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ORIGINAL ARTICLE

Carbon monoxide levels in workers at the Cerro de Guayabal Toll Booth, Ecuador

Niveles de monóxido de carbono en trabajadores del Peaje Cerro de Guayabal, Ecuador

Mercedes K. Montes • **María E. Moreira** • **Ivón Howland**

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Abstract Carboxyhemoglobin is formed when CO binds to hemoglobin with an affinity 240 times greater than oxygen. This research aimed to evaluate carbon monoxide (CO) levels in the Cerro de Guayabal toll booth workers, located on the Portoviejo-Manta highway, km 9 ½. This analytical, descriptive, prospective, and cross-sectional field study determined the risk of CO exposure by measuring the carboxyhemoglobin percentage (%COHb) at the beginning of the workday. The study included 33 workers who spent more than eight hours daily at the toll booth and were exposed to CO emissions from motor vehicles. A case-control design was used, comparing the results of the exposed workers (cases) with a control group that was not exposed but had similar demographic characteristics. The %COHb measurement was conducted in the morning to ensure the accuracy of the results. The data revealed that the toll area, with approximately 20,000 vehicles passing per hour, represents a potential health risk for the workers.

Keywords heparin anticoagulant, carboxyhemoglobin, hemoglobin, carbon monoxide, oxygen.

Resumen La carboxihemoglobina se forma cuando el CO se une a la hemoglobina, con una afinidad 240 veces mayor que el oxígeno. Esta investigación tuvo como objetivo evaluar los niveles de monóxido de carbono (CO) en los trabajadores del Peaje Cerro de Guayabal, ubicado en la vía Portoviejo-Manta km 9 ½. Este estudio de campo analítico, descriptivo, prospectivo y transversal, determinó el riesgo de exposición a CO mediante la medición del porcentaje de carboxihemoglobina (%COHb) al inicio de la jornada laboral. El estudio incluyó a 33 trabajadores que permanecieron más de ocho horas diarias en el peaje, expuestos a emisiones de CO provenientes de vehículos automotores. Se utilizó un diseño de casos y controles, comparando los resultados de los trabajadores expuestos (casos) con un grupo de control no expuesto, pero con características demográficas similares. La medición de %COHb se realizó por la mañana para garantizar precisión de los resultados. Los datos revelaron que la zona del peaje, con un tránsito de aproximadamente 20 000 vehículos por hora, representa un riesgo potencial para la salud de los trabajadores.

Palabras clave canticoagulante de heparina, carboxihemoglobina, hemoglobina, monóxido de carbono, oxígeno.

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PUBLIS EDITORIAL

Introduction

Carbon monoxide was discovered in 1776 by the French chemist de Lassone while heating zinc oxide with coke. Initially, he believed it to be hydrogen due to the blue flame it produced, but in 1800, English chemist William Cruikshank demonstrated that this compound contained carbon and oxygen. In 1846, French physicist Claude Bernard thoroughly investigated the toxic properties of carbon monoxide. During his experiments, he poisoned dogs with this gas and observed that their blood acquired a reddish and bright tone in all tissues (Kashfi & Patel, 2022).

The correlation between carboxyhemoglobin (COHb) levels and clinical symptoms could be more precise due to the concentration of carbon monoxide the patient is exposed to, the depth of breathing, and heart rate. It has been suggested that the severity of poisoning is more related to the binding of CO to cytochromes, which would explain the appearance of symptoms even at levels of COHb considered non-toxic (Bolaños & Chacón, 2017).

In mild or moderate poisoning cases, symptoms are usually nonspecific, making diagnosis difficult. These symptoms are often confused with food poisoning, delirium tremens, acute ethanol poisoning, migraines, or strokes. Studies have shown that even at low COHb levels (2-6%), ischemic changes and ventricular arrhythmias can occur in patients with coronary artery disease. Acute exposures to carbon monoxide with COHb levels between 4 and 6% significantly reduce physical performance in healthy young men (Grover & Ghosh, 2018).

Acute carbon monoxide poisoning is a medical emergency that can lead to severe neurological sequelae or death if not treated promptly. The most common treatment is administering normobaric oxygen until symptoms resolve and COHb levels normalize; however, patients are often discharged without follow-up (Bolaños & Chacón, 2017). It has been shown that significant increases in exposure to carbon monoxide are an important cause of morbidity and mortality in both childhood and adulthood. In Manabí, no studies have been conducted to determine CO concentration levels; thus, this research aimed to evaluate the CO levels in workers at the Guayabal Toll Booth.

