Evaluation of Biosafe® as an Additive to Reduce Odor from Swine Manure

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Abstract:

Bench scale experiments were performed to determine the effect of adding various amounts of the product Biosafe® to swine manure. In particular, it was desired to determine if addition of Biosafe® would: reduce the odor, reduce the volatile solids concentration, and have any effect on the total nitrogen, ammonium-N, nitrate-N, total phosphorous, or total potassium concentrations in the manure.

Two groups of panelists evaluated the odor after 3 and 6 days of treatment. The most important conclusions are listed below.

(1) The smallest amount of Biosafe® that provided a substantial reduction in odor was 1 L of Biosafe® to 10,000 L manure. The average odor score was reduced by 29% after 3 days of treatment, and 36% after 6 days of treatment.

(2) Addition of Biosafe® did not affect the amount of volatile solids, phosphorous, or potassium in swine manure.

(3) The total nitrogen (TN = TKN + NO_3^- -N) was not significantly altered by the addition of Biosafe®. However, 31% of the TN was lost in 6 days of treatment. The loss was by means of volatilization.

(4) The air entrained by mixing and the effect of Biosafe® at concentrations sufficient to reduce odor elevated the nitrate levels in the manure by a factor of 2.47.

INTRODUCTION

South Carolina, like other states, has experienced a growth in the number and scale of livestock facilities. Along with this growth in the animal industries has come an increase in concern by the public over the potential water and air quality impacts. The amount of odor generated from livestock operations can vary greatly from site-to-site and is often the single greatest public concern. Therefore, selection of an appropriate site for a livestock facility, and the implementation of management practices and technologies to reduce the strength of odors is an important part of the planning and permitting process.

The odor that is detected from a livestock operation is a complex mixture of gases. Most often the odor is a result of the uncontrolled anaerobic decomposition of manure. However, feed spoilage can also contribute to the odor. The odor that is detected by the human nose can be a combination of 60 to 150 different compounds. Some of the most important types of odor causing compounds are: volatile fatty acids, mercaptans, esters, carbonyls, aldehydes, alcohols, ammonia, and amines. The odor strength of these compounds does not combine in an additive manner. That is, sometimes mixing several of these compounds can result in reduced odor by dilution of the strongest smelling compounds. In other instances, the mixture is worse than any of the individual compounds. Ammonia can create strong odors near a building, but is not a significant component of odor downwind from an animal production facility. Ammonia is highly volatile and moves quickly upward in the atmosphere, where it is diluted.

For an odor to be detected downwind, odorous compounds must be (a) formed, (b) released to the atmosphere, and (c) transported a receptor. These three steps provide the basis for most odor control. If any one of the steps is inhibited, the odor will diminish.

The most common sources of odor from swine farms are the buildings, manure storages, and land application operations. Odors from uncovered storage structures and land application are somewhat seasonal. However, odor from buildings can persist year round. As a result, many swine producers are interested in management practices, technologies, or products that can significantly reduce the strength of odor from swine buildings.

Bench scale experiments were performed to determine the effect of adding various amounts of the product Biosafe® to swine manure. In particular, the objectives of this study were to determine if addition of Biosafe® would:

1. reduce the odor,
2. have any effect on the concentration of plant nutrients (N, P, K, Zn, Cu),
3. have any effect on the forms of nitrogen in the manure (ammonium-N, nitrate-N, TKN, total-N), or
4. have any effect on total solids, volatile solids, or pH of the manure.

DESCRIPTION OF THE EXPERIMENT

The experiments were carried out using a large sample of swine manure (4.5-5 L) that was collected from the recharge-pit of a feeder-to-finish swine building located in Dillon County, South Carolina. Supernatant (i.e. surface water) from an aboveground manure storage was used as the source of recycle water to charge the manure pit. The large sample was stored on ice while being transported to Clemson University for analysis. The sample was stored in a refrigerator until the experiment began.

Application Rates and Treatment Procedures

The manufacturer's recommendation for the use of Biosafe® was to add small amounts to well-mixed manure. The original concept was to use aeration to mix the manure and the product. However, addition of large amounts of air to swine manure would result in odor reduction and the formation of nitrate that may mask the effect of the additive. A mechanical mixing machine that used a rotating paddle to mix the contents of up to 6, 2 L vessels provided the desired mixing.

The entire sample of swine manure was continuously mixed in an 18.9 L (5 gal) bucket using a paint stirrer and an electric drill. One liter of swine manure was poured into 4, 2 L plastic containers. Representative subsamples of the initial manure sample were also taken from the bucket before and after each plastic container was filled with 1 L of manure. The many subsamples were combined in a single beaker. The composite sample was used to determine the initial concentrations of total solids (TS), volatile solids (VS), TKN, NH_4^+-N, NO_3^--N, total P (expressed as P_2O_5), total K (expressed as K_2O), Zn, Cu, and pH. The total nitrogen (TN) was calculated as (TKN + NO_3^- -N) and included all of the organic and inorganic nitrogen.

Standard methods as given by APHA (1995) were used to determine the TS and VS concentrations. The plant nutrient analyses were performed by the Clemson University Agricultural Service Laboratory.

