Final Project Report

Manure Gas Risks Associated with Gypsum Bedding at Dairy Farms

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Project Manager: Eileen Fabian-Wheeler

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The central goal of this demonstration project was to collect on-farm observations during routine manure storage agitation operations and provide practical information to practitioners relative to potentially dangerous manure gas emissions, especially hydrogen sulfide. Of particular concern were farms managed with gypsum bedding. A promising manure additive was evaluated for ability to reduce hydrogen sulfide release. Personal-safety gas monitors were featured. Target audiences included dairy and livestock producers, professional manure applicators, and agricultural support industries. The project successfully completed all four primary deliverables:

1. A written *document* with recommendations on how project findings may be incorporated into NRCS technical guidelines.
2. *Training* of NRCS engineers in safety, air quality instrument use, and environmental issues associated with open-air manure storages.
3. A non-technical *brochure* for delivery to farmers as NRCS personnel work with them on issues associated with gypsum bedding use and manure handling.
4. *Events* to attend included two webinars and on-farm field day with technical findings suitable for producers and professionals.

In addition, several newspaper stories and trade press articles featured project findings and recommended solutions to improve worker safety around manure storage agitation events. Project findings were also shared at agricultural venues, professional and technical meetings via presentations, papers, and posters.

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Chapter 1 Executive Summary

Recycled gypsum products can provide a cost-effective bedding alternative that is popular among many dairy producers. Manufacturers report reduced odors, moisture and bacteria in the stall environment when compared to traditional bedding and farmers point to agronomic benefit of the gypsum bedding in the manure. Agitation of stored manure promotes release of volatile gases that typically contain ammonia, methane, hydrogen sulfide (H_2S) and various odorants. Prior to the start of this project, incidents anecdotally linked injury and death of people and cattle to dangerous levels of H_2S emission released from movement of manure containing gypsum-based bedding. Gypsum ($CaSO_4 \cdot 2H_2O$) provides a sulfate source that can be converted to hydrogen sulfide under anaerobic manure storage conditions. In order to investigate and potentially mitigate elevated H_2S release at farms using gypsum bedding, a manure amendment compound was identified that reduced H_2S release at manure agitation. Of interest to customers of this project, low-cost personal gas monitors were demonstrated for improving safety around hazardous gas environments. Customers included dairy producers, manure haulers, agricultural service professionals, design engineers, safety personnel, product suppliers, and educators.

> The primary project **goal** was accomplished: *To measure manure gas risks associated with gypsum bedding at dairy farms using appropriate technologies and disseminating such findings in user-friendly materials to the agricultural community*.

The **method** employed was a "full-scale on-farm demonstration" to determine efficacy of a manure amendment in reducing hydrogen sulfide risk. Observations at ten dairy farms from three management categories were compared: those that used (1) traditional, organic bedding; (2) gypsum-based bedding, and (3) gypsum-based bedding amended with a commercial product added to the manure. Portable gas meters placed around the perimeter of each dairy manure storage recorded H_2S concentrations every minute prior to and during nineteen agitation events during fall and spring hauling seasons. Each farm operator wore a personal safety gas monitor to record their exposure to the heavier-than-air H_2S gas. A detailed farm characterization documented manure characteristics and storage design parameters, manure handling practices and manure storage inputs.

Physical results from measurement events show that manure storage agitation at farms using gypsum in bedding were capable of producing H_2S concentrations that were considered immediately dangerous to life and health (above 100 ppm). Increasing gypsum use significantly increased cumulative H_2S concentrations. But not all gypsum

farms experienced hazardous conditions at all times. Farms that used the manure amendment reported to reduce H_2S concentrations, showed reduced H_2S concentrations compared to gypsum farms not using any amendment. Unfortunately, this effect was not statistically significant. However, this promising trend and effectiveness of other additive compounds offers promise for a simple amendment-based solution.

No farm practice, manure characteristic, or environmental condition consistently and significantly affected H_2S production and release from storage. However, empirical observations indicated lowered H_2S concentrations near storages during agitation when manure had been recently agitated or transferred from temporary pits before placement in long-term storage. Wind directing manure gas into areas where emissions may be trapped by proximate structures increased H_2S concentrations near the storage presumably due to reduced dilution with ambient air inhibiting dissipation. Notably a storage containing gypsum bedding and no surface crust, showed low hydrogen sulfide release during agitation.

Operator safety is enhanced by managing manure agitation activity above grade. Hydrogen sulfide concentrations were notably lower inside a tractor cab. Operators who adjusted manure agitation equipment at grade or within the perimeter of the manure storage were exposed to harmful H_2S gas during our observations. There remains downwind risk for elevated H_2S gas even 33 feet away from manure storage agitation sites.

