Controlling Environmental Emissions from Swine Barns using Zinc Oxide Nanoparticles

Predicala, B.[1] and A. Alvarado[1,2]
[1] Prairie Swine Centre, Box 21057-2105, 8th Street East, Saskatoon, SK, S7H 5N9;
[2]Department of Chemical and Biological Engineering, 57 Campus Drive, University of Saskatchewan, Saskatoon, SK S7N 5A9


B. Predicala

SUMMARY

In this present study, the effectiveness of mixing and filtration methods using zinc oxide (ZnO) nanoparticles to control hydrogen sulphide (H_2S), ammonia (NH_3) and odour emissions from swine facilities were evaluated under conditions that represent normal swine production. The addition of ZnO nanoparticles into the manure achieved more than 95% reduction in H_2S level; no significant effect on NH_3 and odour concentrations was observed. ZnO nanoparticles were persistent in maintaining low H_2S level up to 15 days after treatment application. On the other hand, the ventilation air recirculation system with ZnO filter achieved significant reduction in both H_2S and NH_3 concentrations at the animal- and human-occupied zones.

INTRODUCTION

Environmental emissions from hog production operations have been a long-term concern to humans, animals and to the environment despite several abatement strategies that have been investigated and adopted at the farm scale. Taking advantage of recent advances in nanotechnology, our previous work evaluated the use of nanoparticles in controlling H_2S, NH_3 and odour emissions from swine manure in a fully controlled small-scale test set-up and results revealed that filtration and mixing methods using ZnO nanoparticles showed the greatest potential for controlling these environmental emissions (PSC Annual Report 2008, pp. 21-22). In this present study, the effectiveness of these treatment approaches on H_2S, NH_3 and odour emissions was investigated under actual barn production conditions.

RESULTS AND DISCUSSION

Prior to room-scale experiments, semi-pilot scale tests were conducted to evaluate operational factors such as nanoparticle-to-slurry ratio (mixing method), and filter design, face velocity and nanoparticle loading amount (filtration method) in an open system environment. Results showed that the mixing method required a particle-to-slurry ratio of 3 g of ZnO per litre of slurry to control H_2S and NH_3 levels. Using the air filtration technique, a fluidized bed filter design with 1.8 g/in^2 loading rate and face velocity of 0.5 m/s were found to be the most effective combination for controlling gas levels. Using these parameters, room-scale experiments were then carried out in specially-designed chambers at PSCI barn facility to assess the

> *"Zinc-oxide (ZnO) nanparticles were effective at reducing hydrogen sulfide (H_2S) emissions from manure slurry."*

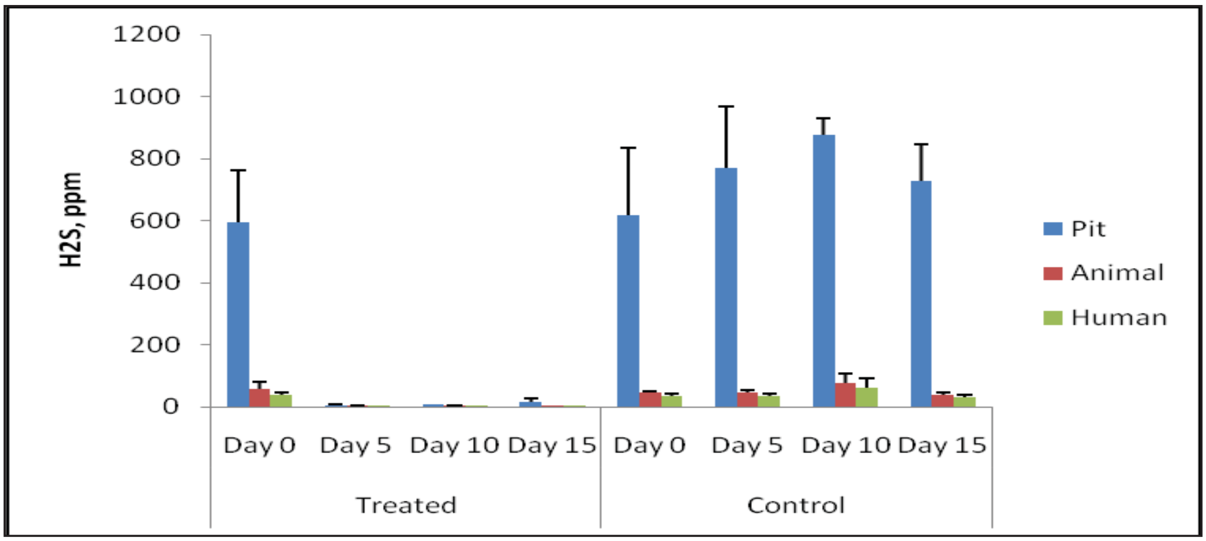
effectiveness of each method under conditions that represent normal swine production; one chamber was operated as a conventional swine room (Control) and the other one as a treatment room.