Methodology

The study was qualitative-quantitative, with a prospective, cross-sectional, and experimental field approach. It was conducted at the Cerro de Guayabal Toll Station on the Portoviejo-Manta Road, km 9. Informed consent was obtained prior to the interviews. A total of 33 members of the Asociación 13 de Junio de Cerro de Hojas participated. All association members were included in the study, provided they had worked at the toll booth for over a year and signed the informed consent form. Those who chose not to participate were excluded.

The laboratory test results were linked to a data collection form that included COHb percentage values from the analyzed samples. The data were tabulated and analyzed using statistical techniques based on direct observation.

The research was approved by the Technical University of Manabí, Faculty of Health Sciences, School of Clinical Laboratory, and authorized by the association's president, Mr. Enrique Roca. Ethical principles of non-maleficence were ensured to avoid harm to participants, and confidentiality was guaranteed to ensure the privacy of the results.

Results and discussion

Table 1 shows the sociodemographic data of the workers at the Cerro de Guayabal Toll Station. The predominant age range in the study population was from 64 to 76 years, and of the total 33 members, the majority were male. According to Bravo and Mora (2016), the population exposed to carbon monoxide in the loading area of the Bus Terminal in the city of Cuenca was represented by 64.4% women and 35.6% men. Regarding the age distribution, 53.3% were between 20 and 40 years old, 33.33% were between 41 and 60, and 13.3% were between 61 and 80 (Vives, 2014).

Table 1. Sociodemographic data of the workers at the Cerro de Guayabal Tollbooth

Indicator	Frequency	Percentage
Gender		
Male	30	90.9
Female	3	9.09
Age (years)		
16 - 28	3	9.09
29 – 40	7	21.21
41 – 52	4	3.03
53 - 64	6	18.18
65 - 76	13	39.39
Level of education		
Primary	25	75.76
Secondary	8	24.24
Higher	0	0
Years of work		
1 -3	3	9.09
4 - 6	7	21.21
7 -10	4	3.03
>10	19	57.57

The toxic dose did not depend on gender, age, or the num-

ber of people exposed in the contaminated area. Personnel working at tollbooths, gas stations, and fire departments were the most vulnerable to carbon monoxide (CO) poisoning (Oilu et al., 2010). Seventy-five percent of the workers had a primary level of education.

Alvarado et al. (2008) reported that 65% of the study population had completed primary school, 10% had secondary education, 2% were illiterate, and 11% had university studies. Similarly, the workers at the tollbooth and the municipal landfill had low educational levels due to their socioeconomic context. Many of them had not had access to formal education in the past and opted to work on the streets, which increased their vulnerability to poisoning and its health repercussions.

Over half of the study population (57%) had worked at the tollbooth for over 10 years. Another study reported that 4% of the respondents had worked less than 5 years, 16% more than 5 years, 62% more than 15 years, and 18% more than 20 years. This research showed that both tollbooth and municipal landfill workers had been exposed for over 10 years, increasing their risk of elevated carboxyhemoglobin levels over time (Núñez, 2015). Moderate to severe CO poisoning can cause damage to the heart muscle, increasing the long-term risk of death (Bolaños & Chacón, 2017).

Table 2 presents the data on smokers and those who use masks for protection. More than half (75.76%) were non-smokers, and none used a mask for protection.

Table 2. Smokers and mask use among the workers at the Cerro de Guayabal Tollbooth

Indicator	Frequency	Percentage
Smoker		
Yes	8	24.24
No	25	75.76
Use of face mask		
Yes	0	0
No	33	100

In the study population (Núñez, 2015), it was observed that 75% of the members of the June 13th Association of Cerro de Hoja were non-smokers, and 100% did not use face masks. On the other hand, Alvarado et al. (2008) determined that 84% of workers were smokers, and 87% did not use protective masks during workdays.

The results of this study differed from those reported by Núñez (2015), where 84% of the population smoked. Regarding protective measures, it was found that in Alvarado et al.'s (2008) study, workers had masks but did not use them, while the tollbooth population did not have access to this protective measure. Therefore, both populations were equally susceptible to carbon monoxide poisoning.

