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Brief Report

Investigation of a Home with Extremely Elevated Carbon Dioxide Levels — West Virginia, December 2003

Investigations of indoor air quality complaints typically focus on mold, water damage, ventilation systems, and combustion byproducts and are guided by the nature of the symptoms observed in affected persons. This report documents the investigation of exposures at a home in which the occupants had unusual respiratory and neurologic symptoms.

Case Report and Initial Investigations

In June 2001, a man and a woman, both of whom were smokers, previously healthy, and aged 42 years, moved into a newly built, two-story home. Shortly after moving in, the woman noted episodic shortness of breath, lightheadedness, dizziness, and fatigue while in the finished basement. The man reported episodic mild confusion, poor concentration, headache, and blurry vision while working in the basement. Their symptoms always resolved within minutes of returning upstairs.

The natural gas water-heater pilot light located in the basement recurrently went out; however, gas company and fire department inspections did not reveal gas leaks, methane, or carbon monoxide (CO). In July 2003, the woman went to a hospital emergency department (ED) on two consecutive mornings with shortness of breath, rapid heart rate, and panic. She was admitted and had new asthma diagnosed, as well as a cardiomyopathy (35% cardiac ejection fraction) attributed to a 1997 varicella infection. However, her basement-related symptoms persisted despite newly prescribed cardiac and respiratory medications.

In October 2003, the man entered a 30- by 70- by 3-foot crawlspace adjacent to the finished basement for a 3-hour period to investigate potential gas leaks. He reported feeling breathless and felt a "strong gush" of air when he opened an access door to the below-grade crawlspace, and later noted hoarseness. In November 2003, the man and a hired contractor became breathless after they entered the crawlspace. That day, another fire department inspection indicated negative readings for CO and methane in the basement. Four hours later, the man went to a hospital ED with rapid respiration and a burning sensation in his eyes. He had a mildly elevated carboxyhemoglobin level (6%) and was discharged with a diagnosis of acute CO exposure (*1*)*.

In December 2003, two contractors had onset of hoarseness and rapid heart rate while at the crawlspace entrance. One man reported a metallic taste. The fire department responded and, on arrival, the first firefighter felt a strong draft at the crawlspace entrance that "took his breath away." Levels of CO, methane, and other explosive gases were below limits of detection. The fire department then called the county Hazardous Materials Incident Response Team (HMIRT).

HMIRT found low oxygen (O_2) levels in the basement and called the West Virginia Department of Environmental Protection (WVDEP) to investigate further. The WVDEP field investigator documented O_2 concentrations as low as 14% in the crawlspace (normal air: 21%). Suspecting that carbon dioxide (CO_2), a colorless and odorless gas, had displaced the oxygen, WVDEP requested technical assistance from CDC's National Institute for Occupational Safety and Health (NIOSH) to measure CO_2 concentrations and, if levels were elevated, to help identify CO_2 sources and recommend control strategies. NIOSH assisted WVDEP with CO_2 sampling, contacted the county and state health departments, and assisted with interviewing the homeowners and reviewing relevant records.

CO_2 Sampling and Monitoring

A direct-reading, high-concentration CO_2 monitor (detection range up to 50% CO_2) was used for short-term sampling and continuous monitoring. WVDEP documented CO_2 concentrations as high as 9.5% in the basement crawlspace, 11% in the crawlspace gravel, and 12% in the basement floor drain (normal air: 0.035% CO_2). CO_2 levels on the upper floors exceeded the upper limit of detection (1%) of a standard CO_2 monitor. CO_2 levels in the soil surrounding the home were as high as 8%. Basement CO_2 levels remained elevated, regardless of whether the furnace was operating. The NIOSH Recommended Exposure Limit for CO_2 in workplaces is 0.5% (5,000 ppm) for a 40-hour workweek and 3.0% for a

* Blood carboxyhemoglobin levels of smokers might be higher than those of nonsmokers. In smokers, levels commonly reach 10% and can exceed 15%, compared with 1%–3% in nonsmokers.

15-minute short-term exposure limit; a level of 4.0% is designated as “immediately dangerous to life or health” (*2*).

Carbon isotopic composition analysis of air samples indicated a carbonate source of the excess CO_2 in the home, likely from mining (*3*). Mine maps confirmed that the home was built on a reclaimed surface coal mine and that an abandoned deep coal mine lay beneath the property. Renovations to the crawlspace redirected and limited ground CO_2 infiltration into the home. CO_2 concentrations have decreased to a maximum of 0.2% measured in the basement; O_2 concentrations have returned to normal, and related symptoms in the homeowners have resolved. Whether any neighboring homes were at risk for elevated CO_2 concentrations was unknown.

The results of this investigation underscore the need for heightened public awareness and special training for emergency response and utility workers, careful environmental measurements to assess potential risks, and precautions to avoid incapacitation and prepare for rescue during immediately dangerous conditions. Building codes that mandate preventive construction, including sealing cracks, maintaining positive pressure within the structure, and subsurface ventilation for new buildings over landfills, caves, and abandoned mines might also be appropriate public health actions.

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Brief Report

Acute Illness from Dry Ice Exposure During Hurricane Ivan — Alabama, 2004

Natural disasters such as hurricanes often impair delivery of essential services, including electricity. When normal refrigeration methods are unavailable, affected populations seek alternative means of protecting perishable foodstuffs. One alternative is to use frozen carbon dioxide (CO_2) (i.e., dry ice).

In September 2004, in anticipation of a power outage during the aftermath of Hurricane Ivan, a man aged 34 years in Mobile, Alabama, purchased a 100-lb block of dry ice from a local ice house. The block of dry ice was divided into four equal parts and packaged in brown paper bags, which were placed in the front seat of the man’s pickup truck. The windows were closed, and the air conditioner was set to recirculate air inside the cab of the truck. After driving approximately one quarter mile from the ice house, the man had shortness of breath; his breathing difficulty increased as he drove the next mile. The man telephoned his wife and asked her to call 911. He then pulled his truck into a parking lot, parked, and lost consciousness. His wife drove to the parking lot and located her husband’s truck; immediately after she opened the door to the vehicle, her husband began to awaken.

Emergency medical services personnel arrived soon afterward. They determined that the man’s vital signs were normal and he required no further medical evaluation. Although the man complained of a headache for the next 24 hours, he recovered completely.

Dry ice has a temperature of -109.3°F (-78.5°C) and can be used to keep perishable foods cold (*1*). As dry ice melts, it undergoes sublimation (i.e., direct conversion from a solid into gaseous CO_2, bypassing the liquid state). Improper ventilation during use, transport, or storage of dry ice can lead to inhalation of large concentrations of CO_2 with subsequent harmful effects, including death (*1,2*). Previous reports have described illness and death caused by occupational exposures and unintentional nonoccupational exposures to dry ice in enclosed spaces such as automobiles and submarines (*1,2*).

Under normal conditions at ambient temperature, CO_2 is a colorless, odorless gas and a simple asphyxiant that displaces oxygen when inhaled. As the inhaled concentration of CO_2 increases, more oxygen is displaced from the lung alveoli, where gas exchange takes place. The central nervous system (CNS) tightly regulates dissolved CO_2 in the blood; changes in the partial pressure of CO_2 cause changes in the respiratory rate. An increase in CO_2 concentrations triggers an increase in respiratory rate, causing further uptake of CO_2, which can ultimately lead to signs and symptoms of hypoxia and hypoxemia, including headache, confusion, disorientation, and death. Respiratory and CNS changes can occur within seconds of exposure to high levels of CO_2, suggesting that the toxicity of CO_2 might be related to systemic effects that are not fully understood.