DEATHS AND ILLNESS FROM HYDROGEN SULFIDE AMONG SHIP WORKERS LOS ANGELES, CALIFORNIA

BACKGROUND

On September 2, 2005, ACDC was notified of three deaths occurring in the propeller room of a cruise ship docked in the Port of Los Angeles. Initial reports suggested that the deaths were related to hydrogen sulfide poisoning occurring while crewmembers were attempting to fix a pipe in the propeller room on the ship. This situation is the first known cluster of deaths caused by hydrogen sulfide poisoning on a cruise ship.

Hydrogen sulfide, a colorless gas and asphyxiant produced from decaying sulfur-containing materials, is the second leading cause of toxin-related deaths in the US. The gas has a noxious odor of "rotten eggs" and is found in industries including rayon dye production, heavy water production, petroleum refining, natural gas, asphalt, waste management, and the fishing industry. Hydrogen sulfide has a density slightly greater than that of air and is therefore commonly found in confined spaces on the bottoms of tanks, hot springs [1], manure pits [2], and holding spaces on ships that contain decaying food [3]. Additionally, hydrogen sulfide is generated by decay of organic material by anaerobic bacteria.

Acute hydrogen sulfide exposure may cause symptoms ranging from mucous membrane irritation to neurologic impairment and cardiopulmonary arrest. Hydrogen sulfide gas is commonly called a "knock-down agent" because acute exposure may lead to rapid loss of consciousness and death. Many case reports have described this rapid toxicity that leads to death in both those primarily exposed and in those who try to rescue the primary victim [4]. Inhaled levels of hydrogen sulfide greater than 700 ppm^2 are immediately fatal [5]. According to the Census of Fatal Occupational Injuries (CFOI), a database run by the United States Bureau of Labor Statistics (USBLS), 52 workers died of hydrogen sulfide poisoning between 1993 and 1999. One fifth of these 52 deaths were accompanied by a co-worker fatality [4]. The majority of fatalities were reported in white males in their first year of employment, most commonly working in waste management, petroleum or natural gas work.

METHODS

On September 2, 2005, ACDC received a call from the Port of Los Angeles to report three deaths in the propeller room of a cruise ship and 19 possibly ill crewmembers that responded to this event. An investigation began at 2:00pm September 2, 2005. ACDC staff conducted interviews with port authorities, port police, cruise ship authorities, and receiving. An informal environmental inspection was conducted at 8:00am the following morning. Clinical information on the three deceased workers and 19 responders including autopsy reports was collected.

ACDC staff interviewed cruise ship staff including engineers who usually work in the propeller room—five of the 19 people who responded to the situation, and the medical staff on board. Questions were asked to elucidate what happened, understand the physical set up of the propeller room, and identify clinical symptoms of the responders.

Measurements of the room where the deaths occurred were obtained and the Office of Hazardous Materials Safety (Hazmat) collected environmental air samples. Additionally, medical records and autopsy results were obtained for the three deceased and medical records were obtained for those who responded to the scene and were subsequently hospitalized.

Summary of Events: Interviews revealed that at 6:00am on September 2, 2005, 3 staff undertook a routine repair of a "leaky pipe" in the propeller room of a cruise ship docked at the Port of Los Angeles. Because the propeller room was not considered a confined space by the staff of the cruise ship, no workers were wearing any personal protective respiratory equipment. During the repair, all 3 workers

were overcome by fumes and fainted. Nearby workers cried out for help, which prompted the ship's staff to administer a ship wide call for help or "Alpha Alert." This call prompted all medical staff to respond without any protective gear. As a result, additional crew members—including doctors and nurses—responded, but they became dizzy and some passed out. Ultimately 19 crewmembers were taken to an emergency department at various hospitals on shore. Most were either fellow engineers or medical staff on board. No passengers were affected.