Figure 1 shows the symptoms presented by tollbooth workers. Fatigue was the most frequent symptom (100%), followed by dizziness (36.36%) and headache (36.36%). Other recorded symptoms included cough, nausea, tachycardia, and difficulty breathing. Durán (2015) indicated that

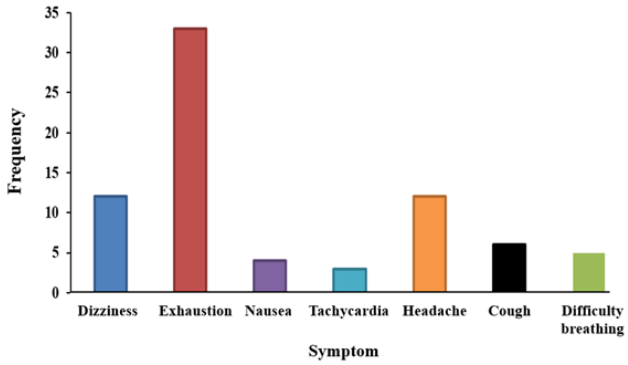

Figure 1. Symptoms of the workers at the Cerro de Guayabal Tollbooth.

the most commonly reported symptoms in workers from the three gas stations were headaches and fatigue.

In both studies, the predominant symptoms were headache, fatigue (tiredness), and dizziness. In the central nervous system, carbon monoxide interferes with the cellular respiratory process by inhibiting the electron transport chain and oxidative phosphorylation; consequently, it slows down the Krebs cycle and ATP production. Individuals with prolonged exposure should be instructed and trained to recognize the symptoms that may result in poisoning.

As seen in Figure 2, the majority (54.54%) of the population was exposed for more than 8 hours. It has been reported

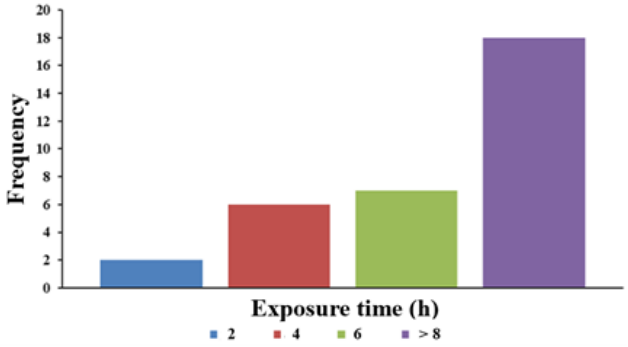

Figure 2. Exposure time of the workers at the Cerro de Guayabal Tollbooth.

that after 6 hours of exposure, neurological symptoms can appear (Bolaños & Chacón, 2017).

Prolonged exposure to low concentrations of CO can cause subtle effects on various structures of the central nervous system. CO activates polymorphonuclear leukocytes, which perform diapedesis and cause lipid peroxidation in the brain, particularly in the globus pallidus, a site rich in iron (Ministry of Environment, 2010). The work hours of the vendors ranged from 2 to more than 8 hours, with 54% of the population being exposed for more than 8 hours daily while working at the toll booth. Durán (2015) indicated that the exposure time was more significant than 8 hours daily.

Figure 3 shows the CO levels of the workers at the Cerro de Guayabal Tollbooth. The CO values determined using the coximetry method ranged from 0.8 to 3.8%. Rosas (2014) reported that 20 patients (44%) had normal carboxyhemog-lobin levels, while the remaining population (56%) showed elevated levels of carboxyhemoglobin in venous blood. In both studies, the CO values were higher than the established range (< 0.5% in non-smokers and < 1.5% in smokers) (Núñez, 2015).

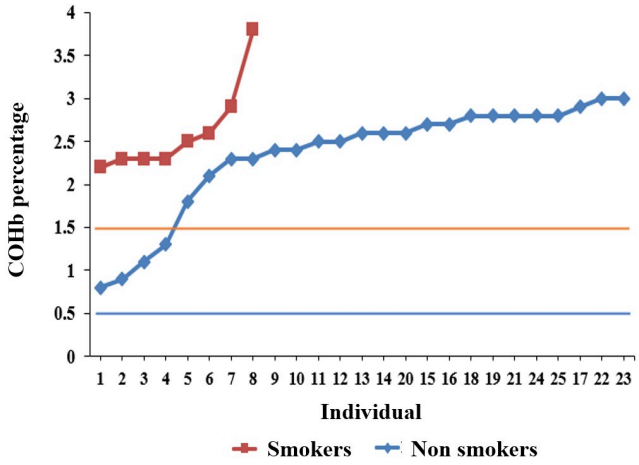

Figure 3. CO levels of the workers at the Cerro de Guayabal Tollbooth.

