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Deaths on shrimp farm from suspected hydrogen sulfide poisoning in the confined well: Experienced people also being at risk

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ABSTRACT

Introduction: On 6 September 2020, the joint investigation team of the Department of Disease Control, Thailand, was notified about the death of three informal workers in a water well on a shrimp farm in Prachuap Khiri Khan Province. **Objective:** The objectives were to verify the diagnosis of the event, to describe epidemiological characteristics of the cases, to identify risk factors of the event, and to assess knowledge, attitude and practice (KAP) on the risk of working in water wells among the villagers. **Methodology:** We conducted a cross-sectional questionnaire survey to identify the event's risk factors and assess KAP of the villagers concerning the experiences of working in water wells. Chi-square test was performed. **Results:** The index case's most likely cause of death was hydrogen sulfide (H_2S) poisoning, followed by drowning. The main fatality risk was a lack of knowledge and insufficient awareness of the danger of working in water wells, especially among those with prior experience of working in water wells. **Conclusion:** Occupational safety regulations and guidelines need to be developed and enforced to protect workers operating in the wells. Mitigation strategies included the avoidance of work in confined spaces as much as possible, and using proper engineering techniques for rescuing the victims if needed.

Keywords: *confined space, drowning, hydrogen sulfide, informal worker, shrimp farming*

Introduction

In Thailand, about one-third of the population working in the agricultural sector [1]. Shrimp farming causes a major export earning in Thailand, especially in the coastal provinces. It is estimated that Thailand supplies 20% of the world trade in shrimps and prawns [2]. Some shrimp farms in Thailand use polyethylene (PE) plastic to cover the pond areas to increase shrimp production [3]. This system comes with a specific waste-water well system that needs an ultra-deep water well. In this regard, the water well is identified as a 'confined space' in the farm. Confined spaces can create hazardous conditions such as asphyxia, sink, fall, trap to those inside the space. Asphyxiants are gases that displace oxygen from the air (simple asphyxiant), or interact with the body system (chemical asphyxiant) [4-5]. Serious occupational accidents in confined spaces have been reported from time to time. According to the Event-based Surveillance (EBS) database of the Department of Disease Control (DDC), the Ministry of Public Health (MOPH), during 2003-2018, of 62 events, two-third occurred in agriculture settings. The case fatality rate in confined spaces was extremely high (61.9%). Most events had secondary victims who went to help primary victims [6].

On 6 September 2020, the joint investigation team of the Division of Epidemiology, DDC, MOPH, Thailand, was notified by the Situation Awareness Team (SAT) about the deaths of three workers on a shrimp farm in Sam Roi Yod District, Prachuap Khiri Khan Province, Thailand. The objectives of this study were to verify the diagnosis of the victims, to describe epidemiological characteristics of the cases, to identify

risk factors of the event and to assess knowledge, attitude and reported practices related to the risk of working in a confined space among informal workers.

Deputy District Chief (for instance, those living further from the Hall or migrant workers who did not understand Thai message). Besides, although the summon of villagers by the Deputy District Chief was a practical approach, it hampered our attempt to perform probability sampling on the populations. Lastly, the answer in the questionnaire might not necessarily be the same as the actual practices of the villagers.

For recommendations, the foremost principle is to reduce the number of confined spaces as much as possible. If the water well needs to exist, limiting the exposure to the confined space is strongly recommended, for instance, prohibiting people entering the well by using a lever to operate the water valve from outside instead of manual operating. For personal level, a proactive health education should be conducted to enable the workers and the villagers to be aware of the danger of injury in confined spaces [24]. A preparation of proper rescue equipment for non-entry rescue technique is suggested. This needs to implement alongside the availability of trained rescue personnel. For the farm owner, flushing the water out of the well for evert 3-5 days is useful. Placing a warning sign and fencing the well opening also help prevent future events to some extent. In addition, the regulations and guidelines for occupational safety on the work in confined spaces (including agricultural well) among informal workers should be developed. The Division of Occupational and Environmental Diseases of the Thai DDC should take a lead in this proposal. Further studies that explore the KAP on the head-to-reach people including migrants are recommended

Methods

We conducted a cross-sectional study on 6-7 September and 27-29 October, 2020. A case was defined as any person working in a water well on the shrimp farm on 5 September 2020 and had at least one of the following symptoms: headache, syncope, dizziness, nausea, difficulty of breathing, or death. Medical records of the deaths were reviewed. We also interviewed with the medical staff and the event witnesses.

