CHEMICAL CONTROL OF HYDROGEN SULFIDE FROM ANAEROBIC SWINE MANURE I. OXIDIZING AGENTS

E.M. Barber
Member CSAE
Agricultural Engineering Branch
B.C. Department of Agriculture
Abbotsford, B.C.

J.B. McQuitty
Member CSAE
Department of Agricultural Engineering
University of Alberta
Edmonton, Alberta

INTRODUCTION

Sulfur-containing gases produced during the anaerobic fermentation of livestock manure have been shown to be major components of the characteristic manure odor (7). Hydrogen sulfide also has been implicated as a principal offender in several human and animal casualties involving manure gases, and has been known to cause structural damage to concrete and metal components of livestock facilities.

Reduced sulfur compounds are produced from manure largely as a result of the combined activities of two groups of bacteria, *Desulfovibrio* and *Desulfotomaculum,* which use manure constituents as substrates in their metabolism or as nutrients for cellular growth and reproduction. Both of these groups of bacteria are strict anaerobes and, as such, are incapable of growth at elevated oxidation reduction potential (ORP) values. This would suggest that the production of hydrogen sulfide in manure may be inhibited by preventing the lowering of the ORP of the manure to a level that is favorable to anaerobic bacteria.

Almost all of the research to date on ORP control in livestock manure has considered air as the oxidizing agent. In general, aeration has been very successful in controlling not only hydrogen sulfide but most other toxic and malodorous compounds as well. However, all the currently available methods of aeration suffer from several disadvantages, perhaps the greatest of which are unreliable cold weather operation and high costs (8).

Chemical oxidizing agents may offer an alternative to aeration for control of odors from manure due to hydrogen sulfide and related sulfur compounds (2). When added to manure, strong oxidizing agents would be expected to oxidize reduced substances in the media, including sulfides, resulting in a lowering of the ORP with much the same effect as aeration, and a reduction in the sulfide content of the media. Added in sufficiently large quantities, chemical oxidants also would exert a direct bacteriocidal effect on all bacteria, including those responsible for the production of odorous gases.

The application of chemical oxidizing agents for the treatment of domestic water and wastewater is considered in most sanitary engineering texts (4); however, there is an apparent lack of information in the literature dealing with the application of chemical oxidizing agents to animal wastes. The major objective of this study, therefore, was to evaluate, by means of a series of exploratory laboratory-scale trials, the effectiveness of some common oxidizing agents for controlling the evolution of hydrogen sulfide from anaerobic swine manure. An attempt also was made to elucidate the mechanisms whereby each of the chemicals exerts its specific effects on hydrogen sulfide production in and/or released from anaerobic manure, and to evaluate the potential practical applications of each chemical. The three oxidizing agents considered for the study were ammonium persulfate, potassium permanganate and sodium nitrate because of their ready availability and apparent ease and safety of application.

EXPERIMENTAL PROCEDURES AND EQUIPMENT

The investigations reported herein formed part of a larger project involving the evaluation of chemical oxidants, lime, and iron for the control of hydrogen sulfide evolution from anaerobic swine manure (1). During this portion of the project, four trials, each of approximately 4 wk duration, were conducted involving eight different chemical treatments. To provide a common basis for comparison, an untreated manure sample was incubated with each group of chemically-treated samples. Ammonium persulfate and potassium permanganate were evaluated during trials III and IV; sodium nitrate was evaluated during trials I and III.

Manure samples for the trials were collected from two commercial swine facilities in the Edmonton area. At one of these, hereafter identified as Installation A, samples were collected from pits beneath the slatted-floor portion of a finisher barn. The manure also included that from all phases of the farrow-to-finish operation. Manure samples were collected with an integrated-depth sampler that has been designed especially for this project.

Samples of manure were collected at the second facility, identified as Installation C, from an underground storage tank receiving wastes from two finisher barns. The samples were collected from a vacuum-tanker during the field-spreading operation. Part of the sample was collected from each of two or three loads to secure a sample that might be considered representative of the holding tank contents.

Manure samples were brought to the laboratory, as soon as possible after collection, in 1-gal Nalgene bottles. At the laboratory, a portion of each was removed for total solids and *p*H determinations and for various chemical analyses required for concomitant projects. The characteristics of the manure used in each trial are summarized in Table I.

