Carbon Monoxide Pollution and Limited Health Service Access in Third-World Countries

ABSTRACT

Despite its complexity, carbon monoxide is a key component of indoor and outdoor air pollution. While carbon monoxide arises from natural sources as well as human activities, the most detrimental exposure risks are within the domestic environment. In third-world countries like Guatemala, a notable positive correlation has been observed between severe respiratory diseases and the concentration of carbon monoxide in the air. This correlation can be attributed to these regions' housing conditions and daily lifestyle practices. Additionally, the limited healthcare services accessibility in third-world nations exacerbated the severity of domestic carbon monoxide poisoning cases. It is evident that effective healthcare interventions still need to be fully utilized in third-world countries, and thus, there is a need to move beyond identifying broad strategies and specific policies. Addressing the issues of carbon monoxide exposure and its impact on public health in these regions requires comprehensive approaches that take into account the challenges faced by these countries.

To access carbon monoxide concentration in the household, EsayLog USB has been used in this study. The study reviews the amount of carbon monoxide present in certain villages with different conditions and high carbon monoxide concentrations, especially near fires using combustible fuels and houses at high altitudes. The study found that third-world countries' decision-makers should educate communities, build the environment to provide better medical access to the public and implement appropriate regulations to deliver better quality health care to people.

Keywords: Air pollution; Domestic environment; Daily lifestyle; Respiratory diseases; Healthcare services accessibility

1. INTRODUCTION

Air pollution, a result of both natural and human activities, creates many adverse effects on public health, particularly respiratory diseases [1]. Anthropogenic activities that result in harmful environmental emissions include vehicle emissions, combustion of fuels, gas, and wood, and the consumption of cigarette smoke [2]. While developed countries, like the United States, engage in these activities, it is evident that third-world countries, such as Guatemala, face higher concentrations of this hazardous pollutant [3]. Carbon monoxide, originating from both natural and human activities, poses significant health risks, with household environments emerging as the primary source of exposure [4].

In many third-world countries, the predominant sources of fire for cooking, heating, and lighting involve burning combustible solid fuels, such as coal, wood, and propane [5] as in Fig.1.

Fig. 1 shows the residential fire field by combustible materials.

Unfortunately, this practice led to a notable increase in carbon monoxide concentration within households and enclosed spaces. This CO level elevation poses a significant threat to public health, exacerbating respiratory diseases among the population [6]. Prolonged and consistent exposure to carbon monoxide presents a substantial concern. However, in contrast to developed countries where advanced medical care enables better recovery from CO poisoning, third-world nations face the challenge of limited healthcare services [7]. Healthcare services accessibility is hindered by an individual's financial situation, education level, or the absence of policies or regulations. In short, they still have less access compared to people in not third-world nations [8].

Carbon Monoxide is a poisonous gas resulting from the incomplete combustion of various fuels like coal, wood, charcoal, gasoline, propane, and natural gas as in Fig. 2. CO pollution

Fig 2 presents the scene of the wood piles used as fuel in a Guatemalan house.

generally occurs from residential wood burning, fossil fuel-powered engines, industrial processes, and natural occurrences of forest fires [9]. The reason carbon monoxide is dangerous to humans is that humans are unable to detect it because it lacks any odor, color, or taste, rendering it undetectable without the reading machine; thus, individuals do not know that they are being harmed by its presence [10]. Such attributes make it especially hazardous, as people may unknowingly inhale this toxic gas, leading to detrimental consequences.

The quantification of carbon monoxide concentration uses the unit "Ppm," which stands for "parts per million." within residential settings where gas stoves or fireplaces are absent, the standard range of carbon monoxide concentrations falls between 0.5 and 5 ppm. However, these levels may vary from 5 to 15 ppm when utilizing properly adjusted flames. Conversely, if the fire is not adequately regulated, the concentration can go up to 30 ppm [11].

