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IMPACT OF SULPHATE LEVELS IN SWINE DRINKING WATER ON MANURE NUTRIENTS AND EMISSIONS

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Abstract: The effect of poor quality water available in many swine production areas on air emissions and manure nutrient properties is largely unknown. Because drinking water can contribute significantly to the sulphur intake of pigs, and sulphur was identified as an integral component of the most odourous gases identified in swine odour, experiments were conducted to determine the impact of varying sulphate levels in drinking water on manure emissions, nutrient properties, and pig performance. Results from two completed replicate trials showed that increased levels of sulphate in drinking water tended to result in higher odour concentrations, but had no marked effect on the levels of other gases monitored (ammonia, carbon dioxide, hydrogen sulphide). Manure nutrient levels were higher in stored manure taken from rooms provided with high-sulphate drinking water. Feed intake and average daily gain of pigs were not affected by increasing water sulphate levels. These preliminary trends and observations will have to be verified after all of the five planned replicate trials are completed.

Keywords: Air quality, odour emissions, drinking water, manure nutrients, sulphate, swine

Introduction

Odour and gaseous emissions from swine operations is a major environmental concern for the pork industry. These emissions consist of thousands of compounds, only about 400 of which have been identified so far (Schiffman et al, 2001). Out of the 10 most odourous components of swine odour identified, six are sulphur-containing compounds (O'Neill and Phillips, 1992). Because odour is produced mainly from anaerobic breakdown of unutilized nutrients excreted by pigs, manipulating the pig intake level of nutrients that are strongly associated with odour (such as sulphur) has been explored as a potential means for mitigating gaseous emissions (Whitney et al., 1999). However, further studies are needed to fully assess the extent of the impact of the pig's sulphur intake levels on air quality and on manure characteristics, especially under actual production conditions.

Drinking water can contribute significantly to sulphur intake of pigs. One major source is the sulphate content in water supplies, which has been found to exceed 1600 mg/L in certain geographic areas (McLeese et al., 1991; Veenhuizen, 1993). Studies showed that pigs offered water with increased sulphate 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 (Patience et al., 2004), but average daily gain, feed intake, gain-to-feed ratio, and nutrient digestibility were not compromised. Pigs 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 regarding water quality that could be related to odour and gas emissions, when considering sites for new barn facilities and developing water sources for swine operations.

Objectives

The overall goal of this study is to assess the impact of animal drinking water quality on swine manure nutrients and on air emissions. Specifically, this study aims to determine the effect of varying input levels of sulphur in drinking water on odour and gaseous emissions and on swine manure properties.

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

1. will elevated levels of sulphur intake from water affect manure nutrient composition, odour and gaseous emissions, and pig performance?

2. at what level of sulphate in drinking water should water treatment be considered to mitigate potential adverse environmental effects?

Materials and Methods

Based on the above hypothesis, the basic approach of this study was to compare air emissions and properties of manure from pigs provided with water with different levels of sulphate with those from pigs given low-sulphate water and standard production diets.

Description of facilities

This work was conducted at Prairie Swine Centre Inc. (PSCI) barn facilities in Saskatoon, Saskatchewan, Canada, using four (4) all-in-all-out grow-finish rooms of similar construction.

Each room held 60 pigs in 6 pens (10 pigs per pen); each pen had a partially-slatted floor (1/3 of pen area) over a 0.61 m-deep manure pit. Each room was mechanically ventilated, with airspace totally isolated from adjacent rooms.

Treatments

Each room was randomly assigned to one of four treatments and was reassigned again in subsequent replicate trials. The treatments are summarized below:

Treatment 1: Standard diet (NRC requirement) + normal water (low-sulphate content)

Treatment 2: Standard diet + 600 mg/L sulphate water

Treatment 3: Standard diet + 1200 mg/L sulphate water

Treatment 4: Standard diet + 1800 mg/L sulphate water

Treatment 1 was the control, in which pigs were given standard production diets and low-sulphate drinking water (~75 mg/L sulphate content). The other treatments were chosen to determine the impact of varying levels of sulphate in water. Based on estimated feed and water intake, and estimated proportion of dietary sulphur utilized by the animals for growth and metabolism, Treatments 1 to 4 corresponded to a daily intake resulting in the amounts of 2.0, 3.1, 4.2, and 5.4 g S per day, respectively, that may potentially be excreted in urine and faeces 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 sulphur intake.

