NOFOR
NOVEL FORENSIC RESEARCH

DOI: 10.5455/NOFOR.2025.11.09

NOFOR. 2025;4(2):42-7

Original Article

Investigation of carbon monoxide-poisoning related deaths

Abuzer Gulderen[1], Murat Kamalak[1], Sertac Dalgic[2], Tuba Sahinoglu Gunes[3]

[1]Gaziantep Forensic Medicine Group Directorate, Gaziantep, Türkiye
[2]Akhisar Forensic Medicine Branch Directorate, Manisa, Türkiye
[3]Independent Researcher Forensic Medicine Specialist, Tokat, Türkiye

Received March 03, 2025; Accepted May 26, 2025; Available online August 15, 2025

Abstract

Aim: Carbon monoxide (CO) is a colorless and odorless gas. This non-irritating gas is produced by the combustion of carbon-containing compounds in the presence of insufficient oxygen. Because it is non-irritating, exposure is often detected late, which can lead to severe injury or death. This study aimed to discuss the mortality rates due to CO poisoning in our country, examining the factors and etiology of CO poisoning through the example of Gaziantep province, and to raise awareness about preventable accidents.
Materials and Methods: Postmortem examinations—including external examination, autopsy, toxicological, and histopathological analyses—and forensic investigations conducted in Gaziantep over a three-year period between 2022 and 2024 were included to identify deaths caused by carbon monoxide poisoning. Cases were evaluated based on age, gender, month, season, origin, time to death, CO source, and carboxyhemoglobin (COHb) levels.
Results: It was determined that 41 of 3274 forensic cases died due to carbon monoxide poisoning. Among the cases, 31.7% were female and 68.3% male. The highest recorded COHb level was 78.6%, and the lowest was 17%. The majority of poisonings were attributed to gas originating from stoves.
Conclusion: The findings of this study were generally consistent with the existing literature. No cases of suicidal CO poisoning were identified in the region; all deaths were determined to result from preventable accidents. Implementing necessary precautions is essential to reduce such fatalities. Taking the necessary precautions, conducting annual maintenance of stoves and heaters, and installing CO alarms in homes will reduce fatalities caused by CO poisoning.

Keywords: Forensic medicine, forensic death, carbon monoxide poisoning

INTRODUCTION

Carbon monoxide (CO) is a colorless and odorless gas. This non-irritating gas is produced by the combustion of carbon-containing compounds in the presence of insufficient oxygen [1]. Due to its lack of irritating properties, CO exposure is often detected late, leading to serious harm and potentially fatal outcomes [2,3].

The density of CO is 0.97, making it slightly lighter than ambient air. It is present in trace amounts in normal atmospheric air, with higher concentrations found in enclosed spaces and urban centers [4,5]. While the CO level is approximately 2% in non-smokers, it can reach up to 10% in smokers [5-7]. CO is commonly generated by incomplete combustion of heating devices fueled by coal, wood, and gas, such as stoves, barbecues, braziers, automobile exhausts, and water heaters. Furthermore, if the heating device lacks a chimney or if the chimney is obstructed, environmental CO levels will progressively increase, resulting in greater inhalation exposure [8-11].

CO poisoning remains a significant global health issue. In developed countries, CO poisoning frequently occurs in the context of fire-related accidents and suicides, whereas in developing or underdeveloped countries, such as ours, accidental poisonings related to stoves and heaters are more prevalent during the winter months [8,12,13].

CITATION
Gulderen A, Kamalak M, Dalgic S, Sahinoglu Gunes T. Investigation of Carbon Monoxide Poisoning-related Deaths. NOFOR. 2025;4(2):42-7. DOI: 10.5455/NOFOR.2025.11.09

Corresponding Author: Abuzer Gulderen, Gaziantep Forensic Medicine Group Directorate, Gaziantep, Türkiye
Email: md.abuzergulderen@gmail.com

DOI: 10.5455/NOFOR.2025.11.09

Inhalation or ingestion of methylene chloride (dichloromethane), an industrial paint remover, can lead to endogenous CO production through hepatic metabolism even without exposure to exogenous CO gas, resulting in elevated internal CO levels and may cause toxicity even in the absence of CO in the ambient air [14].

When exposed to CO gas, CO competes with oxygen and binds to hemoglobin, resulting in hypoxia. The affinity of CO for hemoglobin is approximately 250 times greater than that of oxygen, which impedes the release of oxygen bound to hemoglobin into the tissues, thereby causing tissue-level hypoxia. CO also binds to myoglobin, leading to symptoms of muscle weakness and fatigue. By disrupting oxygen transport and exchange within tissues, CO causes damage and cell death, particularly in organs that are highly sensitive to oxygen deprivation [9,15,16].