This research has utilized the EL-USB-CO data logger, ensuring strict adherence to instruction and maintenance of appropriate conditions throughout the procedure. The primary objective of this study is to assess CO levels in various households and surrounding neighborhoods in Guatemala. The purpose of the study is to investigate the relationship between carbon monoxide concentrations and potential health hazards associated with air pollution in areas with high emissions. Furthermore, this study is also designed to examine the accessibility of medical care for the people of Guatemala, thus, impacting the overall public health of the nation and addressing the shortage of healthcare services, and potentially prompting government efforts to improve healthcare accessibility and services in the country. Guatemala is notorious for the highest rate of stunting in the Western Hemisphere and the fifth highest rate in the world, with nearly half of all children under five stunted, and the maternal mortality ratio is 113 deaths per 100,000 live births. Inequities drive the health and nutrition challenges in Guatemala, where indigenous people, people with lower educational levels, and people living in poverty are disproportionately affected [12]. The public healthcare sector is known to include approximately 88% of the country's population. However, hospitals and clinics in Guatemala under the public system are highly underfunded and often lack basic medicine and equipment. This is because the Guatemalan Government allocates very little spending on healthcare; in fact, healthcare spending in Guatemala is one of the lowest in Central America [13]. This study might set an alarm for the government to place more of its resources into the healthcare system.

2. EXPERIMENTAL METHODS

2.1 *Materials and Devices*

Fig. 3 presents the EL-USB-CO used in the study.

The Lascar EL-USB-CO data logger continuously monitors and stores up to 32,510 readings, offering a measurement range of 3 to 1000 pm and functioning in temperatures between 14 to 104 °F. Users have the flexibility to adjust logging rates and start times and can easily retrieve the stored data. Setting up the data logger is simple, requiring a connection to a PC's USB port and the use of the provided EsayLog software. The data can be graphed, printed, and exported. The device is powered by a ½ AA lithium battery and a clip for handling [14].

The EL-USB-CO data logger comes preconfigured with warning indicators and a sounder set to activate when carbon monoxide (CO) levels reach 50 ppm or higher. Nevertheless, users can adjust these parameters according to their specific requirements.

Despite the EL-USB-CO's light and sound warnings, they may not effectively alert individuals to excessive CO levels due to the limitations. This toxic gas poses significant risks even at low concentrations, and prolonged exposure can lead to severe injuries or fatalities [15].

2.2 Data Collection

As mentioned, carbon monoxide (CO) concentration is monitored using the Easy Log EL-USB-CO device in a diverse range of households and locations across Guatemala. This assessment has been conducted in both transit settings and stationary areas. To ensure the efficiency and systematic organization of data collection, information is gathered through two approaches: the data acquired by the Easy Log EL-USB-CO device itself and detailed logging performed by the researchers involved in the study. This comprehensive approach is aimed to yield an accurate understanding of CO levels in the areas.

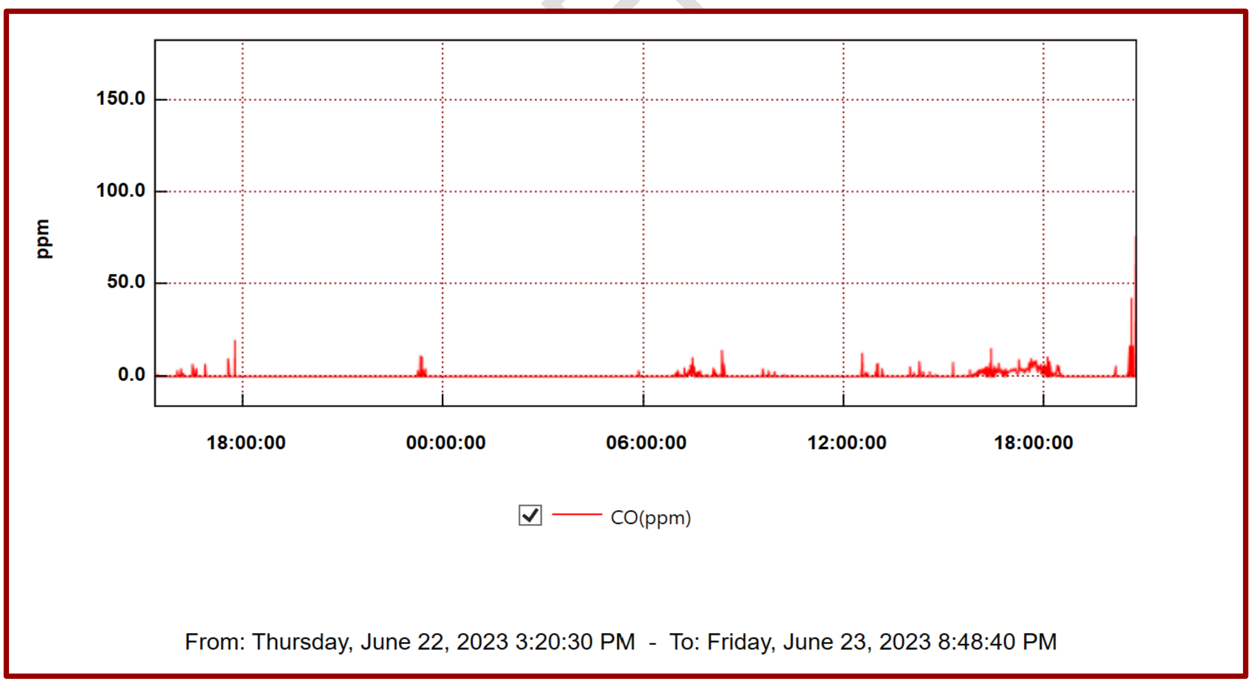
The device continuously evaluates CO levels in ppm at ten-second intervals across various locations. The logging process captures emission factors, such as time, location, atmosphere type (indoor or outdoor), vehicle presence (cars, motorcycles, and buses), number of individuals, plant count, type of ventilation, and altitude. Measurements are taken daily from 8 AM to 10 PM over six days.