The same general procedure was followed in each of the trials and each digestor involved in a particular trial was treated in an identical manner. At the beginning of each trial, 2,000 g of raw manure were weighed into each of six laboratory digestors. Inlet gas-diffusion

RECEIVED FOR PUBLICATION JANUARY 20, 1975

TABLE I DESCRIPTION AND CHARACTERISTICS OF MANURE SAMPLES USED IN INCUBATION TRIALS WITH THE CHEMICAL OXIDANTS

Characteristic	Trial I	Trial III	Trial IV
Total solids (%)	5.99	3.89	8.30
*p*H	6.7	6.5	6.6
Color	Black-green	Green-brown	Black-green
Total nitrogen			
(% WB)	0.260	0.307	0.364
(% DB)	4.34	7.89	4.39
Total sulfur			
(ppm WB)	251	252	331
(% DB)	0.340	0.648	0.470
Water soluble			
Sulfate-sulfur (ppm WB)	47	136	46

TABLE II DESCRIPTION OF INCUBATION TRIALS

Trial	Manure used	Treatment	Description
I	Installation A (2,000 g)	Control	---
		Nitrate	$NaNO_3$ – 10.6 g
III	Installation C (2,000 g)	Control	---
		Persulfate	$(NH_4)_2S_2O_8$ – 20 g
		Permanganate	$KMnO_4$ – 100 ml Concentrated solution (2 g)
		Nitrate	$NaNO_3$ – 19.8 g
IV	Installation A (2,000 g)	Control	---
		Persulfate	$(NH_4)_2S_2O_8$ – 20 g
		Permanganate	$KMnO_4$ – 5 g

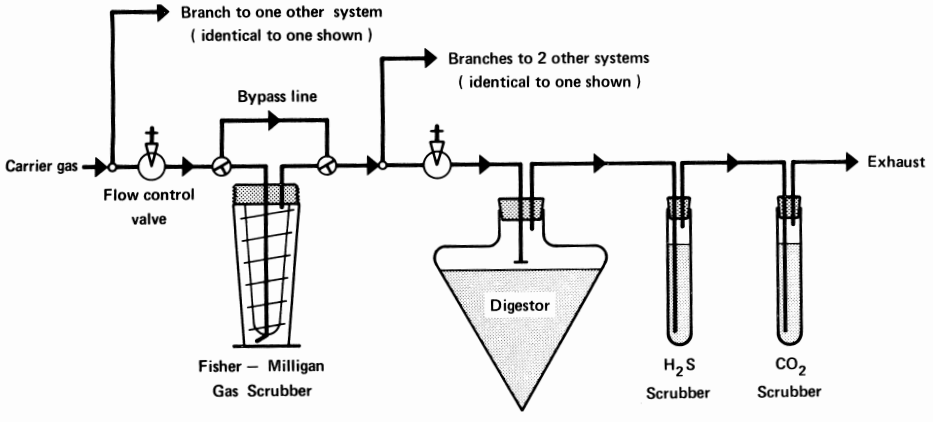

Figure 1. Schematic of equipment used in laboratory incubation trials to monitor gases from fermenting manure.

tubes then were adjusted to sweep gas across the surface of the manure in an attempt to simulate, as closely as possible, actual storage conditions in the field. Furthermore, by continually flushing manure gases out of the digestor, the rate of production of these gases by the fermenting manure could be monitored.

A schematic of the gas-sampling apparatus used in these trials is shown in Figure I. The nitrogen carrier gas was supplied from a pressurized cylinder. The gas, as purchased, contained small amounts of carbon dioxide that were removed during the carbon dioxide monitoring period by passing the carrier gas through a Fisher-Milligan gas scrubber containing barium hydroxide. The carrier gas entered the digestors through sintered-glass gas diffusion tubes and was allowed to escape continuously through ports in the digestor tops. The gas leaving each digestor, carrying gases released by the manure, was conducted through a two-stage gas-scrubbing train consisting of two conventional gas scrubbers connected in series.

The first gas scrubber in the absorption train contained a solution of cadmium acetate in which hydrogen sulfide is trapped as insoluble cadmium sulfide (Ksp = 4×10^{-29}). Only one scrubber was used to trap the hydrogen sulfide from each digestor as preliminary trials had shown hydrogen sulfide recoveries in a single scrubber to be close to 100%. Every 2 - 5 days, the scrubbers were changed and the amount of hydrogen sulfide released during the collection period was calculated from the weight of dry cadmium sulfide precipitate collected during that period.

The second scrubber in the absorption train contained barium hydroxide solution in which carbon dioxide is trapped as insoluble barium carbonate (Ksp = 8×10^{-9}). Initial attempts to use a single scrubber for collection of carbon dioxide indicated recoveries of less than 90%. Addition of a few drops of n-butanol to each scrubber, however, boosted the efficiency of a single scrubber to nearly 100%. Because of the problems associated with handling the copius amounts of carbon dioxide released from the manure, the rate of carbon dioxide generation was monitored only for a few hours every 2 - 4 days. The rate of production of carbon dioxide over the sampling period, which was assumed to be representative of the rate of production over the longer incubation period, was calculated from the weight of dry barium carbonate collected during the sampling period.

During the 1st 4 days after the beginning of the incubation period, the amounts of hydrogen sulfide and carbon dioxide released from each digestor were monitored to ensure that all digestors were behaving similarly. On the 4th day, the chemical treatments were applied. Because the weight of chemical added was not the same in every case, sufficient distilled water was added to make a total addition of 100g to each digestor, including the control.

The quantities of chemicals added in each treatment are given in Table II. The weight of chemical added in the initial trial with each treatment was based largely on recommendations from the literature and rough calculations from theory, tempered by experience and practical limitations. Estimates for a subsequent trial with the same treatment were based largely on the experience gained from the previous trial.

