RESEARCH REPORT
ENVIRONMENT

Title: Assessing the impact of swine sulfur intake from drinking water on odor and gaseous emissions and manure nutrients – **NPB #05-115**

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Abstract

The impact of a specific input to the pig on the resulting air emissions and manure characteristics was assessed. Specifically, the impact of varying sulfate levels in drinking water on odor and gaseous emissions and on swine manure properties was determined. Sulfur intake is of particular concern because 6 out of the 10 most odorous components of swine odor have been found to contain sulfur. Five replicates were completed in four separate grow-finish rooms, each containing 6 pens and about 10 pigs per pen and given drinking water ranging in total sulfate content from about 80 ppm (control) up to 1800 ppm sulfate. Each treatment was applied over an 8-week growth period, with an average initial pig weight of 40 kg. Thus, a total of 30 pens and 300 pigs per treatment were employed, providing a high level of statistical power. Results showed that high sulfate levels in water had no adverse impact on pig performance, on gas and odor emissions or on manure nutrient properties. However, when using high-sulfate drinking water, proper measures should be in place to consider the increased potential for generating high spikes in hydrogen sulfide levels during manure handling operations, such as pulling pit plugs. Overall, this study showed that water treatment is not necessary when using drinking water containing up to 1800 ppm sulfate from the persecptive of pig health, pig performance, financial returns and environmental impact. This can pave the way for the use of water with sulfate levels exceeding the existing limit for livestock water, allowing the pork industry to expand into areas previously considered as having unacceptable or undesirable drinking water sources.

Introduction

Odor and gaseous emissions from swine operations is a major environmental concern for the North American pork industry. These emissions consist of thousands of compounds, only about 400 of which have been identified so far. Out of the 10 most odorous components of swine odor identified, six are sulfur-containing compounds (O'Neill and Phillips, 1992). Because these odor components are produced mainly from anaerobic breakdown of unutilized nutrients excreted by pigs, manipulating the level of input of nutrients that are strongly associated with odor (such as sulfur) has been explored as a potential means for mitigating gaseous emissions (Whitney et al., 1999). No studies have been undertaken to fully assess the extent of the impact of the pig's sulfur intake levels on air quality and on manure characteristics, especially under actual production conditions.

Drinking water can contribute significantly to sulfur intake of pigs. One major source is the sulfate content in water supplies, which has been found to exceed 1600 mg/L in certain geographic areas in the United Stated. Studies showed that pigs offered water with increased sulfate levels (up to 1800 mg/L) had increased prevalence of non-pathogenic diarrhea (Veenhuizen et al., 1992). Similar observations were documented in weanling pigs given poor quality water on a 1,200

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sow farrow-to-finish commercial pig farm; average daily gain, average daily feed intake, gain-to-feed ratio, and nutrient digestibility were not compromised (Patience et al., 2004). Pigs have typically exhibited considerable ability to handle water of widely varying quality with no significant effect on overall performance (Maenz et al., 1994). However, further studies need to be conducted to assess the impact of poor water quality on air emissions and swine manure properties, especially under typical barn conditions. Such work is needed to resolve concerns with water quality that could be related to odor and gas emissions, when considering siting of new barn facilities and developing water sources for swine operations.

In line with the target priorities of the NPB Environmental Research program, this study was conducted to assess the impact of inputs (sulfur in water) on air quality and manure management. Specifically, this study explored the possibility of using high-sulfur water without adversely affecting emissions and manure properties, which could potentially lead to the use of water sources with sulfur contents above the established limit. Additionally, this work was intended to contribute towards addressing a growing concern in the industry regarding hydrogen sulfide (H_2S) and odor emissions from swine operations. Recent legislation pertaining to H_2S emissions exemplify the need by pork producers for better information on factors that affect H_2S generation and for management options that can be implemented to comply with these regulations.

Objectives

The overall goal of this study was to assess the impact of animal drinking water quality on swine manure nutrients and on air emissions. Specifically, this study aimed to determine the effect of varying sulfur in drinking water on odor and gaseous emissions and on manure properties.

The hypothesis for this study was that increased sulfur intake in drinking water will increase emissions of odor and gases from swine manure and adversely affect manure composition and animal performance. Hence, the experiments were conducted to answer the following questions:

1. will elevated levels of sulfur intake from water affect manure nutrient composition, odor and gaseous emissions, and pig performance?
2. at what level of sulfate in water should water treatment be considered to mitigate adverse environmental effects?

Materials & Methods

To achieve the stated project objective, the overall approach was to conduct experimental trials to compare the emissions and manure properties from separate grow-finish rooms provided with varying levels of sulfate in drinking water. During each trial, emissions and manure nutrient properties were monitored in each room.