All 4 of the plastic jars containing 1 L of swine manure were placed under the mixing machine. The mixing paddles rotated at 280 to 300 rpm. One jar did not receive any Biosafe® and served as the control. The other three 1 L samples received different amounts of Biosafe® as defined in Table 1. The required amount of Biosafe® was added using a micropipette. The application rates used in the experiments were equivalent to adding 0, 0.67, 1.0, and 2.0 L per 10,000 L of swine manure.

Table 1. Definition of treatments.

Treatment No.	Volume of Biosafe® added per L of Swine Manure	Biosafe® Application Rates
1	0	0
2	67 μL	0.67 L / 10,000 L
3	100 μL	1.0 L / 10,000 L
4	200 μL	2.0 L / 10,000 L

The four containers were mixed continuously for 6 days. The concentrations of total solids (TS), volatile solids (VS), TKN, NH_4^+-N, NO_3^- -N, P_2O_5, K_2O, Zn, and Cu were determined after 6 days of treatment.

Procedures to Evaluate Odor

Odor levels were observed after 3 and 6 days of treatment. The effect of Biosafe® on odor was evaluated by asking a panel of individuals to rate the odor from each container on a scale of 1 to 5. A score of 5 indicated a strong odor, and a score of 1 indicated a low odor. Odor evaluations were made of the 4 containers, defined in Table 1, in the afternoon on the third and sixth day of treatment. Ten individuals evaluated the odor on day 3. Five of the panelists were male and five were female. A different group of 8 individuals evaluated the odor level on day 6 and included 5 men and 3 women. Unfortunately, we were not able to locate 2 additional women within the required time frame to evaluate the odor on day 6.

The procedures used to evaluate the odor were the same on both days and are summarized as follows.

- Each of the 4 plastic jars containing the three treated samples and control were sealed with a lid and were placed on a table outside of the building. The evaluation was conducted outside in fresh air away from odor in the laboratory and from other odors. Also, adequate fresh air allowed the panelists to cleanse their noses between evaluations.
- A panelist was not allowed to observe the reactions or answers of any other panelist before completing the evaluation.
- The panelist was positioned, and the jars were presented in such a way that the panelist did not know which jar he or she smelled at any time.
- The panelist was instructed to rate the odor on a scale of 1 to 5 with 1 being low odor and 5 being high odor. Furthermore, each panelist was instructed that he or she was not to try to determine what the odor smelled like, but briefly smell the jar and give a score based on their first impression.
- The jar was immediately covered following the evaluation by the panelist.
- Several minutes (2 to 5) were provided between smelling each jar to allow the individuals olfactory system to recover. The evaluation did not proceed until several cleansing breaths were performed and the panelist indicated that he or she was ready to proceed.
- In some cases, the panelist appeared to try to evaluate the odor in too much detail (offering comments about the type of odor, etc.). In those cases, the individual was required to

evaluate the odor of each container again in random order. The two responses were averaged.

RESULTS

The characteristics of the untreated swine manure are given in Table 2. On the average, the total solids concentration was 49.79 g/L (4.98% TS) and 68% of the TS were volatile solids. The ammonium-N concentration was high accounting for 81.5% of the total nitrogen (TN) in the manure. The nitrate-N content was quite low and accounted for only 1.4% of the total-N.

Table 2. Characteristics of the untreated swine manure.

TS (g/L)	VS (g/L)	TKN ppm	NH_4^+-N ppm	NO_3^--N ppm	TN ppm	P_2O_5 ppm	K_2O ppm	Zn ppm	Cu ppm	pH
49.79	33.77	5885	4788	86	5871	4236	3894	56	66	8.25

Effect of Biosafe® on Odor Scores

Statistical analyses were performed on the odor scores to determine if there was a significant difference depending on (1) the gender of the panelists, (2) the Biosafe® application rate, and (3) the duration of treatment. The least-significant-difference test was used to test for significance between treatment means since only planned comparisons were made.

Comparison of Odor Scores Reported by Men and Women on the Third Day of Treatment

After 3 days of treatment with Biosafe®, 10 panelists, 5 men and 5 women, were asked to score the odor on a scale of 1 to 5. An analysis of variance (ANOVA) was performed on the odor scores using gender and the amount of Biosafe® added as the variables yielding 8 treatments with 5 replications. The pooled estimate of the variance was 0.7125 and the error degrees of freedom was 32. The least significant difference at the 95% level, LSD (0.05), was 1.088. A comparison of the treatment means based on gender is given in Figure 1. The females gave a higher odor score than the males for the control and the 1.0 L application rates, but indicated a greater amount of odor reduction for the 0.67 L and 2.0 L applications rates. The statistical analysis indicated that the average odor scores reported by the male and female panelists were only significantly different for the 1.0 L / 10,000 L application rate. Given these mixed results, it was concluded that gender was not a strong factor and the remainder of the statistical comparisons were made after pooling all observations.

Comparison of the Pooled Odor Scores on the Third Day of Treatment

Pooling all of the odor scores based on gender yielded 4 treatments with 10 replications. As a result, the error degrees of freedom was increased from 32 to 36 and yielded a lower LSD (0.05) of 0.832. A lower LSD provided a more sensitive test between treatment means for the pooled data.

