Engineering Controls to Reduce Hydrogen Sulfide Exposure of Workers in Swine Buildings

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Summary

Three engineering control measures were developed and tested for effectiveness in protecting swine barn workers from exposure to hydrogen sulfide (H_2S) gas during manure handling events. A remote manure pit plug pulling system allowed the worker to pull the manure pit plug from outside the room, thereby significantly reducing risk of worker exposure to H_2S. A water sprinkling apparatus was also devised, which resulted in 79% reduction of H_2S gas concentration under optimal laboratory conditions. However, the use of a similar system on agitated manure showed the opposite effect. A manure scraper system was installed to remove manure daily from the manure pit of a grower-finisher room. Preliminary measurements showed that H_2S levels were 80 to 96% lower in the scraper room than in a similar room with a conventional pull-plug system. However, higher ammonia emissions were observed in the scraper room compared to the conventional grower-finisher room.

Introduction

High levels of H_2S can have detrimental effects on both workers and swine. Previous research by the Prairie Swine Centre Inc. (PSCI) indicated that workers are at risk of exposure to potentially hazardous H_2S levels when performing manure management tasks, such as pulling manure pit plugs. The main goal of this project is to develop practical measures that can prevent or reduce worker exposure to high H_2S concentration in swine buildings. Three different systems were investigated in separate modules.

Module 1 – Improved Design for Pit Plugs

In this module, an improved pit plug concept that allowed for pulling the plugs from a remote location was designed and evaluated. Two undergraduate students, assisted by technical staff at University of Saskatchewan and PSCI, designed and built a prototype system (Fig. 1). The system was installed in two grower-finisher rooms at PSCI and tested by measuring H_2S concentrations using a H_2S monitor (Draeger Pac III monitor with a H_2S sensor, Draeger, Lübeck, Germany) during the plug-pulling operations.

After examining several plug designs, the extended cone plug was selected and installed. Monitoring of H_2S levels during nine plug-pulling events showed that the maximum H_2S concentration in the room over the plug area was 68 ppm, while corresponding concentrations at the alleyway near the winch was 0 ppm. Hence, the system was very effective in protecting the worker from being exposed to H_2S by allowing the worker to perform the task away from the plug area.

Module 2 – H_2S Abatement by Water-based Liquid Spray

Because H_2S is water soluble, it was hypothesized that spraying a water-based liquid over agitated manure would reduce emissions into the air. In this module, a laboratory spray chamber was set up to determine the impact of a water-based spray on H_2S levels in the chamber (Fig. 2). Preliminary tests were done to investigate the reduction in H_2S levels as affected by various parameters such as type of spray nozzle, water pressure, temperature and pH, as well as the use of various chemical additives.

Laboratory tests with various combinations of test parameters consistently reduced the concentration of pure H_2S gas released into the chamber (Fig. 3). Using a hollow cone nozzle at 200 kPa with water at pH = 9 resulted in a 79% reduction of the peak H_2S levels. The treatment was applied to a set of barrels filled

with swine manure. In four control barrels where no spray was applied, manure agitation produced an average of 148 ppm, with a peak reading of 520 ppm measured from the exhaust air. However, application of the water-spray treatment increased the average and maximum H_2S concentrations to 273 and 690 ppm, respectively. Because these were not consistent with the observations in the laboratory study, it was suspected that other gases generated in the manure barrel affected the Draeger Pac III monitor. Additional tests are on-going to investigate the water-spray treatment further.

Module 3 – Manure Scraper System to Reduce H_2S Levels

In this module, a manure pit scraper system (Fig. 4) was installed in a grower-finisher room to remove swine manure on a daily basis. Its effectiveness was evaluated by comparing the air quality in the scraper room and a similar room (Control) with conventional manure pit-plug system.

The scraper system was evaluated over two production cycles; during each trial both rooms were monitored closely over four one-week periods. Table 1 summarises the maximum H_2S concentrations measured at two locations in the rooms. Compared to the control room, the maximum H_2S concentrations were lower in the scraper room by an average of 80% over the plug area and by an average of 96% over the middle pen. Additionally, the maximum H_2S levels in the control room exceeded the 15-ppm ceiling occupational exposure limit (OEL) value on three occasions during the two trials, while no peak H_2S readings were higher than this limit value in the scraper room. The ceiling OEL is the maximum concentration of a biological or chemical agent to which a worker may be exposed, i.e., no worker should be exposed to any levels above this limit at any time.

