

Acute Carbon Dioxide Intoxication in A Fire Control Facility

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Abstract

Carbon dioxide is noted to be a simple asphyxiant and can reduce air oxygen concentration in a confined space. The injury mechanism of carbon dioxide intoxication was thought to be more than simple asphyxia on several dry ice accident reports. Here, we present an incident with seven persons involved due to unpredictable discharge of a carbon dioxide fire extinguisher system in an underground parking lot. We demonstrate these cases in brief to expound and discuss the possible toxic mechanism of carbon dioxide in addition to asphyxia only.

Introduction

Carbon dioxide is one of primary exhaust gas breathed out by human beings. Carbon dioxide is not in itself a physical irritant and does not harm the respiratory tracts directly. Carbon dioxide is considered a type of simple asphyxia gas because of its ability to reduce air oxygen concentration in a confined space. In industry, carbon dioxide can use as a fire retardant [1]. The carbon dioxide fire extinguishers are thought to be clean since carbon dioxide is a naturally occurring atmospheric gas and no chemical residue leaving behind. The carbon dioxide fire extinguishers usually use pressurized liquid carbon dioxide, which then can be spread out to displace the oxygen. As the pressure is released through the nozzle, the liquefied chemical expands about 450 times of volume as it returns to a gaseous state quickly and enough for firefighting.

Carbon dioxide is one of important asphyxiants to induce mortality rate as high as 78.64% [1,2]. Although several episode of accidents and deaths resulting from the discharge of carbon dioxide fire extinguishing systems had been collected by American government in early years, [1] the frequent reports of carbon dioxide intoxication were attributed to improper use of dry ice in cooling facilities. Here we report an incident of unpredicted discharge of a carbon dioxide fire extinguisher linkage system in an underground parking lot that resulted in two deaths and 5 injured.

Case Report

At noon of March 8, 2008, five workers implemented a fire safety inspection at basement level 2 (B2, with an area of 294.17 square meters and 2.5 meter high) and basement level 3 (B3, with an area of 234.48 square meters and 2.5 meter high) of a parking tower for patients files storage in a hospital. There were 84 liquid carbon dioxide steel cylinders on B2 and 74 on B3 with each containing 68 liters of carbon dioxide (Figure 1). Someone working on B3 incautiously triggered the manual switch of the fire extinguishing system and lead huge amount of carbon dioxide to emit instantaneously from 71 steel cylinders of B3. The five workers fell unconscious shortly. Another worker on the ground level rushed into the basement when he heard

the alarm and then collapsed on B2. A security guard (case 6) near the parking tower also fell unconscious on the way of B1 to B2 while trying to rescue someone without wearing any protecting equipment. The emergency medical technicians (EMT) arrived about 5 minutes later and rescued the guard and other workers from B2 and B3. The medical personnel outside the parking tower then provided the victims with resuscitation on site and transported them to emergency room (ER), which is 0.35 mile away. Two cases were found to be death on arriving ER and persisted to be in vegetative state after intensive treatments, including hyperbaric oxygen therapy. The other five patients recovered without any residual complications. The clinical features were summarized in Table 1.



Figure 1: Liquid carbon dioxide steel cylinders in basement.

Incident investigation revealed that the workers had not removed the launchers of liquid carbon dioxide cylinder in B3 when they turned off the fire warning broadcast system during the inspection. This

caused CO₂ almost simultaneously emitted from 71 cylinders, and seven people to be mired in carbon dioxide poisoning.

Se x	Age	Patient found	Clinical Features	PH	PCO ₂	PO ₂	HCO ₃ ⁻	Bass excess	Outcome
1 M	45	B3	OHCA	7.122	40.2	227.6	13.3	-14.6	Expired
2 M	24	B3	OHCA	6.649	87.2	234	9.7	-28.2	Expired
3 M	25	B2	E1M2V1	7.021	69.5	237	18.2	-14.1	Alive
4 F	45	B2	E4M6V5	7.367	34.2	186	19.9	-4.2	Alive
5 M	22	B2	E4M5V4	7.085	56.2	110	17.1	-12.5	Alive
6 M	26	B1-2	E4M6V5	7.332	35.4	230	19	-5.6	Alive
7 M	45	1F	E4M6V5	7.453	23.9	297	16.9	-4.5	Alive

Table 1: The clinical data of 7 patients while presenting to ER. OHCA: out of hospital cardiac arrest.