The environmental survey of the shrimp farm in which this event occurred was conducted. We observed the water pumping system on the farm. We conducted a gas measurement by QRAE-II diffusion multi-gas monitor at different depths of the well. The gas detector was able to measure oxygen (O_2), carbon monoxide (CO), hydrogen sulfide (H_2S), and the lowest explosive limit (LEL) of combustibles.

We then surveyed knowledge, attitudes, and practices (KAP) about work experience in agricultural wells among the villagers in Sam Roi Yod District. The survey was conducted during the public gathering called by the Deputy District Chief. We hypothesized that people who were used to working in the well might have different risk perceptions compared those without or with little experience. Therefore, we divided meeting participants into two groups – 1) experienced people: well owners or those having experience in entering the water wells and 2) non-experienced people: participants who were not well owners or those who had never entered the wells. We excluded health care workers or village health volunteers in the analysis. We tested the face validity of the questionnaire with a few villagers before the meeting date. The survey questionnaire consisted of four parts. The answers were “yes” or “no” in the first two parts. Part 1 aimed to evaluate knowledge of danger recognition (e.g., “the Are agricultural wells a confined place?”, and “Can a well that is less than 3-meters deep cause hypoxia?”). Part 2 measured knowledge on self-protection (e.g., “Well that never had an event/accident before is still dangerous,” and “If sewage is present, you should not enter the well.”). Part 3was an assessment of attitudes on self-protection strategies. The answers were “agree,” “disagree,” and “not sure” (e.g., Death in confined space is preventable). The last part (Part 4) examined practices or experiences of entering an agricultural well. The questions focused on symptoms that might occur while entering the well. The participants were recruited by convenience sampling during the meeting at the district hall 28 October 2020. We scored the answers of each participant and assessed the percentage of participants that showed the correct answers. A Chi-square test was used to compare the percentage of correct answers between the experienced and non-experienced participants.

Results

Description of the event

On 5 September 2020, the event occurred among five Myanmar males (Workers A-E). Three of these five cases died. The median age was 30 (min, max = 25, 33) years. Worker A went into the well to turn on a water valve. None of them wore respiratory protective devices. Then the water came out strongly and the sewage splashed. The witnesses reported that the victim rushed climbing up the ladder but soon became unconscious and fell into the water. Five minutes later, workers B and C climbed down to rescue the primary case but they were untrained rescuers. Workers B and C both fell into the water. They struggled for a while before drowning. Workers A, B and C were brought

out by workers D and E who went to rescue. An ambulance arrived 30 minutes later as the Myanmar witnesses could not remember the ambulance hotline until a Thai worker who could recall the hotline came to the scene. Workers A and C were declared dead on the scene by the emergency medics. Worker B was transferred to Sam Roi Yod Hospital. The physician at the emergency room declared worker B dead after cardiopulmonary resuscitation for half an hour. Chest radiography showed diffuse ground-glass and multifocal patchy opacities in both lungs. The doctor found that foul water came out from mouth and nose of worker B. The electrolyte test of the death cases showed acute metabolic acidosis and hyperkalaemia. Workers D and E informed that they experienced eye and nose irritation while entering the water well. The survived cases entered the well to help the victims while tying the rope around their body as a lifeline.

Environmental study

The victims worked in one of the costliest shrimp farms in the province. The farm contained 18 ponds, all of which were covered by PE plastics. The well that the event took place is used to circulate water from one shrimp pond to another every 8-10 weeks. The reuse of drained water from the pond bottom was designed to keep essential minerals in the water. Since there was no rain for a few months prior to the event, the water in the well became stagnant and consisted of composed of mud, sludge, and biofloc (plankton, protozoa, heterotrophic bacteria). The well was ten-meter deep and three-meter wide. There were two water valves at the bottom. To operate the valve, the worker needed to climb down to open the valves manually. The water system model is shown in Figure 1.