Description of facilities

The research work was conducted at Prairie Swine Centre Inc. (PSCI) barn facilities located near Saskatoon, Saskatchewan, Canada, using four (4) all-in-all-out grow-finish rooms (each 5.3 m wide and 14.2 m long) of identical construction. Each room had 6 pens; each pen (4.2 x 2.0 m) has a partially-slatted floor (1/3 of pen area) over a 0.61 m-deep manure pit; each pit is 2 m wide and 12 m long, with a pit drain on each end capped by a pit plug. Each room was mechanically ventilated, with airspace totally isolated from adjacent rooms. Thus, conditions within the experimental rooms were typical of those existing in commercial practice, although of a smaller scale. Flooring, penning, feeders, drinkers and the ventilation system were identical to those used in commercial pig barns; pen size was somewhat smaller than commercial scale, e.g., 10 pigs per pen.

Treatments

Each of 4 rooms was randomly assigned to one of four treatments; at the end of each replicate, each room was randomly reassigned to experimental treatments. The treatments are summarized below:

- Treatment 1: Normal water (low-sulfate content)
- Treatment 2: 600 mg/L sulfate water
- Treatment 3: 1200 mg/L sulfate water
- Treatment 4: 1800 mg/L sulfate water

All animals were given standard production diets (based on NRC requirements) throughout the study. Treatment 1 was the Control, in which pigs were given normal, untreated drinking water with low sulfate content (~80 mg/L (or parts per million, ppm) sulfate). The other treatments were aimed to determine the impact of varying levels of sulfate in water. Based on estimated feed and water intake, and estimated proportion of dietary sulfur (S) utilized by the animals for

growth and metabolism, Treatments 1 to 4 corresponded to a daily sulfur intake of 2.0, 3.1, 4.2, and 5.4 g S per day, respectively, that may potentially be excreted in urine and feces and thereby contribute to air emissions. The corresponding contribution from water ranged from 6.5% (Treatment 1) to 65.5% (Treatment 4) of the estimated total daily sulfur intake.

A water dosing system (Model A10-10%, Dosmatic USA, Carrollton, Texas) was used to deliver water with desired sulfate levels to specific experimental rooms. The dosing system was used to blend (at a specified ratio) artificially-formulated high-sulfate water with the existing low-sulfate control water supply to achieve the desired sulfate level. Additionally, the blended drinking water was constituted such that it contained the same proportion of ion components typically found in naturally-occurring high-sulfate water to account for the potential interaction of these various constituents that may occur in natural water. In this experiment, the major ions considered in addition to sulfates were sodium, magnesium, and bicarbonate, with the desired levels determined from analysis of naturally-occurring high-sulfate water samples in a previous study (Patience et al., 2004**).** Magnesium sulfate (Epsom salt) and sodium bicarbonate were used in formulating the solutions.

Preliminary tests indicated that solutions with concentrations up to 80X the desired sulfate level can be formulated without saturating the solution. Thus, the required amounts of magnesium sulfate and sodium bicarbonate were added to prepare solutions with 80X the desired 600, 1200, and 1800 ppm sulfate levels, and was injected into the water line using the dosing system set at 80:1 dilution ratio.

Animal and room preparation

For each replicate, a total of 240 finishing pigs at starting weight of about 40 kg was distributed equally to the four rooms. Each room had 6 pens, which held 10 pigs per pen for a total of 60 pigs per room. The pigs were segregated by sex such that each pen was of the same gender and each room had an equal number of pens of males and females. At the start of each replicate, animals were weighed and assigned to rooms such that the average starting weight across all rooms was within ±2 kg of each other (balanced by pen weights). The animals were weighed again at the end of week 4 and 8 to determine the gain in bodyweight.

Experiment duration and replication

Each replicate ran for 8 weeks, which included an initial 2-wk acclimation period followed by 6 wks of data collection from each room. The details of data collection for each replicate are summarized in Table 1. The experiment was replicated five (5) times, with a 1-week downtime between replicates. Each room was cleaned thoroughly between replicates, including room, pen, and pit surfaces, and room was randomly reassigned to treatment in each subsequent replicate.

The manure pits in these swine rooms were emptied every 2 wks (on day 7 of each week). To evaluate the effect of the treatments on manure properties and gaseous emissions from manure under long-term storage, a manure sample (30 L) was taken from each room just before emptying the pits, starting on Wk 2 (see Table 1). The manure sample was transferred into a 205-L barrel (one for each room, total of 4 barrels per replicate). The barrels were filled in the same manner until Wk 8 and stored for additional 5 wks after the room replicate to simulate long-term manure storage.