Because the initial symptoms of CO poisoning are nonspecific, it is often difficult for individuals to recognize that they have been poisoned. Symptoms associated with CO poisoning are nonspecific and may be mistaken for viral infections; these include dizziness, nausea, vomiting, cough, numbness, and weakness. Binding to myoglobin induces profound weakness, so even when individuals realize they have been poisoned and attempt to reach a fresh environment, fatalities frequently occur due to collapse near windows or doors. In CO toxicity, where the heart and brain are particularly sensitive to hypoxia, symptoms such as impaired consciousness, confusion, and coma are observed. Among survivors of poisoning, neurological and cardiac sequelae may persist, including cardiomegaly, myocardial infarction, arrhythmias, coma, seizures, behavioral disorders, cognitive impairments, fecal and urinary incontinence, ataxia, muscle rigidity, memory deficits, and personality changes [15,16].

Approximately 30.000 people worldwide die annually due to accidental CO poisoning. Although exact figures are not available for our country, hundreds of deaths from CO toxicity occur each year. While some survivors achieve full recovery, others may suffer permanent neurological damage. In our country, the majority of fatalities are generally attributable to preventable accidents [8,17,18].

This study aims to examine the mortality rates related to CO poisoning in our country, using Gaziantep as a representative sample, and to explore the contributing factors and etiology of CO poisoning. Additionally, it seeks to raise awareness regarding preventable accidents through a review of the literature.

MATERIAL AND METHOD

Forensic deaths that occurred in Gaziantep province between the beginning of 2022 and the end of 2024 and were examined/autopsied at the Gaziantep Forensic Medicine Autopsy Branch were retrospectively reviewed, and deaths due to CO poisoning were included in the study. A total of 3.836 forensic deaths occurred in our branch during the 3-year period, of which 562 were excluded because they were related to the February 6 earthquake. Thus, 3.274 forensic deaths were retrospectively analyzed. Data were obtained from the autopsy archive, histopathological and toxicological report results, and the Gaziantep Forensic Medicine Group Presidency Morgue Specialization Department reports after obtaining ethical approval from the Council of Forensic Medicine. This approval was granted by the Council of Forensic Medicine Education and Scientific Research Board with decision number 21589509/22025/352 dated 18.03.2015.

The cases were evaluated in terms of age, gender, month, year, season, COHb level, duration of hospital stay, source of carbon monoxide, place of residence, cohabitation status, and cardiac findings. Due to the insufficient number of cases for statistical comparison, subgroups were compared by calculating percentages.

RESULTS

Our study examines deaths due to carbon monoxide poisoning in Gaziantep Province over a three-year period from January 2022 to December 2024. During this time, a total of 3.836 autopsies/corpse examinations were conducted in the province, of which 562 were excluded from evaluation as they were related to earthquake fatalities. It was determined that 41 (1.25%) of the 3.274 non-earthquake deaths were attributable to CO poisoning.

Thirteen cases (31.7%) were female, and 28 cases (68.3%) were male. The cases were analyzed according to age groups, with infants aged 0–1 year categorized separately. Other age groups were classified by decades. The youngest case was 1 year old, and the oldest was 98 years old. The highest number of deaths occurred in the seventh decade of life. The lowest number of deaths was observed in the second and third decades. No deaths were recorded in the 0–1 year age group, and four deaths occurred in the first decade. The gender distribution of the cases is presented in Figure 1, and the distribution by age groups is shown in Figure 2.