The research involved subgroups of researchers collecting data, leading to clear identification of spikes in carbon monoxide levels based on human activity, population density, and vehicular presence. The collected data will significantly enhance our understanding of the root causes and regions associated with elevated carbon monoxide levels. This valuable insight will aid in addressing CO poisoning and related health issues and the development of practical solutions to mitigate these health risks.

3. RESULTS

Data revealed that location, population, altitude, the presence of transportation utilizing fossil fuels, and the presence of fire are significant factors in CO emissions. The gas stove and opened fire that requires the combustion of propane gas, wood, and charcoal in the households are key factors to high carbon monoxide levels. Additionally, vehicles such as cars, buses, planes, and motorcycles that need to combust fossil fuel are also key contributors to high carbon monoxide. Considering the data graph and the researchers' logging, there is a potential to show an increase in CO concentration as the machine gets closer to the cooking area. High CO levels have also been observed in rural villages located at a high altitude. Additionally, the device's warning buzzer alerted researchers to elevated CO levels when they were near individuals smoking or candles.

Random CO spikes in the data resulted from errors in data collection, sudden changes in movement, and outliers. CO peaks appeared in the graphs due to human error, such as dropping the device during the data collection and sudden running. Moreover, data would be lost when the device's battery ran out. The analysis was slightly off since the time and duration at a location were recorded in the hour-minute form. The sample means and standard deviation was affected by the data's small intervals of ten seconds, which left few degrees of freedom.



3.1 CO level spikes recorded on Days 1 and 2

Fig. 4 is the data on the concentrations of CO on June 22 and 23.

Fig 4 above presents a detailed account of recorded carbon monoxide (CO) levels measured between June 22 at 15:00 at JFK Airport and June 23 at the hotel. Unfortunately, data collection on June 22 was only partially successful due to a delayed start. Therefore, the researchers have not reset the device until June 23 to facilitate the analysis of daily CO exposure. Parts per million (ppm) measurements of CO levels are shown on the y-axis, while time measurements (hour, minute, second) are shown on the x-axis. A notable high in CO levels was seen at about 18:00. It has been discovered via further analysis of the time series and associated data by each researcher that this peak was recorded at the passenger boarding bridge. The increased CO levels have been caused by planes burning fuel on the runway, providing a possible source of pollution at the airport. On June 23, the data showed sharp increases in CO levels between 7:00 and 8:00, with the highest recorded level reaching 14 ppm. These increases have been attributed to various types of vehicles, such as cars, motorcycles, and buses. The research team has used a bus with open windows to travel to a different location at this time,

highlighting the impact of

Fig. 5 illustrates the school bus onboarded by the research team.

transportation that uses the combustion of fossil fuels on carbon monoxide emissions. Dynamic variations in CO levels were noticeable in the afternoon, from around 16:00 to 19:00. The researchers visited nearby residences in San Andrés and traveled to Antigua, one of the urbanized cities in Guatemala, after that. The average carbon monoxide levels in these regions have been recorded at 4 ppm, caused by the use of open fires in households, which require burning wood to cook. This emphasizes how domestic tasks affect the local air quality and people. The range of carbon monoxide concentrations has increased from 6 to 9 ppm upon arrival in Antigua, primarily due to the region's higher population density and transportation. This finding emphasizes how changes in lifestyle in third-world countries can result in chemical accumulation in living space, which increases the risk of health diseases.