Sixteen to twenty days after the application of the chemical treatments, the contents of each digestor was agitated and the amount of hydrogen sulfide released during the period of agitation

TABLE III EVOLUTION OF SULFIDES FROM CHEMICALLY-TREATED MANURE

Trial	Treatment	Sulfides evolved† (mg H_2S) A	B	C	D	E
I	Control	70.8	132.4	11.6	165.6	380.4
	Nitrate	72.9	95.8	4.5	--‡	--‡
III	Control	39.4	84.5	34.9	62.6	221.4
	Persulfate	40.1	0.0	0.0	4.7	44.8
	Permanganate	38.0	39.4	25.3	65.9	168.6
	Nitrate	41.5	33.1	4.7	>56.2	>135.5
IV	Control	68.9	99.1	17.2	143.5	328.7
	Persulfate	68.9	5.9	0.0	2.5	77.3
	Permanganate	63.0	27.8	5.4	35.2	131.4

† A, sulfides released between start of incubation and time of chemical additions; B, sulfides released between time of chemical additions and end of incubation; C, sulfides released by agitation at end of incubation; D, total sulfides in digested manure at end of incubation; E, total sulfide production to end of incubation = A + B + C + D.

‡ No data collected.

TABLE IV PERCENT REDUCTION IN SULFIDES EVOLVED FROM CHEMICALLY-TREATED MANURE COMPARED TO CORRESPONDING CONTROLS

Treatment	Sulfide released after chemical additions† Trial I	Trial III	Trial IV	Sulfide released upon agitation† Trial I	Trial III	Trial IV
Persulfate	--	100	94	--	100	100
Permanganate	--	53	72	--	28	69
Nitrate	28	61	--	61	87	--

† Expressed as a percent of the sulfide released during the same period by the corresponding control.

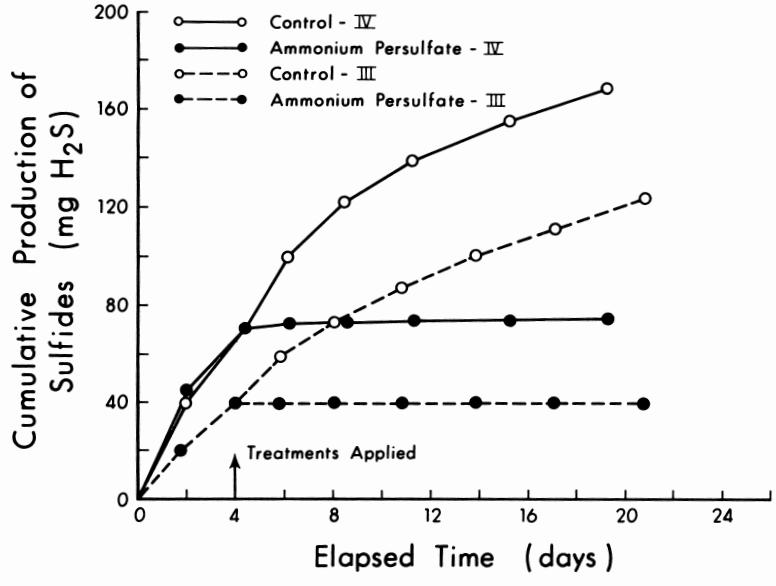

Figure 2a. Hydrogen sulfide production from manure treated with persulfate.

was measured. Agitation was accomplished by repositioning the inlet diffusion tube such that gas was bubbled from the bottom of the digestor, and by swirling the disgestor by hand several times. The length of the agitation period was set arbitrarily at 1 h.

Immediately after the cessation of agitation, the tops were removed from each digestor and 50-ml samples of the digestor contents were removed for *p*H determinations. The contents of each digestor were then acidified to a *p*H of approximately 1.0 by the addition of 60-100 ml of concentrated hydrochloric acid, depending on the original *p*H of the manure, and purged with nitrogen gas until tests showed that no more hydrogen sulfide was being released. The total sulfide content of the manure in each digestor was calculated from the weight of cadmium sulfide precipitate collected subsequent to the addition of acid. The *p*H of the manure after acidification was checked to ensure that a *p*H value nearly equal to 1.0 had been achieved. At *p*H = 1.0, essentially all sulfides in solution exist as dissolved hydrogen sulfide gas and hence are removable by purging the solution with a carrier gas.

During trial III, about 1 wk after the time of chemical additions, manure samples were assayed for sulfate-reducing bacteria by the most-probable-number technique. No other bacterial analyses were conducted during this investigation.

RESULTS AND DISCUSSION

Data pertaining to the quantities of sulfide evolved from the manure when treated with the various chemicals used in the trials are summarized in Table III. The calculated reductions in sulfide evolution from the treated manures compared to the corresponding controls ranged from 28 to 100% (Table IV).

