Red brick Kilns Emissions on Ambient Carbon Monoxide Concentration.

**Materials and Methods:** A cross- sectional descriptive analytic – controlled study, conducted in the red bricks kilns area along the Blue Nile bank in Alkamleen, Gazira State, Central Sudan. The area was divided into study area 1 and control area 2, area 1 was further divided into 3 longitudinal zones (A, B, C), with zone A the closest to the kilns; each zone contains 6 squares numbered (1-6) to allow studying the effect of air direction, environmental temperature, and location related to kilns. Ambient CO concentration was measured in both areas using standardized techniques during winter and summer seasons of the year 2016. The CO concentration in the studyand control areas has been measured using the spectrometer . The study was ethically cleared by the local authorities and National Ribat University Ethics and Review board.

**Results:** During winter in all zones, it was found that the highest CO concentration was in squares 4, 5 and 6 and the lowest concentration was in squares 1, 2 and 3. During summer in all zones it was found that the highest CO concentration was in squares 1, 2 and 3 and the lowest concentration was in squares 4, 5 and 6 respectively. CO concentration was significantly higher during winter particularly in zones A and C.

**Conclusion:** Ambient CO concentration in Alkamleen kiln's area was more than that permitted by WHO estimation and concentration was significantly higher during winter than summer.

**Key Words:** red brick kilns; carbon monoxide; metrological factors; seasonal variation

عنوان البحث

# تأثير انبعاثات كمائن الطوب الأحمر على تركيز أول أكسيد الكربون في الهواء: دراسة مترولوجية في منطقة الكاملين- السودان

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## المستخلص

خلفية:

من المعروف أن أفران الطوب الأحمر مصدر للتلوث البيئي عن طريق إنتاج جزيئات الكربون والغازات مثل أول أكسيد الكربون بسبب الاحتراق غير الكامل للكتلة الحيوية المستخدمة في حرق الطوب. الهدف من هذه الدراسة هو تقييم تأثير انبعاثات قمائن الطوب الأحمر على تركيز أحادي أكسيد الكربون المحيط.

المواد والأساليب:

دراسة مقطعية وصفية تحليلية مضبوطة أجريت في منطقة قمائن الطوب الأحمر على طول ضفة النيل الأزرق في الكملين ، ولاية الجزيرة ، السودان الأوسط. تم تقسيم المنطقة إلى منطقة الدراسة 1 ومنطقة التحكم 2 ، وتم تقسيم المنطقة 1 إلى 3 مناطق طولية (أ ، ب ، ج) ، مع المنطقة أ الأقرب إلى الأفران ؛ تحتوي كل منطقة على 6 مربعات مرقمة (1-6) للسماح بدراسة تأثير اتجاه الهواء ودرجة الحرارة البيئية والموقع المتعلق بالأفران. تم قياس تركيز أول أكسيد الكربون المحيط في كلا المجالين باستخدام تقنيات موحدة خلال فصلي الشتاء والصيف من عام 2016. تم قياس تركيز أول أكسيد الكربون في مناطق الدراسة والمراقبة باستخدام مقياس الطيف. تمت الموافقة أخلاقياً على الدراسة من قبل السلطات المحلية ومجلس الأخلاقيات والمراجعة بجامعة الرباط الوطنية.

النتائج:

خلال فصل الشتاء في جميع المناطق ، وجد أن أعلى تركيز لأول أكسيد الكربون كان في المربعات 4 و 5 و 6 وأقل تركيز كان في المربعات 1 و 2 و 3. خلال فصل الصيف في جميع المناطق وجد أن أعلى تركيز لأول أكسيد الكربون كان في المربعات 1 و 2 و 3 وكان أقل تركيز في المربعات 4 و 5 و 6 على التوالي. كان تركيز أول أكسيد الكربون أعلى بشكل ملحوظ خلال فصل الشتاء ، خاصة في المناطق A وC

الخلاصة: كان تركيز أول أكسيد الكربون المحيط في منطقة فرن الكاملين أكثر من المسموح به في تقديرات منظمة الصحة العالمية وكانت التركيزات أعلى بكثير خلال الشتاء مقارنة بالصيف.