For each replicate trial, a total of 240 finishing pigs at a starting weight of about 50 kg were distributed equally to the four rooms. At the start of each trial, animals were weighed and assigned to rooms such that the average starting weight across all rooms were within ±2 kg of each other. Additionally, the pigs were segregated by sex such that each pen were either males or females only, and each room had an equal number of pens of males and females. Each trial ran for 8 wks, which included an initial 2-wk acclimation period followed by 6 wks of data collection from each room. Five (5) replicate trials were planned; each room was cleaned thoroughly between replicates and room was randomly reassigned to treatment on each subsequent trial.

Data collection

The parameters monitored include: feed and water properties, odour emissions, gas (ammonia (NH_3), hydrogen sulphide (H_2S), carbon dioxide (CO_2)) concentrations, manure nutrient composition, water and feed intake, and pig performance. Additional air quality parameters such as relative humidity, temperature, and ventilation rates were monitored in each room. The physico-chemical properties of the manure in the pits were also characterized by taking oxidation-reduction potential (ORP), pH, and temperature measurements of the manure pit in each room during manure sample collection because these parameters can directly influence the emission of gases from the slurry. The sampling and monitoring schedule for each parameter were as follows:

Gases: NH_3, CO_2 – continuous direct readings every 60 min over 24 hr

H_2S – weekly measurement with H_2S monitor (over 8 hrs on day 6 of each week)

Odour: bagged samples on day 6 of wk 4, 6, 8

Water analysis: composite sample from drinkers per room on wk 0, 4, 8

Feed analysis: composite sample from feed bins on wk 0, 8

Manure composition: composite sample per room taken on wk 4, 6, 8

Water intake: water meter readings taken daily

Air quality parameters (T, RH) and ventilation rate: continuous readings every 60 min over 24 hr

Pit properties and manure depth: multi-site readings taken on wk 4, 6, 8

Pig bodyweight: pig weights taken at wk 0, 5, 8

Feed intake: daily weighing of feed added to each feeder, feeder weigh-back on wk 5, 8

Normal production practice requires emptying of the manure pits in these swine rooms every 2 wks. To evaluate the effect of the treatments on manure properties and gaseous emissions from manure under long-term storage, manure samples (30 L) from each room were taken just before emptying the pits, starting on wk 2. These manure samples were transferred into a 170-L barrel (one for each room, total of 4 barrels per trial). The barrels were filled in the same manner until wk 8 and stored for additional 5 wks after the data collection from each room to simulate long-term manure storage. Each barrel was monitored for odour and gaseous emissions as well as for manure composition on wk 6, 8, and 13.

Experimental set-up and analytical procedures

A water dosing system (Model A10-10%, Dosmatic USA Inc., Carrollton, Texas) was used to deliver water with desired sulphate levels to specific experimental rooms. The dosing system was used to blend artificially-formulated high-sulphate water with the existing low-sulphate water supply to achieve the desired sulphate level. The blended drinking water was constituted such that it contained the same proportion of ion components typically found in naturally-occurring high-sulphate water to account for the potential interaction of these various constituents that may occur in natural water.

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

An H_2S monitoring instrument (Model PacIII, Dräger, Lübeck, Germany; reproducibility of 5%) was used to measure the H_2S levels in each room on day 6 of each week. Additionally, gas samples were collected in Tedlar bags both for odour analysis and for determination of H_2S concentration using a gas chromatograph (GC)-based analytical method for reference. This GC system (5890 Series II Gas Chromatograph, Hewlett Packard) was configured according to the specifications of the U.S. EPA Method 15 for determination of hydrogen sulphide, carbonyl sulphide and carbon disulphide emissions from stationary sources (EPA, 2004). The odour sample bags were sent on the same day to University of Alberta olfactometry laboratory for odour analysis based on the European Standard, EN 13725: Air quality - determination of odour concentration by dynamic olfactometry.