Data collection

The parameters monitored include:

1. water (sulfate, total dissolved solids, magnesium, sodium, bicarbonate)
2. feed (protein, moisture, P, K, Ca, Mg, Na, and S)
3. gas (ammonia, carbon dioxide, H_2S) and odor emissions
4. manure nutrient composition (total N, total solids, P, K, S, Na)
5. air quality parameters (room temperature, relative humidity, ventilation rates)
6. manure pit physico-chemical properties (oxidation-reduction potential (ORP), pH, temperature)
7. water use per room
8. average daily gain.

Using the same sampling and measurement procedures, the content of the manure barrels were monitored for chemical composition, odor, and gases concentrations on Wk 6, 8, and 13.

Table 1. Sampling and monitoring schedule for each replicate.

Week	0	1	2	3	4	5	6	7	8	--	13
		Acclimation		Room sampling							
Room sampling											
Water analysis	x				x				x		
Feed analysis	x								x		
Manure composition					x		x		x		
Odor analysis					x		x		x		
Gases	x	x	x	x	x	x	x	x	x		
Water intake (weekly)		x	x	x	x	x	x	x	x		
		(Plug-pull)		Barrel fill		Barrel fill		Barrel fill		Barrel fill	
Barrel sampling											
Manure composition							x		x		x
Odor analysis							x		x		x
Gases							x		x		x

Gas sampling set-up and analytical procedures

An existing manifold system connected to a network of Teflon sampling tubing was expanded to cover all four experimental rooms; this allowed drawing of a gas stream from the ventilation inlet and exhaust of the four swine rooms. The manifold had a solenoid valve system that allowed sequential introduction of the gas stream from individual rooms into a gas analyzer; hence, all rooms were monitored on a rotating basis (every 60 min). An ammonia (NH_3) analyzer (Model Chillgard RT, MSA Canada, Edmonton, AB; accuracy of ±2 ppm) and a carbon dioxide (CO_2) analyzer (Model Guardian Plus, Topac, Hingham, MA; accuracy of ±60 ppm), were used to monitor levels of NH_3 and CO_2, respectively.

An H_2S monitoring instrument (Model PacIII, Dräger, Lübeck, Germany; reproducibility of 5%) was used to measure H_2S levels in each room on day 6 of each week.

Gas samples were collected into 20L Tedlar bags for odor analysis, using a negative-pressure lung apparatus. The bags were sent on the same day to the University of Alberta olfactometry laboratory for odor analysis (within 24 hrs) based on the European Standard, EN 13725: Air quality - determination of odor concentration by dynamic olfactometry.

Feed, water, and manure samples were collected and sent to a laboratory accredited by the Standards Council of Canada for analysis using the appropriate standard analytical methods.

Results

Treatment and room conditions

The mean water sulfate levels, ventilation rate, room temperature, and relative humidity in each room are summarized in Table 2. Water sulfate levels were determined from analysis of water samples periodically taken from the drinkers in each treatment room during each replicate. Ventilation rate, temperature, and relative humidity readings were taken from each room every 10 min and recorded in a datalogger; all these readings (about 144 per parameter per day) were averaged weekly over the 8-week replicate, and the mean average weekly readings for each treatment covering all 4 replicates are shown in Table 2. As can be seen, the mean water sulfate levels were close to the desired values. Overall, the different treatment rooms were maintained under similar environmental conditions; the mean values for ventilation rates, temperature, and relative humidity readings from all rooms over the duration of the study did not differ significantly ($p>0.05$).

Table 2. Average water sulfate levels, ventilation rate, temperature, and relative humidity in the treatment rooms throughout the study.

	Drinking water sulfate (ppm)			Room ventilation rate (L/s)		Room air temperature(°C)		Room relative humidity (%)	
Treatment	**Mean**	**SE**	**n**	**Mean[a]**	**SE**	**Mean[a]**	**SE**	**Mean[a]**	**SE**
1 (Control)	84.5	1.8	14	1667.2	193.0	18.5	0.6	55.0	1.0
2 (600 ppm)	658.5	37.6	15	1760.0	169.8	18.8	0.6	53.8	0.9
3 (1200 ppm)	1210.0	109.8	15	1953.1	189.8	18.8	0.6	54.5	1.0
4 (1800 ppm)	1674.2	157.3	15	1585.0	171.1	18.8	0.5	54.5	0.9

[a] – Treatment mean values not significantly different (p>0.05)

Gas concentrations

The levels of NH_3 and CO_2 in each room were monitored continuously during each replicate on a rotating basis. Each sampling location was sampled every 60 min; the weekly average concentration and emission levels are shown in Table 3. The NH_3 and CO_2 levels were not markedly different between the treatment rooms, although the room with 600 ppm sulfate seemed to have slightly higher levels for both gases compared to the other rooms. Statistical tests showed no significant (p>0.05) impact of the treatment (increasing levels of water sulfate) on the concentrations and emissions of these gases (NH_3 and CO_2) from the treatment rooms.