Signs of myocardial ischemia were reported in the electrocardiogram of a 12-year-old child exposed to carbon monoxide due to defects in the heating system of their home. Although the child was asymptomatic and had low levels of carboxyhemoglobin, cardiac alterations were observed (Chi et al., 2022).

Table 3 shows the relationship between concentration and exposure time to CO. It was observed that in non-smokers, all had elevated values (0.8 to 3.0%). In another study (Mayorga et al., 2020), 62% of the population had worked for more than 15 years, and 18% had worked for more than 20 years. Most (56%) showed elevated carboxyhemoglobin levels in venous blood, while 44% had normal carboxyhemoglobin levels. In both studies, most of the population was exposed for over 10 years. In this research, values above the normal range for COHb were obtained in non-smokers, while the population in Mayorga et al. (2020) showed both normal and elevated levels of COHb.

Table 3. Relationship between CO concentration and CO exposure time

Indicator	COHb percentage	Exposure time (years)			
		1 - 3	4 - 6	7 - 10	>10
Non-smoker	0.6 – 1.0	1	1		
	1.1 – 1.5				1
	1.6 – 2.0				1
	2.1 – 2.5	1	2	1	3
	2.6 – 3.0		2	1	10
	3.1 – 4.0				
Smoker	0.6 – 1.0				
	1.1 – 1.5				
	1.6 – 2.0				
	2.1 – 2.5	1	2	1	
	2.6 – 3.0				3
	3.1 – 4.0				1

Daily exposure to 30 ppm of carbon monoxide (equivalent to 2.5% COHb) was comparable to smoking 20 cigarettes a day, which could cause short- and medium-term effects, including neuropsychiatric symptoms that might manifest several days after exposure. These symptoms included a vegetative state characterized by mutism and immobility; parkinsonism; apraxia, agnosia; vision problems; amnesic states; depression; dementia; psychosis; paralysis; spasmodic movements in the face, arms, and legs; cortical blindness; peripheral neuropathy, and incontinence. Additionally, personality changes such as irritability, verbal aggression, violence, impulsivity, and bad mood could occur. It was concluded that the longer the exposure, the higher the CO concentration levels in smokers and non-smokers.

Smokers had levels between 2.2 and 3.8%, surpassing the established range of 1.5% due to prolonged exposure (more than 10 years). According to Rosas (2014), a group of smokers had recorded COHb values of 6.0%, confirming this trend.

The COHb levels in smokers from this study and those in Rosas (2014) were higher than the established range for non-smokers (<1.5%). In the long term, smokers could experience adverse effects from carbon monoxide exposure, such as nerve system damage and heart issues. The habit of smoking increases their exposure to CO and raises the risk of heart disease, lung cancer, emphysema, and other respiratory

problems. Existing conditions caused by chemical exposure worsened; however, quitting smoking reduced the risk of health problems, even in people who had smoked for a long time (Díaz et al., 2017).

Smokers could also suffer CO poisoning at their workplaces, such as gas stations and tollbooths, where they were exposed to vehicle exhaust fumes. This type of poisoning was common in professions where carbon monoxide emissions represented a constant risk (Chi et al., 2022).

Conclusions

The study revealed that the tollbooth staff, predominantly male with an average age of 64 to 76, has been exposed to carbon monoxide (CO) for over 10 years during work shifts of 2 to 8 hours per day without using protective equipment such as masks. The predominant symptoms include fatigue, headache, and dizziness, and it was found that the carboxyhemoglobin (COHb) percentage in their blood exceeds the established limits in smokers and non-smokers.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

Conceptualization: Mercedes K. Montes, María E. Moreira. **Data curation:** Mercedes K. Montes, María E. Moreira. **Formal analysis:** Mercedes K. Montes, María E. Moreira. **Research:** Mercedes K. Montes, María E. Moreira, Ivón Howland. **Methodology:** Ivón Howland. Supervision: Ivón Howland. **Validation:** Ivón Howland. **Visualization:** Mercedes K. Montes, María E. Moreira. **Writing the original draft:** Mercedes K. Montes, María E. Moreira, Ivón Howland. **Writing, review and editing:** Mercedes K. Montes, María E. Moreira, Ivón Howland.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statement on the use of AI

The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.

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