Primary project findings:

- Gypsum bedding adds sulfur to manure that can lead to dangerous levels of hydrogen sulfide gas emission at agitation; but not all farms using gypsum had safety problems.
- Manure storage agitation creates greatest gas levels during the first hour of agitation.
- Crust-free manure and additives that inhibit crust formation seem to allow for continuous low level H_2S release lowering risk at agitation.
- Gypsum benefits for cow bedding and agronomic values must be balanced against the potential gas hazard.

Recommendations include:

1. Position operators above ground-level and away from edge of manure storage during agitation of manure storage that contains gypsum bedding.
2. Save lives by requiring operators working around manure storages with gypsum bedding to wear a hydrogen sulfide personal gas monitor.
3. Keep non-essential people (and cattle) away during agitation, especially children who are at increased risk, as H_2S concentration is greatest close to the ground.
4. Do not use gypsum bedding with under-barn manure storage. Potential is high for release of dangerous level of H_2S during any manure movement under such conditions.

Chapter 2 Introduction

Overview: Recent lethal and near-lethal exposures of humans and dairy cattle to unidentified conditions during open-air manure storage agitation prompted investigation. One seemingly-innocent common factor was gypsum bedding being used for good purpose in the barn for animal comfort and economic benefit. Yet could this be the culprit, based on anecdotal and preliminary laboratory findings? An on-farm project documented conditions that operators and nearby surroundings were exposed to during manure storage agitation in relation to safe air quality conditions. Theory suggests that increased sulfur content in manure, such as from gypsum bedding, promotes elevated H_2S gas emission concentrations. However, no scientifically-defensible evidence has linked gypsum bedding use with dangerous levels of H_2S.

Project primary objective: *To measure manure gas risks associated with gypsum bedding at dairy farms using appropriate technologies and disseminating such findings in user-friendly materials to the agricultural community.*

This project was a collaboration among those who could help diagnose and offer practical solutions to the agricultural community. Partners included the family farms (ten dairies), material suppliers (USA Gypsum), safety equipment manufacturer (Industrial Scientific), manure storage design agricultural engineers (NRCS) and academic professionals (Penn State Extension safety and air quality).

Primary Project Personnel at Penn State:
Eileen Fabian (Wheeler)
Michael Hile
Davis Hill
Robert Meinen
Dennis Murphy
Robin Brandt
Hershel "Chip" Elliott
Vance Brown

Collaborators with significant roles:
Terry Weaver, USA Gypsum
Mike Platek, Industrial Scientific
Farm owners: ten family-owned dairies
NRCS Engineers

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Chapter 3 Background

3.1 Hydrogen Sulfide

Benefit to the agricultural industry is immediate and distinct when risk to dangerous conditions is reduced, particularly when those risks are invisible and often otherwise undetectable. In 1990, the agricultural industry had a death rate of 52 per 100,000 workers per year, more than five times the combined rate for all other industries in the United States (Purschwitz and Field, 1990). Injuries due to agricultural machinery, vehicles and animals constitute the majority of this statistic. Exposure to dangerous invisible levels of manure gases including hydrogen sulfide (H_2S), ammonia (NH_3), methane (CH_4), and carbon dioxide (CO_2) are rare but yield an extremely high mortality rate (Hallam, et al., 2012). Though manure gas is not the leading cause of injuries and fatalities, eliminating preventable accidents clearly benefits the industry.

Hydrogen sulfide is considered to be the most dangerous emission in manure gases because it is toxic and can cause serious injury or death during short-term exposures at high concentrations (>500 ppm). Routine day-to-day exposure at low concentrations (<10 ppm) (Costigan, 2003) can also cause injury. Because H_2S is heavier than air, it has the potential to displace fresh air in low lying areas causing an oxygen deficient environment where workers may be exposed. Exposure is especially dangerous in confined spaces. Despite the 'rotten egg' smell of this colorless gas, this warning sign disappears within a few minutes of exposure as olfactory senses are fatigued, thereby facilitating further exposure to unknowing victims above 100 ppm.

Conditions that promote H_2S production are a sulfur source and a population of bacteria in an oxygen deficient environment. Because there is little or no oxygen, the bacteria utilize the energy from the organic matter and reduce sulfate, which generates H_2S gas. These conditions commonly occur in dairy manure storage lagoons. When a manure storage crust is present, H_2S is trapped within the manure beneath a relatively impermeable crust layer. When the manure is agitated and the crust layer containment broken-up, high levels of various gases can be released into the environment, potentially creating a hazard for humans and/or livestock unfortunate enough to encounter the gas plume.

3.2 Gypsum bedding

Hydrogen Sulfide emissions have been implicated in incidents of human and animal death and injuries on dairy farms in Pennsylvania, New York and Maryland. Penn State Extension personnel have recorded elevated levels of H_2S at the sites of some of these tragedies. Anecdotally, some of these cases have been linked to farms that use gypsum as a bedding material. With removal of manure from the barn floor one to three times each day, bedding that spills from cow beds (including any added gypsum product) is carried with the manure from the barn floor into the manure storage. Gypsum (calcium sulfate - $CaSO_4 \cdot 2H_2O$) provides a sulfur source that potentially increases H_2S production from manure storage facilities.