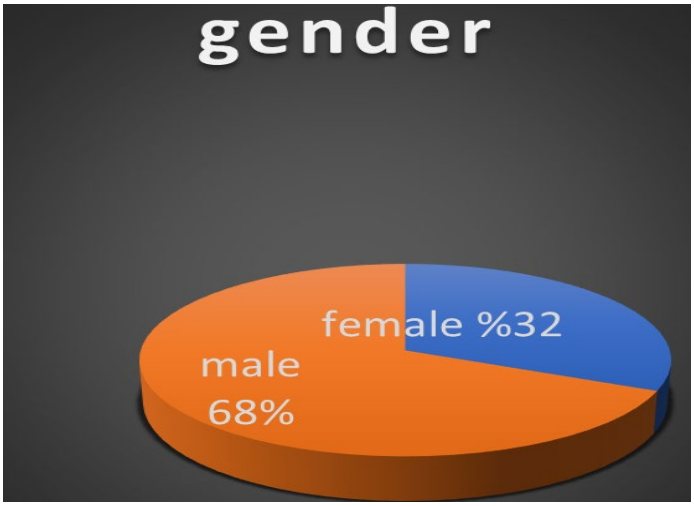

Figure 1. Distribution of cases by gender

DOI: 10.5455/NOFOR.2025.11.09

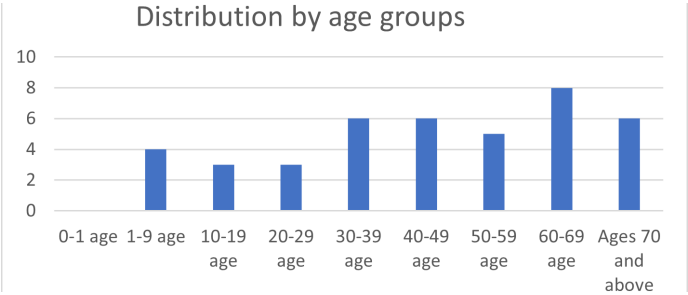

Figure 2. Distribution of cases by age groups

When the death cases were analyzed according to the months in which they occurred, the highest number of deaths was observed in February, with 9 cases (21.9%). No deaths due to CO poisoning were recorded in May, July, August, and September. When the death cases were evaluated by season, the majority occurred in winter, with 24 cases (58.5%). It was noted that 3 deaths occurred during the summer season, all resulting from CO poisoning caused by fire. The distribution of cases by month is presented in Figure 3.

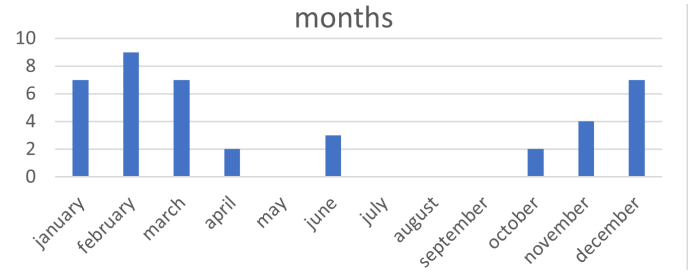

Figure 3. Distribution of cases by month

In the analysis conducted by year, it was found that the highest number of deaths occurred in 2022, with 23 cases (56.09%) reported that year. Ten deaths occurred in 2023, and eight deaths were recorded in 2024.

When evaluating CO levels, the lowest COHb level among fatal poisonings was 17%, and the highest was 78.6%. Most deaths occurred at COHb levels of 60% and above. While 27 cases were found deceased at the scene, the longest hospital stay due to CO poisoning was four months. The majority of deaths in men were observed at COHb levels of 60% and above, whereas in women, the most frequent deaths occurred at COHb levels between 50% and 59%. The distribution of COHb levels by gender is presented in Table 1. The distribution of COHb levels by age groups is shown in Table 2.

In 32 cases, the source of CO was the stove, while in 6 cases, poisoning was attributed to CO gas originating from a fire. It was identified that 3 cases were poisoned due to gas leaking from a water heater. Among the cases, 21 individuals resided in the city center, and 20 lived in districts and villages. The distribution according to the CO source is presented in Figure 4.