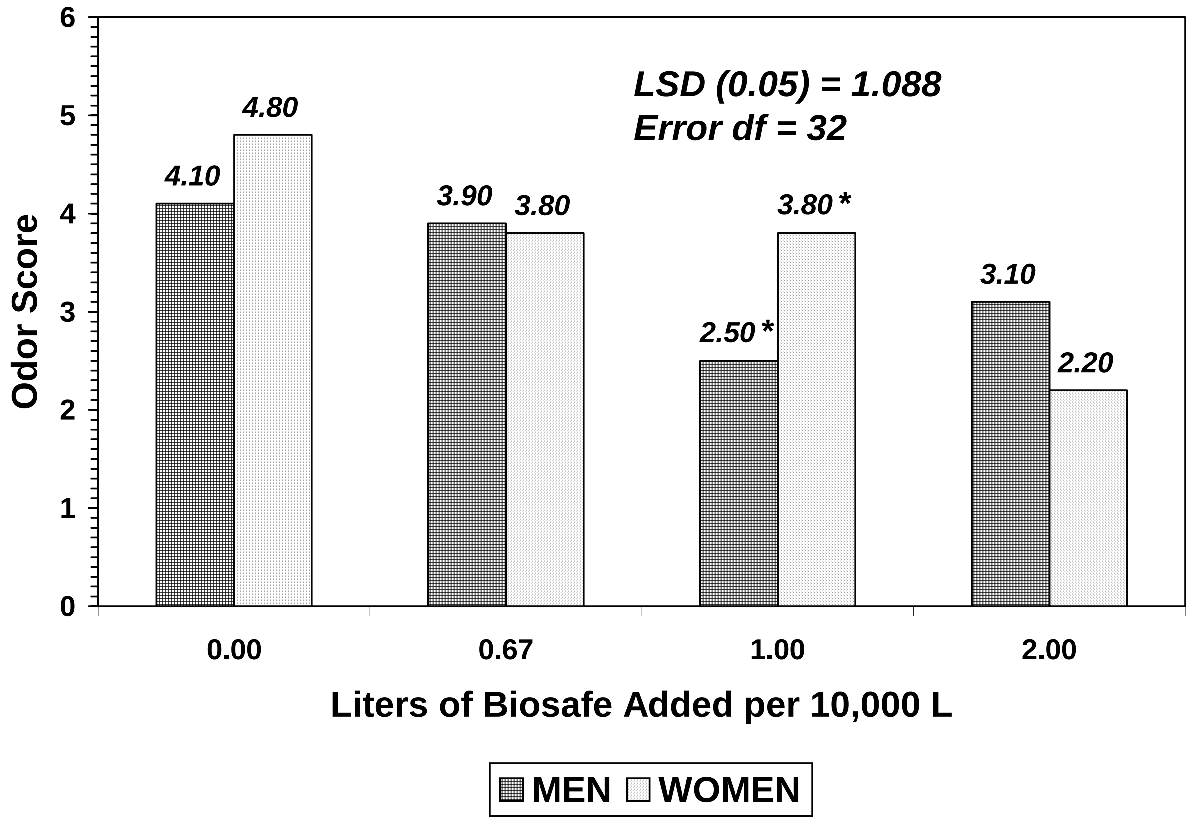

Figure 1. Comparison of the mean odor scores reported by men and women on the third day of treatment using the least-significant-difference test at the 95% level. Treatment means that were significantly different based on gender are indicated by an *.

The treatment means for the pooled data on the third day of treatment are compared in Figure 2. The results indicated that:

- application of 0.67 L / 10,000 L did not have a significant effect on odor score,
- application of 1.0 to 2.0 L / 10,000 L provided a significant reduction in odor score as compared to the control,
- the 1.0 L/10,000 L application rate reduced the odor score by 29% and the 2.0 L/10,000 L application rate reduced the odor score by 40%, and
- the additional reduction in odor score for 2.0 L / 10,000 L was not statistically different from the 1.0 L / 10,000 L rate.

These results clearly indicate that the addition of 1 to 2 L of Biosafe® to 10,000 L of swine manure reduced the odor significantly after 3 days of treatment.

Comparison of the Odor Scores on the Third and Sixth Days of Treatment

A different group of eight panelists evaluated the odor from the same 4 containers during the afternoon on the sixth day of treatment. The treatment means are compared in Figure 3. The odor score results followed the same general pattern on the sixth day of treatment as was observed on the third day of treatment. An LSD test, LSD (0.05) = 0.810, was conducted to compare the treatment means on the third and sixth days of treatment and it was determined that the average odor scores reported by the two different groups of panelists were not significantly different at the 95% level. Therefore, the reduction in odor observed for the 1.0 and 2.0 L / 10,000 L application rates persisted for 6 days. The data for both days were pooled to provide a more sensitive statistical test.

