Lack of Safety Systems in Agricultural Settings in Rural Thailand: A Report of Three Worker Death

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Background: *Three farm workers lost consciousness within a few minutes after entering a silo pit on a farm located in a rural Thai village. All victims died later in the hospital.*
Objective: *To identify the cause of unconsciousness in these victims and to determine safety systems for agricultural enterprises containing silos.*
Material and Method: *Medical records of the three decedents were reviewed for demographic characteristics, clinical manifestations, and the cause of deaths. Co-workers of the decedents were interviewed to obtain details of the victims' work on the farm during the incident. Concentrations of oxygen and other potentially hazardous gases were measured in the pit where the victims collapsed. All agricultural enterprises that have silos in the district were identified and investigated for safety systems.*
Results: *Of the three decedents, two died in a rescue attempt. They all developed metabolic acidosis and died 1-3 days following admission. Oxygen concentration at the top of the pit was 20.9% and decreased to 0.8% at a depth of 1 meter and to 0.0% at the bottom of the three-meter pit. Carbon dioxide, which is heavier than air, was the major asphyxiant displacing oxygen in this confined space. Lack of safety systems were detected on this farm and in all settings containing silos in the district.*
Conclusion: *Asphyxiation due to oxygen depletion was the cause of all deaths. It is essential to install safety systems for work in confined spaces in agricultural settings.*

Keywords: *Asphyxiation, Oxygen depletion, Confined space, Agricultural settings*

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Thailand is a leading global exporter of rice, corn, and tapioca. With the expansion of agribusiness, many silos have been built to store grain and food products. A moving conveyor chain loader is commonly found with a silo and a pit is usually below the chain loader. Both silos and pits are potentially dangerous confined spaces in which certain gases may accumulate to hazardous levels leading to poisoning or asphyxiation due to oxygen (O_2) depletion[1-7]. Asphyxiants are gases that displace O_2 from the air (simple asphyxiant), or interact with the body system (chemical asphyxiant). Incidents of work-related deaths in confined spaces have occasionally been reported in the country but most of them are not well investigated[7]. This paper reports an investigation of three farm worker deaths during a silo pit cleanup in a rural Thai village and emphasizes the importance of installation of safety systems in the farm environment.

On September 25, 2009, three comatose male workers aged 25, 30 and 31 years old from the same farm were admitted to Mae Sot General Hospital, Tak Province, northwestern Thailand. All these men had collapsed within a few minutes after entering a silo pit on the farm. They received cardiopulmonary resuscitation by the emergency medical team of the nearby community hospital, located 5 kilometers away from the farm. They were taken to Mae Sot General Hospital for intensive care management. They all died later in the hospital. Silo work-related coma has not been reported in this district for more than 10 years.

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An epidemiological investigation was carried out to determine the cause of unconsciousness in these victims.

Material and Method

Medical records of the victims admitted to the hospital were reviewed for demographic characteristics, clinical manifestations, and the cause of deaths. An environmental survey of the farm where the victims collapsed was conducted four hours after the incident. Details of the victims' work on the farm during the incident were obtained from three workers who appeared at the scene of the incident. All the farm workers were asked about their usual work and history of safety training. The farm owner and workers were asked about worker-safety training programs, work practice manuals, and equipment for safe work.

Measurements of O_2 concentration and other potentially hazardous gases were taken at different depths in the pit. Concentrations of O_2, carbon monoxide (CO), hydrogen sulfide (H_2S), and volatile organic compounds (VOCs) were determined by a portable gas detector (Entry RAE Model PGM-3000, USA). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2), and ammonia (NH_3) were measured by a portable gas analyzer (Miran SapphIRe Model 205B-XL, USA).

All agricultural enterprises containing silos in the district were identified from the Tak Provincial Industry Office. In each setting, a survey was conducted to determine a safe work environment including presence of confined-space warning signs, ventilation equipment, personal and respiratory protective devices, gas detectors and safety procedures for working in and around silos and pits. Measurements of O_2 concentration were taken in all silo pits. All silo workers in these settings were interviewed about safety training and safe work practices.

Results

Epidemiological investigation

The farm where the incident took place contained two conventional upright silos for storage of corn. It also had three silo loaders and two concrete pits. During the process of loading, some corn frequently fell into the pit. To clean the pit, one worker would enter the pit to collect corn that had fallen and pass it to a co-worker who was outside the pit. The pit in which the victims entered was three meters (m) wide by 5m long and 3m deep, and was covered with a steel sheet containing three hatches, one for entering and two for ventilation. Experienced workers would open the ventilation hatches (0.6 m wide by 0.8 m long) for a few minutes before entering the pit. This pit was last cleaned 20 days before the presented incident. There was no confined space warning signs or entry procedures posted around the pit.