3.2 CO level spikes recorded on Day 3

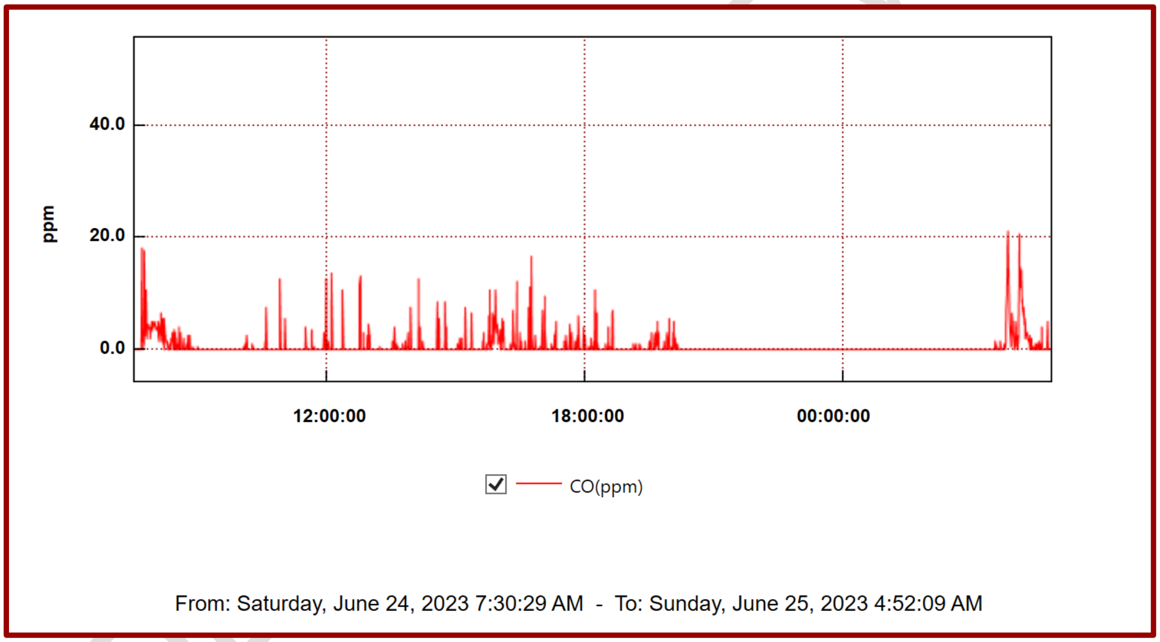


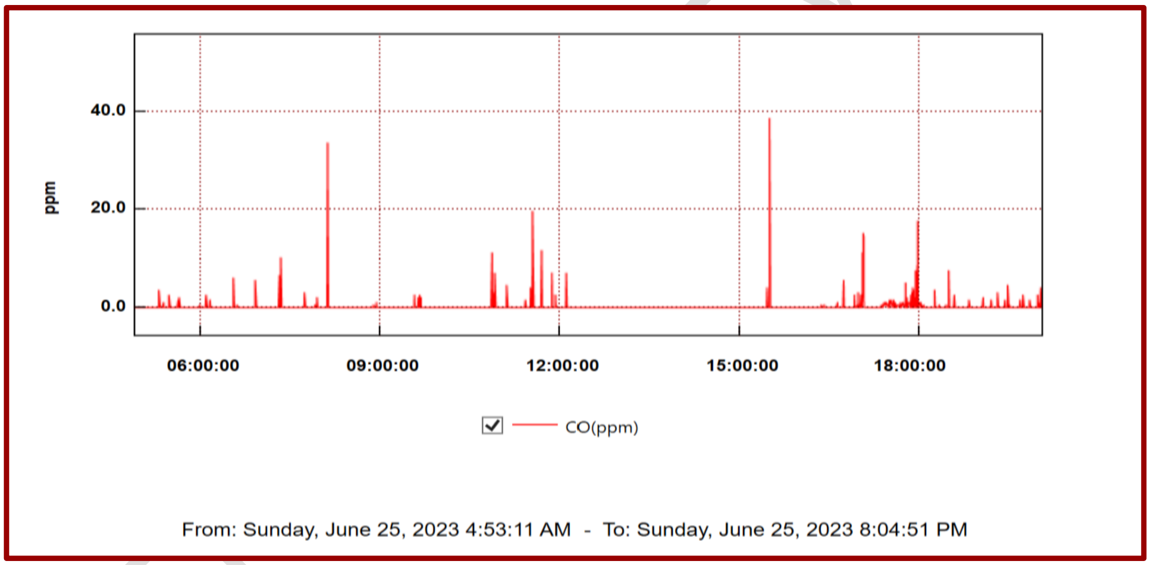
Fig 6 shows the data on the concentrations of CO on June 24.