Ammonium Persulfate

Initial research with ammonium persulfate applied to swine manure (6) indicated that the chemical effectively controlled odors from manure when added at the rate of 17 kg/ton of manure. However, a more recent report (9) suggested that much lower rates of application may be effective.

In both of the trials reported herein, ammonium persulfate was applied at the rate of 1% by weight, or approximately 10 kg/ton of manure. At this rate, the chemical effectively prevented the evolution of hydrogen sulfide from the manure solution (Figure 2a). No hydrogen sulfide was released upon agitation of the digested manure and essentially no sulfide remained in the digested manure (Table III). Analysis of the manure for sulfate-reducing bacteria indicated that most of these bacteria had been killed by the chemical treatment (Table VI). However, the rates of carbon dioxide production from the treated manure were not substantially different than those from the corresponding controls (Figure 2b), suggesting that some bacteria, supposedly facultative anaerobes, had not been killed by the treatment. Thus, the primary effects of ammonium persulfate added to

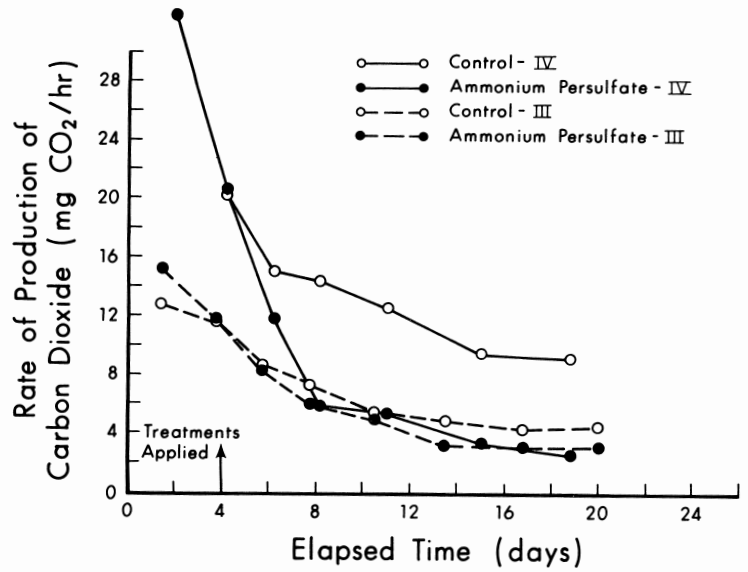

Figure 2b. Carbon dioxide production from manure treated with persulfate.

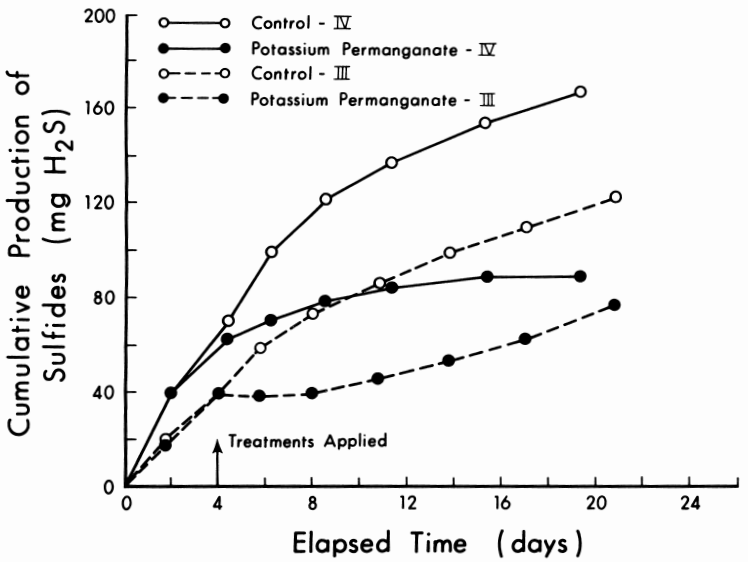

Figure 3a. Hydrogen sulfide production from manure treated with permanganate.

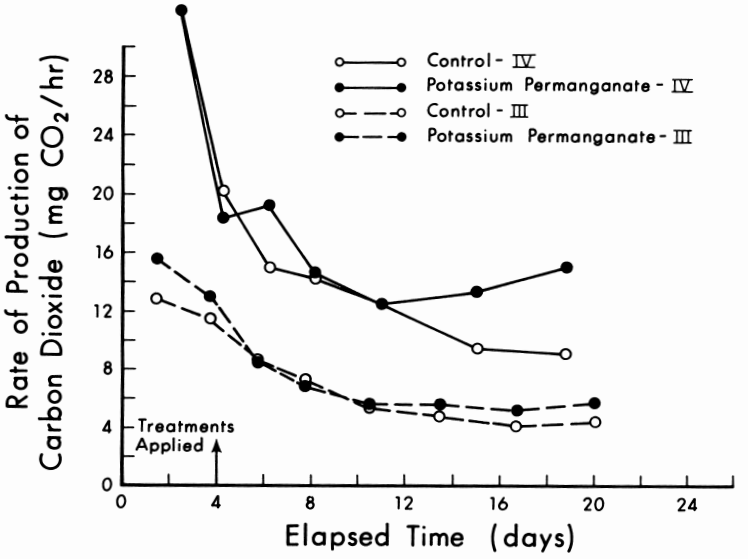

Figure 3b. Carbon dioxide production from manure treated with permanganate.

anaerobic manure would appear to be oxidation of sulfides existing in the manure and elimination of the activity of anaerobic sulfide-producing bacteria.

