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Assessment of Carbon Monoxide (CO) Gas Poisoning in Coal Mining

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Abstract: Mine fires are an extremely important problem in underground coal mining in terms of both loss of life, loss of reserves and production stoppages. For this reason, it is necessary to keep the underground under constant control with CO measurements, to constantly monitor it, and to activate a warning system at critical levels. In this study, fires and related CO gas poisoning were evaluated together with the events that occurred, and it was emphasized to what extent they caused mass deaths at a catastrophic level.

Keywords: Coal mining, mine fires, CO poisoning, monitoring, warning.

Introduction

In addition to toxic (CO, H_2S, SO_2, nitrogen oxides, etc.), explosive (CH_4, C_2H_6, H_2, CO, etc.), suffocating (CO_2, CH_4, N_2 etc.) gases, explosive (coal dust) and dusts that are harmful to health (quartz dust) in the mine air, cause unfavorable and dangerous working environments in underground coal mines.

It is known that coal is formed by the accumulation of organic materials in swamp environments and under appropriate temperature and pressure. Due to their decomposition in water, methane gas, also known as swamp gas, is formed in the first stage. Although gases such as CO and H_2S do not occur naturally in environments where coal is present, these gases are formed after partial combustion or reactions.

Apart from combustion and explosion in mining operations, the most important sources of CO are the exhaust fumes of internal combustion engines and the oxidation of coal. Areas where CO is found in high concentrations are secluded places in the mine and areas with inadequate ventilation.

CO Properties, Formation and Physiological Effects

CO is a colorless, odorless, tasteless, poisonous and flammable gas that is produced as a result of incomplete combustion of carbon-containing materials (Krenzelok et al., 1996). CO is both toxic at very low concentrations and explosive over a wide range (12.5-74.2% in air and 29% hazardous explosion limit). Its density is 1.225 kg/m^3 and its specific gravity relative to air is 0.97, and it is very difficult to dissolve in water. The maximum limit of CO gas that does not pose a danger is 50 ppm for an 8-hour exposure period (Hartman et al. 1997; McPherson, 1993; Ayvazoğlu, 1984).

It is a gas known as "white damp" or "calm killer" among miners, and people who inhale it can lose their lives or experience serious health problems. The physiological effects of CO concentration on humans over time are given in Table 1 (MSHA, 2024).

Table 1. Physiological effects of CO concentration on humans over time.

Amount of CO, ppm	Physiological Effect
50	It is possible to work for 8 hours without a oxygen device
200	Mild headache, fatigue, nausea and dizziness occur
400	Severe headaches and other symptoms increase, and life becomes threatened after 3 hours.
800	Dizziness, nausea and convulsions, loss of consciousness within 2 hours, and death within 2-3 hours may occur.
1600	Headache, dizziness and nausea, and death may occur within 1-2 hours.
3200	Headache, dizziness and nausea, and death may occur within 1 hour.
6400	Headache, dizziness and nausea, and death may occur within 25-30 minutes.
12800	If inhalation occurs within 1-3 minutes, death occurs

CO poisoning is one of the most frequently reported toxicological causes of death. Hemoglobin in the blood carries oxygen from the air to the lungs and other tissues in the body. If CO is present in the air, hemoglobin combines with CO instead of oxygen. Because the ability of CO to bind to hemoglobin is 250-270 times greater than oxygen. Thus, hemoglobin carries less oxygen. Physical examination has a limited role in the diagnosis of CO poisoning, and the COHb level in the blood should be measured as soon as possible (İncekaya et al., 2017).

CO poisoning affects all organs such as brain, heart, kidney, skin and peripheral nerve. In addition, symptoms and findings may appear early or may occur weeks later (Kandiş et. al., 2009). The relationship between COHb level and symptoms is given in Table 2.

Table 2. Symptoms and findings according to COHb level (Hartman et al. 1997; McPherson, 1993).

Blood Saturation % COHb	Symptoms
5-10	First noticeable effect, loss of some cognitive function
10-20	Tightness across forehead, possible headache
20-30	Headache, throbbing in temples
30-40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting and collapse
40-60	Increased likelihood of collapse and unconsciousness, coma with intermittent convulsions
60-70	Coma, depressed pulse and respiration, possible death
70-80	Respiratory failure, death

Self-rescuers (oxygen or filtered) are used to escape from increases in CO gas levels that occur in underground mines. Filtered self-rescuers convert CO gas into CO_2 thanks to the catalyst layer containing CuO and MnO_2. Since ambient air is breathed with this type of masks, it cannot be used in environments where O_2 concentration drops below 18% and CO is more than 1.5%. Oxygen type masks are closed-circuit respirators and are not affected by the ambient air (Demirel et al., 2001).