**الكلمات المفتاحية:** أفران الطوب الأحمر, أول أكسيد الكربون, عوامل مترولوجية , الاختلاف الموسمي

## 1. Introduction

### 1.1. Red Bricks Kilns in Sudan

Red bricks are the main building material in Sudan's urban areas (MEPD & HCENR, 2003) and are largely produced using traditional biomass energy from cow dung and firewood. Less than 2% of the total red bricks are produced using fossil fuel (1). During the last decades, the overall production of red bricks in Sudan has increased from an estimated 134 Million in 1975 to 1,804 Million in 2004 and 2,800 million in 2006 (2,3) . In Sudan, the total kiln number increased from 1,750 in 1995 to 3,450 in 2005, of which 2000 are located in Khartoum and Gezira States (1) . Thus, due to this escalating growth, the red brick kilns represent the principal industrial source of CO in Sudan (4).

### 1.2. Red Bricks Kilns CO and Gases Emissions:

Carbon monoxide (CO) is an inorganic compound, colorless, odorless, and tasteless gas that is slightly less dense than air. It is toxic to humans and animals when encountered in higher concentrations (5). The annual average estimations of CO concentration in the south of the globe is around 0.04 parts per million per volume(ppmv) compared to 0.12 ppmv in the north of the globe. There is a seasonal CO concentration variation in both hemispheres, the maximum concentration of 0.20 ppmv detected in the winter decreasing to about 0.03 ppmv at the end of the summer (6). A rapid increase in brick production and the clustering of brick kilns has given rise to environmental worries worldwide (7).

In Sudan, as in most developed countries, the brick kilns utilize immense amount of poor-quality coal and other solid waste material as tires rubber to ignite the fire of the oven, which results in the production of SOx, NOx, COx, and PM along with many other organic pollutants. Therefore, with this an impetuous uncontrolled expansion, kilns' emissions are continuously increasing and harshly distressing the environment (8,9). In Sudan and besides the production of mentioned detrimental volatiles, the red brick kilns are an essential source of urban greenhouse gas (GHG) emissions, compile mainly of $CO_2$, methane, NO, and water vapor as direct gases and CO as indirect gas due to the low combustion efficiency of the fuels used (4). In an oven kiln, the air streamed through a heated bed of coal. The initially produced $CO_2$

equilibrates with the remaining hot carbon to give CO that and due to insufficient oxygen supply, will not re-oxidized to carbon dioxide (CO2) (5).

### 1.3. CO Ambient Concentration and Affecting Metrological Factors:

Studies showed the carbon monoxide concentration gradients are related to the distance from the source of the gas. CO decreases quickly with distance, but the linear regression between CO and distance concentration is not significant. The significant statistical test model is the exponential decrease at different points of height chimney from (0.5m to 80m). So the distant residency might not be a safety factor (10).

The temperature has an inverse effect on CO concentration because cold temperatures make combustion less complete and cause inversions that trap pollutants close to the ground. On the other hand, increasing the temperature depletes CO by accelerating the CO-to-CO2 conversion, reflecting the seasonal variation of CO air concentration (11).

Air relative humidity has a significant positive correlation with CO concentration and inversely related to wind speed and direction as it disperses CO away and distributes it in the air (12,13,10).

### 1.4. Cycle of CO in the Environment:

Carbon monoxide mainly enters the environment from natural sources and the burning of fuel oils. Stays in the air for about two months before broken down in the air by reacting with other chemicals and is changed into carbon dioxide. It is also broken down in soil by microorganisms into carbon dioxide. It does not build up in plants or the tissues of animals (5).