Potassium Permanganate

Faith (5) recommended that potassium permanganate be applied to manure as an aqueous solution. In the first trial with permanganate (trial III), the chemical was added as a concentrated water solution at the rate of approximately 0.1% $KMnO_4$ by weight. As shown in Figure 3a, the evolution of sulfides was completely curtailed for the 1st 2-4 days after addition of the chemical; thereafter, there was a slow recovery back to normal sulfide evolution. The sulfate-reducing bacteria count (Table VI) approximately 10 days after chemical treatment did not differ greatly from that in the untreated manure. Carbon dioxide production during incubation of the treated manure paralleled that of the control manure (Figure 3b). At the end of the incubation period, the total sulfide contents of the control and treated manure were essentially the same, as were the amounts of sulfide released upon agitation of the digested manure. The measured total sulfide production over the entire incubation period, however, was much less than for the untreated manure.

These results suggest that sulfides in the media were oxidized by the permanganate. After all the permanganate had been reduced, sulfide production by the treated manure returned to the same rate as that by untreated manure. Unlike ammonium persulfate, potassium permanganate did not have a lethal effect on sulfate-reducing bacteria, although permanganate probably did retard sulfide production by these bacteria during the first few days after addition to the manure.

The results of the first trial with permanganate indicated that the treatment might have been more effective had more of the chemical been added. Therefore, in the second trial (trial IV), the rate of application was increased to 0.25% by weight; however, to avoid excessive dilution of the treated manure, the permanganate had to be applied in solid form. As shown in Figure 3a, the rate of evolution of sulfides from the treated manure decreased relative to an untreated control after addition of the chemical, and continued to decrease even further during the remainder of the incubation period. Throughout the trial, spots of undissolved solid potassium permanganate could be seen throughout the manure. The total sulfide content of the digested chemically-treated manure was consider-

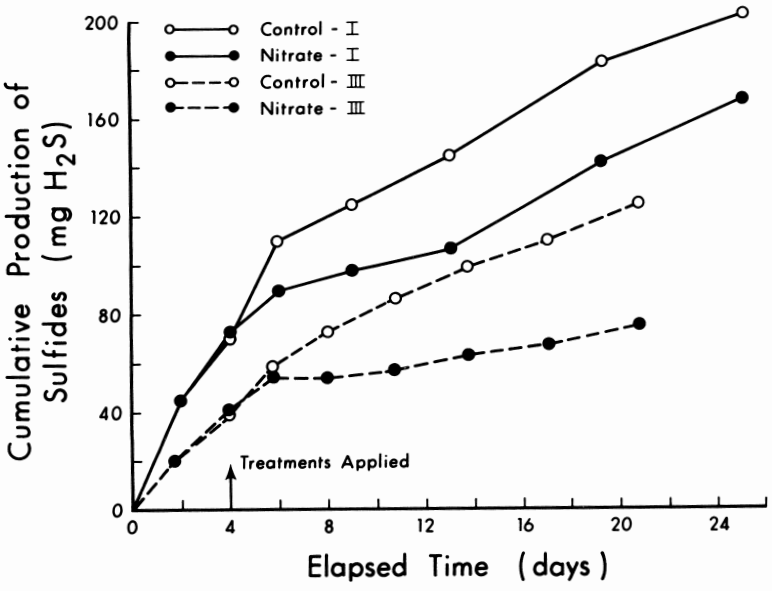

Figure 4a. Hydrogen sulfide production from manure treated with nitrate.

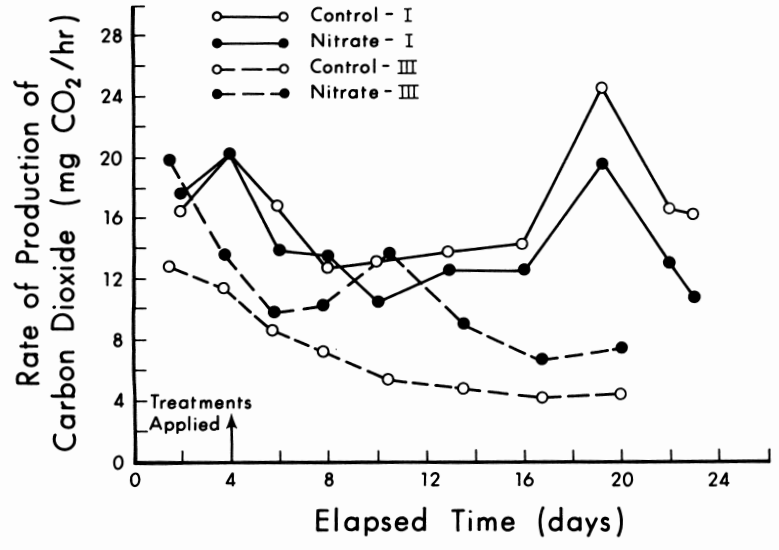

Figure 4b. Carbon dioxide production from manure treated with nitrate.

ably less than that of the untreated manure and consequently, less sulfide was released upon agitation. Furthermore, the total sulfide production during incubation was considerably less for the treated manure than that of the corresponding control.