Table 3. Average weekly gas (NH_3 and CO_2) concentration and emission levels from the treatment rooms during the replicates.

	Ammonia concentration (ppm)			Ammonia emission rate (g/hr)			Carbon dioxide concentration (ppm)			Carbon dioxide emission rate (g/hr)		
Treatment	Mean[a]	n	SE	Mean[a]	n	SE	Mean[a]	n	SE	Mean[a]	n	SE
1 (Control)	9.9	40	0.5	12.1	38	2.0	728.6	40	36.4	1880.1	39	154.4
2 (600 ppm)	10.7	40	0.6	13.4	40	1.5	769.6	40	44.9	2052.3	40	69.4
3 (1200 ppm)	10.0	40	0.4	12.5	38	1.6	740.8	40	38.0	2077.7	38	93.3
4 (1800 ppm)	9.7	40	0.4	9.8	37	1.4	735.0	40	36.1	1896.5	37	108.9

[a] – Treatment mean values not significantly different (p>0.05)

Initial day-long monitoring of H_2S levels in each room using a direct-reading H_2S monitoring instrument showed that the H_2S levels in the treatment rooms were typically below the detection limit of the H_2S monitoring instrument used (<1 ppm H_2S); thus, for the remainder of the study, day-long monitoring of H_2S levels was done mainly to confirm this observation (Table 4). However, on the day that the manure pit-plug was pulled to clear the manure from the pits (every two weeks), the H_2S monitor showed measurable H_2S levels during the approximately 15-min period in which the manure slurry was flowing out of the pit. A typical plot of the H_2S levels during the plug-pulling day is shown in Figure 1; a similar pattern was also monitored in the other treatment rooms. Monitoring of H_2S levels was then conducted mostly during the days that the pit-plugs were pulled in each room.

Table 3. Average H_2S concentrations measured in each room throughout the study.

	Peak H_2S concentration (ppm)			Day-long H_2S monitoring (ppm)	
Treatment	**Mean** [*]	**n**	**SE**	**Mean**	**n**
1 (Control)	22.5 [a]	17	8.4	0.0 [**]	11
2 (600 ppm)	21.0 [a]	17	7.6	0.0	2
3 (1200 ppm)	54.2 [b]	17	22.4	0.0	2
4 (1800 ppm)	27.9 [a]	17	8.4	0.0	6

[*] – Treatment mean values followed by same letter are not significantly different (p>0.05)

[**] - below detection limit of H_2S monitor (< 1 ppm)

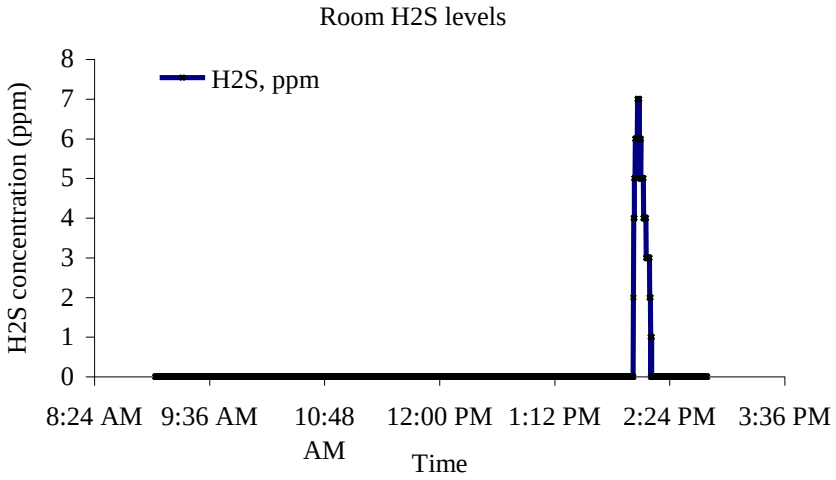

Figure 1. Typical H_2S levels monitored in a treatment room, showing no detectable values throughout most of the day, except during the plug-pulling event (indicated by the spike in H_2S levels).

The average peak H_2S values obtained during plug-pulling from each treatment room are summarized in Table 3. Statistical tests showed a significant ($p<0.01$) effect of the treatment on the peak H_2S levels during pit-plug pulling. The peak H_2S levels in the treatment rooms that received high-sulfate water (1200 and 1800 ppm) tend to be higher than in the low-sulfate rooms (Control and 600 ppm). During the individual replicates, the maximum peak H_2S values measured during pit-plug pulling in the treatment rooms provided with drinking water with 1200 and 1800 ppm sulfate were 288 and 134 ppm H_2S, respectively; these spikes occurred for only a short period of time and the high levels dissipated to less than 10 ppm in less than 10 min. Nevertheless, these observations would appear to indicate that high-sulfate levels in drinking water could contribute to the generation of high H_2S levels during manure clearing operations, which could potentially lead to exposure of barn workers and pigs to elevated H_2S if not conducted properly.