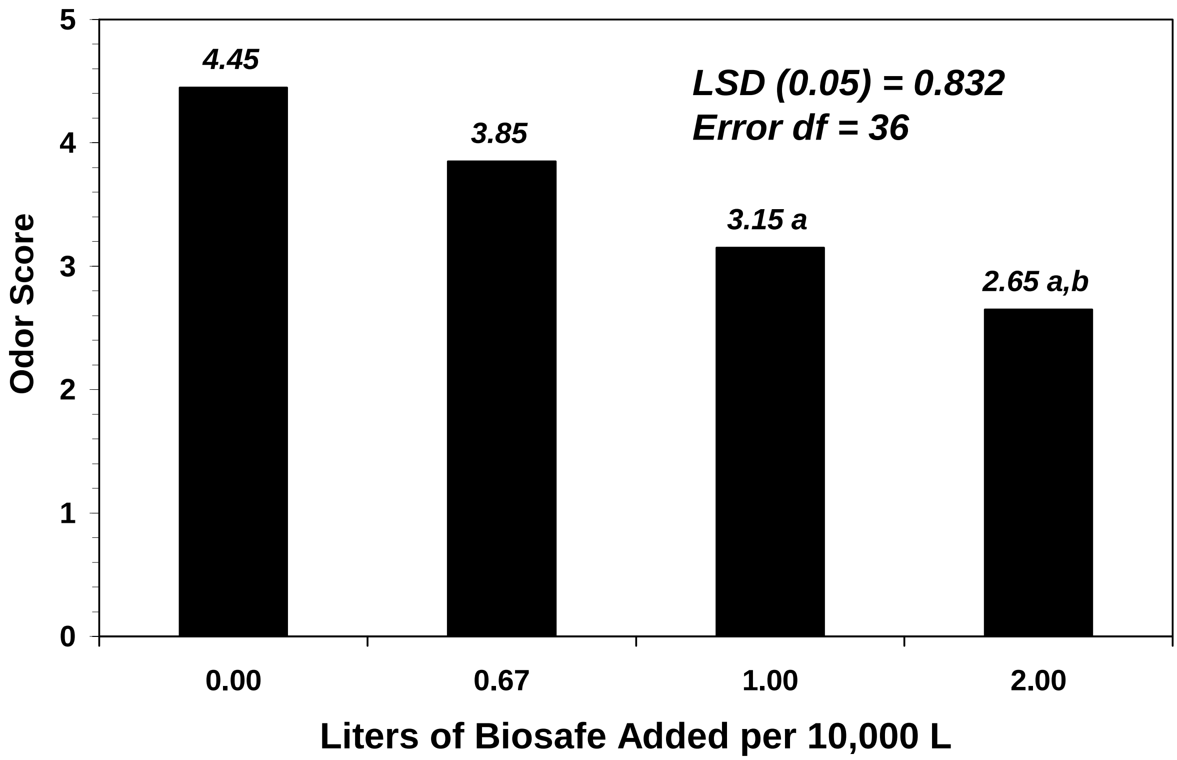

Figure 2. Effect of treating swine manure with Biosafe® on odor after 3 days of mixing, pooled data.

a = significantly different from the control
b = significantly different from 0.67 L / 10,000 L
c = significantly different from 1.0 L / 10,000 L

Comparison of the Pooled Odor Scores from the Third and Sixth Days of Treatment

Pooling all of the odor scores from the third and sixth days of treatment provided an ANOVA based on 4 treatments with 18 replications. The error degrees of freedom was 68 and the LSD (0.05) was 0.287. The treatment means for the pooled data are compared in Figure 3. The results indicate the following.

- Odor scores from all application rates were significantly different from the control.
- Application of 0.67 L / 10,000 L provided an 11% reduction in odor score.

- The odor scores for the 1.0 L and 2.0 L per 10,000 L application rates were not statistically different. On the average, the odor score was reduced by 36% for these two application rates.
- The 1.0 L / 10,000 L application rate results were significantly different from the 0.67 L / 10,000 L results.
- The optimum application rate for odor reduction is 1.0 L / 10,000 L of swine manure based on these data.