These results indicate that the permanganate may have acted in a similar manner in both trials, except that in the second trial there was a continual slow release of oxidant into the manure solution throughout the incubation period. The ineffectiveness of potassium permanganate for controlling sulfide evolution from anaerobic manure during these trials appears to have been the result of insufficient rates of application in one case and inadequacy of mixing the chemical into the manure solution in the other.

Sodium Nitrate

In the first trial with nitrate (trial I), the chemical was applied as sodium nitrate at the rate of 0.5% by weight. The rate of evolution of sulfides was depressed after chemical addition, but about 8 days afterwards returned to the same rate as observed for the control (Figure 4a). During the period in which sulfide evolution was reduced, the color of the manure changed from a dark greenish-brown to an amber color but, as sulfide evolution resumed, the color changed back to its original condition.

In the second trial (trial III), nitrate was added again as sodium nitrate, but at twice the rate used in the first trial, or 1% by weight. In this trial, sulfide evolution from the treated manure was less than

TABLE V CHANGES IN *pH* OF MANURE SAMPLES DURING INCUBATION

Treatment	Before incubation	After incubation
Persulfate		
Trial III	6.50	6.10
Trial IV	6.65	5.50
Permanganate		
Trial III	6.50	7.35
Trial IV	6.65	7.00
Nitrate		
Trial I	6.70	7.70
Trial III	6.50	8.90
Control		
Trial I	6.70	7.70
Trial III	6.50	7.10
Trial IV	6.65	6.55

TABLE VI COUNTS OF SULFATE-REDUCING BACTERIA IN CHEMICALLY-TREATED MANURE SAMPLES (TRIAL III)

Treatment	Number of organisms in 1 g of manure†
Control	0.79×10^6
Persulfate	13.9
Permanganate	100×10^6
Nitrate	493

† Determined using the most probable number (MPN) technique.

that from the untreated control throughout the entire incubation period. As in the first trial, the color of the manure changed to an amber color during the first part of the incubation period, but by about the 12th day of incubation had changed back to the original dark greenish-brown color. Unlike the first trial, the rate of carbon dioxide production from the nitrate-treated manure was higher than that from the control manure throughout the incubation and was much higher for a short period beginning about 2 days after the chemical was added (Figure 4b). During the period of high rates of carbon dioxide production, excessive bubbling and foaming were noted on the surface of the treated manure as compared to the untreated manure. Microbial examination of the manure after this time indicated that some sulfate-reducing bacteria had survived the nitrate treatment (Table VI).

At the end of the first trial with nitrate, and just prior to the determination of the total sulfide content of the digested manure, the digestor holding the treated manure was broken accidentally; consequently, no further determinations could be made. In the second trial, a violent reaction occurred when acid was

added to the digested nitrate-treated manure and some of the digestor contents foamed out over the top of the digestor. The analysis for total sulfides was continued, however, and the data for total sulfide content and total sulfide production are reported in this trial as minimum values (Table III).

The results reported in Table III suggest that the sulfide content of the nitrate-treated manure was probably as great as that in the untreated manure. However, the amounts of sulfides released upon agitation of the nitrate-treated manure were much less in both trials than the amounts released from the untreated manure, probably because of the much higher *p*H of the treated manure (Table V).

The results of the two trials with nitrate indicate that the addition of nitrate to anaerobic manure delayed the evolution of sulfides. This delay in sulfide evolution may have been achieved through an alternation of the ORP of the manure. Nitrate did not appear to be capable of directly oxidizing sulfides, and was not lethal to all sulfide-producing bacteria.

Practical implications

Mixing

To be effective, all chemicals must be mixed thoroughly into the manure that is to be treated. Mixing was not found to be a problem in the case of sodium nitrate or ammonium persulfate, as both these chemicals are very soluble in an aqueous media. However, the inability to achieve a uniform distribution in the manure of the chemical in the case of potassium permanganate may have decreased the effectiveness of that chemical. The requirement for large amounts of mixing may limit seriously the practicality of using potassium permanganate for most applications. Complete mixing is difficult to attain, and may result in an increased evolution of noxious and malodorous gases.

Safety

Toxic concentrations of poisonous gases could arise as a result of the rapid reduction of large amounts of chemical oxidants under special conditions. Until this aspect has been clarified further, these chemicals should be applied to manure only under well ventilated conditions.