Mixing tests

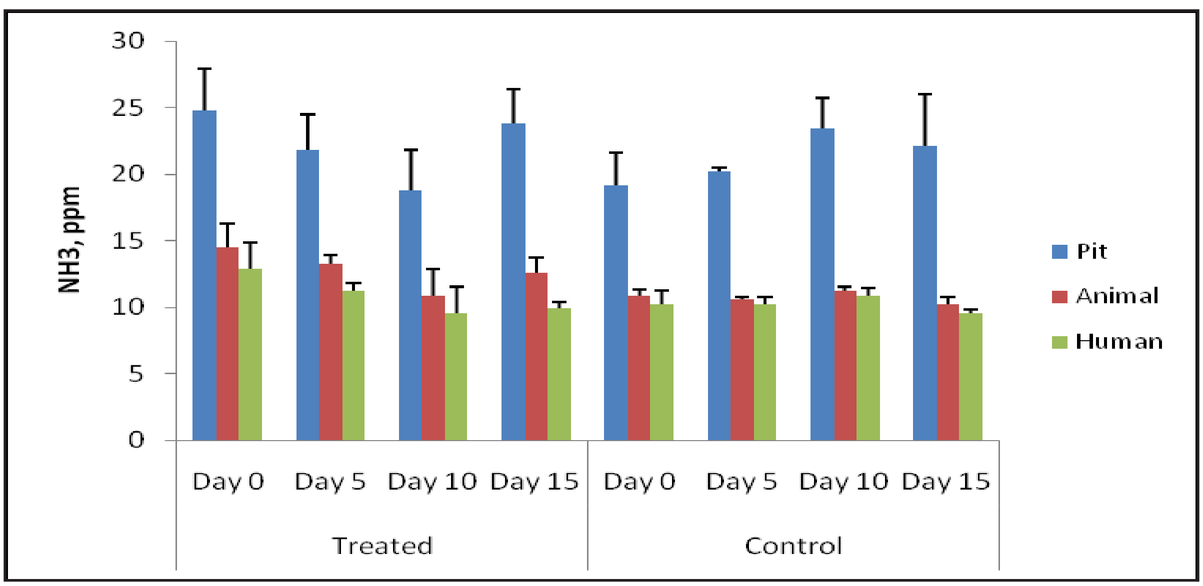
Figure 1 shows the actual concentrations of H_2S (A) and NH_3 (B) from the samples collected in both chambers during manure agitation. To account for the inherent variation in initial concentration of manure gases, gas samples were collected in each chamber prior to the application of ZnO nanoparticles (in the treated chamber). The H_2S and NH_3 concentrations on this day were plotted as Day 0 values which served as baseline for subsequent sampling events. In the treated chamber, initial H_2S concentrations of 596, 57 and 39 ppm in the pit, animal and human levels, respectively, were reduced significantly ($P<0.05$) to 5, 1 and 1 ppm, respectively, on Day 5 after ZnO nanoparticles were applied into the manure. These levels were almost unchanged to Day 15 which implied that the effect of the treatment in reducing H_2S levels was persistent for at least 15 days. The concentrations of H_2S in the different sampling locations (pit, animal and human levels) in the untreated (control) chamber were not significantly different ($P>0.05$) from each other over the 15-day monitoring period. On the other hand, mean NH3 concentrations in the control and treated chambers plotted in Figure 1-B showed no statistically significant reduction in NH_3 levels arising from the treatment ($P>0.05$). Additionally, odour concentrations in the treated chamber were not significantly different from the control chamber ($P>0.05$) with mean values of 1960±642 OU/m^3 and 2423±648 OU/m^3, respectively.