Discussion

Carbon dioxide naturally occurs in the air with the concentration of 360 to 377 ppm or approximately 0.04%. In industry, carbon dioxide is a colorless, odorless, non-inflammable and non-irritating gas and commonly seen in various types of beverage and ice cream plants, chemical plants, breweries, greenhouses, welding work, or fire extinguishing. As a fire extinguisher, carbon dioxide is used due to its ability to displace air oxygen and create an oxygen deficient environment to put out a fire. Its toxicity is not as high as other toxic chemicals. However, oxygen deficiency can lead to severe asphyxia or possible carbon dioxide intoxication in airtight spaces, such as a ship's cabin, cold storage chamber, or underground tank [1,3-6].

Being a fire extinguisher, carbon dioxide is usually compressed to a liquid state for convenience of storage and delivery. In this incident, the fire extinguishing system discharged a massive amount of carbon dioxide in a very short period. Each cylinder contains 68 liters of carbon dioxide and 71 of them discharged at B3 almost simultaneously. The liquid carbon dioxide of each cylinder was calculated to be about 74.6 Kg, as the density of liquid carbon dioxide is 1.1 kg/L and in gas form is 1.98 g/L. The liquid carbon dioxide vaporized to gas immediately, resulting in more than 2 million liter of CO₂ gas spreading out, and would fall upon B3 and possibly B2 to compromise oxygen concentration into deadly low level. Because this concentration was reached within one minute the victims were not able to leave the scene and rapidly fell into unconsciousness. The molecular weight of carbon dioxide is 44.01, which is heavier than the air. Therefore, gaseous carbon dioxide might accumulate in relative lower areas to replace air oxygen. As a result, the workers in B3 might succumb quickly, and workers in B2 had better chance to escape. In addition, difficult to be rescued and prolonged hypoxia may explain the poor outcome of workers in B3.

In work place, the exposure limit of carbon dioxide is 5000 parts per million (9000 mg/m³) or 0.5% for an 8-hour time-weighted average, and 10% or above was considered to be potentially lethal and not tolerable [7]. In our case, the carbon dioxide discharged nearly occupied the total space of B2 and B3, leading to an extremely hypoxic condition to suffocate all victims who were in or tried to get in like the guard.

The precise mechanism of the impact of carbon dioxide intoxication has been investigated in animals and exposed patients before. Direct toxicity due to high concentration of carbon dioxide might also play a critical role, in addition to oxygen deficiency that attributed to the replacement of oxygen in the atmosphere by carbon dioxide [1,3]. In cases of carbon dioxide intoxication, the increased absorption might lead to an increase of carbon dioxide concentration in the blood (patient 2, 3, and 5). Then, the elevated blood carbon dioxide concentration will act on central nervous system to stimulate the respiration rate in order to compromise more oxygen deficiency, causing more carbon dioxide to be absorbed in this accident. These changes are often seen within a few seconds after a high concentration of carbon dioxide is inhaled [3]. When a patient exposed to high concentration of carbon dioxide, he or she may develop convulsions, acidosis (combined metabolic and respiratory acidosis as our cases), hypoxemia, cardiopulmonary dysfunction or even death caused by apnea [3-6]. In an animal study, dogs presented with apnea died in few minutes after inhaling a mixed gas containing 20% oxygen and 80% carbon dioxide for about one minute, indicating that carbon dioxide intoxication is not significantly related to oxygen concentration [8]. However, in our cases the victims demonstrated that oxygen therapy and resuscitation on site might lead to fair outcomes.

In conclusion, our cases study shows that the improper use of the carbon dioxide fire suppression system in a confined space can also cause a catastrophic incident. Resuscitation with prompt ventilator support might rescue the victims of carbon dioxide poisoning. Appropriate site assessment and self-protection measures are essential safety steps when trying to rescue victims in confined spaces.

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