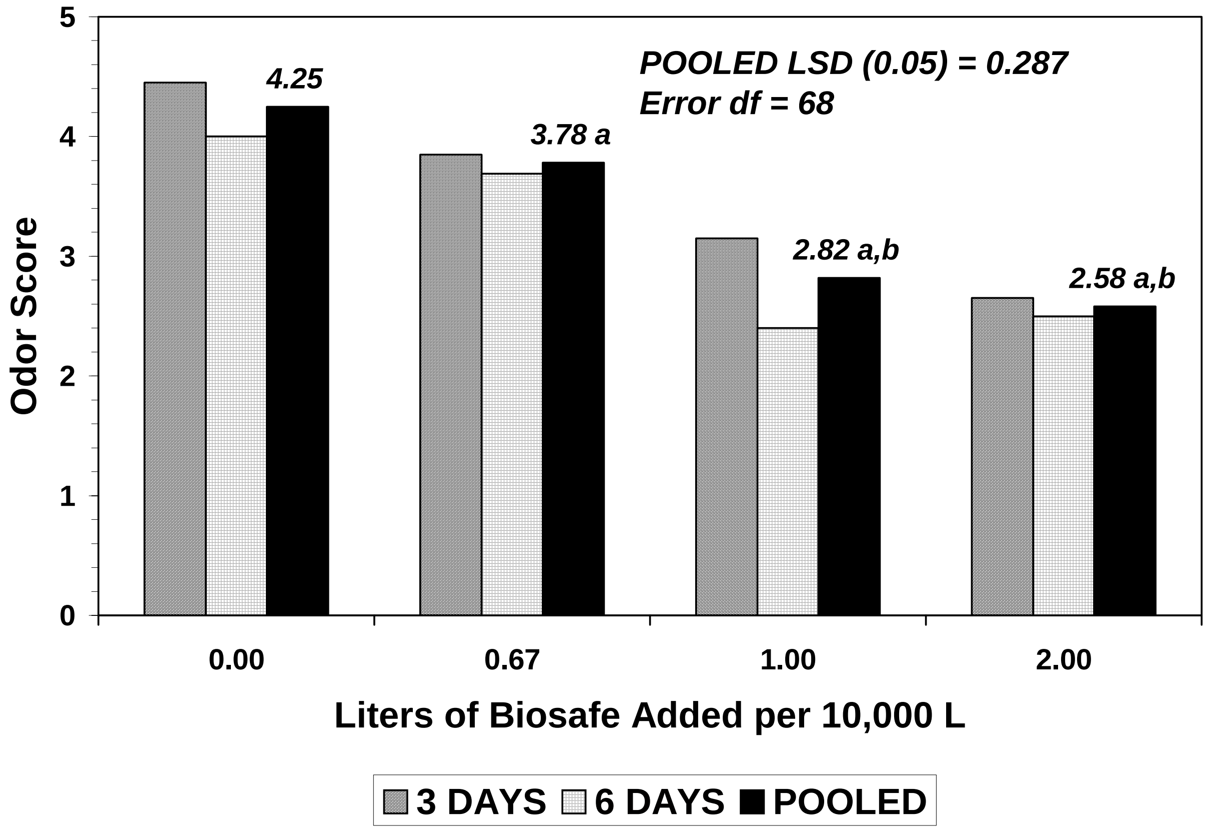

Figure 3. Comparison of odor scores after 3 and 6 days of treatment.

a = significantly different from the control
b = significantly different from 0.67 L / 10,000 L
c = significantly different from 1.0 L / 10,000 L

Effect of Treatment on TS, pH, Plant Nutrients, and VS

The amount of total solids (TS), volatile solids (VS), TKN, NH_4^+-N, NO_3^--N, total N (TN), total P (expressed as P_2O_5), total K (expressed as K_2O), Zn and Cu for the initial sample from the building are compared with the treated samples in Table 3. The data shown in the table are on an as sampled or wet basis and are the average of 4 replications.

Table 3. Comparison of the solids and plant nutrient contents of the untreated swine manure and manure treated with 0 to 2.0 L Biosafe® added per 10,000 L of manure (day 6, as sampled basis).

Treatment	TS g/L	VS g/L	TKN ppm	NH_4^+-N ppm	NO_3^--N ppm	TN ppm	P_2O_5 ppm	K_2O ppm	Zn ppm	Cu ppm
Untreated	49.79	33.77	5885	4788	86	5971	4236	3894	56	66
Control (0 L)	59.87	41.08	4743	2998	131	4873	5069	4638	56	66
0.67 L	59.50	40.64	4848	2955	208	5055	4784	4421	63	73
1.0 L	64.08	44.21	4870	2540	259	5129	5186	4754	67	78
2.0 L	63.08	43.22	4993	2540	283	5276	4984	4594	65	76

Effect on Total Solids Content

One of the unexpected results was the significant increase in solids content (or decrease in moisture content) induced by treatment with Biosafe® (Figure 4). The manure sample taken from the building, without any type of treatment, had a TS of 49.79 g/L and is equivalent to a moisture content of 95.02%. Mixing the manure for 6 days in the plastic jar without Biosafe® increased the solids content to 59.87 gTS/L. This increase in TS concentration was caused by evaporation during the 6-day mixing period. Since the initial volume was 1 L, approximately 168

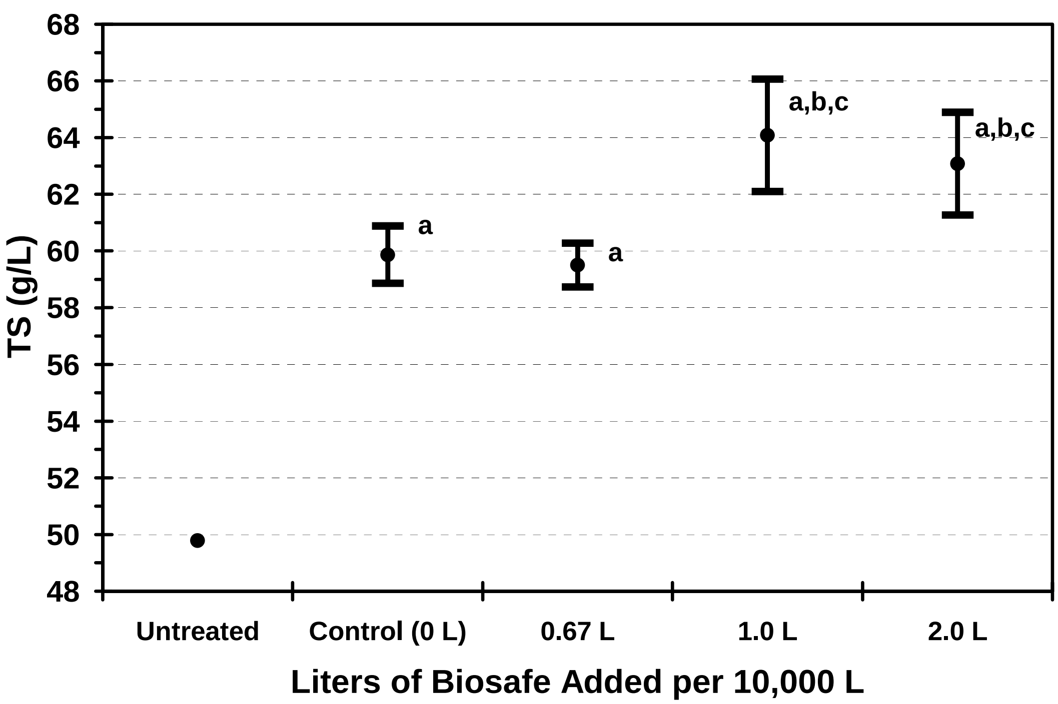

Figure 4. Effects of treatment on TS of swine manure. Data is presented as the mean ± C.I. (0.05). Where, C.I. (0.05) is the 95% confidence interval about the mean.