Results

The combined data presented below covers the results from the first two completed trials out of five planned replicate trials.

Treatment and room conditions

The mean sulphate levels, ventilation rate, room temperature, and relative humidity in each room are summarized in Table 1. Water sulphate levels were determined from analysis of water samples sent to a commercial analytical laboratory. As can be seen in Table 1, the mean water sulphate levels were close to the desired values; wide variability was evident for the high-sulphate rooms, which necessitated more frequent water sampling during the initial week of the trial to fine-tune the settings of the water dosing system. Overall, the different treatment rooms were maintained under similar environmental conditions as can be seen from the close mean values for ventilation rates, temperature, and relative humidity readings across all rooms. However, the ventilation rates in all rooms during the second replicate trial (Rep2) were higher compared to those from Rep1, mainly due to increased prevailing ambient temperatures during Rep2.

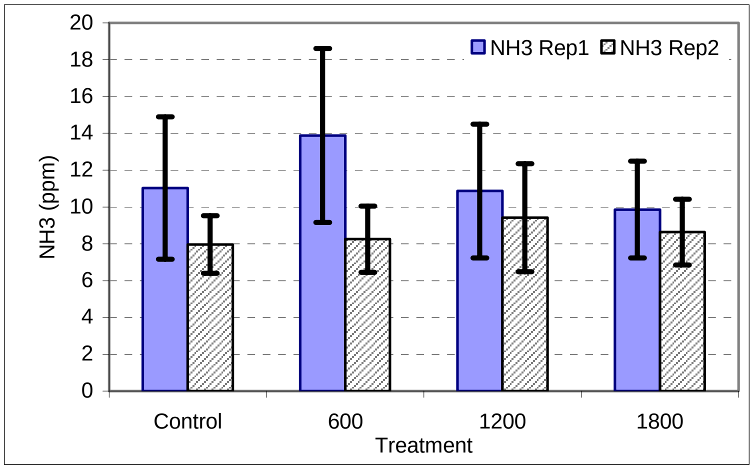
Table 1. Average water sulphate levels, ventilation rate, temperature, and relative humidity in the treatment rooms.

	Treatment	Control		600-ppm Sulphate		1200-ppm Sulphate		1800-ppm Sulphate	
Parameter	Rep#	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Water sulphate (ppm)	Rep1	75.5	0.7	591.2	168.7	1114.7	353.0	1777.0	1046.6
	Rep2	77.7	4.2	607.8	52.7	948.8	131.9	1908.3	546.6
Ventilation rate (L/s)	Rep1	402.2	71.1	425.1	69.3	439.2	68.0	476.1	58.6
	Rep2	1150.3	948.4	1163.2	979.3	1156.3	868.0	1053.1	825.8
Room temperature (ºC)	Rep1	15.3	1.0	16.6	1.1	15.9	1.3	16.2	1.6
	Rep2	17.0	2.7	16.1	2.7	16.9	2.6	17.3	2.4
Room RH (%)	Rep1	49.9	5.5	54.8	4.7	52.7	4.1	52.6	3.7
	Rep2	50.2	10.4	49.8	8.5	48.7	12.3	50.9	8.8