A significant surge in CO levels occurred at 7:42, just after data collecting began, reaching a value of 18 ppm. The main reason for increasing carbon monoxide concentration is

the use of a Tuktuk taxi, a three-wheeled vehicle wrapped with clothes, as shown in Fig 7.

Fig. 7 shows the Tuktuk taxi in Guatemala.

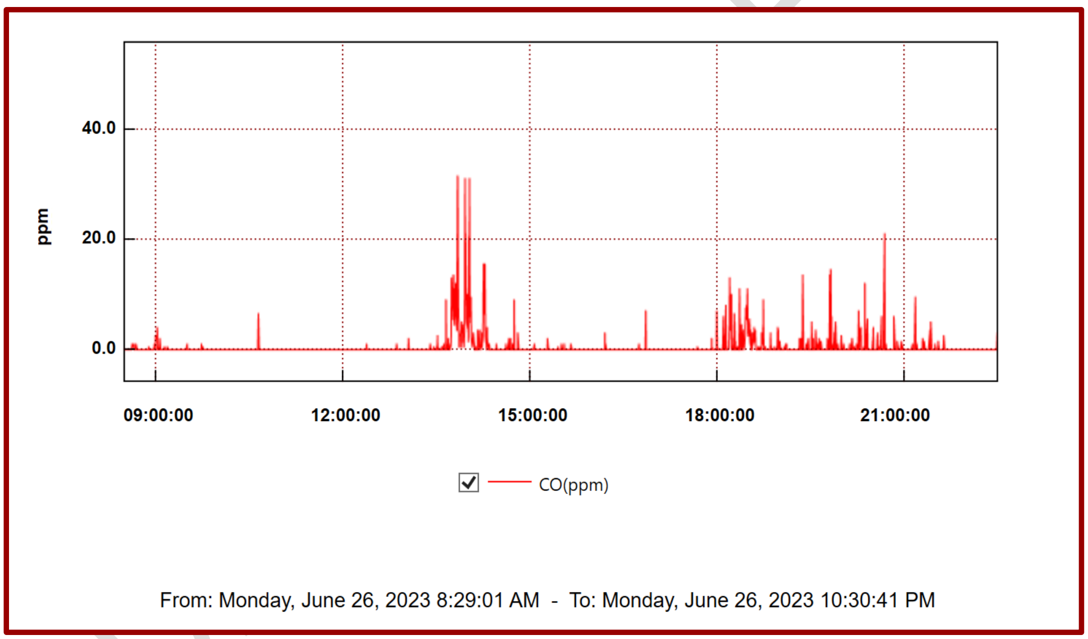
It directly exposed passengers to the outside environment, resulting in higher carbon monoxide measurements. The combined effects of the fuel combustion of Tuktuk and other moving vehicles cause a high CO level. The research team is located in Sumpango, a rural area away from the city, at an altitude of around 6000 feet, surrounded by mountains, and agricultural land, from 9:00 to 17:00. The data consistently showed increasing carbon monoxide emissions during that time. The observed increase in CO levels at this time has probably been influenced by the high altitude of Sumpango and the low oxygen availability of the area. During this period, the team visited many houses around the neighborhood, and their usage of trucks and motorcycles around the village and wood for the fire also caused a high carbon monoxide concentration. Another increase in CO levels has seen after entering a restaurant sound 18:00. The smoke coming from the kitchen, which indicates the combustion of propane gas, and the restaurant's closeness to a busy street with moving cars be contributing causes to the elevated carbon monoxide content. The high CO levels and spikes in the data were assumed to be related to cooking utilizing fires. The graph shows that around 3:40 on June 25, the CO levels increased significantly and suddenly, peaking at 21 ppm. This increase has been attributed to moving vehicles on the street, and the hotel room's opened window has allowed outside smoke to enter. The research team has concluded that the high altitude of Sumpango, different types of fire for cooking, and vehicle combustion are the primary source of high spikes of CO levels on the third day of the study. Due to the influence of decreased oxygen availability, the team has found out that an area's altitude significantly impacts CO levels. These results highlight how several elements, such as geography, cooking methods, and transportation, affect the amount of carbon monoxide people are exposed to in the area. The team also has assumed that people living in high altitudes may have a higher risk of respiratory diseases due to lack of oxygen.



