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VENTILATION EFFECTS ON AMMONIA AND HYDROGEN SULFIDE GASES IN A MANURE STORAGE PIT

by

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Summary:

This paper reports the results of a preliminary study on the effect of ventilation air on the generation and release of ammonia and hydrogen sulfide gases from stored swine manure. Manure storage pits were simulated using three barrels 0.4 m in diameter by 1.2 m high filled with untreated swine manure to a depth of 0.9 m. Each barrel had a ventilation box attached to the top. Ventilation air was passed through two of the boxes at 0.15 m/s and 0.5 m/s. The third barrel served as the control. The results generally showed higher levels of ammonia and hydrogen sulfide in the control treatment compared to the other treatments.

Keywords: Ammonia, Hydrogen Sulfide, Manure , Storage Pits, Ventilation.

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BACKGROUND AND LITERATURE REVIEW

Storage of livestock manure in earthen or concrete pits for a period of time to await treatment or disposal, is a popular waste management practice for environmentally controlled building facilities. Liquid manure is usually stored in under-f loor pits or in outside tanks or pits (MWPS-18). Outside manure storage is typical for most new buildings, while a large number of old buildings have under-floor storage pits.

Swine manure is a very complex material. It consists of undigested and unabsorbed feed ingredients, catabolic products of metabolism, tissue and microbial cells (Day and Harmon, 1975). While in storage, manure undergoes settling and microbial degradation. The settling, which is due to density differences, gives the manure different physical and chemical properties along the depth of the pit (Zhang, 1992). Anaerobic conditions are normally prevalent in manure storage pits. The microbial degradation can take place in aerobic, facultative or anaerobic conditions. Under anaerobic conditions gases such as methane(CH_4), hydrogen sulfide(H_2S), ammonia(NH_3), carbon dioxide(CO_2) and volatile organic compounds (VOC's) can be produced.

The design and operation of the pits greatly affect the environments in the pits and consequently, the production and release of manure pit gases. The manure pit gases can create oxygen deficient, toxic, and/or explosive atmospheres. Deaths have occurred from lack of oxygen or from the toxic effects of these gases(NIOSH, 1993). The fatalities occurred when emptying or repairing manure pits. Most manure pit deaths or serious injuries have resulted in multiple fatalities. In some situations, entire families have virtually been lost in manure pit tragedies (Maddery et al., 1993 and NIOSH, 1993). The general recommendation to farm workers is to ventilate the pits before entering. In addition to the fatalities, methane and hydrogen sulfide may present an explosion hazard. Also, some of these compounds are responsible for the odors that emanate from manure. Odor is becoming a big problem to livestock producers. Farmers have been sued for odor nuisances by their neighbors resulting in fines or being forced out of production (Hamilton, 1992).

Although manure pit gases are potentially present at all times, they are more hazardous during the warm months when temperatures are more favorable for bacterial activity that can result in increased gas generation. To prevent serious or fatal exposure, NIOSH recommends that; manure pits be identified as confined spaces, farm workers should never enter manure pits or even attempt rescue unless appropriate safety measures are used. In addition, where possible, manure waste systems should be designed to provide access to all serviceable parts from outside the pit. NIOSH has published recommendations on how manure pits should be treated. Some of these recommendations are

- all manure pits should be ventilated
- The atmosphere within the pit should be tested before entry

- provide a powered, continuous fresh air ventilation system for each manure pit. Ventilation is particularly important when agitation of waste is initiated after it has been fermenting.

The objective of this experiment was based on NIOSH recommendation on how to manage manure storage pit. The objective was to test the effect of air velocity through the manure pit head space on the generation and release of manure pit gases (ammonia and hydrogen sulfide). This is a preliminary study of a major project on reducing fatality risks from livestock manure storage, currently being done at the University of Illinois.

PROCEDURE

Three barrels, 0.4 m in diameter by 1.2 m high, were filled to a depth of 0.9 m with untreated swine manure. Each barrel had a ventilation box attached to the top. The dimensions of the boxes on top of the barrels were 0.46 X 0.46 X 0.15 m for the control and 1.42 X 0.46 X 0.15 m for the 0.15 and 0.5 m/s air velocity barrels. The boxes provided spaces to simulate dilution of pit gases in manure pit head space. The manure used was collected from the finishing building of the Swine Research Farm at the University of Illinois. The pigs were fed normal corn soybeans diet.

Air velocities (treatments) through the ventilation boxes were 0.15 m/s, 0.5 m/s and none (room air velocity) for the control. These air velocities give a volume flow rate to surface area ratio of 0.0824 $m^3/s/m^2$ and 0.275 $m^3/s/m^2$ for 0.15 m/s and 0.5 m/s respectively. The experiment was conducted for a period of 6 weeks. The room temperature was kept at 22 ± 4 °C.

The air in the head space was sampled to determine the concentrations of ammonia and hydrogen sulfide gases. The concentration of ammonia and hydrogen sulfide gases in the barrel head space were measured everyday using a PHD meter with ammonia and hydrogen sulfide sensors. Manure sampling was done every day for the first five days, every other day for the next ten days, and every five days for the rest of the test period. The manure samples were analyzed for ammonia-nitrogen (NH_3-N) and total sulfide concentrations, pH, and solids degradation. The NH_3-N in the manure was determined using an ammonia ion selective electrode (Orion, Model 95-12). Total sulfide was determined by the methylene blue method using a HACH 2000 Spectrophotometer. The pH was be measured using a pH meter (Cole Palmer, Model 5985-80). Total solids were determined by drying the samples in an oven at 103 °C for 24 hours, while the volatile solids were obtained by igniting the dried manure at 550 °C for 1 hour. The detailed procedures are contained in Standard Methods for the Examination of Water and Wastewater (AWWA, 1989).

At the end of the test period, the barrels were stirred to simulate the agitation of a manure storage pit before being emptied. The concentrations of hydrogen sulfide and ammonia gases released were measured. These quantities reflect the concentration of the manure pit gases that can potentially be released when emptying a pit at the end of a storage period.