Many farms that use gypsum bedding have never experienced problematic H_2S emissions. Moreover, farms that have reported episodes of injury do not experience elevated H_2S during every agitation event. Surprisingly, open-air dairy manure storages have shown problems with dangerous gas levels whereas in the past the fresh air surroundings seemed to have dampened impact of manure gas release.

Notably, there are many benefits favoring the use of gypsum bedding. Gypsum bedding amendments originate from recycled wastes generated during gypsum board (drywall) manufacturing and related construction. This diverts a landfill waste stream. Because it is highly absorbent, keeping the animals dry, is non-abrasive and discourages bacterial growth, gypsum is considered to be an excellent alternative bedding material (Drumnakilly, 2015; USA Gypsum, 2015). Richard Webster Nutrition (2013) asserts that gypsum bedding lowers nitrogen loss from the manure storage and retains it for use by crops when land applied. Additionally, as a recycled product in abundant supply year round is a valuable bedding and contributes to agronomic improvements at land application (USA Gypsum, 2015).

Prior to project initiation, scientific investigation had not proven gypsum use as bedding is directly linked to elevated H_2S emissions during manure mixing or transport. Other factors such as sulfur source from water or feed may contribute to elevated sulfur availability. Preliminary bench scale studies conducted at Penn State found higher H_2S concentrations during agitation from gypsum-amended manure, versus manure without gypsum, following several weeks in undisturbed storage. However, these initial trials performed as preliminary experiments suggested the need for further more detailed work at farm-scale, with scientifically defensible findings. Among the preliminary findings was a manure amendment that reduced the burst of H_2S release at manure agitation. Accordingly, the USDA-NRCS in collaboration with private sector contributors and Penn State University launched a farm-scale project incorporating ten farms to demonstrate use and affordability of this manure amendment to reduce H_2S emissions. This project

demonstrated the practicality of personal safety instrumentation to inform and protect farm workers during agitation of manure storages.

In summary, the goals of this demonstration project were to:

1. Explore the impact of a promising manure additive to reduce potential for unhealthy bursts of hydrogen sulfide during manure agitation on farms using gypsum bedding.
2. Demonstrate personal H_2S gas monitors as air quality safety instruments, and
3. Disseminate such findings in user-friendly materials to agricultural producers, manure haulers, and NRCS professionals

3.3 Industry Concern

High levels of hydrogen sulfide (H_2S) gas in and around manure storage areas on dairy farms can present significant health risks to humans and livestock (Donham et al., 1982). Hydrogen sulfide is a hazardous, flammable, colorless gas known by its characteristic rotten egg odor. Human sensory detection is an unreliable indicator for presence of H_2S because prolonged exposure fatigues the sense of smell. Low concentration exposure can burn the respiratory tract and cause swelling around the eyes. At high concentrations, H_2S exposure inhibits respiration and can cause death according the Occupational Safety and Health Administration guidelines (OSHA, 2005). Physical effects for various H_2S exposure levels are summarized in Table 3-1.

Table 3-1: Physical effects of exposure to various levels of H_2S (ANSI, 1972)

H_2S Concentration (ppm)	**Physical Effect**
0.13	*Minimal perceptible odor*
4.6	Easily detected, moderate odor
10	Beginning eye irritation
27	Strong, unpleasant odor, but not intolerable
100	Coughing, eye irritation, loss of sense of smell after 2 to 5 minutes
200-300	Marked conjunctivitis (eye inflammation) and respiratory tract irritation after one hour of exposure
500-700	Loss of consciousness, cessation (stopping or pausing) of respiration, and death
1,000-2,000	Unconsciousness at once, with early cessation of respiration and death in a few minutes. Death may occur even if individual is removed to fresh air at once

According the U. S. Department of Labor (1997), occupational H_2S exposure must not exceed 20 ppm unless no other measurable exposure has occurred during the 8-hour work

shift. Exposure may exceed 20 ppm, but not more than 50 ppm, for a single time period up to ten minutes. At 100 ppm, H_2S is considered an immediate danger to life and health.

Records of human deaths (Dai and Blanes-Vidal, 2013; Hooser et al., 2000) and animal deaths (Maebashi et al., 2011; Oesterhelweg and Püschel, 2008) have been attributed to dangerous levels of H_2S gas from manure storages. Multiple incidents involving deaths in manure storages in the mid-Atlantic region have been reported (Torres, 2012, Harrison, 2012). Penn State extension personnel have reported elevated levels of H_2S shortly after these incidents occurred. The elevated levels of H_2S were often linked to farms that use gypsum-based bedding. Penn State Extension personnel have recorded levels of H_2S gas during manure agitation ranging from <10 ppm to over 300 ppm. Concentrations >50 ppm were measured nearly an hour after agitation was initiated.