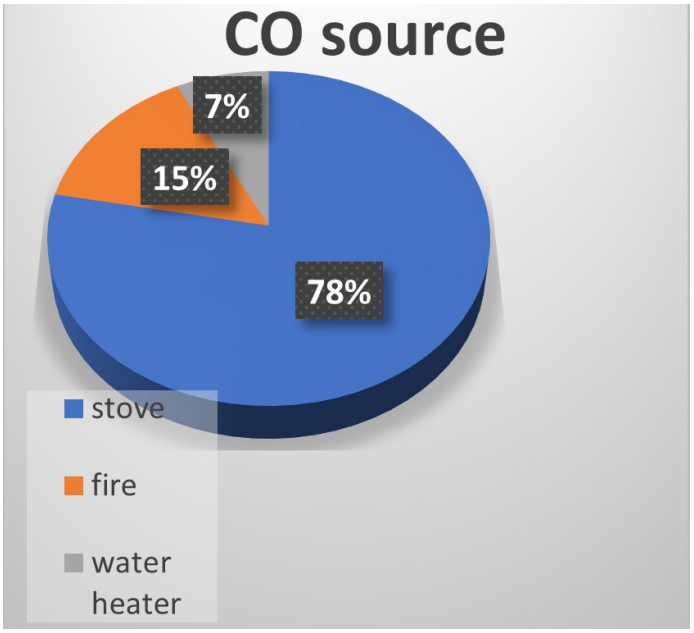

Figure 4. Distribution by CO source

It was determined that 11 of the 41 cases underwent autopsy, while 30 were investigated for cause of death. Among the autopsied cases, one exhibited bridging, one had moderate coronary artery occlusion, one had severe coronary artery occlusion, and the remaining cases showed mild coronary artery occlusion. The CO level in the case with severe occlusion was measured at 37.5%.

Table 1. Distribution of COHb levels of cases by gender

Gender	COHb levels													
	<20%		20-30%		30-40%		40-50%		50-59%		≥60%		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Female	1	2.43	2	4.87	2	4.87	3	7.31	4	9.75	1	2.43	13	31.7
Male	3	7.31	4	9.75	4	9.75	2	4.87	4	9.75	11	26.83	28	68.3
Total	4	9.75	6	14.63	6	14.63	5	12.19	8	19.51	12	29.26	41	100

DOI: 10.5455/NOFOR.2025.11.09

Table 2. Distribution of COHb levels of cases by age groups

Age groups	COHb levels													
	<20%		20-30%		30-40%		40-50%		50-59%		≥60%		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1-9	1	2.43	0	0	0	0	2	4.87	1	2.43	0	2.43	4	9.75
10-19	0	0	1	2.43	0	0	0	0	0	0	2	4.87	3	7.31
20-29	0	0	1	2.43	0	0	0	0	1	2.43	1	2.43	3	7.31
30-39	1	2.43	1	2.43	0	0	0	0	1	2.43	3	7.31	6	14.63
40-49	1	2.43	0	0	0	0	2	4.87	1	2.43	2	4.87	6	14.63
50-59	0	0	1	2.43	2	4.87	1	2.43	0	0	1	2.43	5	12.51
60-69	0	0	2	4.87	2	4.87	0	0	2	4.87	2	4.87	8	19.51
70 and above	1	2.43	0	0	2	4.87	0	0	2	4.87	1	2.43	6	14.63
Total	4	9.75	6	14.63	6	14.63	5	12.19	8	19.51	12	29.26	41	100

DISCUSSION

Humans have been burning carbon derivatives to generate heat since ancient times, aiming to satisfy heating needs in enclosed spaces. CO, which is present in trace amounts in normal air, increases in concentration within closed environments. When carbon derivatives are combusted in such settings and combustion is incomplete, the level of CO rises rapidly. Symptoms of CO poisoning begin to manifest when the COHb level in the blood reaches 10% [5,19,20]. The earliest historical reference to CO is attributed to Aristotle in antiquity, who stated, "Coal fumes cause severe headaches and death." In the 1600s, a Swedish scientist documented bright red livor mortis (postmortem discoloration) on bodies due to inhalation of carbon gas, and clinical CO poisoning was first reported by the French physician Dominique-Benoît Harmant in 1775 [21].

Deaths resulting from accidental CO poisoning are preventable; however, a considerable proportion of accidental fatalities continue to be caused by CO poisoning [8]. In our province, 1.25% of forensic deaths over the three-year study period were attributed to CO poisoning. A study conducted in Eskişehir reported this rate as 1.43%, while in Ankara, it was 3.54%. Although regional differences were observed depending on the types of fuels used for heating, these findings generally align with existing literature [8,22].

When cases were evaluated by gender, the male-to-female ratio in our study was approximately 2:1. Studies have demonstrated that although women and men are exposed to CO at nearly the same rate, mortality in men is about twice as high. This difference has been attributed to faster elimination and shorter half-life of COHb in women compared to men. Consistently, in our study, deaths were twice as frequent in men [5,23].

When the distribution by age groups was analyzed, the highest mortality was observed in the 60–69-year age group, accounting for approximately 20% of deaths, with the youngest fatality being 1 year old. The increased mortality in the older age group is thought to be related to elderly individuals living alone in rural areas or slums, where stoves are used for heating. These individuals tend to light stoves late at night, leading to deaths caused by incomplete combustion of coal. While the average age of death reported in the literature is around 30–40 years, our study found that fatalities occurred more frequently in older age groups [24].