RESULTS

EFFLUENT GAS STREAM

The concentration of ammonia and hydrogen sulfide gases in the manure pit head space are shown in Figures 1 and 2. Ammonia concentration was higher in the control barrel compared to the 0.15 and 0.5 m/s treatments (Figure 1.). This is an expected because the gas produced in the treatment barrels with ventilated head space are diluted and exhausted by the ventilation air. Very little hydrogen sulfide was detected in the effluent gas stream in all the barrels, apart from spike production on one or two days during the test period (Figure 2).

MANURE

Ammonia

Ammonia-N concentration in the manure increased with storage time in all the layers for treatments (Figure 3-5). In general, there was more ammonia-N in the control compared to the other treatments. However, statistical comparison between the control and the 0.15 and 0.5 m/s air velocity treatments show that: the ammonia-N for the control was significantly different from the treatment with 0.15 m/s air velocity through the head space, in all the layers (the p-values were 0.006, 0.003 and 0.001 for the top, middle and bottom layers respectively); and for 0.5 m/s air velocity through the head space treatment, the ammonia-N concentrations were not significantly different in the in all layers of the manure. A comparison between the 0.15 m/s and 0.5 m/s air velocity treatments showed no difference in the top layer and some significant differences in the middle and bottom layers. The p-values were 0.45, 0.006, 0.02 for the top, middle and bottom layers respectively. All the comparisons were made at the 95 % confidence level.

Hydrogen Sulfide

The sulfide content of the manure are reported in Figures 6-8. Generally, there was more sulfide in the control treatment in all the layers compared with the other treatments. During the first ten days, there was a relatively high concentration of sulfide in the manure in all treatments. The amount of hydrogen sulfide generated in all treatments reduced over time. For the top layer, statistical comparison of the hydrogen sulfide content in (1) the control and the 0.15 and 0.5 m/s air velocity treatments showed that the control was significantly different from the other treatments, (2) the 0.15 and 0.5 m/s treatments were not significantly different from each other. The hydrogen sulfide concentration in the middle layer did not show any significant statistical differences in all the treatments. Similarly, the bottom layers showed no statistical difference except for the control and the 0.15 m/s treatment.

pH

The pH of the manure varied between 6 and 7 in all the layers (Figures 9-11). But it decreased from the top to the bottom layers in all the treatments. These pH values are within the range of values (6-8) optimal for microbial activities. Statistical comparisons showed that the pH values were different between all the treatments and between all the layers.

Solids

Degradation of the total volatile solids are shown in Figures 12-14. Statistical analysis showed; no significant differences on the total volatile solids in the top layers, that there was a significant difference between the control and both the air flow treatments in the middle layer and, no significant difference for the bottom layers.

Stirred Manure Pits

At the end of the test period, the manure was stirred and the levels of ammonia and hydrogen sulfide gases measured. The results are presented in Table 1

Table 1:

Gases	Head space treatments		
	Control	0.15 m/s	0.5 m/s
Ammonia-N (mg/L)	1234	1000	881
Hydrogen sulfide(mg/L)	>502	352	379

DISCUSSION

The organic constituents of animal waste can be metabolized by bacteria both under aerobic and anaerobic conditions. Under aerobic conditions, the organic material is ultimately reduced to carbon dioxide and water. On the other hand, under anaerobic conditions, bacteria break down the complex organic substances into simple organic acids, and then ferment these acids to ultimately form methane and carbon dioxide (Merkel, 1981). Merkel (1981) further report that the first step in the breakdown of animal waste is marked by the rapid disappearance of the available oxygen. Urea, ammonia, and other products of putrefaction are partially oxidized rapidly consuming the available oxygen and causing the waste to become anaerobic. Under anaerobic conditions, proteins are broken down to form urea, ammonia, hydrogen sulfide, mercaptans aliphatic and aromatic acids, amines and amides to name a few of the by-products.

Based on the above processes, a parallel can be drawn from the magnitudes of the ammonia-N concentration obtained in the different treatments. The fact that the control had relatively higher concentrations of ammonia-N indicate that the air that was passed through the 0.15 and o.5 m/s air velocity treatments influenced the degree of aerobic and anaerobic conditions in the manure pits. Passing air through the head space possibly made the treatments more aerobic in the top layers. If this is true, then nitrifying bacteria will use ammonia as an electron donor. Under these circumstances, the ammonia-N is oxidized to nitrite-N and nitrate-N, hence, the relative lower concentrations of ammonia-N in the manure. The same reason that the 0.15 and

0.5 m/s treatments were more aerobic than the control could also be used to explain the relative high concentration of hydrogen sulfide in the control over the other treatments

Solids reduction in the top layers was relatively higher in the treatments compared to the control. For the top layer, though there was no statistical significant difference in the magnitudes of the total volatile solids, the solids were lower in the 0.5 m/s barrel compared to the control and 0.15 m/s treatments. This could have been due to either settling of the solids or microbial activity or both. There was an overall 50% solids reduction during the storage period for the manure in the top layers of all the treatments. The volatile solids in the manure in the middle layers had almost similar magnitudes of solids throughout the test period. Mixed results were obtained for the bottom layers.

Under aerobic conditions, hydrogen sulfide production is not expected . The 0.15 and 0.5 m/s air velocity treatments possibly created partially aerobic conditions in the top layer of the manure. The partial aerobic conditions created by the air flow treatments, possibly explains the lower hydrogen sulfide production in these treatments compared with the control.

Results from stirring the manure after six weeks of storage indicate that the potential hazards that may exist when the pits are to be emptied. The results reported in Table 1 are considerably over the limits of NIOSH and OSHA.