In 2012, the Natural Resources Conservation Service (NRCS) issued a news release warning farmers of the potential for dangerous levels of H_2S during agitation of their manure storage (NRCS, 2012). In the United Kingdom, H_2S concentrations > 2,700 ppm have been observed on farms using gypsum as a bedding material (RREC, 2013). Parts of the United Kingdom have considered restricting or banned gypsum use as animal bedding (SEPA, 2012; EA, 2012; RWN, 2013).

Research is very limited regarding H_2S production of dairy and cattle manure (Andriamanohiarisoamanana et al., 2015). Moreover, dangerous H_2S levels on dairy farms using gypsum bedding have not been reported in the scientific literature. Notably, the majority of work performed on manure H_2S production originates from the swine industry (such as in Blanes Vidal et al., 2009; Bicudo et al., 2002; Blunden and Aneja, 2008).

3.4 Hydrogen Sulfide Generation

Conditions that promote H_2S generation in manure include a population of sulfur reducing bacteria and sufficient sulfur (S) content in an anaerobic environment. Sulfate reducing bacterial include *desulfovibrio, desulfatomaculum, desulfobacter, desulfococcus, desulfonema* and *desulfosarcina* (Atlas and Bartha, 1987). These anaerobes utilize the energy produced from the breakdown of organic matter and transfer electrons from the organic substrate to the most oxidizing electron acceptor in the environment to maximize the energy yield. Table 3-2 lists the oxidation-reduction potential hierarchy for common electron acceptors.

Table 3-2: Oxidation-reduction potential (ORP) ranges for microbial utilization of potential electron acceptors.

Reaction		Oxidation-Reduction Potential (Volts)
Oxygen Respiration	$O_2 \rightarrow H_2O$	0.38 to 0.32
Denitrification	$NO_3^- \rightarrow N_2$	0.28 to 0.22
Manganese Reduction	$Mn^{4+} \rightarrow Mn^{2+}$	0.22 to 0.18
Iron Reduction	$Fe^{3+} \rightarrow Fe^{2+}$	0.11 to 0.08
Sulfate Reduction	$SO_4^{2-} \rightarrow H_2S$	-0.14 to -0.17
Methanogenesis	$CO_2 \rightarrow CH_4$	-0.20 to -0.28

When manure is stored in holding structures and accumulates over time, chemically reducing conditions are created in the deeper strata of the manure as the microbial population exhausts the higher yielding electron acceptors, including oxygen.

Typical sources of S in dairy manure come from diet nutrients such as dried distiller's grains with solubles (DDGS), S from drinking water and concentrate-based feed. Gypsum (calcium sulfate, $CaSO_4 .2H_2O$) as part of bedding material, provides an extra source of S and therefore creates potential for additional H_2S production. Hydrogen sulfide is created naturally when bacteria utilize the energy available from the organic content of the manure and use sulfur compounds as the terminal electron acceptor as shown in Equation 3-1 (Arogo et al. 2000 and Castro et al., 2000). As carbon is oxidized, sulfate is reduced in an anaerobic environment. While bacteria population and sulfur content in an anaerobic environment promote potential H_2S generation, other biochemical, environmental and physical factors affect H_2S production.

$$\textbf{Organic Matter}\ (\mathbf{C}, \mathbf{H}, \mathbf{O}) + \boldsymbol{H^+} + \boldsymbol{SO_4^{-2}} \rightarrow \boldsymbol{H_2S} + \boldsymbol{CO_2} + \boldsymbol{H_2O} \qquad \text{Equation 3-1}$$

3.4.1 Biochemical Factors

Figure 3-1 shows H_2S is in equilibrium with bisulfide (HS^-) and sulfide (S^{-2}) based on pH (Snoeyink and Jenkins, 1980). Hydrogen sulfide dominates under acidic conditions (pH<5), while higher pH conditions (pH>8) promote dissociation of H_2S into HS^- and S^{-2} (Figure 3-1). Andriamanohiarisoamanana et al. (2015) found that H_2S concentrations in the reactor headspace above dairy manure almost tripled (increased 285%) when pH decreased from 7.32 to 6.83. Molecular H_2S is elevated at pH below 7 and H_2S gas concentration will increase in reactor headspace under such conditions (Blunden and

Aneja, 2008). Blanes-Vidal et al., (2009) confirmed that H_2S concentrations increase with decreasing pH in swine manure.