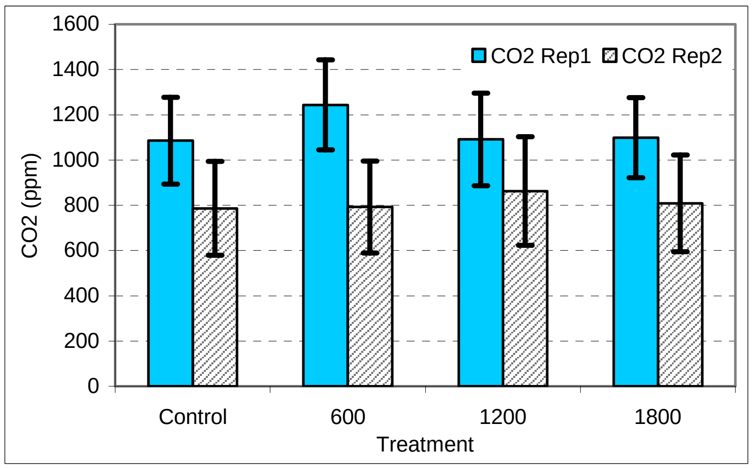
Gas concentrations

As shown in Figure 1, the NH_3 and CO_2 levels were not markedly different between the treatment rooms, although the room with 600-ppm sulphate seemed to have slightly higher levels for both gases compared to the other rooms during Rep1. However, the mean gas levels in all rooms were close to each other during Rep2. Additionally, Rep2 gas levels were lower compared to Rep1 values; this can be attributed to higher ventilation rates in all rooms during Rep2 because of increased ambient temperatures (see Table 1).

Initial day-long monitoring of H_2S concentrations in the experimental rooms showed that the H_2S levels were typically below the detection limit of the H_2S monitoring equipment used (Draeger PacIII). However, on the day that the manure pit-plug was pulled to clear the manure from the pits of each room (every two weeks), the H_2S monitor showed H_2S readings during the approximately 15-min period in which the manure was agitated. A typical plot of the H_2S levels during the plug-pulling day is shown in Figure 2; a similar pattern was also monitored in the other treatment rooms, with peak readings ranging from 5 to 15 ppm H_2S. These values were verified by the readings from the GC-based reference analytical method on bagged gas samples collected from the rooms during day-long monitoring and during pit-plug pulling events. Based on these observations, day-long monitoring of H_2S levels was discontinued; instead, the H_2S monitors were set in place only during each plug-pulling event in each room.



(a)



(b)

Figure 1. Concentrations of (a) ammonia and (b) carbon dioxide measured in different treatment rooms.

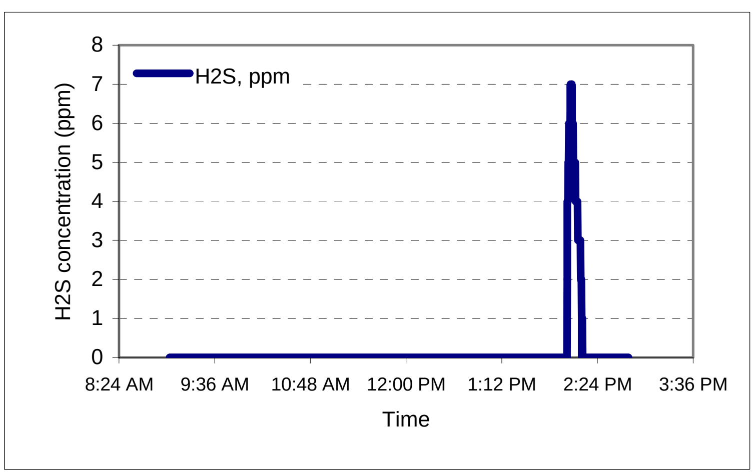


Figure 2. Typical hydrogen sulphide levels monitored in a treatment room, showing no detectable values during most of the day, except during the plug-pulling event (indicated by the spike in H_2S levels).

Odour levels

Results of odour analysis of samples from the two completed replicates shown in Table 2 indicated that odour concentration (Odour Unit/m^3) tended to be higher in treatment rooms with high sulphate levels in drinking water (Figure 3). This was more evident in the barrels which held stored manure; interestingly, the treatment with 600-ppm sulphate showed the lowest odour concentration levels, even lower than the Control. Because of the wide variability in these measurements, statistical tests will be conducted after all the replicate trials are completed to verify these observed trends.

