The Hazards of Nitrogen Asphyxiation

US Chemical Safety and Hazard Investigation Board

Introduction

- Nitrogen makes up 78% of the air we breath; because of this it is often assumed that nitrogen is not hazardous.
- However, *nitrogen is safe to breath only if it is mixed with an appropriate amount of oxygen.*
- Additional nitrogen (lower oxygen) cannot be detected by the sense of smell.

Introduction

- Nitrogen is used commercially as an inerting agent to keep material free of contaminants (including oxygen) that may corrode equipment, present a fire hazard, or be toxic.
- A lower oxygen concentration (e.g., caused by an increased amount of nitrogen) can have a range of effects on the human body and can be fatal if if falls below 10%

Effects of Oxygen Deficiency on the Human Body

Atmospheric Oxygen Concentration (%)	Possible Results
20.9	Normal
19.0	Some unnoticeable adverse physiological effects
16.0	Increased pulse and breathing rate, impaired thinking and attention, reduced coordination
14.0	Abnormal fatigue upon exertion, emotional upset, faulty coordination, poor judgment
12.5	Very poor judgment and coordination, impaired respiration that may cause permanent heart damage, nausea, and vomiting
<10	Inability to move, loss of consciousness, convulsions, death

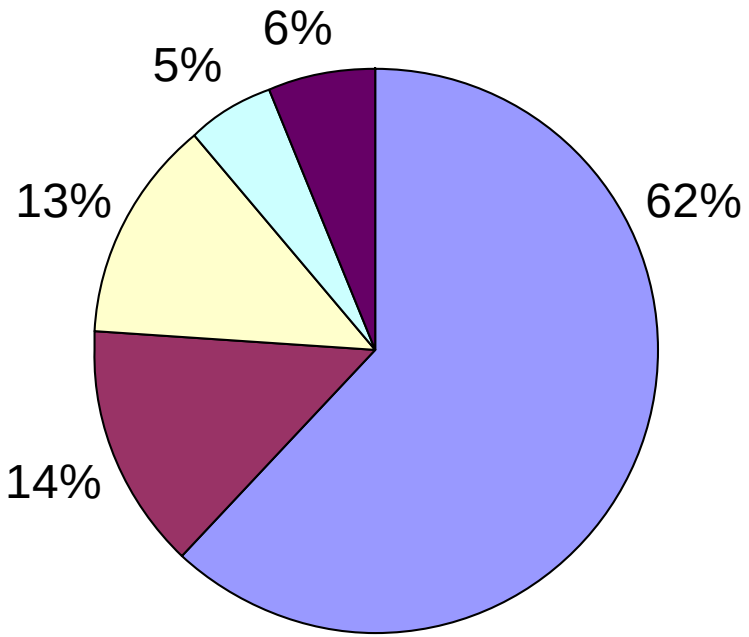
Source: Compressed Gas Association, 2001

Statistics on Incidents

CSB reviewed cases of nitrogen asphyxiation that occurred in the US between 1992 and 2002 and determined the following:

- 85 incidents of nitrogen asphyxiation resulted in 80 deaths and 50 injuries.
- The majority of incidents occurred in manufacturing and industrial settings, but several incidents occurred in other settings including laboratories and medical facilities.

Facilities and Areas Where Incidents Occurred



- Manufacturing/industry
- Trenches, manhole covers (not identified)
- Maintenance activities (not necessarily at manufacturing sites)
- Laboratories
- Miscellaneous (including medical facilities and transportation)

Statistics on Incidents (cont'd)

- The majority of incidents occurred in and around confined spaces, though several incidents occurred in "open" areas, including inside buildings and outdoors near equipment.
- Almost half the incidents involved contractors, including construction workers. Contractors account for over 60% of the fatalities.

Statistics on Incidents (cont'd)

Causes of the incidents included:

- Failure to detect an oxygen-deficient atmosphere in and around confined spaces.
- Mistakenly using nitrogen instead of breathing air.
- Inadequately preparing for rescue.

Data Sources for Statistics

- Data sources for the CSB review included regulatory agencies, media reports, technical publications, and contacts with safety personnel; however, only those incidents that were reported and accessible are evaluated. Statistical analysis is based on the available, limited information.
- Although the summary data reported above are not all-inclusive, the numbers clearly indicate that nitrogen asphyxiation presents a serious hazard in the workplace.

Case Study: Failure to Recognize Asphyxiation Hazards Near Confined Spaces

Three workers were cleaning filters in a hydrogen purifying tank.

- Tank was purged with nitrogen during cleaning.
- One worker leaned over a manway opening in the upper portion of the tank.
- He was found unconscious and later died.

Case Study: Failure to Recognize Asphyxiation Hazards Near Confined Spaces

An operator was conducting a flammable gas test on a line connected to a flare in order to issue a hot work permit.