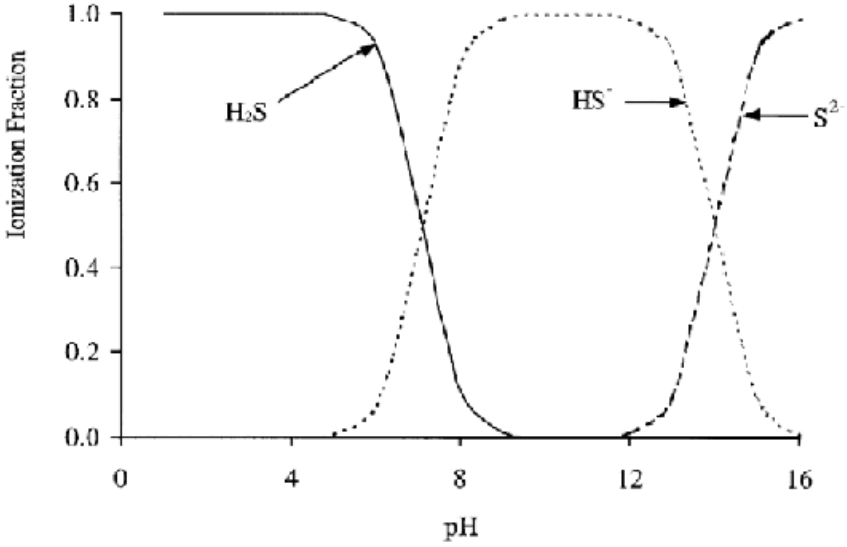

Figure 3-1: Fractions of sulfide species vs. pH at 25°C showing that increasing manure pH above 8 will reduce hydrogen sulfide formation (Snoeyink and Jenkins, 1980).

3.4.2 Environmental Factors

Ni et al. (2000) found that a decrease in temperature reduces sulfur reducing bacteria activity. Bicudo et al. (2002) confirmed a negative temperature correlation with ambient H_2S concentrations downwind of swine facilities, however, Bicudo's et al. (2002) measurements for temperature and humidity are of the ambient air and not of the manure. Andriamanohiarisoamanana et al. (2015) measured a tenfold decrease in H_2S concentrations (3,500 ppm to 306 ppm) above dairy manure when temperature decreased from 23.9 to 9.8 °C. Further experimental results show an exponential increase in H_2S concentration as temperature increases from 8 to 26 °C as shown in Figure 3-2 (Andriamanohiarisoamanana et al. (2015). In addition to sulfur-reducing bacteria activity, the rate of transformation from aqueous H_2S to gaseous H_2S is slower when temperature is decreased (Ni et al., 2000 and Yongsiri et al., 2004). Zhu et al. (2002) found that 75% of the aerobic bacteria counts were destroyed in swine manure when the temperature rose 10 degrees (15 °C to 25 °C) and the oxidation reduction potential decreased 100 mV (+40mV to -60 mV). This implies that increased temperatures yield reducing environments and may produce more sulfide. However, Wang et al. (2014) concluded that temperature had no effect on H_2S emissions when investigating digested pig slurry.

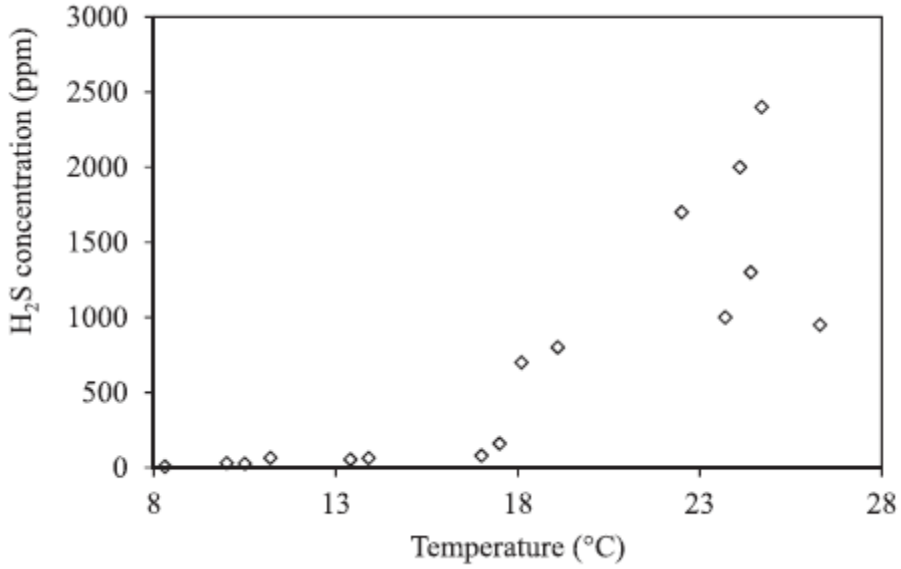

Figure 3-2: H_2S concentration increase with increase in temperature. (Andriamanohiarisoamanana et al. 2015).

A negative correlation was also observed between wind speed and H_2S concentration (Bicudo et al. 2002). Wind will dilute and dissipate H_2S concentrations, so even with elevated H_2S emissions, ambient H_2S concentrations above open manure storages may not persist in the presence of high wind speeds.