The farm owner employed 20 workers, none of whom had formal training on hazards associated with a confined space or a safe entry program. The three decedents were non-smokers and had no underlying health conditions. Of the three decedents, two had worked on this farm for one month (workers A and B) and the other worker for two years (worker C). According to witnesses, worker A climbed down a fixed ladder to the bottom of the pit and collapsed within a few minutes. He did not open the ventilation hatches prior to entry into the pit. Workers B and C who saw worker A collapse entered the pit to rescue him. Unfortunately, both collapsed shortly after entering the pit. To rescue the victims, workers E and F who had experience on a pit cleanup opened the ventilation hatches for a few minutes before going into the pit. Safety harness and lifelines were used during the rescue attempt. Workers E and F became drowsy and fainted after extricating the victims, but recovered uneventfully. There were no respiratory protective devices on the farm.

All three comatose workers admitted to the hospital developed metabolic acidosis and required mechanical ventilation. Workers A and B died one day following admission and worker C died three days later in the hospital.

Gas measurements

The ambient air generally is composed of approximately 21% oxygen and 79% nitrogen, with trace amounts of other gases. Gas measurements in the pit revealed that O_2 concentration rapidly decreased from 20.9% at the top to 0.8% at a depth of 1 m and to 0.0% at the bottom of the 3 m pit (Table 1). In contrast, CO_2 rapidly increased from 2,769 ppm (0.3%) at the top of the pit to 300,483 ppm (30.0%) at a depth of 1 m. The levels of CO, CH_4, N_2O, SO_2 and NH_3 at 0.5 m and 1 m depths were higher than the concentrations at the top of the pit. Unfortunately, measurements of these hazardous gases by a gas analyzer (Miran SapphIRe) were not taken at depths greater than 1 m because of unavailability of self-containing breathing apparatus during the investigation.

There was a dark dirty liquid with unpleasant odor at the bottom of the pit. The farm workers informed

Table 1. Concentration of oxygen and other toxic gases in the silo pit involved in worker deaths, by level of depth

Depth (meters)	O_2 (%)	CO (ppm)	H_2S (ppm)	VOCs (ppm)	CO_2 (ppm)	CH_4 (ppm)	N_2O (ppm)	SO_2 (ppm)	NH_3 (ppm)
0 (surface)	20.9	BLD	BLD	BLD	2,769	105.6	0.1	BLD	BLD
0.5	7.7	16	BLD	5	236,733	432.8	57.8	31.2	19.8
1.0	0.8	30	BLD	6	300,483	2,215.3	73.9	66.8	38.5
1.5	0.9	22	BLD	6					
2.0	0.2	28	BLD	9			Not measured		
2.5	0.2	34	BLD	9					
3.0 (bottom)	0.0	35	BLD	5					

O_2 = oxygen; CO = carbon monoxide; H_2S = hydrogen sulfide; VOC = volatile organic compounds; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; SO_2 = sulfur dioxide; NH_3 = ammonia; BLD = below limit of detection (1 ppm for CO, H_2S, and VOC: 1.2 ppm for SO_2: 0.7 ppm for NH_3)

that rain would enter this pit because the roof of the corresponding silo loader was being repaired. The other pit on this farm was dry and contained 20.9% O_2 concentration at the bottom.

Survey of silo worker safety in the district

There were 13 silos and 12 pits located on seven farms or agricultural enterprises in the district. Only one setting had safety harness and lifelines. None had ventilation equipment, respiratory protective devices, gas detectors, or safety procedures for working in and around silos and pits. Interviews of 114 workers in these settings showed that none had any formal training on hazards associated with a confined space or a safe entry program. Of the 35 workers whose usual work was a pit cleanup, 18 (51.4%) did not use personal protective equipment while working. The remainder reported using only facial cotton masks and/or boots. O_2 concentrations were measured in all the survey pits in the district and ranged between 20.4% and 20.9% at the bottom.

Discussion

Asphyxiation due to oxygen depletion was the cause of these worker deaths. All the victims were previously healthy before entering the pit and rapidly lost consciousness after entry into the pit, which had a very low concentration of O_2. They developed metabolic acidosis following acute severe hypoxia. Gas measurement in the pit showed that CO_2, which is heavier than air, was the major asphyxiant displacing oxygen in this confined space. Other hazardous gases present in the pit were above safe gas concentrations[8] and might increase this hazardous situation by their direct toxic effects or O_2 displacement. A fermentation process or organic matter decomposition of corn in the pit could consume O_2 and produce some hazardous gases, including CO_2. Poor ventilation would allow these gases to accumulate in the pit.

Of the three worker deaths, two died in a rescue attempt. Many studies have shown that confined space incidents often result in multiple deaths when rescues are attempted[2,5,7,9]. Would-be rescuers in agricultural settings should therefore be trained to understand the potential hazards associated with confined spaces and conduct a rescue with safety equipment.