- **The operator issued a permit that required an air-supplied respirator.**
- **Two contractors wore respirators to remove a valve, but the operator did not.**
- **Nitrogen inadvertently entered the flare and the operator lost consciousness.**

Case Study: Inadequate Monitoring of Atmosphere

A tank car at a refinery contained white mineral oil, and an employee started cleaning it.

- **The mineral oil was offloaded by injecting nitrogen gas into the car.**
- **The nitrogen was still present when the employee started to clean the car and he was asphyxiated.**

Case Study: Corrupt Breathing Air Supply

Two contractors were abrasive blasting tubes inside a boiler.

- They wore supplied-air respirators connected to compressed air cylinders.
- After the workers failed to respond to an air horn, they were found unconscious.
- Follow-up testing of the air supply – which had been manufactured by mixing oxygen and nitrogen - found that it contained less than 5% oxygen.

Case Study: Mix-Up Nitrogen and Air, and Improper Rescue

The atmosphere inside a coated tank was tested and ventilated the day before work was to be performed inside.

- A contractor entered the tank to clean it the next day and collapsed.
- Two plant employees attempted rescue and were overcome. All three workers died.
- The tank had mistakenly been ventilated with nitrogen instead of compressed air.

Case Study: Mix-up Nitrogen and Air

A contract employee planned to use a hammer powered by air to chip residue from a furnace in an aluminum foundry.

- He wore an airline respirator.
- Two compressed gas lines were available, one was labeled “natural gas” and one was labeled “air”.
- Once the respirator was in place, the employee was asphyxiated. The “air” line actually contained pure nitrogen.

Case Study: Mix-up Breathing Air Supply in a Medical Facility

A supplier mistakenly delivered a cylinder of nitrogen during a delivery of oxygen cylinders.

- **The nursing home employee mistakenly accepted the nitrogen tank.**
- **The cylinder was labeled with a nitrogen label partially covering an oxygen label.**

Case Study: Mix-Up Breathing Air Supply in a Medical Facility (cont'd)

- The tank had nitrogen-compatible fittings.
- A maintenance employee removed the fittings from an empty oxygen cylinder and used it as an adapter to connect the nitrogen tank to the oxygen system.
- Four patients died and six were injured.

Good Practices for Safe Handling of Nitrogen

Implement warning systems and continuous atmospheric monitoring of enclosures

- Continuously monitor for oxygen-deficient, toxic, or explosive atmospheres.
- Employ warning systems including flashing lights, alarms, and auto-locking entryways.
- Use personnel monitors to indicate low oxygen concentrations.
- Remember that the atmosphere can change over time.

Good Practices for Safe Handling of Nitrogen

Ensure ventilation with fresh-air in confined and enclosed areas.

- **Maintain continuous forced draft ventilation with fresh air before job begins and through completion.**
- **Ensure that ventilation systems are properly designed, evaluated, and maintained.**
- **Use warning systems to alert personnel if the system fails.**

Good Practices for Safe Handling of Nitrogen

Implement a system for the safe retrieval and rescue of workers

- Employees in confined spaces should wear equipment to facilitate retrieval, such as a body harness, anklets, or wristlets, and a lifeline.
- Standby personnel must be present at all times and have constant communication with personnel inside.
- Personnel should not attempt rescue unless they are properly trained and equipped.

Good Practices for Safe Handling of Nitrogen

Ensure the uninterrupted flow and integrity of breathing air

- Take steps to ensure that supplied air is not interrupted. Steps include having alternate sources of power for air compressors, inspecting and replacing air hoses, and restricting traffic in areas with supply hoses.
- Carry escape packs.
- Ensure the composition of supplied breathing air is correct. Continuously monitor the air supply.

Good Practices for Safe Handling of Nitrogen

Prevent inadvertent mix-up of nitrogen and breathing air

- Ensure that personnel understand the reason for specific unique fittings on cylinders of different compressed gases. Do not fabricate "adapters" to defeat their purpose.
- Ensure that cylinders are clearly labeled.
- Use color coding to identify systems.

Good Practices for Safe Handling of Nitrogen

Develop and implement training programs for employees and contract personnel, including information on:

- **Proper use of ventilation, retrieval, air monitoring, and air supply systems.**
- **Safe practices for confined space entry and rescue. Precautions to take when working around confined areas.**
- **Dangers of nitrogen enriched atmosphere and preventing mix-ups between breathing air and nitrogen.**
- **Implementing good hazard communication.**

More Information

A safety bulletin and 1-page brochure on the hazards of nitrogen asphyxiation, as well as this presentation, are available from the US Chemical Safety and Hazard Investigation Board.

www.csb.gov

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