3.4.3 Physical Factors

Ni et al. (1999) observed release of H_2S concentrations in bursts, or highly concentrated pockets of H_2S gas from stored swine manure. Hydrogen sulfide is most likely generated in the deeper strata of the manure storage where there is little to no oxygen. Delayed emissions to the surface can be due to the time it takes for the gas to migrate to the surface and through a crust that forms on top of the storage creating a sealed top layer. Clanton et al. (2001) found that straw covering can reduce H_2S emissions from dairy manure storages. Bicudo et al. (2000) measured elevated H_2S concentrations above swine and dairy manure during agitation. Andriamanohiarisoamanana et al. (2015) found low H_2S concentrations emitted from dairy manure at low mixing speeds (<200 rpm), short mixing durations (<15 min) and frequent mixing events (>4 times per day). Scully et al. (2007) provides a review of studies investigating dairy and beef manure that found elevated H_2S concentrations at or above hazardous levels during agitation and mixing of manure.

Bicudo et al. (2002) documented significant differences in H_2S emissions based on types of manure storage structures and production facilities for the swine industry. Facility management practices may also influence H_2S emissions.

3.5 Need for Solution

The need for odor control and the prevalence of H_2S in the swine industry have prompted discussion and research endeavors regarding H_2S reduction from swine manure storages. Clanton et al. (2001) provides an overview of research conducted by various scientists on temporary covers made of various materials for manure storages to reduce odors, H_2S and NH_3. Though successful, manure storage covers are not typically practical during agitation of the manure unless extensive resources are invested in a permanent structure that would enable control of emissions from the manure surface.

As noted in Table 3-2, selected microbes are able to utilize alternative terminal electron acceptors in the absence of oxygen. The highest electron potential or energy yield available will be reduced. Xue and Chen (1999) reported that adding potassium permanganate and hydrogen peroxide both reduced H_2S emissions by increasing the redox potential in the manure. The energy yield for reducing sulfate to H_2S is much less than the energy yields for these oxidizers. Thus, the presence of electron acceptors having higher energy yield inhibit H_2S emissions. Smith and Nicolai (2005) found that potassium permanganate and hydrogen peroxide oxidized H_2S into its elemental sulfur form and reduced H_2S emissions by over 90% for each category. The cost to treat a swine pit sized at 61m x 12m x 1.5 m (200ft x 40ft x 5ft) was approximately $2,000 to $5,000. Dairy manure storages can be significantly larger and the cost for these additives would not be practical in most cases.

Most farms using gypsum bedding have not reported deaths or injuries due to H_2S exposure. Farms that have had reported safety incidents have not experienced problems every time the manure is agitated. However, anecdotal occurrences of multiple events in the northeast raise concern over health issues from H_2S exposure potentially related to use of gypsum-containing bedding.

This review of the literature has not identified any scientific evidence that proves gypsum-based bedding is linked to excessive release of H_2S gas from manure. A substantial set of observations is first required for analysis. Biochemistry supports the conditions for H_2S production from gypsum mixed with manure. Dangerous levels of H_2S emissions occur due to a variety of factors. Environmental conditions, biochemical characteristics and even management practices can promote H_2S production. Yet, addition of products or thoughtful management practices can reduce H2S emission at

manure movement and agitation. Understanding the factors beyond the conditions that generate H_2S is crucial to identifying solutions that reduce or eliminate hazardous conditions. Developing evidence for commercial amendments that mitigate H_2S emission levels would provide solutions for those in the dairy industry that use gypsum bedding.

Chapter 4 Review of Methods with Quality Assurance

This demonstration comprised quality-assured field measurements of manure gas concentrations and manure physical and chemical properties as well as a characterization of each farm involved. The field measurements compared bedding categories via statistical comparisons to find conditions that promote accelerated H_2S production.

4.1 Field Measurements Collection

Farms in Pennsylvania were chosen in each of three categories to demonstrate the use of manure amendments to reduce the potential for H_2S release: [1] farms that use traditional bedding (non-gypsum); [2] farms that use gypsum as bedding or as part of the bedding material (gypsum), and [3] farms that use gypsum-based bedding along with a manure amendment to reduce H_2S emission levels (gypsum with amendment). Ten farms participated in the demonstration study. In total, 19 site visits were conducted for measurements during manure storage agitation. Protocol insisted that measurements be during the first agitation of the manure hauling and application season (spring or fall). Table 4-1 lists the farms, category and amendment used at participating farms. Each farm was characterized by their management practices. Any differences in farm characteristics or management were noted at each visit. Manure gas concentrations emitted during agitation of the storage were measured and manure was sampled and analyzed for physical and chemical properties. All storages were open-air, unroofed structures with most (9 of 10 farms) in-ground structures. The primary manure additive demonstrated as an amendment was Vital™ Breakdown (manufactured by Homestead Nutrition, New Holland, PA; information sheet included in Appendix A). Another amendment, OK-1000 (manufactured by Pro-soil Ag Solutions, Hawkins, TX) was used on one farm included in this demonstration (Appendix A).