During the two trials, significant levels of ammonia were measured in the incoming inlet air for both rooms, possibly due to recirculation of air exhausted from the fans into the supply air as well as from possible back draft of ammonia from adjacent rooms into the barn attic. The weekly average ammonia concentrations measured at the exhaust was significantly ($p<0.05$) higher in the scraper room (11.3 ppm, SD = 2.3 ppm) than in the control room (9.8 ppm, SD = 2.1 ppm), although the mean difference was smaller than the indicated accuracy of the ammonia analyser. The calculated ammonia emissions were about 44% higher in the scraper room, which was attributed to the formation of a film of excreta on the pit bottom surface after scraping; this has been previously reported as possibly causing increased ammonia emissions in scraper systems. However, the observed ammonia levels were still lower than the 25-ppm OEL for ammonia, despite the presence of ammonia in the incoming air. Additional tests are on-going to determine the effectiveness of maintaining a layer of standing water at the bottom of the manure channel to control ammonia emissions.

Conclusions

A remote manure plug pulling system was successfully developed. Results showed that the system was effective in preventing worker exposure to H_2S by allowing the pulling of the plugs from the alleyway. A water-spray treatment showed consistent reduction in H_2S levels in a laboratory study. However, application of the treatment on agitated manure showed opposite effect on H_2S. A manure scraper system used for daily manure removal from a swine room was effective in reducing H_2S to levels below the maximum exposure limit for worker's safety. The system generated higher ammonia levels, although peak readings did not exceed the ammonia exposure limit value. Additional tests are being conducted to further investigate both the scraper and the water-spray systems.

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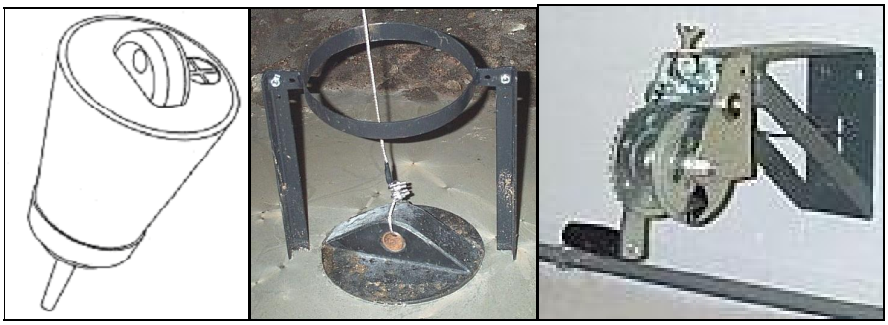
Table 1. Summary of maximum H_2S concentration (ppm) measured in the scraper and control rooms.

		Control		Scraper	
	Date	Over plug	Middle pen	Over plug	Middle pen
Trial 1	10-Mar-04	4.0	2.0	0.0	0.0
	24-Mar-04	0.0	0.0	0.0	0.0
	7-Apr-04	9.0	0.0	11.0	7.0
	21-Apr-04	12.0	4.0	0.0	0.0
Trial 2	30-Jun-04	12.0	2.0	0.0	0.0
	21-Jul-04	95.0	N/A	6.0	N/A
	11-Aug-04	40.0	30.0	2.0	0.0
	25-Aug-04	30.0	10.0	1.0	2.0
	Average	25.3	6.9	2.5	1.3
	SD	31.2	10.8	4.0	2.6

N/A – data not available, instrument malfunction



(a) (b) (c)

Figure 1. Improved pit-plug design showing the (a) extended cone plug, (b) with cable attached and plug-height stop, and (c) the cable-winch system for remotely pulling the plug from outside the room.

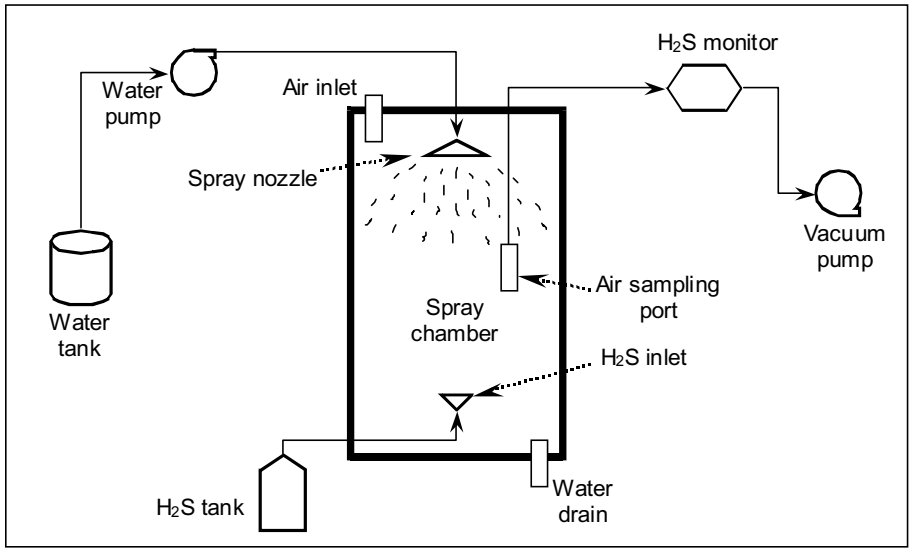


Figure 2. Schematic diagram of laboratory set-up used to determine the effect of water-based spray on H_2S levels in the chamber.