SUMMARY

The objective of this experiment was to test the effect of air velocity through the manure pit head space on the generation and release of ammonia and hydrogen sulfide gases from stored manure. Manure storage pits were simulated by using three barrels 0.4 m in diameter by 1.2 m high filled with untreated swine manure to a depth of 0.9 m. Each barrel had a ventilation box attached to the top. Ventilation air was passed through two of the boxes at 0.15 m/s and 0.5 m/s. The third barrel served as the control. Levels of ammonia and hydrogen sulfide gases in the head space were measured every day. Manure samples were taken at regular intervals from three regions--top, middle, and bottom--and analyzed for ammonia-nitrogen, and total sulfide, pH, total and volatile solids. The experiment was ran for six weeks. At the end of the test period, the barrels were stirred and the amounts of ammonia and hydrogen sulfide released were measured.

The results showed higher ammonia levels in the head space of the control compared to the treatments that were ventilated. Very little hydrogen sulfide was detected in the effluent gas streams in all the barrels. The ammonia nitrogen in the manure increased with time for all the treatments but, there was generally more ammonia nitrogen in the control barrel compared to the other treatments. The sulfide content in the control was always higher compared to the other treatments. Gas levels at the end of the storage period were higher for the control compared to the treatments. Ammonia levels were 1234, 1000, and 881 mg/L for the control, 0.15 m/s and 0.5 m/s treatment respectively. The hydrogen sulfide gas levels were >502, 352, and 379 mg/L for the respectively for the treatments as listed above.

ACKNOWLEDGEMENT

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REFERENCES

AWWA. 1989. Standard methods for the examination of water and wastewater. 17 th Edition. American Water Works Association.

Day, D.L. and B.G. Harmon. 1975. Properties of livestock manure related to utilization. In: Standardizing Analytical Methods Related to Animal Waste Research. ASAE, St Joseph, MI. SP-275:48-58.

Hamilton, N.D. 1992. A livestock problems guide to: Nuisance, Land use control, and Environmental law. Drake University Agricultural Law center, Des Moines, Iowa.

Maddery, G., D. Parker, and J. Schutske. 1993. Fatalities attributed to entering manure waste pits-Minnesota 1992. Journal of America Medical Association. 269(24):3098, 3102.

Merkel, J.A. 1981. Managing livestock wastes. AVI publishing company, inc. Westport Connecticut.

MWPS-18. 1985. Livestock facilities handbook. 2 nd Ed. Midwest Plan Service, Iowa State University, Ames, IA.

NIOSH. 1993. NIOSH warns: Manure pits continue to claim lives. U.S. Department of Health and Human Services. Center for Disease Control.

Zhang, R.H. 1992. Degradation of swine manure and a computer model for predicting the desorption rate of ammonia from an under-floor pit. Ph.D. Dissertation. Library, University of Illinois at Urbana-Champaign, Urbana, IL.