Odor levels

Odor measurements were done by collecting gas samples in Tedlar bags and sending the samples to an olfactometry laboratory at the University of Alberta. Odor samples were collected inside each treatment room (near the ventilation exhaust fans) and from the headspace of each manure storage barrel at specified intervals during each replicate. The mean odor concentration and emission values and the corresponding hedonic tone score for the samples are summarized in Table 4. Following procedures done in similar previously reported studies, the logarithm of the odor values was used in the statistical analysis of the odor values. Results showed that odor concentration and emissions from the rooms were not significantly ($p>0.05$) affected by the treatment applied. Interestingly, the room with 1200-ppm water had the highest mean odor values while the room with 1800-ppm water had the lowest, even lower than the control room; however, wide variability in the odor values contributed to the difference being not statistically significant. This could also be attributed to the fact that the generally accepted method of analyzing odor samples (i.e., by sensory evaluation done by a panel of trained people) can inherently result in wide variability in odor values, even with duplicate samples. In addition, a statistically significant difference between two sets of odor samples would be detected only if the magnitude of difference between the two sample sets is consistently large (Clanton et al., 1999). Although the odor concentration values may appear higher for the 1200-ppm room, statistical tests did not indicate that these values are significantly higher than in the other rooms due to the inherent variability in odor values obtained from odor panels ($p>0.05$).

The hedonic tone score is a measure of the (un)pleasantness of the odor using a 9-point scale which ranges from '9 - Like extremely' to '1 - Dislike extremely'. As can be seen from Table 4, all samples had hedonic scores below 5, indicating that all odors were deemed unpleasant. The mean hedonic scores were not significantly ($p>0.05$) different between treatments, although the samples taken from the high-sulfate treatment rooms (and barrels) tend to have lower hedonic tone scores, indicating more unpleasant odor compared to the control samples and those from the room with low-sulfate drinking water (600 ppm).

Table 4. Mean odor levels (in Odor Units (OU) per m^3) and hedonic tone score for samples from the treatment rooms and barrels used to simulate long-term storage.

	Room odor concentration (OU/m^3)			Room odor hedonic tone score			Room odor emission rate (OU/s)			Barrel odor concentration (OU/m^3)			Barrel odor hedonic tone score		
Treatment	**Mean**	**SE**	**n**	**Mean**	**SE**	**n**	**Mean**	**SE**	**n**	**Mean**	**SE**	**n**	**Mean**	**SE**	**n**
1 (Control)	3,141	751	15	2.5	0.14	15	8,443	2,814	13	10,555	2,050	13	2.3	0.16	13
2 (600 ppm)	2,133	369	15	2.4	0.12	15	4,259	952	15	10,132	2,005	13	2.4	0.18	13
3 (1200 ppm)	3,639	913	15	2.2	0.13	15	9,723	3,172	14	13,222	2,444	13	2.2	0.22	13
4 (1800 ppm)	1,995	511	15	2.3	0.12	15	2,435	538	13	9,644	2,109	13	2.1	0.13	13

Manure nutrient properties

Samples collected from the manure pit of each room and from the barrels used to simulate longer-term manure storage were analyzed, with the results plotted in Figures 2 and 3. In general, the nutrient levels in the manure samples were consistent with typical reported levels found in swine manure. However, the nutrient levels tended to be lower for the stored manure compared to levels found in samples taken from the room manure pits. For the room samples, comparison between different treatments showed no significant ($p>0.05$) differences in levels of Total Nitrogen, Ammonia-N, Total Solids or Phosphorus in the room manure samples, but there were significant ($p<0.05$) differences in Potassium and Sulfur levels. The significant difference in Sulfur levels was expected because sulfur was added to the drinking water as part of the treatment. However, comparison of nutrient levels for the barrel manure samples showed significant ($p<0.05$) differences between treatments for all nutrients tested. The observed trend was that the manure samples from the treatment rooms with sulfate added to the drinking water tended to have (on the average) about 10% higher nutrient levels relative to the control samples (excluding S and Na which had 50% more than the control due to the treatment). Thus, it would appear that high-sulfate drinking water may result in better retention of nutrients in the stored manure.