### 1.5. Recommended Levels of CO and Effects of High Air Concentration on Human Health :

The health effects of CO depend on the CO concentration and length of exposure, as well as each individual's health condition (14). Most people will not experience symptoms from prolonged exposure to CO levels of approximately 1 to 70 ppm, unless they have other comorbidities like cardiac and pulmonary diseases, manifested by chest pain and short of breathing respectively. As CO levels increase and remain above 70 ppm, symptoms become more noticeable and include headaches, fatigue, and nausea. At sustained CO concentrations above 150 to 200 ppm, disorientation, unconsciousness, and death are possible. The U.S. Environmental Protection Agency

(EPA) set a legal limit of 55 mg/m3 (50 ppmv) for carbon monoxide in air averaged over an 8-hour workday (14,15,16). Physiologically the toxicity of CO results from high affinity of Hb for CO which is 250 times more than oxygen. Carbon monoxide also binds to the myoglobin in the skeletal and cardiac muscles 60 times more than oxygen; this may explain the muscular fatigue companies the CO poising as myoglobin is a vital oxygen store protein Carbon monoxide affects other haem proteins' affinity as cytochrome oxidase, cytochrome p-450, and cytochrome A3, an enzyme in the terminal respiratory chain, which reduces the oxygen-carrying capacity of the blood and biological energy producing reactions (5,17,5). The traditional brick kilns (Kamena) mushrooming the west bank of the Blue Nile River between Alkamleen city and the river. The air in that part of the city is always cloudy by emitted smoke. Therefore, and due to a consensus among the population about vague chronic symptoms like headaches, fatigue, and respiratory problems, we tried to explain these complaints by conducting this preliminary ecological study to measure the concentration of carbon monoxide and define the seasonal meteorological factors in Alkamleen City.

## 2. Materials & Methods

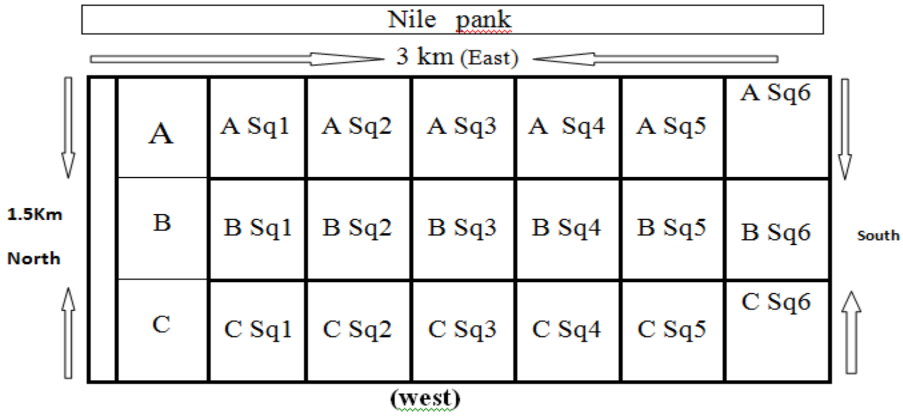
### 2.1. Study Location

This is a cross- sectional description analytic case – control study. It was conducted in Alkamleen, Gazira State, Central Sudan; it is located at the intersection of the latitude 15.23 degrees north and longitude 11.33 degrees east.

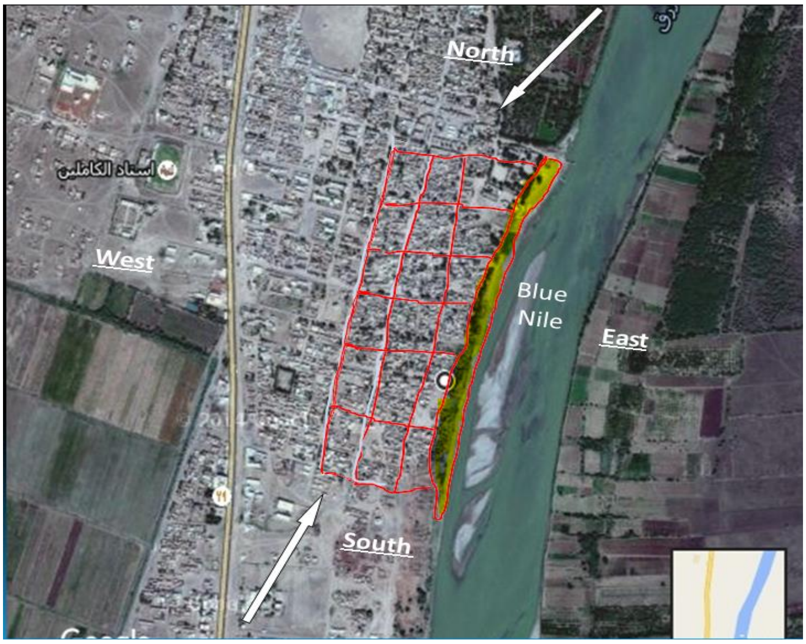
### 2.2. Study Areas Determination & CO measurement:

#### 2.2.1. Study Area (area 1):

The area's length was determined from north to south along the river bank, where the red brick kilns (source of smoke) concentrated, it measured three kilometers. The width was determined from east to west, starting from the river bank according to carbon monoxide concentration, high at the source, then moving west until the sensor's sensitivity reached the lower limit, measured 1.5 kilometers. Eventually, this area was divided by two lines parallel to the river bank to give three horizontal zones (A, B, and C). The area was divided sagittally by five imaginary lines to give six squires in each zone (Figures 1 and 2).




## Zoning of Study Area (Area 1)




## Google Map of Study AREA

### 2.2.2. Control Area (Area 2)

This area was delineated by a horizontal line one kilometer west to area one and a line one kilometer from the highway. Its width was 1.5 kilometers.

### 2.2.3. CO measurement in air:

We measure the CO concentration in the study and control areas using the spectrometer. The spectrometer conformed to the European Standard EN 50543 and British Standard BS 6173:2009. Spectrometer was prepared and raised to height of 3 meters for 5 seconds. The reading for CO concentration, wind speed and humidity were then reported. The readings were repeated three times with an interval of 1 minute. The average reading was then determined. This step repeats five times to each square. The lower limit of sensitivity of the apparatus was 6 parts per million (ppm). This was considered as zero level.

#### 2.2.4. Metrological factors data:

The reference for the weather climate data was obtained from Meterological Authority in Sudan 2013. The data included were CO concentration on air, temperature, humidity, wind direction and wind speed.

### 2.3. Ethical clearance and consent:

The Ethics committee approved the study, National Ribat University, Khartoum, Sudan. Moreover, governmental permissions had been issued from all responsible authorities.

## 3. Results

The measurements of the metrological data in study and control area showed in table 1 consistent with reports of Weather Climate Data-Metrological Authority through period of study.

During winter season the highest concentration of CO was 169.2 ppmv, measured in the most southern squire 6 of Zone A while the lowest concertation was 8 ppmv in squire 1 of zone C. In zone B the highest concentration was 90 ppmv and lowest was 18.6 ppmv in squires 6 and 1, respectively. Figure 1 (1,2,3,4,5,6)

Summer readings were lower in all squires of all zones compared to winter's (Table 2 & Figures 2) as the lowest detection of zone A was 12.6 ppmv recorded in squire 6 and the highest in the same zone was 126.8 ppmv in squire 1. The lowest concertation in the summer was 7.08 ppmv in squire 6 of zone C compared to 15 ppmv in the same squire of zone B.

The highest concentration of CO in all zones of control area in summer and winter was 8 ppmv. (Table 3)

**Figure 1 (1,2,3,4,5,6) Level of CO Concentration in (ppm) across the various Zones in Winter and Summer (<u>each squire = 500 meters. sq1 far north sq6 far south</u>)**