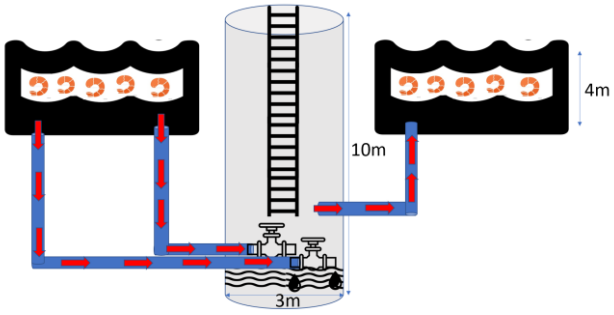

Figure 1 Water-circulating system in the shrimp farm

The dead victims had experience of entering the well before. On the event day, the witnesses mentioned that they noticed a foul smell and bubbling from the water inside the well and the scent became more robust once the index case opened the valve. In the nearby villages, the majority of occupations were agriculture and fisheries, so that most informal workers were Thai. The farm is only one PE shrimp farming in the district; most shrimp farming was non-intensive farming.

Laboratory study

We conducted gas measurements twice. The first attempt was on the following day after the event. The second attempt took place two months later as we tried to simulate the water condition of the event date. However, for the first attempt, the well owner had drained the water just before we arrived. In the second attempt, there was heavy rain a week prior to the measurement. This made the water become diluted and rose to the level of the well opening.

Survey on the residents in the community

Fifty-four participants attended the survey. All were Thais. Male to female ratio was 1:1.1. Most of them were farmers (76%). The median age was 46 years (P25, P75 = 38, 52). The low percentage of correct answers in both experienced and non-experienced people was found in certain questions: “combustible gas can cause injury or death in confined spaces”; “any accidents in confined spaces can cause injury or death”; “a well that is less than 3-meter deep can cause hypoxia”; and “confined space can be any space that has limited entrance/exit”. Experienced people appeared to misunderstand some issues. For instance, some experienced respondents answered that “an agricultural well was not a confined place” or “a well that had never had an event/accident before is safe”. Some experienced respondents reported that they would definitely enter a confined space to help the victims unconscious, Figures 2-3.

Figure 4 demonstrates that most of the respondents agreed that “death in confined spaces is preventable”. They concurred that feasible strategies in the community context were to prepare at least two helpers to be available at the entrance. However, only half of the experienced respondents agreed not to enter the confined space in any conditions.

Discussion

This study confirmed the presence of confined-space deaths in the well in a shrimp farm. Three Myanmar migrant workers died. The possible cause of death of the first case could be due to H_2S poisoning followed by drowning; while, the other two secondary victims died due to drowning. The main fatality risks of this event might be insufficient awareness, lack of knowledge, improper rescue technique, and unpreparedness of the protective equipment. The survey on KAP showed that experienced people were complacent about the dangers in the well. This study is probably the first reported outbreak in a shrimp farm. This event corresponded with the prior events reported

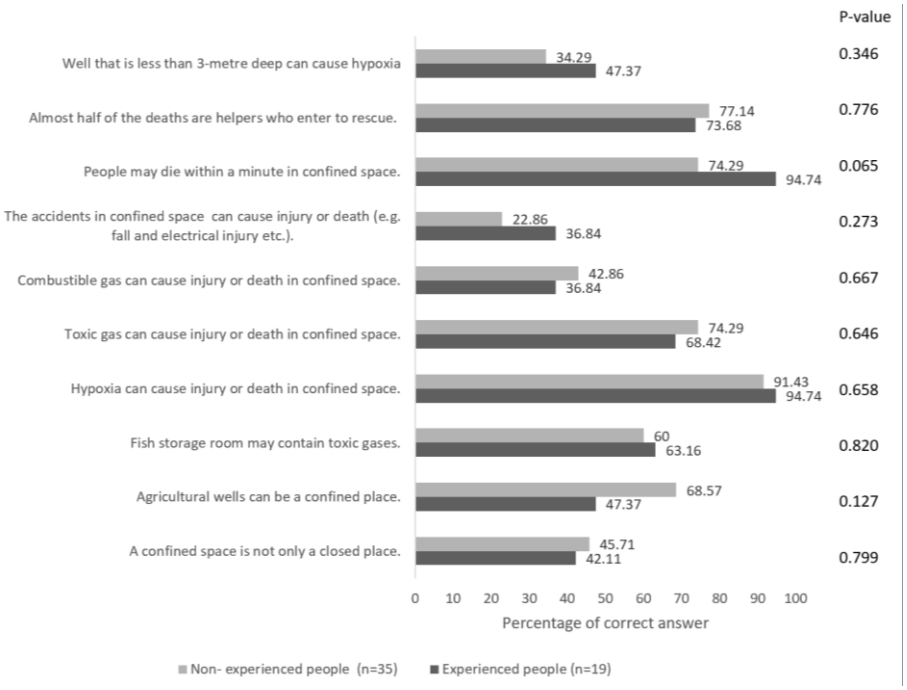

Figure 2 Percentage of correct answers between experienced and non-experienced people about the work in water wells