Table 4-1: Participating farms and their gypsum category

Farm ID	Location	Category	Manure Amendment
CY	Lititz	Gypsum with amendment	Breakdown
HR	Carlisle	Gypsum with amendment	OK 1000
BL	Danville	Gypsum with amendment	Breakdown
BR	Lititz	Gypsum with amendment	Breakdown
CP	New Bloomfield	Non-gypsum	none
SH	Newport	Non-gypsum	none
HT	Belleville	Non-gypsum	none
WR	Lykens	Gypsum	none
WE	Pine Grove	Gypsum	none
SR	Reinholds	Gypsum	none

4.1.1 Farm Characterization

The type of bedding for each farm was identified as being in one of the three categories (non-gypsum, gypsum and gypsum with amendment). The bedding material was further categorized based on how much gypsum was used on a per cow basis. Manure management practices were described in terms of the manure storage loading frequency (barn to storage). Storage design parameters were identified and all storage inputs were noted. Further characterization included the diet consumed by the herd. Information collected for each participating farm is included herewith as Appendix B. Table A-1 summarizes the manure storage and handling characteristics.

4.1.2 Manure Gas Concentrations

A total of nine gas monitors recorded conditions during farm site visits. Three portable multi-gas meters (MX6, Industrial Scientific, Pittsburgh PA; product information sheet is shown in Appendix C) were placed around the perimeter of the manure storage at approximately 1.2 m (4 ft.) above the top of the rim of the storage structure, when possible. When these locations were not accessible, meters were placed on tripods approximately 1.2 m (4 ft.) above ground level adjacent to the exterior wall of the structure. An example of meter placement is shown in Figure 4-1.

Figure 4-1: H_2S concentrations were measured during agitation events using portable meters placed around the manure storage.

Each meter was positioned prior to the start of agitation to datalog multiple gas concentrations, including: H_2S; CH_4; NH_3; carbon monoxide (CO); CO_2; O_2 and % lower explosive limit (LEL). Two gas meters (M40, Industrial Scientific) were placed approximately ten meters downwind from the edge of the storage structure on tripods, one measured gas (H_2S) concentrations 0.3 m (1 ft.) above the ground and the other 1.2 m (4 ft.) above the ground. One single gas meter (Tango, Industrial Scientific; product information sheet is shown in Appendix C) was worn on collar or belt by the agitation tractor operator for the duration of the event for safety. Three other Tango H_2S single gas meters were placed at selected locations around the perimeter of the manure storage to capture additional gas concentration data. All gas monitoring equipment recorded gas measurements on one minute intervals starting at least 30 minutes prior to agitation and continued throughout agitation for at least the first hour of mixing. Additionally, wind speed, wind direction, air temperature and humidity were recorded every minute during these events using a weather station (Kestrel Communicator model 4500, Nielsen-Kellerman, Birmingham, MI). The list of weather parameters recorded during each event and an example measurements set are provided herewith in Appendix D. Table A-2 summarizes the environmental conditions measured in the field for each agitation event.

4.1.3 Manure Analyses

Prior to the start of agitation, two manure samples were collected, one from just below the surface crust and one from the bottom of the storage (just above any accumulated solids on the storage bottom). Once maximum agitation was achieved, based on visual evaluation by equipment operator, another manure sample was collected from the middle of the storage to represented well-mixed manure. Each manure sample was collected using a 5-meter long, hollow core sampling tube equipped with a ball check valve on the end of the sampling tube. Each sample was analyzed for pH, temperature and oxidation-reduction potential (ORP). Sample ORP was measured immediately when brought to the surface using a field probe (Model SDL100, Extech Instruments, South Burlington VT). Samples were analyzed for physical and chemical properties at Penn State's Agriculture Analytical Services Laboratory located in State College, PA. Manure characterization analysis parameters and example results are provided herewith in Appendix D. Table A-3 summarizes the manure analytical results collected at each farm.

4.2 Hydrogen Sulfide Concentrations Comparison

Gas concentrations measured at the perimeter of the storage were compared across bedding groups (non-gypsum, gypsum and gypsum with amendment). Concentrations were plotted over time from the start of agitation. The maximum gas measurement for each time stamp was chosen among the perimeter meters and plotted with time to eliminate variance related to changes in wind direction. Maximum H_2S concentrations were used to demonstrate worst case scenarios since these levels represent the greatest health and safety concerns. The area beneath these time versus concentration curves (cumulative H_2S concentration) was determined via integration over the first 60 minutes. The integration was performed numerically using the trapezoid rule and was calculated in Microsoft Excel™ according to Equation 4-1. The integration generated cumulative H_2S concentration over 60 minutes for each farm, which enabled comparison across categories.

$$\boldsymbol{I_A = I_{A-1} + (T_A - T_{A-1}) * (C_A + C_{A-1})/2} \qquad \text{Equation 4-1}$$

Where: I_A = Integration representing cumulative H_2S concentration at time A
I_{A-1} = Integration at time A-1
T_A = Time at A
T_{A-1} = Time at A-1
C_A = Gas concentration at time A
C_{A-1} = Gas concentration at time A-1

Chapter 5 Findings

Observations collected as a part of this project demonstrate elevated H_2S levels from farms that use gypsum bedding during manure agitation. Hydrogen sulfide concentrations were compared across farm categories.