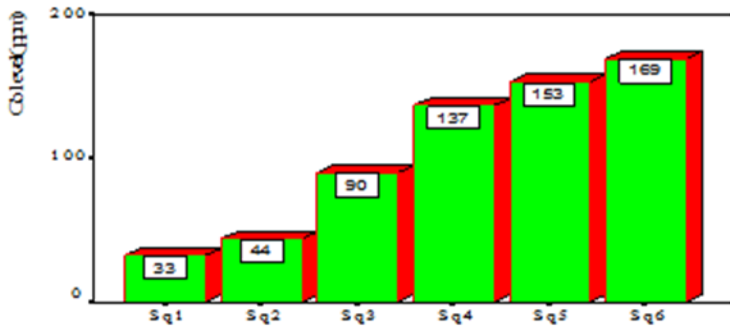



**Figure 1-1 : Zone A, Winter CO Concetrations**

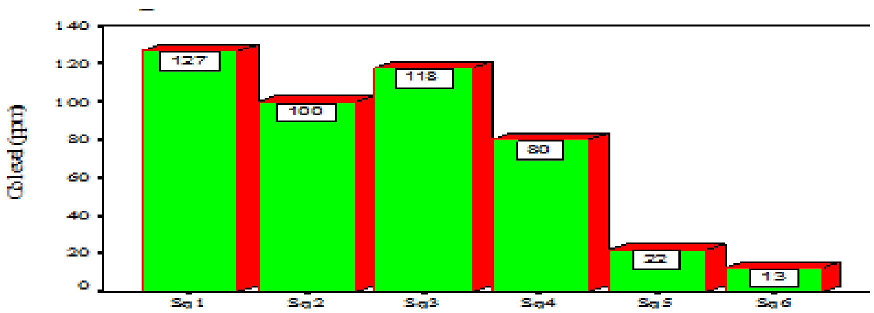



**Figure 1-2: Zone A, Summer CO Concetrations**

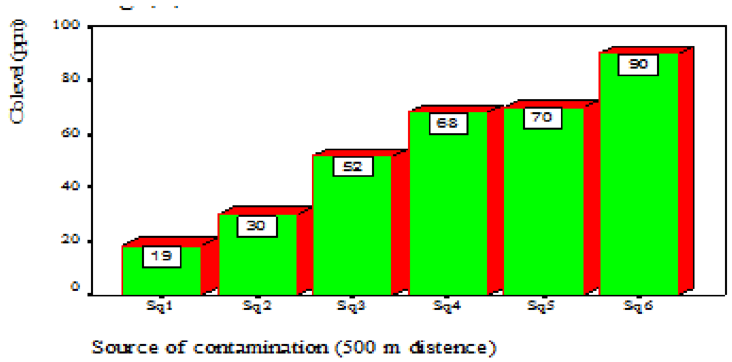
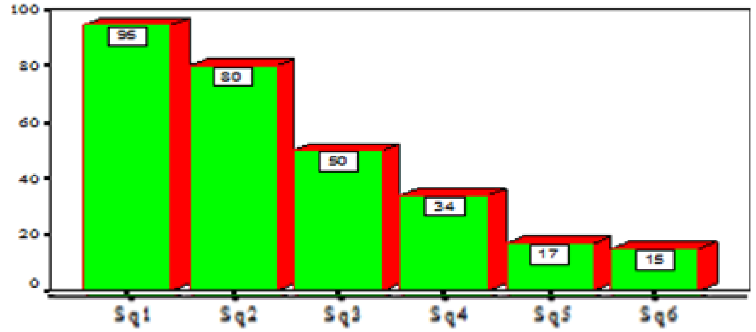
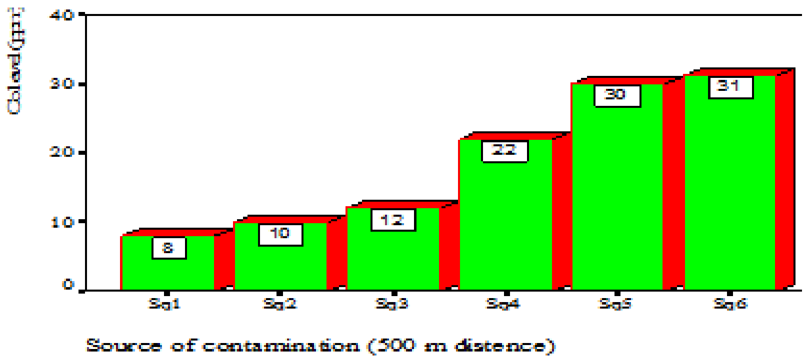