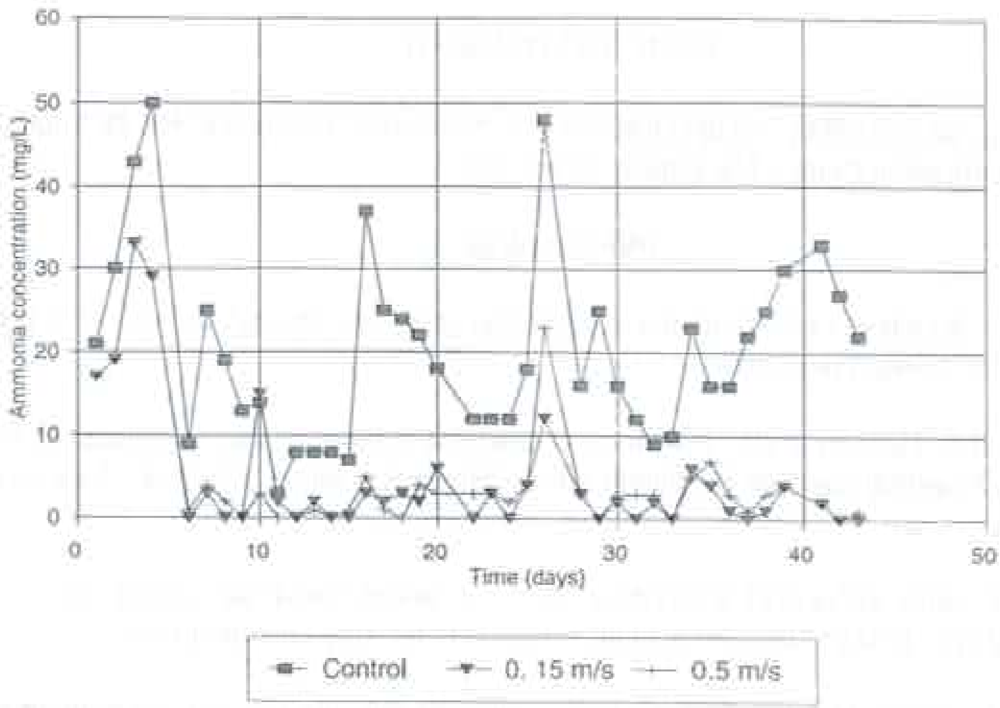

Figure 1. Concentration of ammonia gas in manure storage pit head space

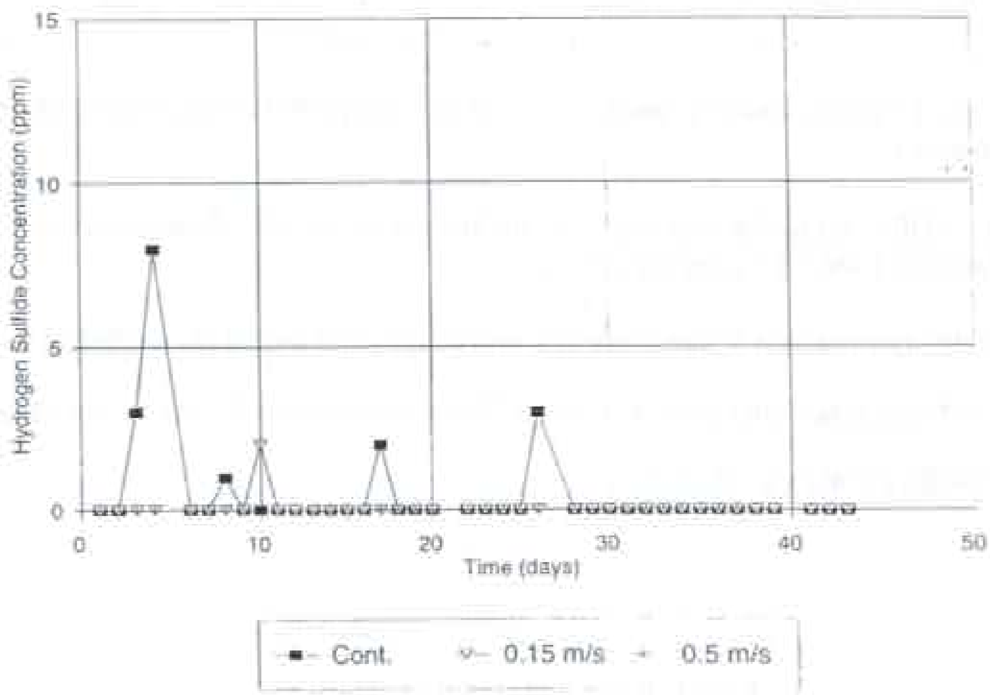

Figure 2. Concentration of hydrogen sulfide gas in manure storage pit head space

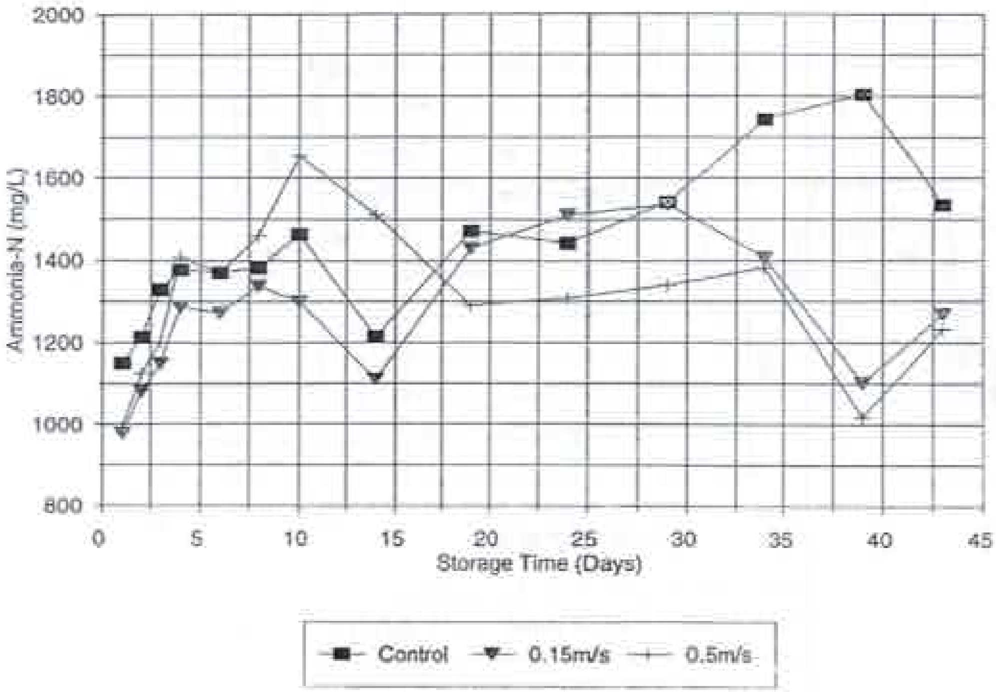

Figure 3. Concentration of ammonia-N in the top layer of stored manure