3.3 CO level spikes recorded on Day 4

Fig 8 presents the data on the concentrations of CO on June 25.

Fig. 8 above shows notable peaks, providing a clear picture of the times when carbon monoxide concentrations are at their highest. Between 8:05 and 8:10, when the researchers waited to purchase Tikal National Park tickets, the first spike occurred, and a large school bus passed by the team. The bus's open windows have allowed outside air to enter, resulting in a CO level of 33.5 ppm, which triggers the device's beeping alert, a warning indicator of potential danger. The second notable increase has observed between 11:30 and 11:35 at Temple IV, where almost 70 people occupied a staircase. CO levels in the crowd are expected to be a concentration of 19.5 ppm. The final period, 15:25 to 15:30, has the greatest carbon monoxide concentration, 38.5 ppm. The bus ride from Tikal to Flores island, which made the device emit beeping alerts, has caused this peak. The researchers noticed smoke coming from a store near the island's entrance and concluded that it was coming from fire grills. Despite Tikal National Park's opened ventilation and the presence of the forest, there have persistent increases in CO levels that are caused mainly by high population density at the temples and high altitudes like Sumpango. Some particular spikes are also detected throughout the day when traveling between various places. The team has seen that CO levels are getting close to 40 ppm on this specific day, which may be seriously detrimental to health with prolonged exposure. This emphasizes the importance of identifying and resolving potential health risks related to high carbon monoxide emissions.



3.4 CO level spikes recorded on Day 5

Fig 9 was plotted with the data on the concentrations of CO on June 26.

Several notable CO level spikes in Fig. 9 have been observed and documented over the data collecting time. On the fifth day of data gathering, when the device was exposed to a barbeque area, the first significant spike appeared between 10:35 and 10:40. This area is within a rural hospital with an outdoor open space that allows for appropriate ventilation. However, the presence of smoke from the burning charcoal and the less than 50 people under a tent have attributed to the carbon monoxide concentration of 6.5 ppm. The carbon monoxide content demonstrated an increasing trend between 13:39 and 13:57, a range of 6 to 31 ppm. The team has on a lengthy bus ride, and windows open suggests that highly concentrated combustible gas emissions have been recorded. Another spike with CO levels between 3 and 16.5 ppm have noticed between 18:00 and 19:00. The machine has located at a soccer field (Onto Antigua) next to a highway where a lot of petrol stations, auto repair shops, and restaurants are releasing a high concentration of carbon monoxide and influencing the neighborhood around during the time period. At 19:22, the team entered a cafe in Antigua Central Park, where a significant amount of carbon monoxide has found. The carbon monoxide concentration changed throughout the recording period. The device was exposed to a small room in an Italian restaurant (Quesos y Vino) from 19:50 to 21:10. This exposure led to relatively high CO levels. Open windows, smokers near the window, the use of gas equipment for cooking, the presence of candles, and crowds are all contributory factors. The measured peaks have averaged 7.7 ppm, with the highest peak being 21 ppm. These data demonstrate the effect of daily lifestyle activities in Guatemala, where large CO gas emissions are caused by sources other than only transportation.

3.5 CO level spikes recorded on Day 6

The figure displays a greater concentration of carbon monoxide in the morning and lower levels in the afternoon on the final day of data collection. The team's bus ride to Santiago Sacatepeques (KFHI) has caused rises between 8:15 and 9:30, peaking at about 23 ppm. Emissions from fossil fuel combustion of vehicles on the village's unpaved road, which releases fumes, chemicals from the cars, and dust, mainly cause the CO level increases. Between 16:10 and 16:15 in Fig. 10, there was a noticeable change in the CO level due to unexpected smoke from the yard's burning of wood and