Table 2. Odour levels in treatment rooms and in barrels used to simulate long-term storage (n=4).

	Room				Barrel			
Treatment	OU/m^3	SD	Hedonic tone	SD	OU/m^3	SD	Hedonic tone	SD
Control	1553.7	529.2	2.2	0.5	3738.0	1503.8	2.4	0.5
600	1680.3	751.0	2.0	0.5	2101.9	1520.8	2.6	0.2
1200	1672.2	810.4	2.0	0.4	6575.0	5233.4	2.7	0.4
1800	1998.4	521.8	2.1	0.4	6088.0	4452.0	2.7	0.8

The hedonic tone score is a measure of the (un)pleasantness of the odour using a 9-point scale which ranges from '9 - Like extremely' down to '1 - Dislike extremely'. As can be seen from Table 2 and from Figure 4, samples taken from the high-sulphate treatment rooms have lower hedonic tone scores, indicating more unpleasant odour compared to the control samples. However, samples from the barrels have higher hedonic tone scores compared to the room samples, even though the odour concentrations from the barrels were higher (Figure 3). Additionally, the hedonic tone scores for the high-sulphate barrels were higher compared to the control samples, indicating that these samples were less unpleasant compared to the control samples and even when compared to the room samples. These observations would have to be verified as more samples are collected as the study progresses.

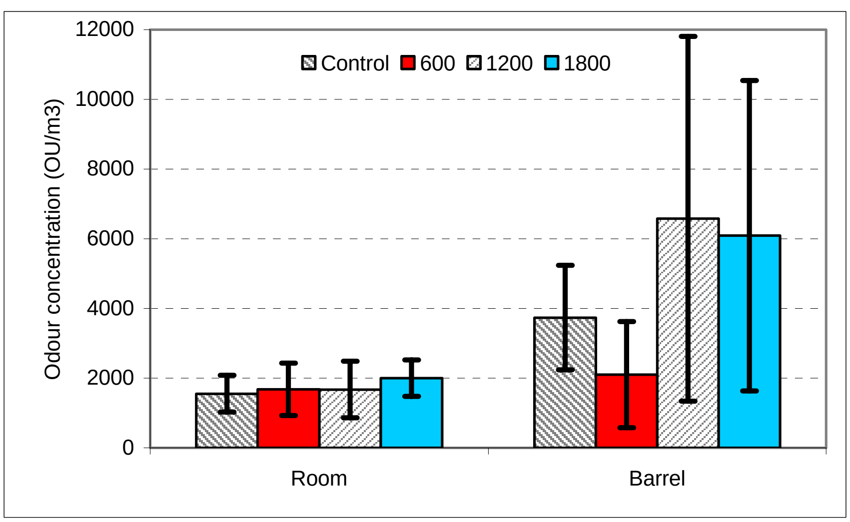


Figure 3. Odour concentration of samples from the treatment rooms and the manure barrels used to simulate long-term manure storage (n=4).