According to the chief engineer on board the ship, the volume of the propeller room was measured at 215m^3 (7,593 cubic feet) and the ventilation was 1100 m^3/hour (38,846 $foot^3$/hour). Hazmat obtained an environmental air sample at 11:00am on September 3, 2005—5 hours after the incident in the propeller room—measuring 100 ppm of H_2S. The OSHA Permissible Exposure Limit (PEL) for General Industry states that "exposures shall not exceed 20 ppm (ceiling) with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes [6]." Therefore, environmental levels of hydrogen sulfide 5 hours after the incident exceeded the maximum limit by 100%.

Upon further investigation, it was discovered that the leaky pipe was a pulper line that conducts solids and remaining liquids from food waste to be expelled into the ocean. The pulper line was running through the ballast tank which functions to keep the boat steady. It was discovered that the pulper line was cracked in the portion that ran through the wall of the ballast tank. Over time, food waste (also known as pulp) slowly leaked into the ballast tank from the pulper line. This waste, in the anaerobic environment of the ballast tank, produced hydrogen sulfide that filtered into the pulper line and collected over time. When the leaky pipe was being fixed, it burst and released the collection of hydrogen sulfide gas.

The three workers in direct contact with the pulper line (males aged 41, 47 and 48), died instantly. Coroner reports revealed levels of 16 mcg/g and 3.2mcg/g of thiosulfate by ion chromatography after correcting for creatinine in two out of three of the deceased. The normal range is 1-5mcg/g. The 19 responders experienced symptoms including dizziness, headaches and throat irritation. No blood samples were obtained and none were known to have experienced prolonged effects beyond the first 24 hours after exposure.

DISCUSSION

Fatalities and acute illness resulted from this unfortunate situation; yet substantial literature notes that working in confined spaces on cargo ships is a risk factor for hydrogen sulfide poisoning and death [3]. The majority of hydrogen sulfide poisonings (approximately 86%) occur in confined spaces and many poisonings are the direct result of others trying to help co-workers in need [5]. However, this is the first known cluster of deaths caused by hydrogen sulfide poisoning on a cruise ship.

The levels of thiosulfate, as determined by the coroner, probably do not reflect the true concentration of hydrogen sulfide that the deceased were exposed to. Thiosulfate is formed by oxidation of sulfide, is one of the predominant metabolites of sulfide, and can indicate the probable dose of H_2S to which the victim was exposed [7]. However, the blood level peaks in 12 hours after acute exposure and declines rapidly thereafter and coroner blood specimens were obtained more than 12 hours after death.

Because of the confined spaces typical of ships and boats, all captains, regardless of vessel type, should have plans to prevent hydrogen sulfide poisoning. In addition, in light of the rapid manner in which co-workers often respond to on-board emergencies, plans should also include the proper methods of response.

The National Institute for Occupational Safety and Health defines a confined space as:

> "a space which by design has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy. Confined spaces include but are not limited to storage tanks, compartments of ships, process

> vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines [8]."

While by this definition the propeller room of the cruse ship may be considered a confined space, ultimately the definition, and the considerations that go along with it, are open to interpretation—and the crew of the ship did not consider the propeller room to be a confined space. As such, the ship staff was not required to wear respiratory personal protective equipment (PPE) while working in that area. Additionally, workers did not carry a gas monitor that was available on the ship for detecting hazardous gases such as hydrogen sulfide.

We therefore recommend that a broader definition of what constitutes confined space be considered for ships and that appropriate PPE be worn when working in these spaces. Additionally, it would be advantageous for ships to purchase additional gas monitors to be available for all who plan to work in confined spaces. As an example, the portable Multiwarn monitor, EntryRAE, or similar instruments and a stationary gas monitor with an alarm system are able to detect hydrogen sulfide levels from 0-100 ppm and thus could have warned workers in the propeller room if the pipe was leaking before they began to fix it. While uncommon, this situation demonstrates that appropriate preventative steps must be taken by cruise lines and other industries that employ workers in confined spaces to prevent fatalities associate with hydrogen sulfide poisoning.

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