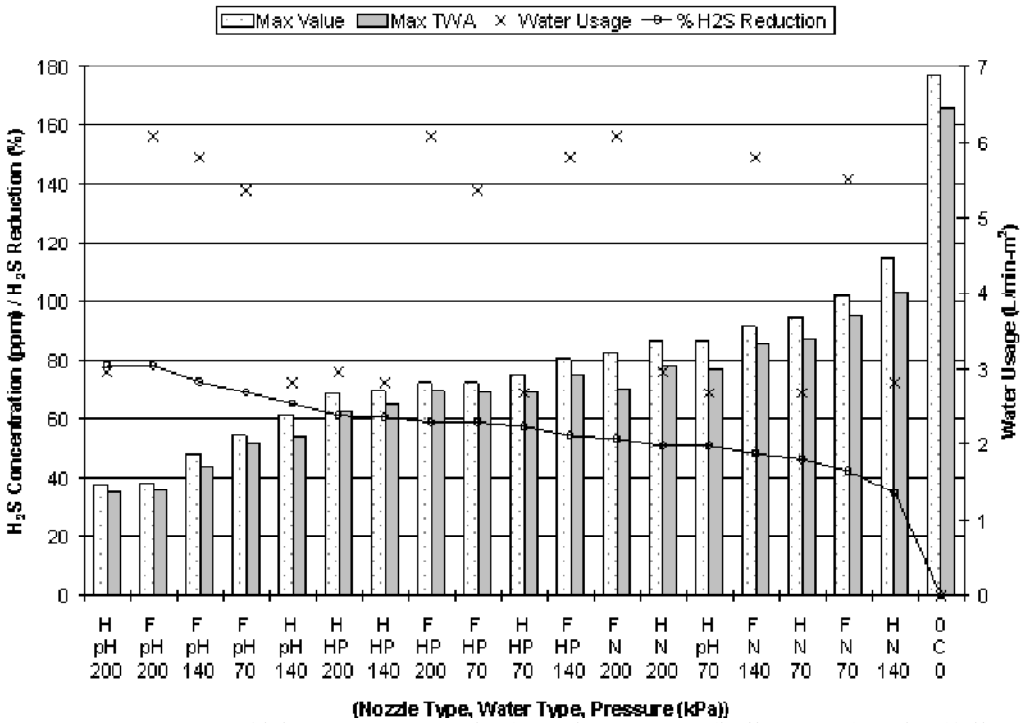


Figure 3. Summary of laboratory test results (Nozzle Types: H (hollow cone) and F (full cone); Water Type: pH (water at pH 9), HP (water with hydrogen peroxide added), and N (normal water); Pressures: 70, 140 and 200 kPa).

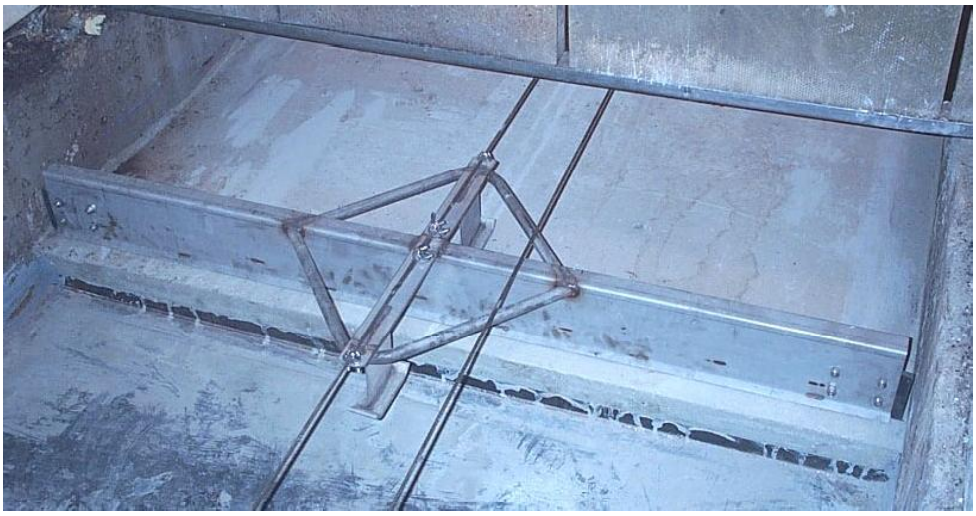


Figure 4. Scraper blade used for daily removal of manure from the pit. The manure pit has drains at both ends, through which the scraped manure was emptied to the sewer line.