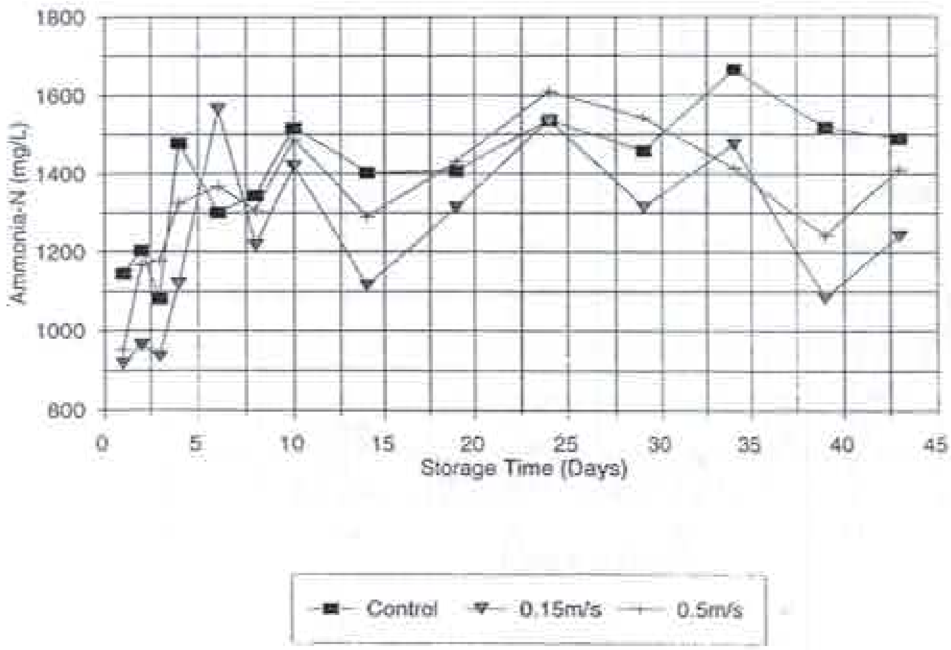

Figure 4. Concentration of ammonia-N in the middle layer of stored manure

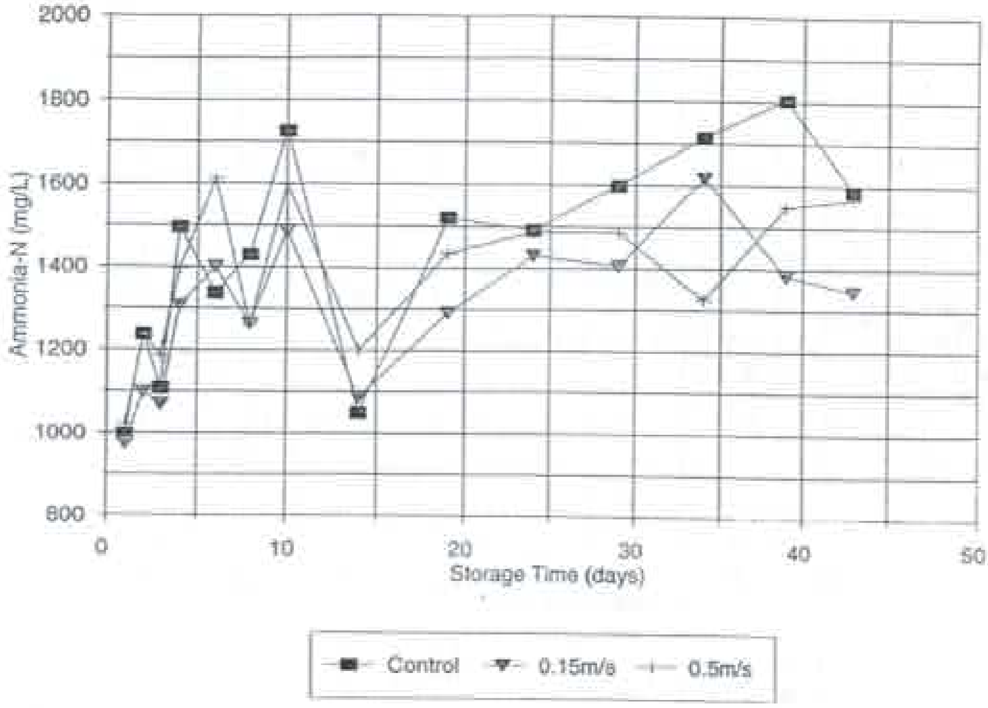

Figure 5. Concentration of ammonia-N in the bottom layer of stored manure

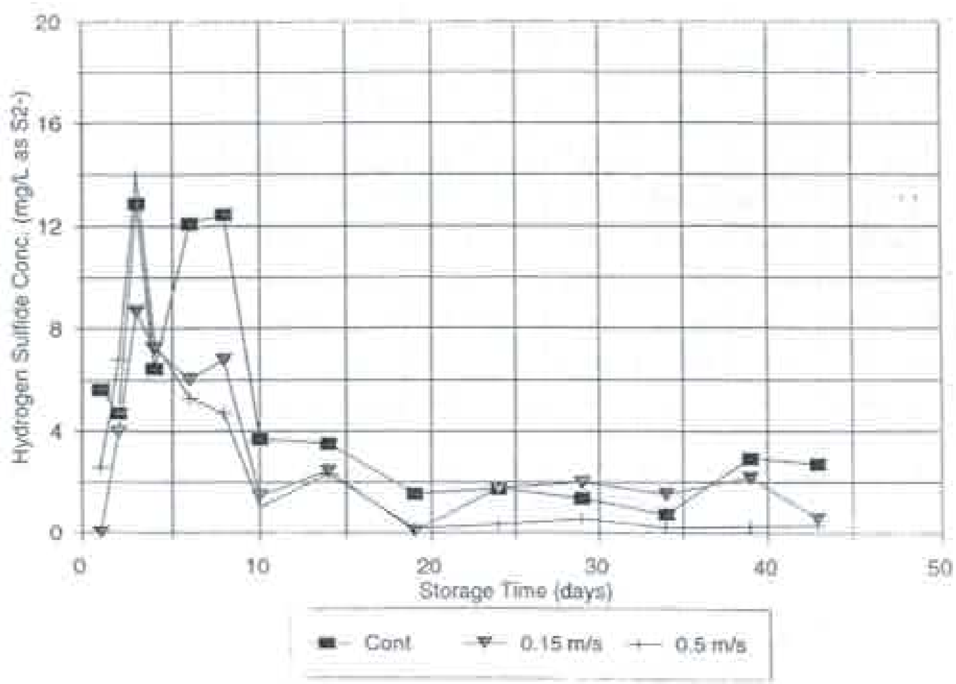

Figure 6. Concentration of molecular hydrogen sulfide in the top layer of stored manure