a = significantly different from the untreated manure
b = significantly different from the control (0 L /10,000 L)
c = significantly different from 0.67 L /10,000 L
d = significantly different from 1.0 L /10,000 L

mL of water, or 16.8%, was lost in six days. The TS concentration of the manure mixed with 0.67 L /10,000 L was not significantly different from the control. However, addition of Biosafe® at the levels of 1.0 to 2.0 L to 10,000 L of manure significantly enhanced the evaporation as indicated by a TS concentration of 63.08 to 64.08 g/L. These values are not significantly different, and on the average, 217 mL of water were evaporated in 6 days. Therefore, addition of sufficient Biosafe® to reduce the odor also enhanced the evaporation rate.

Effect on pH

Addition of Biosafe® also had a small but significant effect on the pH of swine manure as indicated in Figure 5. The initial sample had a pH of 8.25. Mixing the manure for 6 days without the addition of Biosafe® decreased the pH by 0.3 to 7.95. Addition of 0.67 to 2.0 L Biosafe® to 10,000 L of manure decreased the pH in a parabolic manner. The maximum application rate included in the study decreased the pH by 0.35 units to 7.6 as compared to the control and 0.65 units as compared to the untreated manure. A decrease in pH results in a decrease in the rate of ammonia release.

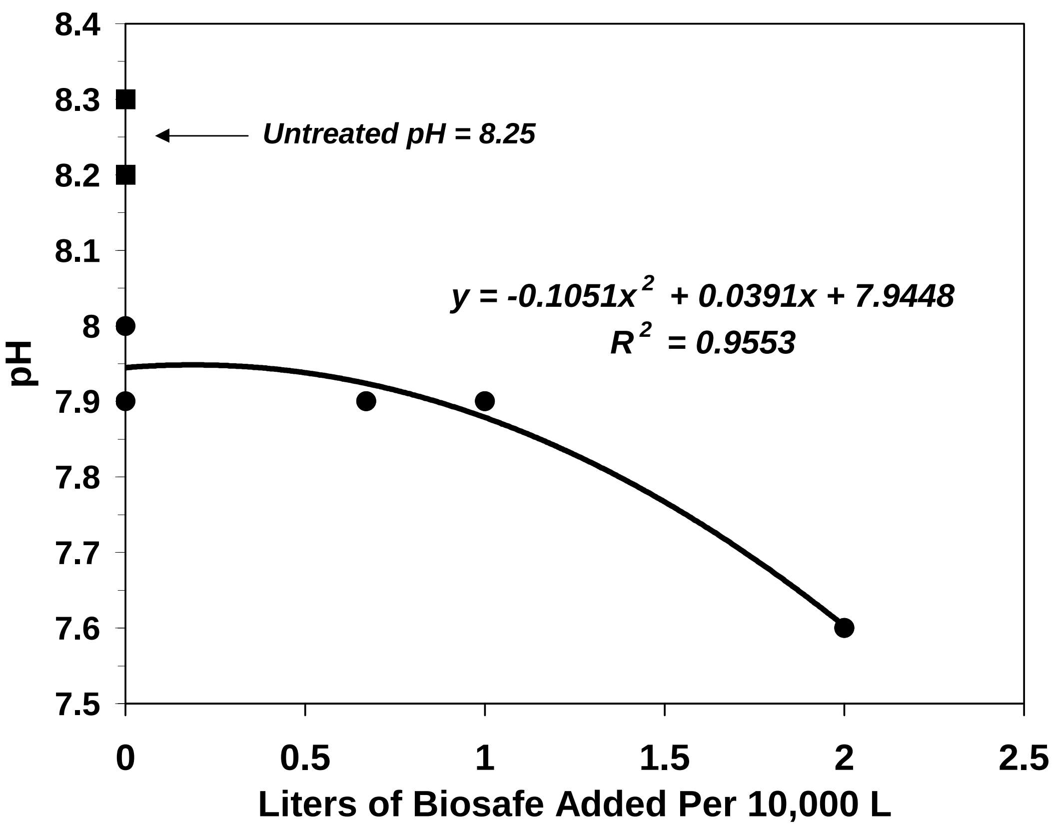

Figure 5. Effect of treatment on pH (2 replications per treatment).

Effect on N, P, K, Zn, and Cu

The concentration of plant nutrients was also effected by the variation in moisture content. Therefore, comparison of the N, P, K, Zn, and Cu concentrations can not be made on an as sampled basis. Instead, comparisons must be made on a dry basis. The concentrations of all of the plant nutrients shown in Table 3 were put on a dry basis and are compared in Tables 4 and 5. Comparisons were made between treatment means using a 90% confidence interval since the coefficient of variation (CV) was greater than 5% in many cases.