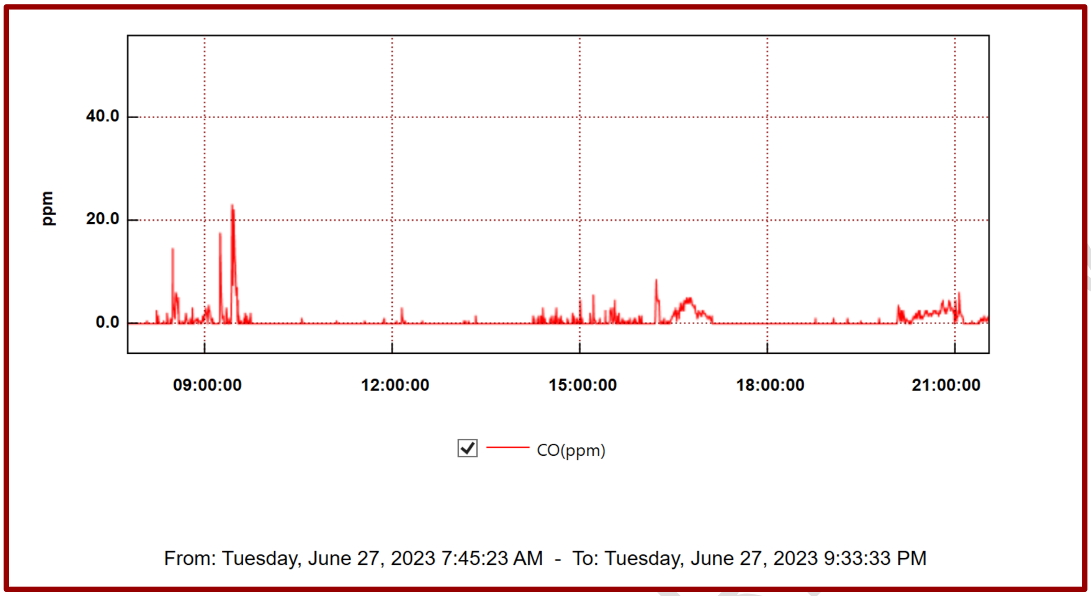


Fig 10 was graphed with the data on the concentrations of CO on June 27.

dry leaves that entered the building through windows. Within ten seconds, the carbon monoxide concentration has increased from 0 to 8.5 ppm, resulting in breathing problems and the need for mask use. The CO level progressively rose as the team moved from a restaurant to La Aurora Airport from sound 20:00 to 21:10. However, the machine has placed far from the cooking area, and the restaurant has excellent ventilation with large open windows, which has led to a relatively low CO level.

4. DISCUSSION

Past research has shown that the presence of motor vehicles in developed areas like Massachusetts, USA, results in carbon monoxide levels between 0 and 0.5 ppm [16]. This is significantly lower than the amounts shown in the result above. Compared to the USA, the data show four times of carbon monoxide concentration in Guatemala [17, 18]. An investigation of the relationship between carbon monoxide (CO) levels and symptoms suggestive of carbon monoxide poisoning, such as headaches and back pains, has been done as part of the 2006 RESPIRE study [19]. The individuals in this 2006 study have exposed to CO levels approximately at 2.2 ppm [20], and it explains that our current study has successfully identified a significant association between abnormally elevated carbon monoxide concentrations in the air and an increased incidence of respiratory diseases associated with CO exposure.

Guatemalans may experience severe detrimental effects from the high CO-level environment [21]. Around 0.2 ppm would be the usual range for carbon monoxide concentrations. However, according to the study's findings, the average concentration of carbon monoxide in Guatemala is significantly higher than the recommended amount of CO for the atmosphere to *contain without having negative impacts.*

Fig. 11 shows various transportation that influence CO emissions.

The data collected during the six days show many similarities. According to research, CO levels increase in locations with high population density, usage of biomass combustion, and the presence of many vehicles, which also combust fossil fuels. The hypothesis that CO levels would be between 0 to 40 ppm in spaced areas is confirmed by all of the data collected.

5. CONCLUSION

Carbon monoxide is an odorless, tasteless, and colorless gas that is invisible to humans. Prolonged exposure to this hazardous gas will lead the citizens within these locations cable plagues with numerous health concerns, including respiratory diseases, asthma, COPD, etc. Along with the high level of CO emissions in third-world countries, their inaccessibility to the proper healthcare service and impotent policies and laws will worsen the health issues that cause an increase in the overall mortality rate in countries.

The results of the study advise individuals who live in high-CO locations to avoid engaging in outdoor activities during the period of congested traffic and burning combustible fuel for household activities, such as cooking, heating, and lighting. These findings highlight the importance of further research to decrease carbon monoxide emissions and encourage a low-CO environment. Furthermore, this study supports Guatemala and other third-world countries to start implementing proper legislation to provide improved healthcare services to prevent the impact of this hazardous pollutant on human health.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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