In our study, the highest number of deaths occurred during the winter season, particularly in February, which aligns with existing literature. Factors contributing to this seasonal increase include the widespread use of stoves in winter months, prolonged time spent indoors, lack of regular chimney maintenance, and the reduced efficiency of chimneys in evacuating smoke due to prevailing southern winds that are more common in winter [8,25].

When examined on an annual basis, 23 cases were recorded in 2022, decreasing to 10 in 2023 and 8 in 2024. Literature reports indicate a general decline in the number of deaths over time [12]. The significant reduction between 2022 and the following year may be attributed to the earthquake on February 6, 2023, which forced people to live in more crowded and outdoor environments during the winter months. The lowest COHb level resulting in death was 17%, and the highest was 78.6%. Although various rates have been reported in studies, an average COHb level of 50% or higher has commonly been observed [8,22,26].

In our study, the most frequent fatal cases occurred at COHb levels of 60% and above. Specifically, deaths in women were most frequent at COHb levels of 50-59%, whereas in men, deaths were most common at levels of 60% and above.

DOI: 10.5455/NOFOR.2025.11.09

When COHb levels were analyzed according to age groups, it was found that 10 cases occurred in individuals up to 39 years of age, while 31 cases were seen in those aged 40 and above. The most frequent deaths occurred at COHb levels of 60% and above in individuals up to 49 years of age, whereas no significant difference in distribution according to COHb levels was observed in those aged 50 and above. The occurrence of death at lower COHb levels in elderly individuals aligns with existing literature, which recognizes chronic diseases as factors that predispose to fatality at lower COHb concentrations [10].

In our study, deaths due to CO poisoning were accidental in origin, with stoves identified as the most common source (81%). Six cases involved smoke inhalation poisoning resulting from building fires without any visible signs of burning. Half of the fire-related poisonings occurred during the summer months. Studies conducted in Ankara and Bursa also reported stoves as the most frequent source [10,11].

It was determined that one autopsied case had severely occluded coronary arteries, and the COHb level in this case was 37.5%. Morbidity was identified as a contributing factor facilitating death, consistent with the literature [1,10].

CONCLUSION

Although CO poisoning has long been recognized, it remains a significant cause of preventable accidental deaths. Such fatalities are frequently encountered by forensic medicine specialists, particularly during the winter months. These poisonings can be reduced through specific preventive measures. According to US Environmental Protection Agency recommendations the most critical precautions include installing CO alarms near sleeping areas, conducting annual inspections of heating systems and devices, avoiding the use of combustion appliances without proper ventilation, never burning fuel indoors except in devices designed for safe use such as stoves or ovens, refraining from using chimneyless devices like barbecues and water heaters in enclosed spaces, recognizing and responding to the possible symptoms of CO poisoning, and prioritizing the use of safer heating systems, especially in households with elderly individuals [27].

Considering that the most frequent deaths in our study occurred during the winter months and were caused by stoves, it is important to perform annual maintenance of chimneys and stoves and to install CO alarms in homes.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

Ethics committee approval for our study was obtained from the Council of Forensic Medicine. This approval was granted by the Council of Forensic Medicine Education and Scientific Research Board with the decision numbered 21589509/22025/352 dated 18.03.2015.