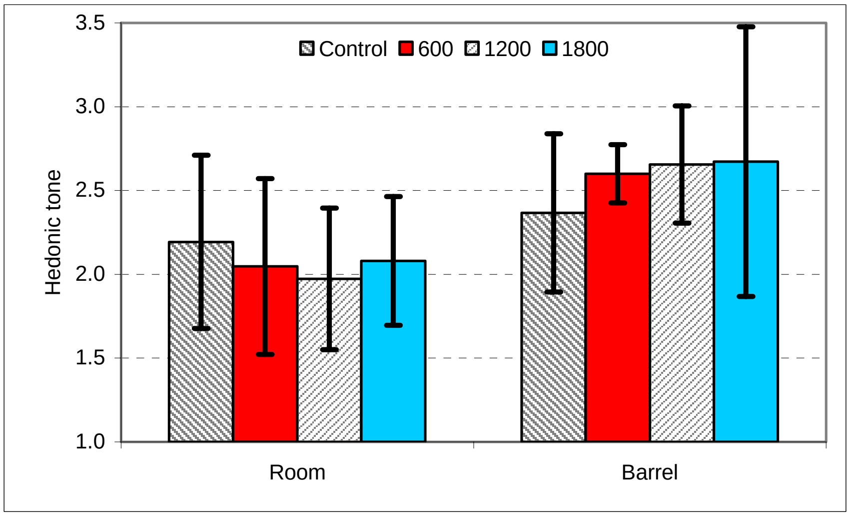


Figure 4. Hedonic tone of samples from the treatment rooms and the manure barrels used to simulate long-term manure storage (n=4).

Manure nutrient properties

Results from analysis of manure samples collected from the manure pit of each room and from the barrels used to simulate long-term manure storage were plotted in Figures 5 and 6. In general, the manure nutrient levels tended to be higher in samples from rooms and barrels with sulphate added to the drinking water, and this was more evident for the stored manure (Fig. 6). Among the different treatment levels, the room with 600-ppm sulphate tended to have higher nutrient levels compared to the other rooms, although sulphur levels increased with increasing levels of sulphate added to the drinking water, as expected. Additionally, nutrient levels tended to be higher for the samples taken from the room manure pits compared to those in the stored manure, but these levels were in the upper range of published typical swine manure nutrient composition values (Schoenau, 1997).

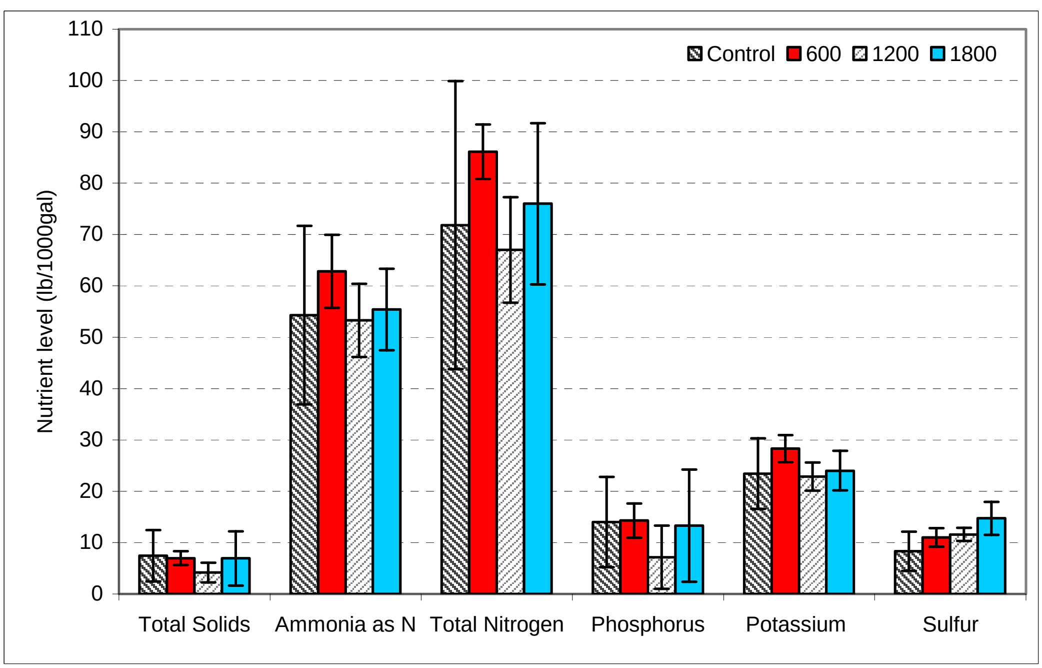


Figure 5. Nutrient properties of manure in the pits of the treatment rooms (n=6).