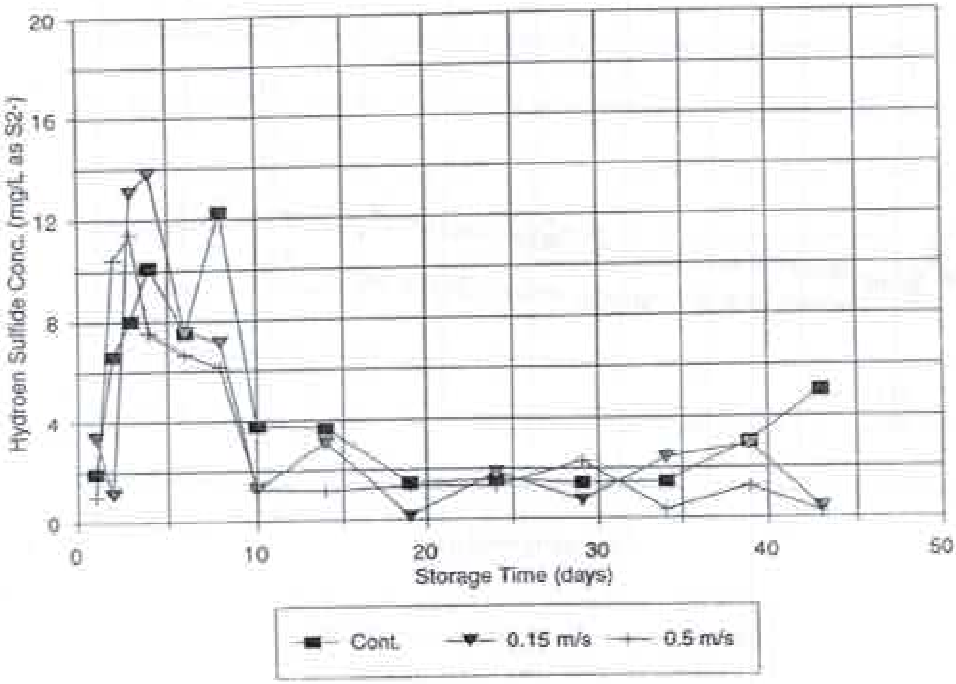

Figure 7. Concentration of molecular hydrogen sulfide in the middle layer of stored manure

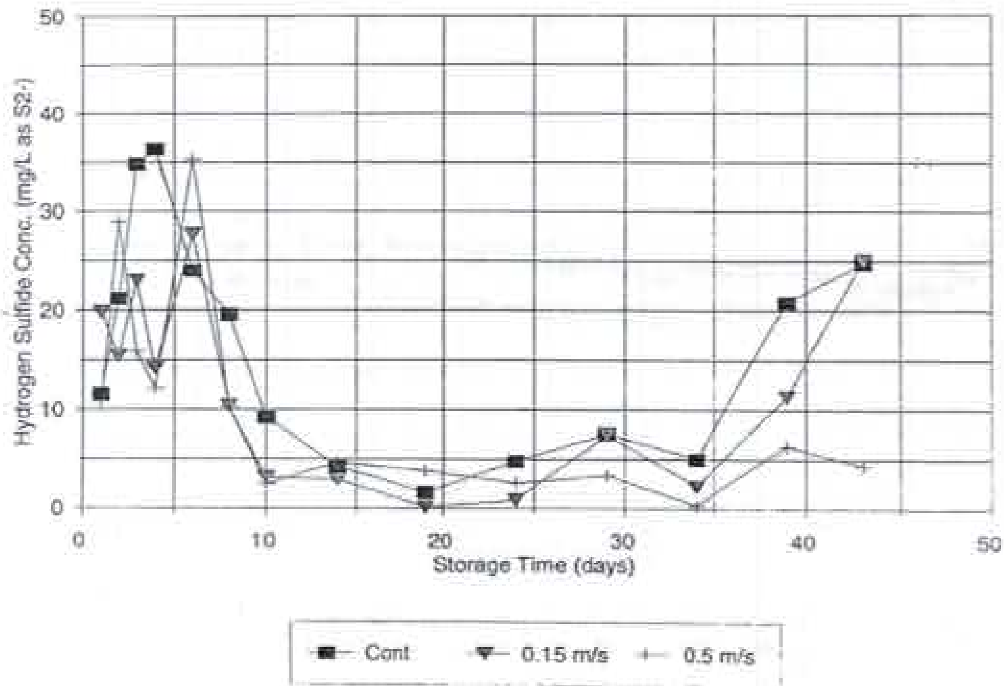

Figure 8. Concentration of molecular hydrogen sulfide in the bottom layer of stored manure