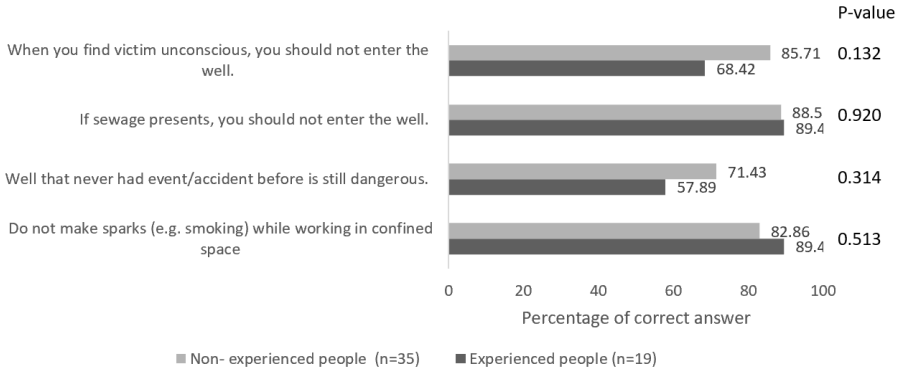

Figure 3 Percentage of correct answers between experienced and non-experienced people about knowledge of self-protection

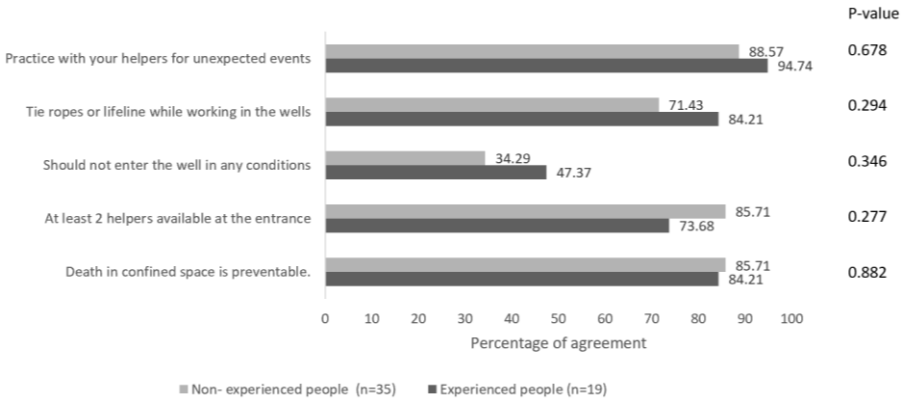

Figure 4 Percentage of agreement between experienced and non-experienced people about attitudes of self-protection strategies

in the EBS which informed that one-third of the events between 2003 and 2018 took place in agricultural areasand most of the victims were informal workers and were secondary victims [6-7].

Although we could not find strong evidence of the presence of H_2S in the well, we hypothesized that H_2S poisoning could be the cause of death of the primary case. The supporting reasons were as follows. Firstly, since H_2S is heavier than air and the witnesses reported that the index case became unconscious just a few seconds before drowning [8-9]. Secondly, the blood test showed acute metabolic acidosis with hyperkalaemia which can be found in chemical asphyxiants toxicity, not in hypoxia [10-11]. Thirdly, the witnesses reported nose and eye irritation while entering the well which is commonly found in areas covered with toxic gases [9]. Fourthly, shrimp farming is at high risk of H_2S generation since the moist soil was normally composed of iron and sulfur from pond [12-13], and the use of polyethylene liners facilitated anaerobic oxidation and H_2S production under the liner as supported by Soraphat et al. [14] and Nóbrega et al. [15]. Lastly, before the event occurred, the water had been stagnant for months without being diluted by the rain. This implied a likely accumulation of toxic gases.

The survey on KAP showed that experienced people seemed to be complacent with the dangers in the well. In addition, there were some misunderstanding points about the knowledge and attitudes of working in a water well. Some of them did not recognise the well as a confined place and some perceived that immediate entrance to help the victims in confined space was an appropriate approach. The findings also suggest that health education might not be effective to prevent further events because people might have a pre-emptive attitude that it is always safe to access a well. Therefore, we need additional strategies apart from health education to prevent further events. Fencing off confined space areas or covering the well entrances might be useful.