Filtration tests

Actual levels of H_2S (A) and NH_3 (B) in specific locations in each chamber during manure agitation are plotted in Figure 2. Prior to the operation of the air recirculation system with filter pad only in the control chamber (Day 0), H_2S concentrations in the pit, animal and human levels were 326, 82, and 58 ppm, respectively, while the corresponding NH_3 levels were 22, 12, and 10 ppm, respectively. On subsequent sampling days after filter installation (Day 5 to Day 15), no significant change was observed in H_2S and NH_3 concentrations in each sampling location ($P>0.05$) in the control chamber. This observation is consistent with the results from the mixing tests. The installation of a ventilation air recirculation system with filter pad only had no significant impact on H_2S and NH_3 levels in the animal- and human-occupied zones. Similar to the control chamber, H_2S and NH_3 concentrations in the pit level in the treated chamber were not significantly different over time ($P>0.05$). This was expected considering that the ventilation air recirculation system with ZnO filter in the treated chamber was intended to treat the target gases after they have been released from the source (pit). In the animal and human zones, however, significant reduction in the concentrations of the target gases relative to their initial concentrations was observed ($P<0.05$) over the 15-day monitoring period. In the animal level, initial mean H_2S and NH_3 concentrations were 94 and 15 ppm, respectively, and decreased to 46 and 10 ppm, respectively, on Day 15 after the filter with ZnO nanoparticles has been installed. Over the same period, mean initial H_2S and NH_3 levels in the human-occupied zone were 58 and 12 ppm, respectively, and became 23 and 7 ppm, respectively, on Day 15. The operation of filter system with ZnO nanoparticles did not significantly impact the odour emissions from the chamber ($P>0.05$).