Nitrogen

The total nitrogen (TN) is the sum of the organic-N, ammonium-N, and the nitrate-N (or TKN + nitrate-N). The data shown indicates that there was a significant difference between the TN content of the initial sample and the mixed samples. However, the TN was not significantly different between the control, and the three applications of Biosafe® following 6 days of treatment. The overall average TN concentration for the 4 mixed samples was 82,509 ppm (dry basis) with a CV of 6.4%. The TN concentration in the initial sample was 119,932 ppm (dry basis). Therefore, 31% of the total nitrogen was lost in 6 days on the average.

The decrease in total N was due to the loss of ammonium-N by volatilization and can be observed in Table 4. The NH_4^+-N concentration of the control and the 0.67 L / 10,000 L treatment was not significantly different, and the average concentration for these two treatments was 49,868 ppm (dry basis). Therefore, the ammonium-N concentration was reduced by 48% in 6 days. The NH_4^+-N content for the treatments defined as 1.0 and 2.0 L / 10,000 L were lower, and the values for these two treatments were the same within measurement error. The average ammonium-N concentration for these two treatments was 39,952 ppm (dry basis). Since evaporation of moisture was enhanced by the addition of Biosafe® at these levels it would be expected that greater volatilization losses would also occur.

Table 4. Effect of the amount of Biosafe® added (L per 10,000 L of manure) on nitrogen content of swine manure after 6 days of treatment (dry matter basis).
Data is presented as the mean ± C.I. (0.10). Where, C.I. (0.10) is the 90% confidence interval about the mean.

	TKN	NH_4^+-N	NO_3^--N	TN
Treatment	mg / kg DM			
Untreated	118205 ± 3486	96161 ± 8528	1727 ± 27	119932 ± 3481
Control (0 L)	79219 ± 6650 **a**	50071 ± 3575 **a**	2184 ± 122 **a**	81404 ± 6630 **a**
0.67 L	81471 ± 4877 **a**	49664 ± 1181 **a**	3492 ± 294 **a,b**	84962 ± 5071 **a**
1.0 L	75997 ± 7482 **a**	39637 ± 2239 **a,b,c**	4038 ± 350 **a,b**	80035 ± 7775 **a**
2.0 L	79148 ± 6217 **a**	40267 ± 2228 **a,b,c**	4486 ± 658 **a,b,c**	83634 ± 5803 **a**

a = significantly different from the untreated manure
b = significantly different from the control (0 L /10,000 L)
c = significantly different from 0.67 L /10,000 L
d = significantly different from 1.0 L /10,000 L

Table 5. Effect of the amount of Biosafe® added (L per 10,000 L of manure) on P, K, Zn, and Cu content of swine manure after 6 days of treatment (dry matter basis).
Data is presented as the mean ± C.I. (0.10). Where, C.I. (0.10) is the 90% confidence interval about the mean.

Treatment	P_2O_5	K_2O	Zn	Cu
	mg / kg DM			
Untreated	85083 ± 2953	78204 ± 1839	1126 ± 25	1328 ± 30
Control (0 L)	84673 ± 3000	77474 ± 2596	937 ± 21 **a**	1104 ± 25 **a**
0.67 L	80399 ± 2483	74294 ± 2588	1060 ± 24 **a,b**	1233 ± 20 **a,b**
1.0 L	80928 ± 4261	74191 ± 2451	1042 ± 59 **b**	1218 ± 91
2.0 L	79005 ± 7476	72822 ± 7751	1032 ± 97	1208 ± 114

a = significantly different from the untreated manure
b = significantly different from the control (0 L /10,000 L)
c = significantly different from 0.67 L /10,000 L
d = significantly different from 1.0 L /10,000 L

However, not all of this ammonium was lost to the atmosphere. A portion of the NH_4^+-N was converted to nitrate as indicated by the data in Table 4. The mixing alone entrained enough air to increase the NO_3^- -N in the control by 26% as compared to the initial sample. Addition of 0.67 L of Biosafe® per 10,000 L of manure increased the amount of nitrate in the swine manure by a factor of 2.02 as compared to the initial sample. The nitrate concentrations associated with addition of 1.0 to 2.0 L of Biosafe® per 10,000 L were not significantly different and resulted in an increase in nitrate by a factor of 2.47 as compared to the initial sample.

The nitrate concentration in the Biosafe® treated manure must also be compared to the control since the mixing action alone resulted in an increase in nitrate. Addition of 0.67 L of Biosafe® increased the nitrate content by a factor of 1.60 as compared to the control. Increasing the application of Biosafe® to 1.0 and 2.0 L /10,000 L increased the nitrate content to 1.95 times the control value.

P_2O_5 ,K_2O, Zn, and Cu

As expected, addition of Biosafe® did not influence the total P or total K content of swine manure. The overall average dry basis concentration of total P expressed as P_2O_5 was 82,018 ppm. The K_2O concentration was 75,397 ppm.

A few of the Zn and Cu concentrations were significantly different based on a 90% confidence interval. However, an obvious pattern due to treatment with Biosafe® was not apparent. It is believed that the sampling error was greater than the analysis error for Zn and Cu.

Effect on VS

The addition of Biosafe® did not influence the VS content of swine manure as indicated in Figure 6. The overall average VS content was 684,533 ppm (mg VS/kg dry matter). Another way of stating this is that 68.5% of the total solids were volatile (0.685 kg VS/kg TS). Previous data collected by Chastain et al. (1998) indicated that 68.7% of the total solids in swine manure from a pit-recharge building are volatile and are within the variation observed in this study.