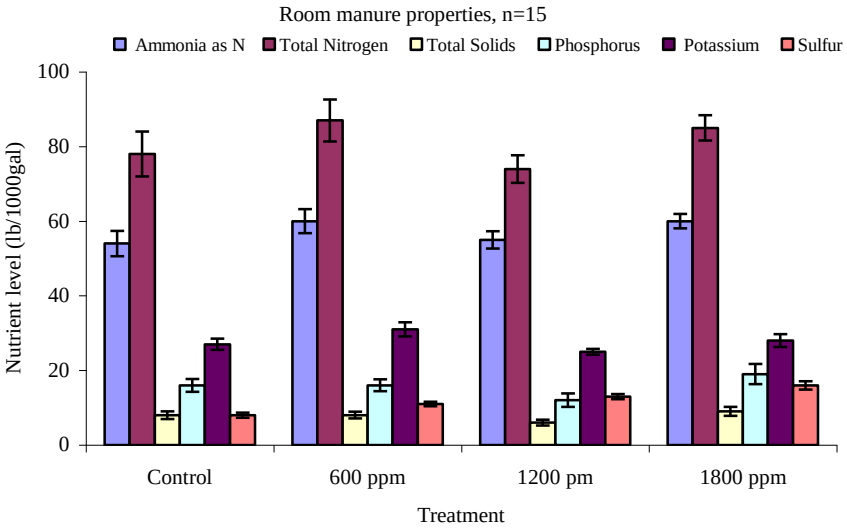

Figure 2. Nutrient properties of manure in the pits of the treatment rooms (each bar, n=15).

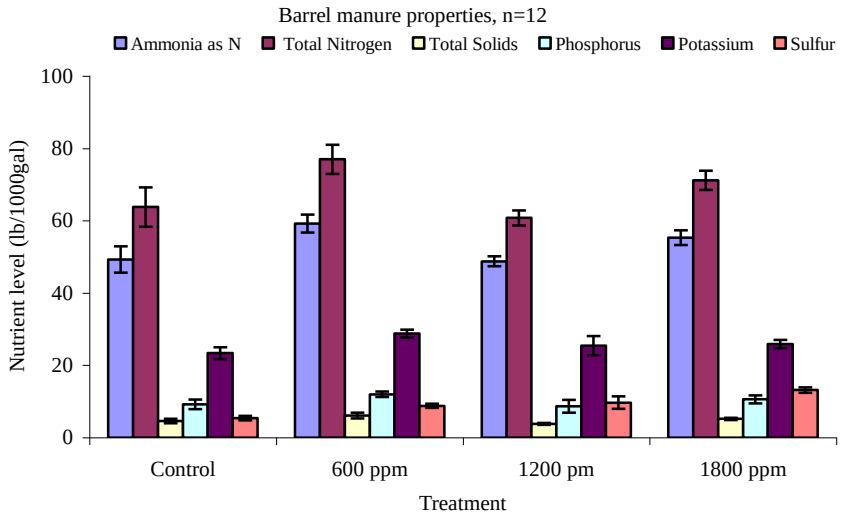

Figure 3. Nutrient properties of manure from the barrels used to simulate long-term storage (n=12).

The physico-chemical properties of the manure pit in each treatment room were also monitored and summarized in Table 5. Statistical tests showed that the pH and temperature of the manure in the pit were not significantly ($p>0.05$) impacted by the treatment applied, although lower mean pH values were observed for the high-sulfate room which would tend to indicate higher potential for the release of H_2S from the manure slurry to occur; this was consistent with the higher peak H_2S levels measured in those rooms during pit-plug pulling. The mean ORP values were significantly ($p<0.05$) different between the treatments; however, the higher mean values obtained for the high-sulfate rooms were not consistent with previously reported trends in ORP values which should favor H_2S production. In wastewater environment, ORP values between 50 to -200 mV favor sulfate reduction into sulfides, while evolution of various sulfur gases from cattle manure slurry has been reported at different ORP levels ranging from 300 to -200 mV (Beard and Guenzi, 1983), with lower negative values favoring more H_2S production. In this experiment, the ORP values measured from the manure pits ranged from -39 to 170 mV, which were within range of the previously reported values (although not for swine manure slurry). To validate the trend for the ORP values observed in this study, additional tests are being conducted to verify the sampling method and the instruments used to collect this data.

Table 5. Summary of physico-chemical characteristics of the room manure pit.

	pH			Oxidation-reduction potential (mV)			Manure pit temperature (°C)		
Treatment	**Mean**	**n ***	**SE**	**Mean**	**n ***	**SE**	**Mean**	**n ***	**SE**
1 (Control)	6.1	15	0.23	31.7	12	8.13	17.8	14	0.82
2 (600 ppm)	6.2	15	0.24	29.5	12	6.89	17.4	14	0.84
3 (1200 ppm)	6.2	15	0.27	27.2	12	11.02	17.3	14	0.94
4 (1800 ppm)	5.9	15	0.25	54.4	12	11.01	17.1	14	0.93

*each value is the average of readings from 2 locations within the pit

Pig performance

In Replicate 1, the feed intake of the pigs in each treatment room was monitored by weighing the feed supplied to each feeder daily and tracking the number of pigs in each pen. The growth of the pigs was also monitored by weighing all the pigs at the start of each replicate, mid-way through the replicate, and at the end of the replicate. As can be seen in Figure 4, the pigs in all treatment rooms performed very well, with average daily feed intake ranging from 3.1 to 3.6 kg/day. Additionally, the treatment did not show adverse effect on feed intake; thus the monitoring of this parameter was discontinued in succeeding replicates.