Investigations of agricultural worker deaths caused by oxygen depletion or toxic gas exposure in confined spaces commonly identify a failure to install safety systems or follow proper safety procedures[2,5,7,9]. In the presented incident, the farm lacked a safety system. The farm had no safety procedures or protective equipment except safety harness and lifelines. All the workers on the presented farm had no safety training. An environmental survey of all settings containing silos and pits in the district discovered similar conditions. Although there have been specific government regulations that require a safe work environment in confined spaces since 1990, none of the farms or settings in the district complied with the law. The present study underscores the needs to educate both owners and workers about the benefits of safety systems in the settings. The owners or managers should identify all confined spaces such as silos, pits, grain bins, tanks, and wells and develop a confined space entry program. Agricultural workers should be trained and encouraged to follow the

confined space entry procedures. The measures should include implementation of a written permit space program, correct use of safeguards, testing and monitoring of air quality, use of proper ventilation equipment and procedures, use of safety harness and lifelines, stationing at a minimum, with two standby attendants outside the space for communication and visual monitoring, and instruction of farm workers in safe confined space rescue procedures.

To minimize an O_2 deficient atmosphere or atmospheres containing toxic contaminants, a ventilation fan or blower should be installed and operated to force air into the confined space prior to entry and while workers are present in these confined spaces. Forced ventilation can rapidly increase O_2 concentration and reduce other toxic gases to safe levels in confined spaces such as a silo[10]. Gas monitoring systems can measure concentrations of gases and provide assurance that the confined space is safe to enter.

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การขาดระบบความปลอดภัยในการทำงานภาคเกษตรกรรมในชนบทไทย: รายงานการเสียชีวิตของคนงาน 3 รายในหลุมไซโล

วิทยา สวัสดิวุฒิพงศ์, ปราณี มหาศักดิ์พันธ์, วินัย ทองชุบ, ทิพวัลย์ ฟั่นเขียว, เศรษฐา สุทธปรีดา

ภูมิหลัง: *คนงาน 3 ราย ได้หมดสติภายในเวลา 2-3 นาที ภายหลังได้ลงไปในหลุมไซโลของฟาร์มแห่งหนึ่งในชนบทไทย และต่อมาทั้งหมดได้เสียชีวิตในโรงพยาบาล*

วัตถุประสงค์: *เพื่อหาสาเหตุของการหมดสติของคนงาน รวมทั้งประเมินระบบความปลอดภัยสำหรับการทำงานในธุรกิจการเกษตรกรรมทั้งหมดที่มีไซโลในอำเภอ*

วัสดุและวิธีการ: *ได้ทบทวนเวชระเบียนของผู้ป่วยที่เสียชีวิตทั้ง 3 ราย เพื่อรวบรวมข้อมูลทั่วไป ลักษณะทางคลินิก และสาเหตุของการเสียชีวิต สำหรับรายละเอียดของการทำงานของผู้ป่วยนั้น ได้สอบถามจากคนงานที่อยู่ในที่เกิดเหตุ รวมทั้งได้ตรวจวัดระดับออกซิเจนและก๊าซพิษอื่น ๆ ในหลุมไซโลที่เกิดเหตุ ส่วนธุรกิจการเกษตรกรรมทั้งหมดที่มีไซโลในอำเภอ ได้ถูกค้นหาและสำรวจถึงระบบความปลอดภัยสำหรับการทำงานในหลุมไซโล*

ผลการศึกษา: *คนงานที่เสียชีวิต 2 ใน 3 รายเป็นผู้เข้าไปช่วยเหลือผู้ประสบเหตุรายแรก ทุกรายมีภาวะเป็นกรดในร่างกาย และเสียชีวิต 1-3 วันต่อมาในโรงพยาบาล จากการวัดระดับออกซิเจนในหลุมไซโลที่เกิดเหตุ พบว่ามีค่าร้อยละ 20.9 ที่ปากหลุม และลดลงเหลือร้อยละ 0.8 ที่ระดับลึกลงไป 1 เมตร และตรวจไม่พบเลยที่ก้นหลุมซึ่งลึก 3 เมตร โดยระดับออกซิเจนที่ลดลงส่วนใหญ่เกิดจากการแทนที่ด้วยคาร์บอนไดออกไซด์ ซึ่งหนักกว่าอากาศ จากการสำรวจฟาร์มที่เกิดเหตุพบว่า ขาดระบบความปลอดภัยสำหรับการทำงานในหลุมไซโล ซึ่งพบเช่นเดียวกันจากการสำรวจฟาร์มหรือธุรกิจการเกษตรกรรมที่มีไซโลในอำเภอ*

สรุป: *ภาวะการขาดออกซิเจนเป็นสาเหตุของการเสียชีวิตของคนงานทั้ง 3 ราย ระบบความปลอดภัยเป็นสิ่งจำเป็นสำหรับการทำงานในสถานที่อับอากาศที่พบในฟาร์มหรือธุรกิจการเกษตรกรรม*