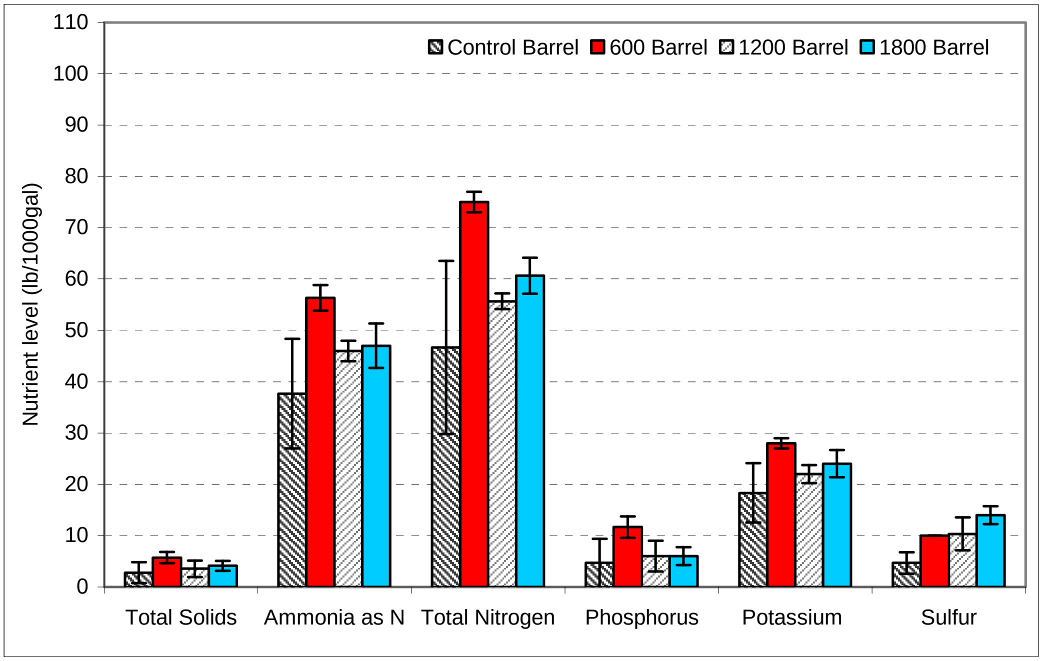


Figure 6. Nutrient properties of manure from the barrels used to simulate long-term storage (n=3).

Water use

The total amount of water supplied to each treatment room was monitored by taking daily readings from each water meter installed on the water supply line to each room. The average daily volume of water used in each room was calculated and shown in Figure 7. The average water use tended to be higher in rooms with high sulphate levels in the drinking water, although this can not be directly translated to increased water consumption by the pigs because water wastage was not accounted for. In Figure 2, the unusually high water use for Rep2 in the Control room was due to a leakage of one of the drinkers in the room, which was found and fixed midway through the replicate. The rooms were re-assigned on each subsequent trial to take into account potential room effects.

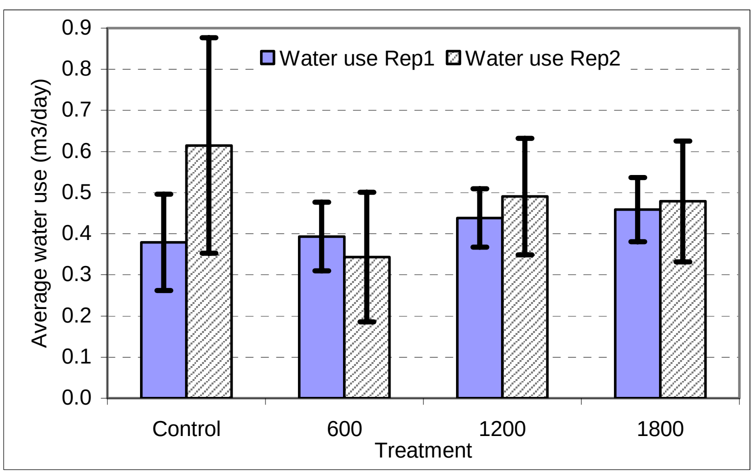


Figure 7. Average daily water use (m^3/day) in the treatment rooms over the two trials.