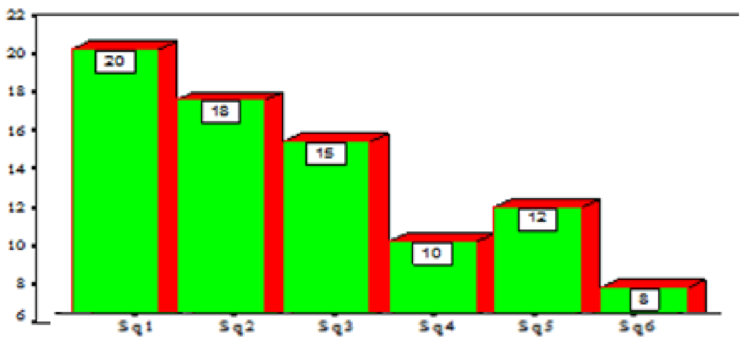

**Figure 1-3: Zone B, Winter CO Concetrations**




## Figure 1-4: Zone B, Summer CO Concetrations




## Figure 1-5: Zone C, Winter CO Concetrations




## Figure 1-6: Zone C, Summer CO Concetrations

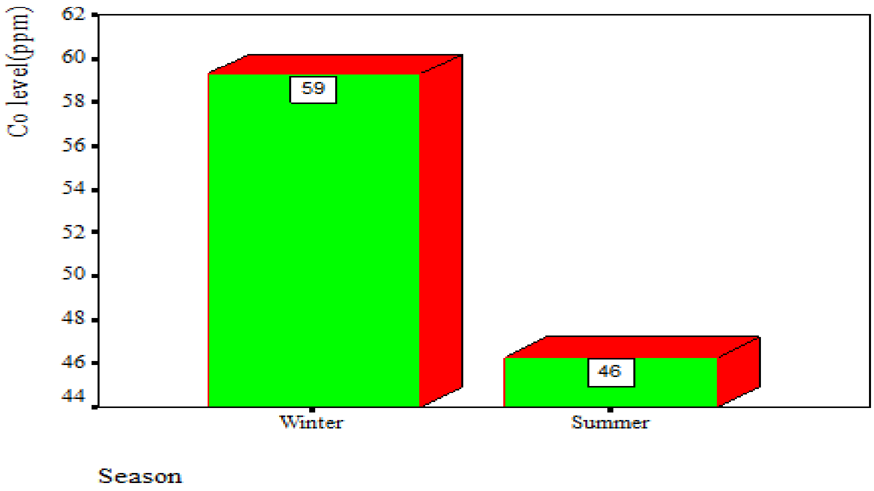



**Figure 2: CO Concentration in Winter and Summer at Study Area**

**Table 1: Meteorological Data in Alkamleen City at Summer and Winter**

| No | Item | Winter | Summer |
|---|---|---|---|
| 1 | Wind direction | North | South west |
| 2 | Temperature | 34.9 $^0$C | 43.1$^0$C |
| 3 | Humidity | 29 | 26 |
| 4 | Wind speed | 5X10$^6$ | 5X10$^6$ |

**Table 2: CO Concentration in all Zones (*ns: not significant***

****: significant at 0.05 level of probability.*)**

| Zones | Winter CO concentration(ppmv) | Summer CO concentration(ppmv) | S.E± | t. value | Sig. |
|---|---|---|---|---|---|
| A | 104.2 | 76.6 | 14.2 | 2.6 | * |
| B | 54.8 | 48.4 | 8.1 | 0.79 | Ns |
| C | 18.9 | 13.9 | 2.5 | 2.04 | * |
| Mean | 59.3 | 46.3 | 7.1 | 1.83 | Ns |

**Table 3: CO Concentration in the Control Area Compared to International Recommended Concentrations in ppm***

| No. | Source of reading | Reported readings |
|---|---|---|
| 1 | Area 2 | 8ppm |
| 2 | World Health Organization (WHO) | 6ppm |
| 3 | National Ambient air quality standard (NAAQS) | 9ppm |
| 4 | EPA | 6ppm |

## 4. Discussion

The present study investigated the hazards related to CO pollutant levels emitted from red-bricks kilns at Alkamleen region (North Gezira state 130 km south of Khartoum) during 2016. The site of red brick kilns is located at the east of Alkamleen city, extending from North to south along the western bank of the Blue Nile. The study area has been divided into three zones; zone A was the nearest part to brick kilns in the west direction, followed by Zone B and then zone C, which was in the far west location. The total width of the area was 1.5 km, and the length was 3 km. Each zone was 500 meters in width, divided into six squares; square 1 and 2 were northern squares while 5 and 6 were southern ones while squares 3 and 4 were in the middle.