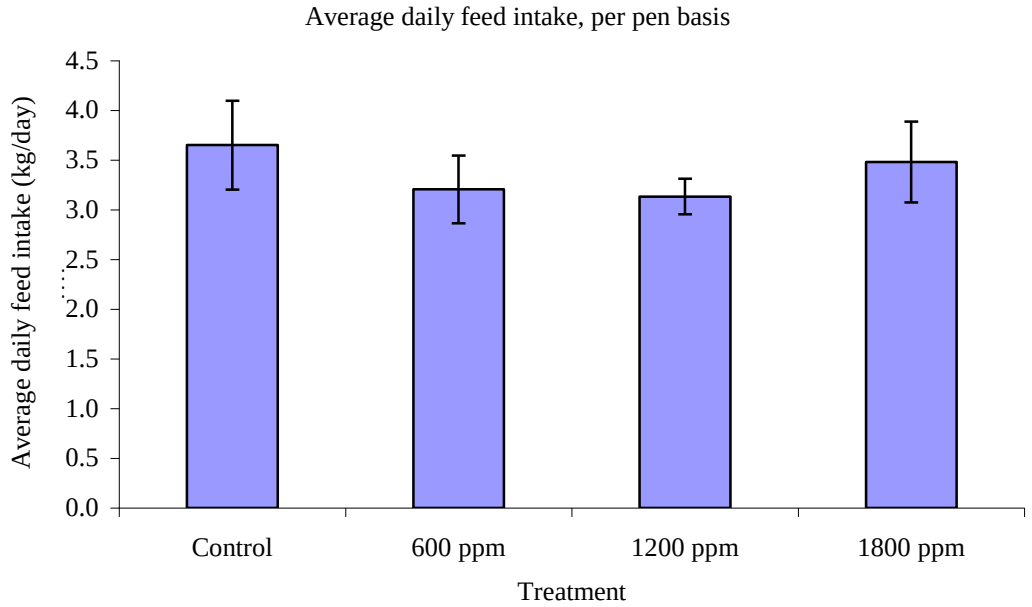

Figure 4. Average daily feed intake of the pigs in the different treatment rooms (n=6).

Summarized in Table 6 are the number of pigs used for each treatment, the average pig weights, and the average gain in bodyweight throughout the replicates. The pigs in the treatment rooms performed well in terms of average daily gain per room and was not significantly ($p>0.05$) impacted by the sulfate levels in the drinking water. For all replicates, the average daily gain ranged between 0.86 to 1.12 kg/day.

Table 6. Average pig weights and average daily gain.

	Total number of pigs (5 replicates)		Average pig weight (kg)			Average daily gain per room (kg/day)	
Treatment	**Start**	**End**	**Start**	**Mid**	**End**	**Mean [a] (n=5)**	**SE**
1 (Control)	300	294	41.1	75.4	100.1	1.00	0.04
2 (600 ppm)	300	296	41.5	75.1	98.5	0.98	0.04
3 (1200 ppm)	300	294	41.6	76.1	99.7	0.98	0.04
4 (1800 ppm)	300	292	41.2	74.8	99.4	1.00	0.03

[a] – Treatment mean values not significantly different ($p>0.05$)

Water use

Water disappearance was monitored by taking daily readings from water meters installed on the water supply line to each room. The average daily volume of water used in each room (Figure 5) was significantly ($p<0.01$) affected by the treatment applied, although the trend was not linear against water sulfate level. There was no clear observable trend to indicate whether high-sulfate drinking water tended to increase water use.