Both potassium permanganate and ammonium persulfate are very strong oxidizing agents. In their solid forms, they accidentally could cause severe "burns" to the skin of both animals and operators. However, at least in the case of persulfate, the chemical would be applied as a water solution and consequently the possibility of it causing such damage would be minimal.

If applied to manure in very large excesses just prior to field spreading, both permanganate and persulfate perhaps could have a bacteriocidal effect on soil microorganisms. However, such large excesses are not likely to be applied for obvious economic reasons. In the case of sodium nitrate, excessive amounts of sodium in the treated manure could affect adversely the structure and salt balance of some soils.

Odor reduction

No attempt was made during this investigation to systematically evaluate the effect of the various chemical treatments on the odor offensiveness of the treated manure. However, notes were made during the incubation trials of significant differences in odor quality between treated and untreated manure.

The application of all three chemical oxidants did change the quality of the odors from the manure noticeably as compared to controls. In the case of the nitrate treatment, the characteristic manure odor was masked largely by a strong ammonia odor. The odor from manure treated with either permanganate or persulfate was judged to be much less offensive than that from either untreated manure or manure treated with sodium nitrate.

Specific applications

The chemical oxidizing agents evaluated in this investigation could be useful for controlling hydrogen sulfide evolution from anaerobically-stored manure in cases where waste stabilization during storage is not of primary importance. Alternatively, they could be applied to stored manure just prior to removal from storage and disposal by field spreading. In addition to controlling hydrogen sulfide, persulfate and permanganate also may effectively control most other malodorous emissions from anaerobically stored manure.

Treatment of manure with ammonium persulfate in particular would appear to be especially advantageous in the case of anaerobic lagoons. Since the worst odor problems occur during the time of emptying anaerobic lagoons and during subsequent field spreading operations, ammonium persulfate could be applied to the surface of the lagoon just prior to agitation of the lagoon contents. In such an application, the minimum effective application rate of the chemical likely would be much less than that used in this investigation, since only short-term control would be necessary. Alternatively, the possibility exists that ammonium persulfate might be applied continuously by a trickling device at the inlet to a lagoon or tank, although such a practice still requires verification as to its effectiveness.

Chemical treatment of individual tankloads of liquid manure also might prove useful as a partial solution to the odor problem. Either potassium permanganate or ammonium persulfate injected into a load of manure would be mixed thoroughly into the manure during the transport operation. Whereas the odor at the place of storage would not be abated, the manure would be much less odorous during and after spreading on the field.

Economics

The costs of treating manure under field-scale conditions for odor control with any one of the three chemicals used in these trials are difficult to estimate since the only accurate cost figures are those based on laboratory chemical supply company prices. Presumably these prices would be significantly reduced through bulk purchases of the chemicals from alternate sources.

Information is also lacking on the optimum application rates of the chemicals for use under practical conditions. The minimum application rates of sodium nitrate and potassium permanganate shown to be effective in laboratory trials were, on a weight basis, 0.5 and 0.25%, respectively. These application rates are probably close to the minimum rates that might be expected to be effective under field conditions. However, as previously noted, ammonium persulfate would probably be effective for short-term odor control at rates considerably lower than that used in these laboratory trials. Assuming that persulfate would be two-thirds as effective as permanganate if each were applied at the same molar concentration[a], the minimum effective concentration of ammonium persulfate could be as low as 0.5% by weight. All of these rates are applicable in the case of swine manure with a total solids content of approximately 5%.

---

[a] Reduction of one mole of permanganate under alkaline conditions involves the transfer of three electrons, compared to two electrons transferred by the reduction of one mole of persulfate.

Using the figures presented above for minimum effective application rates and a calculated discount rate for each chemical similar to that obtainable for lime when purchased in bulk as compared to laboratory chemical supplier prices, swine manure might be treated with the chemicals for something in the order of \$0.50-\$0.90 per hog marketed. These costs are based on a lifetime production of manure by feeder pigs equal to 5,000 lb.[b]

Clearly, these estimates are only approximate, and are based on a large amount of speculation regarding effective application rates and bulk chemical prices. Nevertheless, they may serve to indicate the relative economies of chemical treatment and aeration of odor control. One of the lowest reported costs of aerating hog wastes is \$0.25/hog marketed (10); however, usually much higher estimates are given. Furthermore, in the case cited, the operating cost was based on an electrical cost of 1.1¢ per kw-h, a figure which would increase several times in the near future as a result of impending world energy shortages. Thus, after an accounting is made for the extra capital costs associated with aeration, chemical treatment of manure may be an economical alternative to aeration as a solution to the manure odor and toxic gas problem.

CONCLUSIONS

A summary of results obtained in this exploratory investigation, and the conclusions drawn, are as follows:

1. Addition of ammonium persulfate to anaerobic swine manure at the rate of 1.0% by weight as $(NH_4)_2S_2O_8$ was shown to effectively eliminate the evolution of sulfides from the manure during laboratory incubation trials. Added at this rate, soluble sulfides in the manure were oxidized and most sulfate-reducing bacteria apparently were killed by the chemical treatment.