CO Poisoning Statistics

Between 1999 and 2004, 16,447 death certificates in the USA showed that deaths were due to CO poisoning. In addition, it is seen that more than 50000 applications are given to the emergency room every year, and more than 4000 of them are hospitalized (CDC, 2024; Hampson et al., 2007). Moreover, in most countries, more than half of the fatal poisoning cases are due to CO poisoning (Raub et al., 2000).

In Turkey, 10154 CO poisoning cases were detected in just one year (2010) and 39 people lost their lives in these cases (Metin et. al., 2011).

In underground coal mining, CO gas generally occurs as a result of the combustion of carbon-containing substances or firedamp (CH_4) explosions. Another important source of CO is internal combustion engine exhaust fumes and detonations. Places where CO gas is found in high concentrations are secluded places with inadequate ventilation (Toprak, 2014).

Similarly, in fires occurring in tunnels, in the events such as Mont-Blanc (Austria) in 1999 where 41 people died and Daegu (South Korea) in 2003, where 198 people died, or other underground fires causing more toxic carbon monoxide produced due to lack of oxygen supply and incomplete combustion. Studies have shown that toxic gases such as CO are the most lethal factors in fires, and approximately 85% of people killed in building fires die from toxic smoke (Vuilleumier et al. 2002; Hong, 2004; Hu et al., 2010).

Evaluation of disasters that occur in underground mining due to reasons such as fire and related CO poisoning is given in Table 3.

Table 3. Number of deaths from some fires in underground mines and the resulting CO poisoning (CDC, 2024; Roberts, 1984; Swanepoel et al., 2008; Şensöğüt & Ören, 2016).

Date	Mine	Country	Death
May 31, 1892	Marie Mine, Pribram	Austria-Hungary	319
November 13, 1909	Cherry Mine, Illinois	USA	259
June 8, 1917	Speculator Mine, Butte, Montana	USA	168
January 12, 1918	Minnie Pit, Staffordshire	England	155
July 2, 1937	Holditch Colliery, Chesterton	England	30
August 8, 1956	Bois du Cazier, Marcinelle	Belgium	262
July 7, 1961	Dukla Coal Mine, Dolni Sucha	Czechoslova kia	108
December 27, 1974	Lievin Coal Mine	France	41
January 18, 1984	Miike Coal Mine, Fukuoka	Japan	83
July 10,1984	Meishan Coal Mine, Ruifang	Taiwan	103
December 5, 1984	Haishan Coal Mine	Taiwan	93
September 16, 1986	Kinross Mining	South Africa	177
June 4, 2009	Harmony Gold Mine	South Africa	82
May 13, 2014	Eynez Coal Mine, Soma	Turkey	301
November 25, 2021	Listvyazhnaya Mine, Oblast	Russia	>40

It is known that the incidents that occurred, caused mass deaths, many injuries and financial losses. For example, the biggest mining disaster in Türkiye's history occurred on May 13, 2014 in the Soma Eynez/Karanlıkdere Colliery, and 301 people lost their lives and approximately 90 people were injured. In autopsies, "carbon monoxide poisoning" was determined as the general cause of death (TBB, 2014).

In cases of CO poisoning, the casualty who is taken to open air should be given oxygen without being moved (oxygen need should not be increased) and transported to the hospital. It has been observed that the application of oxygen at normal pressure (1 atm.) or high pressure (2.4-2.8 atm.) with a non-rebreathing mask with a reservoir within 6 hours after the poisoning event reduces the death rate from 30% to 14%, and reduces the development of neurological disorders (Hampson et al., 2012; Metin et al., 2011). It is extremely important to restrict physical activity and avoid areas with air pollution for 1-3 weeks after CO poisoning. Additionally, drugs that depress respiration and cause alveolar hypoxia should not be used (Kandiş et al., 2009).

Results and Discussion

Underground coal mining has an important place in terms of fatal work accidents caused by CO poisoning, which occurs as a result of spontaneous combustion of coal. Explosive materials are used in underground coal mines and the dilution time required for CO and nitrogen oxides formed as a result of explosions must be determined.

In order to prevent spontaneous combustion events, the appropriate production method (block caving, retreat longwall, etc.) should be chosen and coal should not be left in the goaf area. Additionally, necessary precautions should be taken to prevent air from escaping into the goaf. In addition to the constantly measured CO levels in underground coal mines, leakage air flows and temperature changes should be evaluated immediately at the monitoring station, necessary interventions should be made.

In order to prevent losses occurring in mine fires, it is extremely important to carry out risk assessments in mines, learn from past accidents, have CO and/or oxygen masks on employees, suitability of the gas monitoring system, improve ventilation conditions and the work of rescue teams. Internal auditing in businesses, professional training, the creation of a safety culture and the effectiveness of public inspections are also necessary to prevent accidents. Additionally, in case of CO gas accumulation in underground mines, emergency procedures should be activated as soon as possible. The underground mine must be evacuated safely in accordance with the training given to all workers in advance.

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