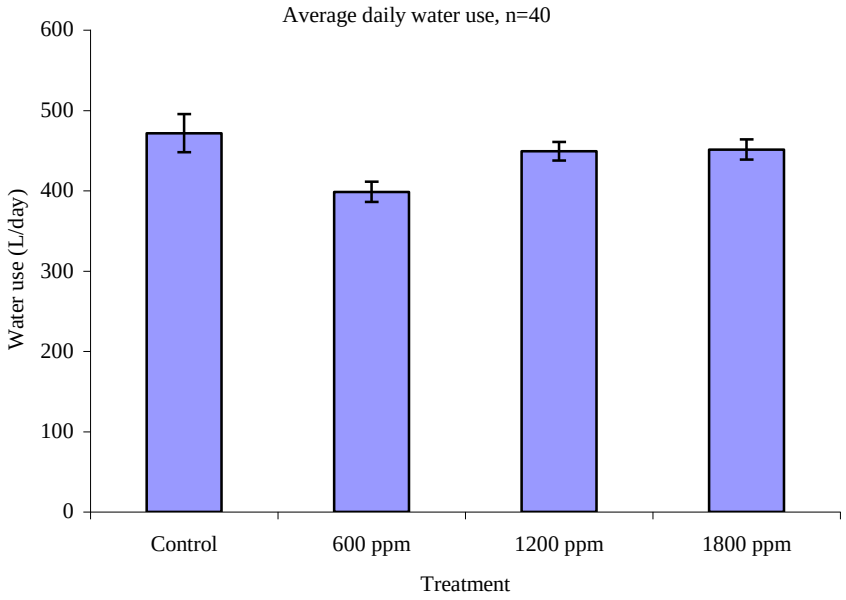

Figure 5. Average daily water use in the different treatment rooms (n=40).

Feed analysis

Feed samples collected from the feeders in each room were analyzed and results shown in Table 6. The main ingredients monitored did not vary significantly ($p>0.05$) between the treatments, indicating that the pigs were given similar diets throughout the study.

Table 6. Summary of results of analysis of feed samples (% as fed, n=8).

	Moisture		Protein		Sodium		Phosphorus		Potassium		Calcium		Magnesium		Sulfur	
Treatment	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
1 (Control)	11.25	0.27	18.96	0.6	0.20	0.01	0.56	0.04	0.63	0.02	0.82	0.07	0.19	0.01	0.22	0.01
2 (600 ppm)	11.36	0.26	18.79	0.62	0.20	0.01	0.56	0.04	0.62	0.02	0.80	0.07	0.18	0.01	0.22	0.01
3 (1200 ppm)	11.33	0.23	18.89	0.65	0.20	0.01	0.56	0.04	0.62	0.03	0.82	0.06	0.18	0.01	0.22	0.01
4 (1800 ppm)	11.19	0.23	19.04	0.65	0.20	0.02	0.57	0.04	0.62	0.03	0.85	0.06	0.19	0.01	0.22	0.01

Discussion

This study showed that supplying pigs with high-sulfate drinking water (up to 1800 ppm) had no adverse impact on the levels of certain gases (NH_3 and CO_2) and on odor emissions. No measurable impact on levels of H_2S gas was observed when manure was undisturbed. However, high-sulfate drinking water could potentially lead to generation of higher H_2S gas levels when manure slurry is agitated, such as during pit-plug pulling.

Except for the levels of sulfur, the nutrient properties of fresh manure from the treatment rooms were generally not affected by the amount of sulfate in the drinking water. Fresh manure generally had higher nutrient levels compared to stored manure. Stored manure from pigs given high-sulfate water tended to retain nutrients better compared to stored manure from pigs with low-sulfate water.

Pig performance was not adversely affected by high levels of sulfate in the pig's drinking water. During the study, no notable incidence of scouring or diarrhea was observed. This was reported in previous similar studies although in those instances, weanlings were used (Maenz et a., 1994; Veenhuizen et al., 1992).

It can be concluded that elevated levels of sulfur intake from water had no adverse impact on manure nutrient composition, odor and gas (NH_3 and CO_2) emissions or on the performance of grower-finisher pigs. Thus, for water sources with up to about 1600 to 1800 ppm sulfate content, water treatment is not necessary. However, when using high-sulfate drinking water, proper measures should be in place to consider the increased potential for generating high spikes in H_2S levels during manure handling operations. These results support the possibility of constructing pig barns in locations where the available ground water is high in sulfate (up to 1600 ppm), without concern for adverse impact on growing-finishing pig performance, odour emissions, and manure nutrient value.

Lay Interpretation

To assess the impact of inputs to the pig on air quality and manure management, a study was conducted to assess the effect of varying sulfate levels in drinking water on odor and gaseous emissions and on swine manure properties. Sulfur intake is of particular concern because out of the 10 most odorous components of swine odor identified so far, six were found to contain sulfur. Five experimental replicates were conducted in four separate grow-finish rooms given varying levels of sulfate in drinking water, ranging from about 80 ppm up to about 1800 ppm sulfate. Each treatment was applied over 8 weeks to a total of 300 pigs starting at starting weight of around 40 kg. Results showed that high sulfate levels in water had no adverse impact on pig performance, on odor and gas emissions, and on manure nutrient properties. However, the use of drinking water with high-sulfate levels could potentially lead to generation of higher levels of H_2S when manure slurry is agitated, thus proper measures should be in place to account for this possibility. Overall, this study showed that water treatment may not be necessary when using water sources with up to 1800 ppm sulfate content, without resulting to adverse environmental effects. This can pave the way for the use of water with sulfate levels exceeding the existing limit for livestock water, and possibly allowing the pork industry to expand to areas previously considered as having water sources with less than ideal water quality.

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