2. Potassium permanganate, added to anaerobic swine manure as a saturated water solution at the rate of about 0.1% by weight as $KMnO_4$ eliminated the evolution of sulfides for about 4 days during laboratory-scale incubation trials. Added as solid $KMnO_4$ at the rate of 0.25% by weight, potassium permanganate reduced, but did not eliminate, the evolution of sulfides from anaerobic swine manure. At the rates applied, the chemical apparently oxidized soluble sulfides and retarded the activity of the bacteria that produce sulfides.

3. Nitrate, added to anaerobic swine manure in laboratory trials at the rate of 750 ppm as NO_3–N, effectively delayed the production of sulfides from the manure for up to 8 days. Added as NO_3–N at the rate of 1,400 ppm, sulfide production was delayed for over 2 wk. The presence of nitrate in anaerobic manure apparently retards the activity of the bacteria that produce sulfides.

4. Although no systematic evaluations were made of the effects of each chemical treatment on the overall odor of the treated manure, odor from the manure treated with either permanganate or persulfate did not seem to be as offensive as the odors from untreated manure.

5. The relative effectiveness of each of the various chemicals for controlling the evolution of hydrogen sulfide from anaerobic swine manure has been demonstrated in batch incubation trials. Before any of the chemicals can be recommended for application under field conditions, however, further testing in pilot-scale continuous-flow trials is necessary. A more detailed economic analysis also is required to evaluate the practicality of chemical control of sulfides and other odorous gases.

SUMMARY

The effects of three chemical oxidizing agents on the evolution of hydrogen sulfide from anaerobic swine manure were investigated in a series of exploratory laboratory-scale incubation trials.

Sodium nitrate, potassium permanganate and ammonium persulfate were shown either to delay or to eliminate the release of sulfides from the treated manure. Both persulfate and permanganate also appeared to reduce the odor-offensiveness of the treated manure compared to untreated controls. The results of these trials suggest that a more detailed economic analysis and evaluation of chemical oxidizing agents may be warranted.

ACKNOWLEDGMENTS

The authors acknowledge the financial support of the Alberta Hog Producers Marketing Board and the Alberta Environmental Research Trust. Acknowledgment also is due to the Alberta Soil and Feed Testing Laboratory and the Department of Soil Science, University of Alberta, for their assistance with the chemical analysis. The assistance of Dr. F.D. Cook, Soil Microbiology, University of Alberta, in the microbial analyses is much appreciated.

REFERENCES

1. Barber, E.M. 1974. A study of the production and control of hydrogen sulfide from anaerobic swine manure. M.Sc. thesis, Dep. Agric. Eng., University of Alberta, Edmonton, Alta.

2. Barber, E.M. and J.B. McQuitty. 1974. Hydrogen sulfide evolution from anaerobic swine manure. Faculty of Agriculture & Forestry Publication, University of Alberta, Edmonton, Alta. 69 pp. 122 ref.

3. Canada Committee on Agricultural Engineering. 1972. Canada animal waste management guide. Canada Committee on Agricultural Engineering, Agriculture Canada, Ottawa, Ont.

4. Fair, G.M., J.C. Geyer, and D.A. Okun. 1968. Water and wastewater engineering. Volume 2. Water purification and wastewater treatment and disposal. John Wiley & Sons., Inc., New York, N.Y.

5. Faith, W.L. 1964. Odor control in cattle feed yards. J. Air Pollut. Contr. Assoc. 14: 459-460.

6. Lindvall, T., O. Nõren, and L. Thyselius. 1972. Luktreducerande åtgärder vid flytgödselhantering. (Measures to reduce malodours during the handling of liquid manure). Special Meddelande S22, Jordbrukstekniska Institutet, Ultuna, Uppsala 7, Sweden.

7. Merkel, J.A., T.E. Hazen, and J.R. Miner. 1969. Indentification of gases in a confinement swine building atmosphere. Trans. Amer. Soc. Agric. Eng. 12: 310-313, 315.

8. Pos, J. and J.B. Robinson. 1973. Winter operation of aerated liquid animal waste storage systems. Can. Agric. Eng. 15: 43-48.

9. Robertson, A.M. 1973. The control of odours from piggeries. Farm Building Progress No. 33, Scottish Farm Bldg. Investigation Unit, Aberdeen, Scotland. pp. 21-24.

10. Windt, T.A., N.R. Bulley, and L.M. Staley. 1971. Design, installation and biological assessment of a Pasveer oxidation ditch on a large British Columbia swine farm. Livestock Waste Management and Pollution Abatement, Proc. Int. Symp. Livestock Wastes, Columbus, Ohio. Amer. Soc. Agric. Eng., St. Joseph, Mich. pp. 213-216.

[b] Weekly production of manure with a moisture content of 95% is approximately 3.75 ft^3/hog. Multiplied by 22 wk, the lifetime production would be 82.5 ft^3 or 5,190 lbs. These figures are calculated from data given in the Canada Waste Management Guide (3).