REFERENCES

1. Shin M, Bronstein AC, GliddenE, Malone M, Chang A, Law R, Boehmer TK, et al. Morbidity and mortality of unintentional carbon monoxide poisoning: United States 2005 to 2018, Ann Emerg Med. 2023;81:309-17.
2. Centers for Disease Control and Prevention (CDC). Nonfatal, unintentional, non--fire-related carbon monoxide exposures--United States, 2004-2006. MMWR Morb Mortal Wkly Rep. 2008;57:896-9.
3. Sircar K, Clower J, Shin MK, Bailey C, King M, Yip F. Carbon monoxide poisoning deaths in the United States, 1999 to 2012. Am J Emerg Med. 2015;33:1140-5.
4. International Chemical Safety Cards (ICSCs), ICSC 0023 Carbon monoxide, April 2024, https://chemicalsafety.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0023&p_version=2, access date 01.07.2025
5. Mattiuzzi C, Lippi G. Worldwide epidemiology of carbon monoxide poisoning. Hum Exp Toxicol. 2020;39:387-92.
6. Rose JJ, Wang L, Xu Q, McTiernan CF, Shiva S, Tejero J, et al. Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy. Am J Respir Crit Care Med. 2017;195:596-606.
7. Penney D, Benignus V, Kephalopoulos S, Kotzias D, Kleinman M, Verrier A. Carbon monoxide. In: WHO guidelines for indoor air quality: selected pollutants. 2010. http://www.ncbi.nlm.nih.gov/books/NBK138710/ access date 23.08.2016
8. Yetiş Y. et al. 20-Year Analysis of Deaths Due to Carbon Monoxide Poisoning in Eskisehir. Adıyaman University Journal of Health Sciences. 2017;3:396-406.
9. Kandis H, Katırcı Y, Çakır Z, Aslan Ş, Uzkeser M, Bilir Ö. Retrospective Analysis of Cases Presenting to the Emergency Department with Carbon Monoxide (CO) Intoxication. Academic Emergency Medicine Journal. 2007;5:21-5.
10. Cantürk N, Başbulut AZ, Cantürk G, Dağalp R. Evaluation of Autopsy Cases of Carbon Monoxide Poisoning in Ankara Between 2002 and 2006. Journal of Forensic Medicine. 2008;22:25-30.
11. Türkmen N, Akgöz S. Deaths due to carbon monoxide poisoning confirmed by autopsy in Bursa. Journal of Forensic Medicine. 2005;19:20-5.
12. Heckerling PS, Leikin JB, Terzian CG, Maturen A. Occult carbon monoxide poisoning in patients with neurologic illness. J Toxicol Clin Toxicol. 1990;28:29-44.
13. Balzan MV, Agius G, Galea Debono A. Carbon monoxide poisoning: easy to treat but difficult to recognise. Postgrad Med J. 1996;72:470-3.
14. Jain KK. Textbook of Hyperbaric Medicine. In: Jain KK, editor. Carbon Monoxide and Other Tissue Poisons. 6th edition. Springer International Publishing. 2016:131-54.
15. Goldstein M. Carbon Monoxide Poisoning. J Emerg Med. 2008;34:538-42.
16. Cobb N, Etzel RA. Unintentional carbon monoxide-related deaths in the United States, 1979 through 1988. JAMA. 1991;266:659-63.
17. Centers for Disease Control and Prevention (CDC). Carbon monoxide exposures--United States, 2000-2009. MMWR Morb Mortal Wkly Rep. 2011;60:1014-7.
18. QuickStats: Number of Deaths Resulting from Unintentional Carbon Monoxide Poisoning,* by Month and Year - National Vital Statistics System, United States, 2010-2015. MMWR Morb Mortal Wkly Rep. 2017;66:234.
19. Gozubuyuk AA, Dag H, Kacar A, Karakurt Y, Arica V. Epidemiology, pathophysiology, clinical evaluation, and treatment of carbon monoxide poisoning in child, infant, and fetus. North Clin Istanb. 2017;4:100-7.

DOI: 10.5455/NOFOR.2025.11.09

20. Chiew AL and Buckley NA. Carbon monoxide poisoning in the 21st century. Crit Care. 2014;18:221.

21. Lanska DJ. Carbon monoxide poisoning. Medlink Neurology. Updated 04 February 2025. Released 06 June 1997. CME expiration 04 February 2028. https://www.medlink.com/articles/carbon-monoxide-poisoning Access date 07.02.2025

22. Uysal C, Celik S, Duzgun Altuntas A, Kandemir E, Kaya M, Karapirli M, et al. Carbon monoxide-related deaths in Ankara between 2001 and 2011. Inhal Toxicol. 2013;25:102-6.

23. Zavorsky GS, Tesler J, Rucker J, Fedorko L, Duffin J, Fisher JA. Rates of carbon monoxide elimination in males and females. Physiol Rep. 2014;2:e12237.

24. Buyuk Y, Kocak U. Fire-related fatalities in Istanbul, Turkey: analysis of 320 forensic autopsy cases. J Forensic Leg Med. 2009;16:449-54.

25. Zhou L, Liu L, Chang L, Li L. Poisoning deaths in Central China (Hubei): A 10-year retrospective study of forensic autopsy cases. J Forensic Sci. 2011;56:S234-7.

26. Azmak D, Çetin G, Kolusayın Ö, Soysal Z. Deaths due to carbon monoxide poisoning. J For Med. 1994;10:73-81.

27. US Environmental Protection Agency, Preventing Carbon Monoxide Poisoning, available at Preventing Carbon Monoxide Poisoning. https://www.epa.gov/sites/default/files/2015-08/documents/pcmp_english_100-f-09-001.pdf 01.2009