The number of red bricks kilns increased dramatically in Alkamleen area as it is a cheap and profitable industry in addition to weak environmental legislation that restricts random construction. Air subjected to severe pollution during the operation phase of brick kilns, the community's residents and kilns workers were exposed to harmful emissions directly related to the numbers of working kilns(18).

The clamp kilns are types of an up-draft intermittent kiln built-in the form of a clamp and roofed over to protect the bricks from the rain. The clamp kilns are very similar to our Sudanese traditional Kamena, so that the bricks are established in an open pattern up to 40 courses high forming a steep truncated pyramid (19). In Alkamleen city all red brick kilns owners continue to use traditional chimneys emitting smoke directly over the nearby Alkamleen citizens. One solution can be like construct kilns of heights exceeding 120 feet zig-zag chimneys and using coal to burn bricks (19).

We analyzed almost all recent available studies related to red bricks kilns industry expansions and destructive impacts on Sudan's ecological system. The conclusions of the most two prominent studies conducted by Alam & Starr 2009 and Ishtiaq et al. 2012 confirmed that the bricks kilns are the primary CO source in Sudan (1,4). Our team results scaffold these conclusions as the CO is significantly high in the air of area 1 in all zones throughout the year compared to recommended levels in the control area.

The wind direction had an apparent effect on CO concentration in air, evident by the detection of a high level of concentration during winter in the southern squares (sq5 and 6), when the wind direction was from north to south. While it was low during the summer season in the same squares as the wind was in the opposite direction. The effect of wind direction and strength on CO dispersion may put all neighboring areas in the face of seasonal CO pollution. Another factor that affected air concentration was the distance from the source of CO; the study showed higher readings in zone A compared to zone C in both winter and summer and steady readings in zone B. It is worth mentioning that the emitted CO levels violated the WHO standards during both winter and summer seasons. This agrees with the results reported by researchers like Odat (2009) and Alkam et al (2007), who showed that pollutant disperses away from the source of discharge until the lower level of the sensor sensitivity (6ppm) was reached (20,10). The decrease of CO follows an exponential shape according to distances. The distant factor is crucial as living far away from kilns is an effective solution if governmental and ecological legislation fails to control kilns' impacts. In Sudan and other developing countries, residences' replacement might not be practical and unachievable for many socioeconomic factors. Noise barriers were adopted in many countries to reduce noise pollution generated from road traffics; some studies found them able to trap pollutants and reduce CO pollution by 50 %. (5). Therefore, the noise barriers could be more practical than residential displacement.

During summer and as the ambient midair temperature rises in Alkamleen city, CO's concertation reduces in all zones of the study area. The high temperature catalyzes the oxidation of CO to $CO_2$, and also the heated air density will decrease, and the upgoing air current increases. While the air is upstreaming, the vertical and horizontal currents will be mixed, and the pollutant concentrations reduce. All mentioned process filliped during winter, and high concertation of CO reported on all study area zone. These seasonal variations were supported by Odat research, which settled on similar results (20).

Kilns are built close to the river, where the humidity of air is relatively high and constant throughout the year. In our study, the constancy in air humidity explains the high levels of CO during winter and relatively high levels during summer compared to the recommended international values.(21,11).

## Conclusions & Recommendations

Traditional Red Bricks Kilns are the sole source of CO in Alkamleen City and responsible for the air's significant pollution. The seasonal metrological variations are significant, but readings throughout the year is higher than the internationally recommended guidelines. The control area is safe to live until now, but with the unrestricted expansion of kilns, it might face the same study area.

Results with problem solution suggestions have been submitted to local government authorities to inform the local population about the effects of living close to kilns.

Conduction of community-based study to detect the possible harmful effects of chronic exposure to high CO on Alkamleen resident's health in area 1, mainly on the hematological and pulmonary system, is complementary and necessary.

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