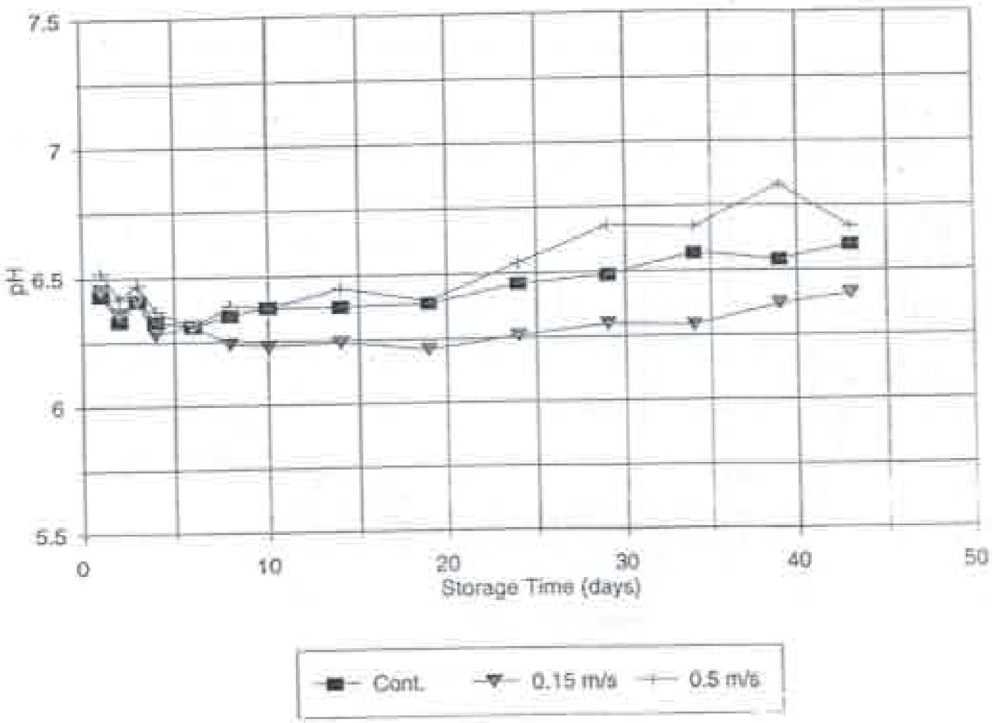

Figure 9. The pH of top layer of stored manure

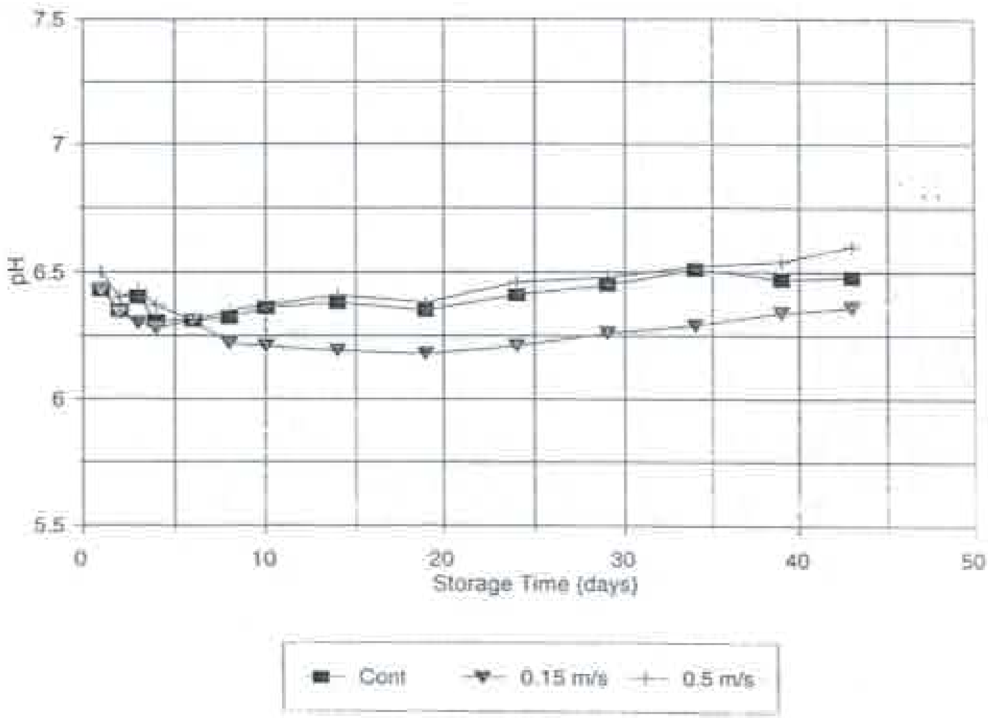

Figure 10. The pH of the middle layer of stored manure

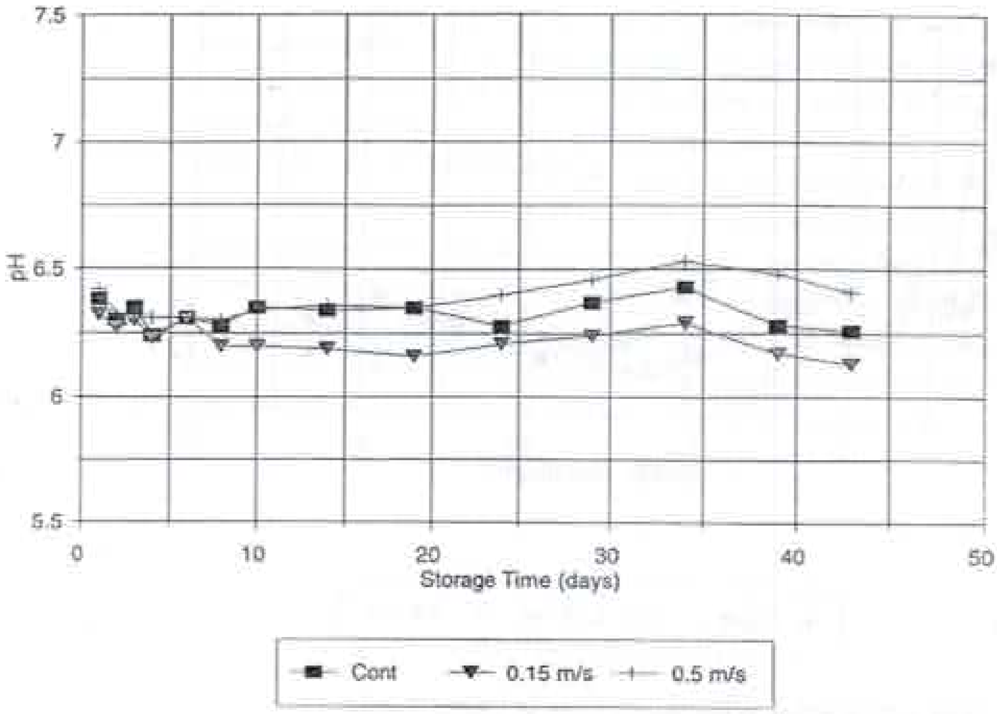

Figure 11. The pH of bottom layer of stored manure

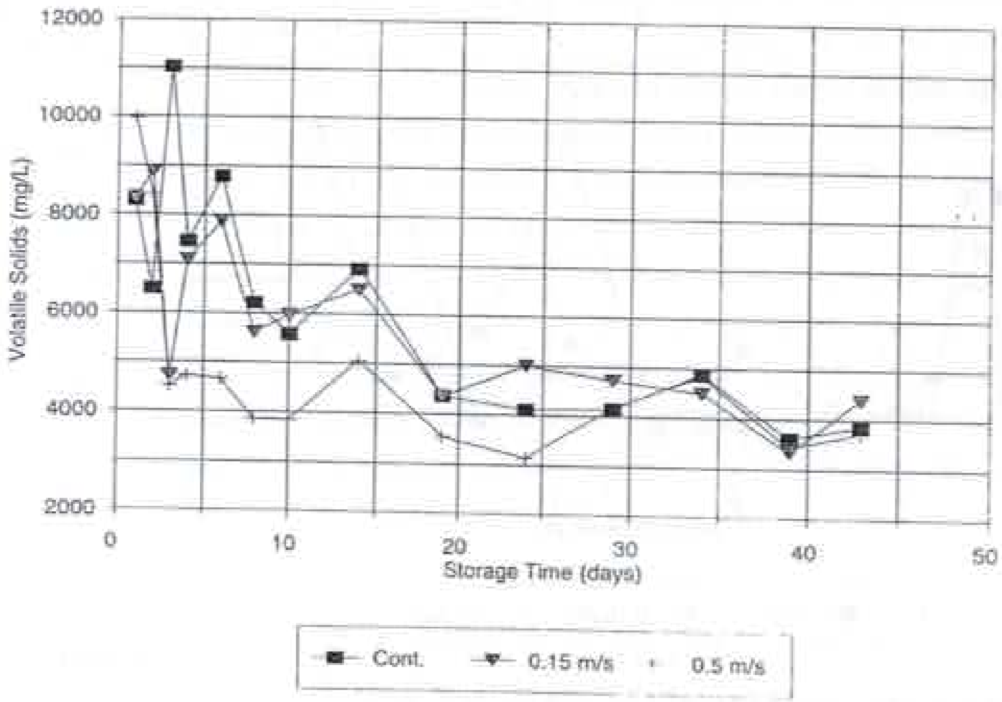