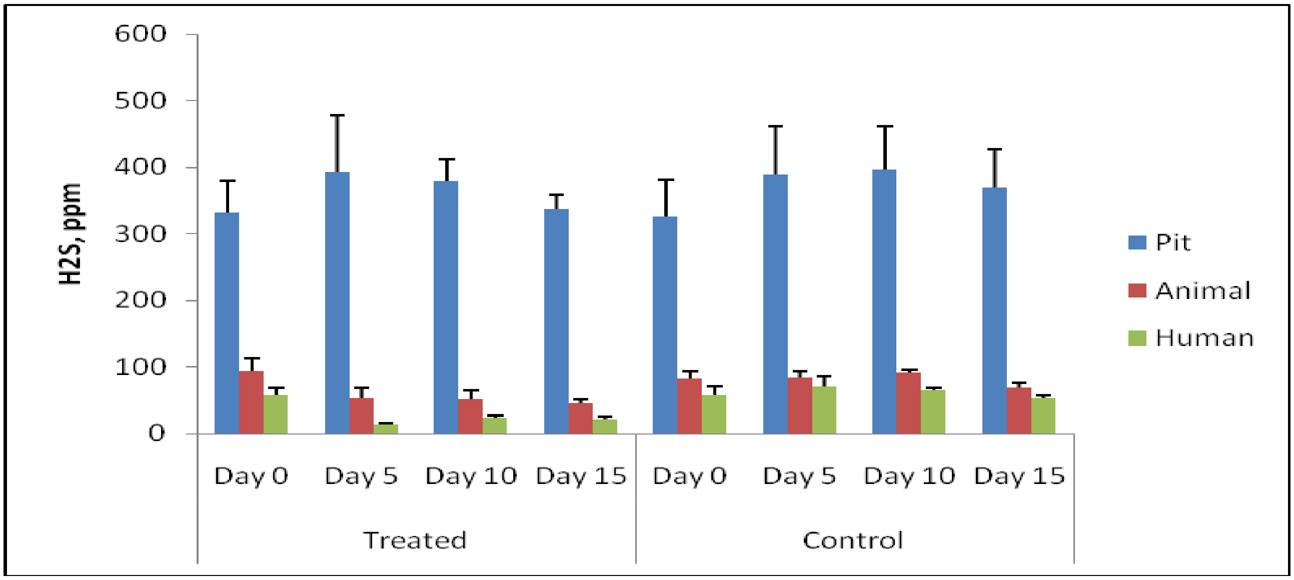


A

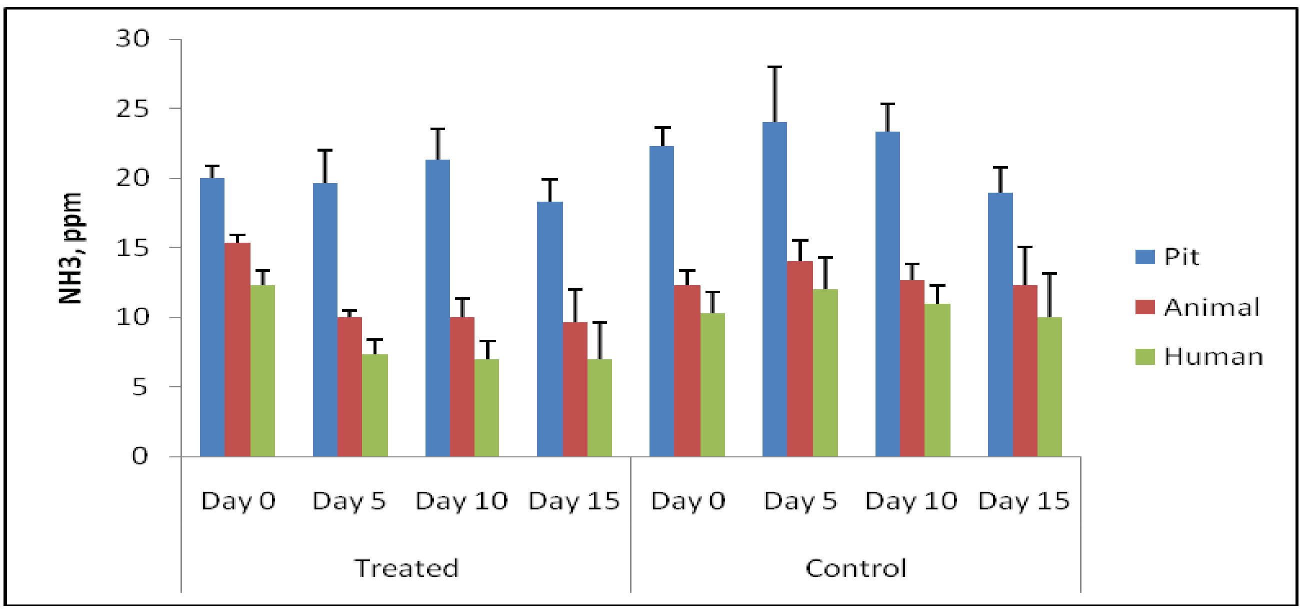


B

Figure 1. Mean (±SE) actual concentrations of H_2S (A) and NH_3 (B) in gas samples collected from untreated (control) slurry and slurry mixed with ZnO nanoparticles at different sampling locations and monitoring periods during room-scale tests using the mixing method n=3.



A



B

Figure 2. Mean (±SE) actual concentrations of H_2S and NH_3 in gas samples collected from untreated (control) chamber and chamber with ZnO filter during room-scale tests using the filtration method, n=3.

CONCLUSIONS

Room-scale experiments revealed that the addition of ZnO nanoparticles into the slurry reduced gas levels, specifically H_2S, at the source (manure pit), resulting in almost undetectable levels at the animal- and human-occupied zones. On the other hand, partial filtration of the gases from the source using a ZnO filter installed in a recirculation duct set-up did not decrease the gas levels at the source but could likely reduce the gas concentrations at the animal and human levels to comply with the Short-term Exposure Limit values (i.e., 15 ppm for H_2S).

ACKNOWLEDGEMENTS

Strategic funding provided by Sask Pork, Alberta Pork, Manitoba Pork Council, and Saskatchewan Agriculture and Food Development Fund to the research programs at PSCI are gratefully acknowledged. Project funding provided by Saskatchewan Agriculture Development Fund and the National Science and Engineering Research Council are also acknowledged.