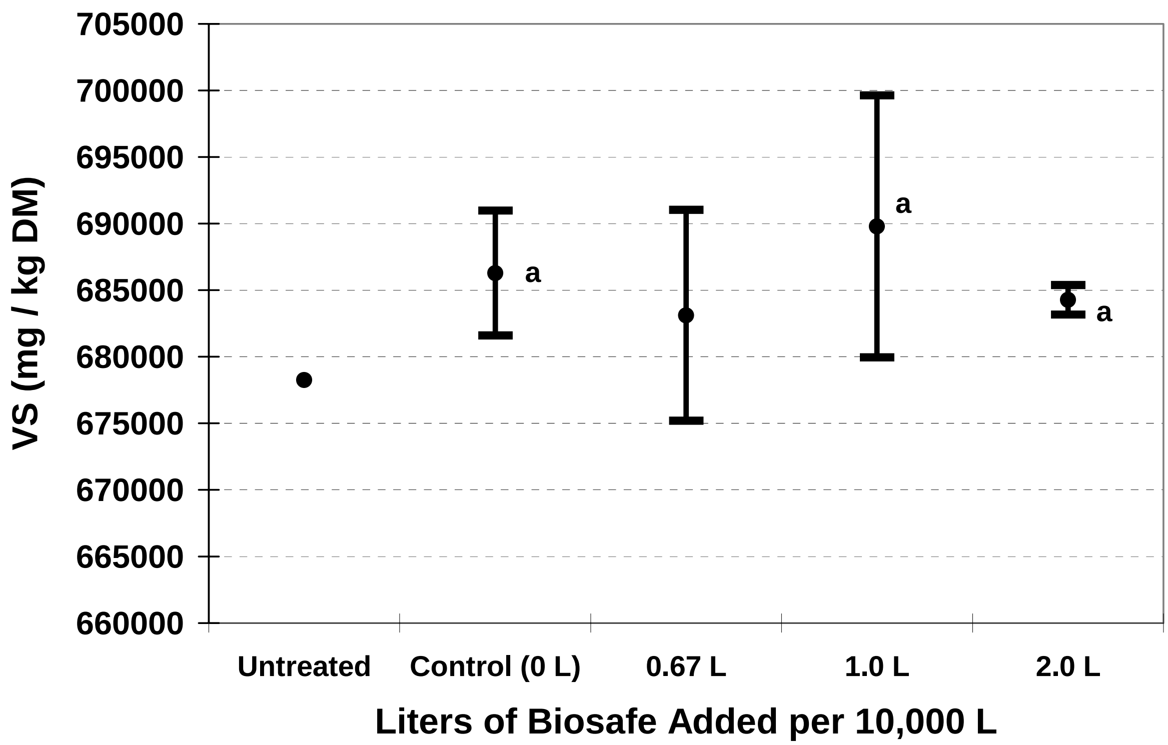

Figure 6. Effects of treatment on VS of swine manure on a dry matter basis. Data is presented as the mean ± C.I. (0.05). Where, C.I. (0.05) is the 95% confidence interval about the mean.

a = significantly different from the untreated manure
b = significantly different from the control (0 L /10,000 L)
c = significantly different from 0.67 L /10,000 L
d = significantly different from 1.0 L /10,000 L

CONCLUSIONS

- The smallest amount of Biosafe® that provided a substantial reduction in odor was 1 L of Biosafe® to 10,000 L manure. The average odor score was reduced by 29% after 3 days of treatment, and 36% after 6 days of treatment.
- The odor scores on the third and sixth days of treatment were not significantly different at the 95% level.
- Gender did not have a significant effect on odor score.
- Increasing the application rate of Biosafe from 1.0 L to 2.0 L / 10,000 L of manure did not decrease the odor score by a significant amount. Therefore, the optimum application rate for odor reduction is 1.0 L / 10,000 L of swine manure based on these data.
- Treatment of swine manure with Biosafe® at the levels required for significant odor reduction enhanced the evaporation of water by 4.9 % (21.7% vs 16.8% for control).

- Addition of Biosafe® reduced the pH in a parabolic manner as the amount of Biosafe® was increased. An application rate of 2 L / 10,000 L provided a 0.35 unit decrease in pH as compared to the control. A reduction in pH would reduce the rate at which ammonium is converted to ammonia.
- Addition of Biosafe® did not effect the amount of volatile solids, phosphorous, zinc, copper, or potassium in swine manure.
- The total nitrogen (TN = TKN + NO_3^- -N) was not significantly altered by the addition of Biosafe®. However, 31% of the TN was lost in 6 days of mixing. The loss was by means of volatilization.
- The ammonium-N concentration was reduced by the mixing action and by addition of 1 to 2 L Biosafe® per 10,000 L manure. Part of the ammonium was converted to ammonia and was lost by volatilization. A significant fraction was converted to nitrate nitrogen.
- The air entrained by mixing and the effect of Biosafe® at concentrations sufficient to reduce odor elevated the nitrate levels in the manure by a factor of 2.47. However, nitrate nitrogen accounted for only 5% of the total nitrogen on an as sampled basis. Therefore, Biosafe® treated manure should be tested for nitrate prior to land application, but the concentration of nitrate is not high enough to be detrimental.

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