Knowledge and information that should be promoted to the villagers include: (1) combustible gas, drowning, fall and injury can occur in a confined space; (2) a shadow well can cause hypoxia just like a deep well; (3) a well that has never had a previous event is still dangerous; and (4) a confined space is not only a closed space, but also includes areas with limited openings.

Death among rescuers from improper rescuing techniques is very common [16-17]. According to National Institute of Occupational Safety and Health (NIOSH), approximately 60% of confined-space fatalities happen in rescuers [18]. Besides, some local rescuing teams do not have enough capacity or skill to rescue victims in a confined space [19-20]. Thus it is critical to make rescuers aware that they need proper preparation before entering the space to help others.

There were some worth-learning lessons from this event. Inadequate preparation before working in wells always enhance the risk of injury for the workers. The surviving rescuers used the lifeline and had an assistant standing by at the well opening while the deceased rescuers promptly jumped into the well to help the primary cases without proper preparation. This confirmed that the rescuers should be very well prepared before helping others. However, the best method to prevent injury is to avoid entering the well from the outset.

In this event, the rescuers conducted an entry-rescue technique, which is the riskiest choice. Those who survived used a rope tied around their body with assistants available at the well opening. Non-entry rescue technique is a safer choice according to the recommendation of the Occupational Safety and Health Administration (OSHA) [21]. It was the technique that use a retrieval system such as tripods to bring the employee out of the space. However, in many settings (like this event), it cannot be exercised in a timely manner.

In addition, there has been no guidance on occupational safety, health and environment management for confined space working for informal workers [22]. The available guidance is only for the factory context [4]. The farm owners and the employees in this event had never been trained for a safe rescuing before.

More importantly, most agricultural workers in Thailand are recognised as informal workers and are composed of both Thais and non-Thais. Therefore, the campaign to raise awareness of occupational safety for the informal workers need to account for the language and cultural barriers and should consider the outreach strategies to reach the hard-to-reach populations (like migrants) as much as possible [23].

There remained some limitations in this study. Firstly, we could not perform the gas measurement right on the scene. Even though we measured the gas in the well twice, the first attempt was not valid as the farm owner drained out the water from the well before we arrived and the second attempt was interfered by heavy raining. We did not take the third attempt because all recommendations to prevent gas forming in the well were already implemented. Secondly, the attendance of the participants for the KAP assessment was voluntary. This meant that we might miss the villagers who missed the gathering message from the Deputy District Chief (for instance, those living further from the Hall or migrant workers who did not understand Thai message). Besides, although the summon of villagers by the Deputy District Chief was

a practical approach, it hampered our attempt to perform probability sampling on the populations. Lastly, the answer in the questionnaire might not necessarily be the same as the actual practices of the villagers.

For recommendations, the foremost principle is to reduce the number of confined spaces as much as possible. If the water well needs to exist, limiting the exposure to the confined space is strongly recommended, for instance, prohibiting people entering the well by using a lever to operate the water valve from outside instead of manual operating. For personal level, a proactive health education should be conducted to enable the workers and the villagers to be aware of the danger of injury in confined spaces [24]. A preparation of proper rescue equipment for non-entry rescue technique is suggested. This needs to implement alongside the availability of trained rescue personnel. For the farm owner, flushing the water out of the well for evert 3-5 days is useful. Placing a warning sign and fencing the well opening also help prevent future events to some extent. In addition, the regulations and guidelines for occupational safety on the work in confined spaces (including agricultural well) among informal workers should be developed. The Division of Occupational and Environmental Diseases of the Thai DDC should take a lead in this proposal. Further studies that explore the KAP on the head-to-reach people including migrants are recommended

Conclusions

The study is probably one of the first reported shrimp-farming accidents. The most likely cause of death of the index case was due to H_2S poisoning, followed by drowning. All of the cases were Myanmar informal male workers on the shrimp farm. Rescuers were at risk of death, as was the primary victim. The lack of knowledge and insufficient awareness, especially among those who had prior experience of well entry, were amongst key risk factors of the accidents. Occupational safety guidelines for informal workers working in confined spaces should be developed and enforced. Mitigation strategies should highlight on avoiding to work in confined spaces as much as possible. A preparation of proper rescue equipment with available well-trained rescue staff is recommended.

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