Pig performance

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 trial, mid-way through the trial, and at the end of the trial. As can be seen in Figure 8, 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 seemed to have no adverse effect on the feed intake, thus monitoring of this parameter was discontinued in succeeding replicate trials because of the intensive labour required to collect this data; even without this data, the final data set that will be used in determining the impact of sulphate intake levels on manure emissions and properties will not be affected.

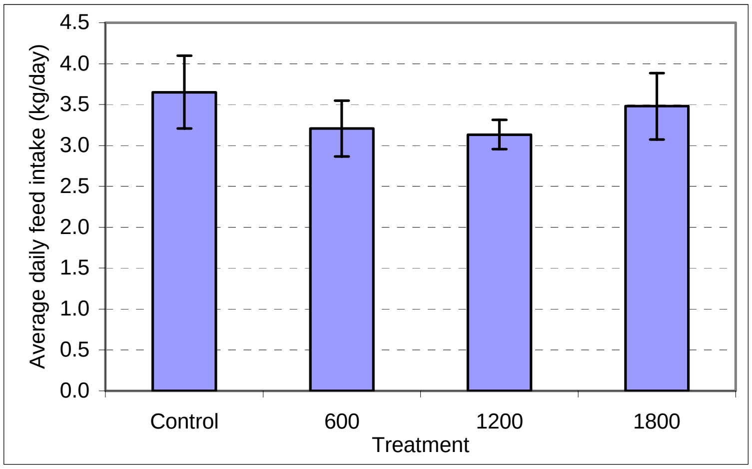


Figure 8. Average daily feed intake of the pigs in the different treatment rooms.

The pigs in all treatment rooms also performed exceptionally well in terms of gain in bodyweight throughout the trials. The average daily gain ranged from 0.98 to 1.12 kg/day, and seemed to have not been adversely impacted by the sulphate levels in the drinking water (Figure 9). For the two completed replicate trials, a total of 480 pigs were used, starting at an average weight of 42.6 kg and were taken off the trial 8 weeks later at an average weight of 102.5 kg.

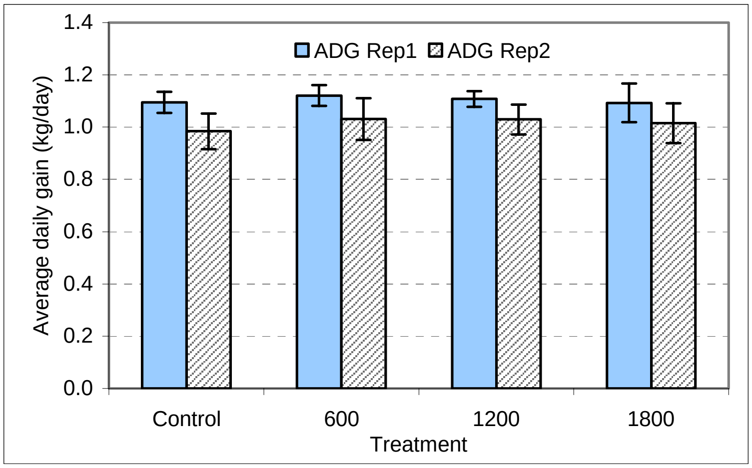


Figure 9. Average daily gain of the pigs in the different treatment rooms.

Concluding remarks

Experiments were conducted to gain a better understanding of the relationship between swine drinking water quality and manure emissions and nutrient properties. Increased levels of sulphate in drinking water tended to result in higher odour concentrations, but had no marked effect on the levels of other gases monitored (ammonia, carbon dioxide, hydrogen sulphide). Manure nutrient levels were evidently higher in stored manure taken from rooms provided with high-sulphate drinking water. Pig performance was not affected by varying water sulphate levels. The observations and trends indicated above are considered preliminary and will have to be verified after all the trials are completed.

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