Figure 12. Total volatile solids in the top layer of stored manure

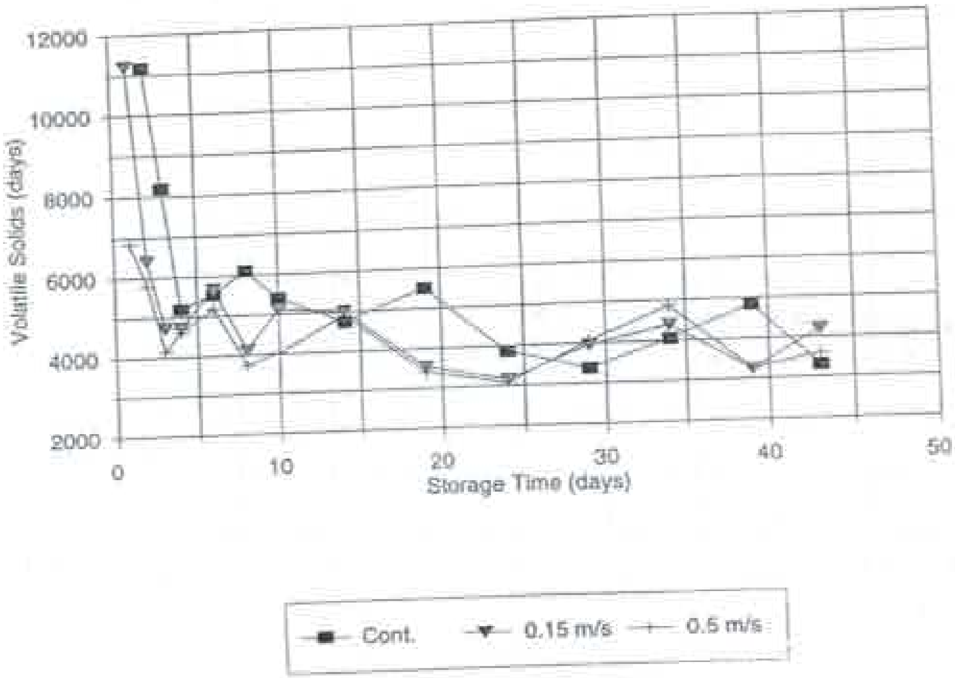

Figure 13. Total volatile solids in the middle layer of stored manure

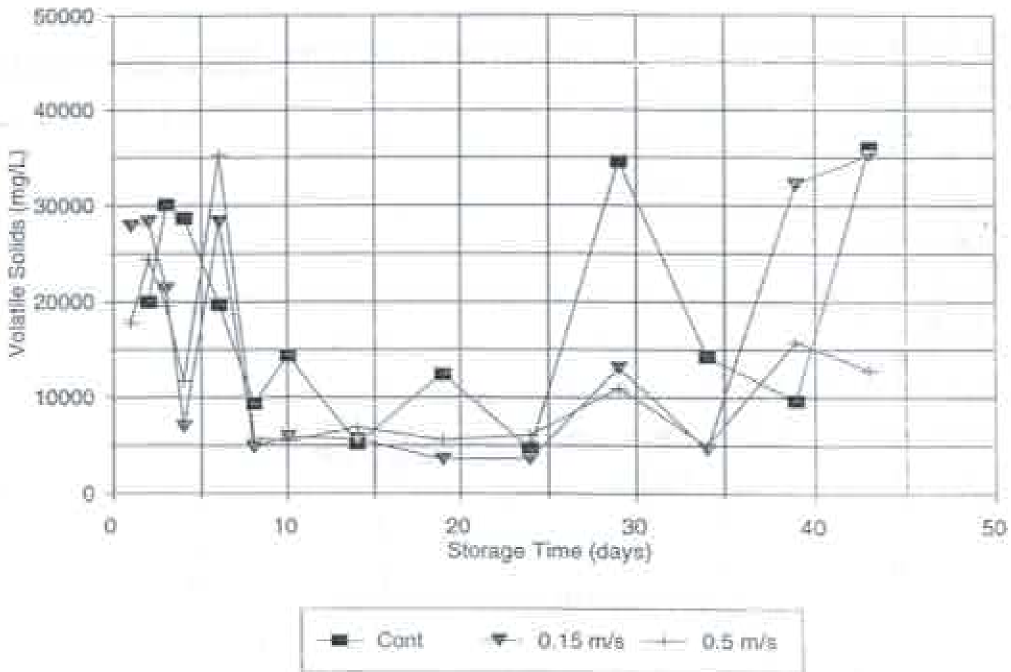

Figure 14. Total volatile solids in the bottom layer of stored manure