5.1 Hydrogen sulfide

Figure 5-1 shows H_2S concentrations observed at the perimeter of manure storages for farms observed in all three categories. These figures present H_2S concentrations at identical scales to facilitate visual comparison. It is readily evident that farms using gypsum, with or without manure amendments, exhibited elevated H_2S concentrations and farms that did not use gypsum bedding were observed to have low (<20 ppm) H_2S concentrations. Notably, less than 1 ppm H_2S was observed prior to the start of manure agitation for all farms.

Observations confirm anecdotal reports of elevated hydrogen sulfide (H_2S) levels during manure agitation from farms that use gypsum bedding. Figure 5-2 summarizes the cumulative H_2S concentrations over 60 minutes during agitation plotted against amount of gypsum used for each cow per day, for all participating farms.

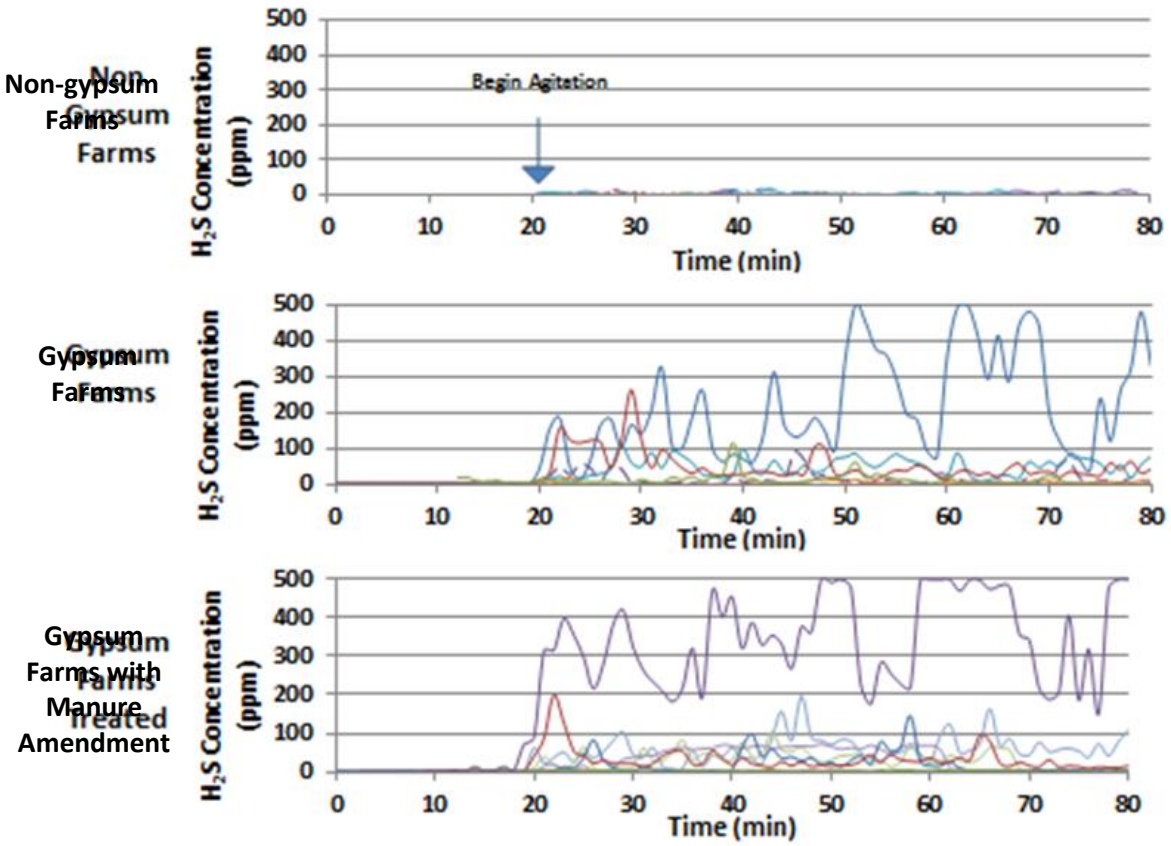

Figure 5-1: Maximum H_2S concentrations over the first 60 minutes of agitation for participating farms show elevated H_2S concentrations at farms that use gypsum bedding.

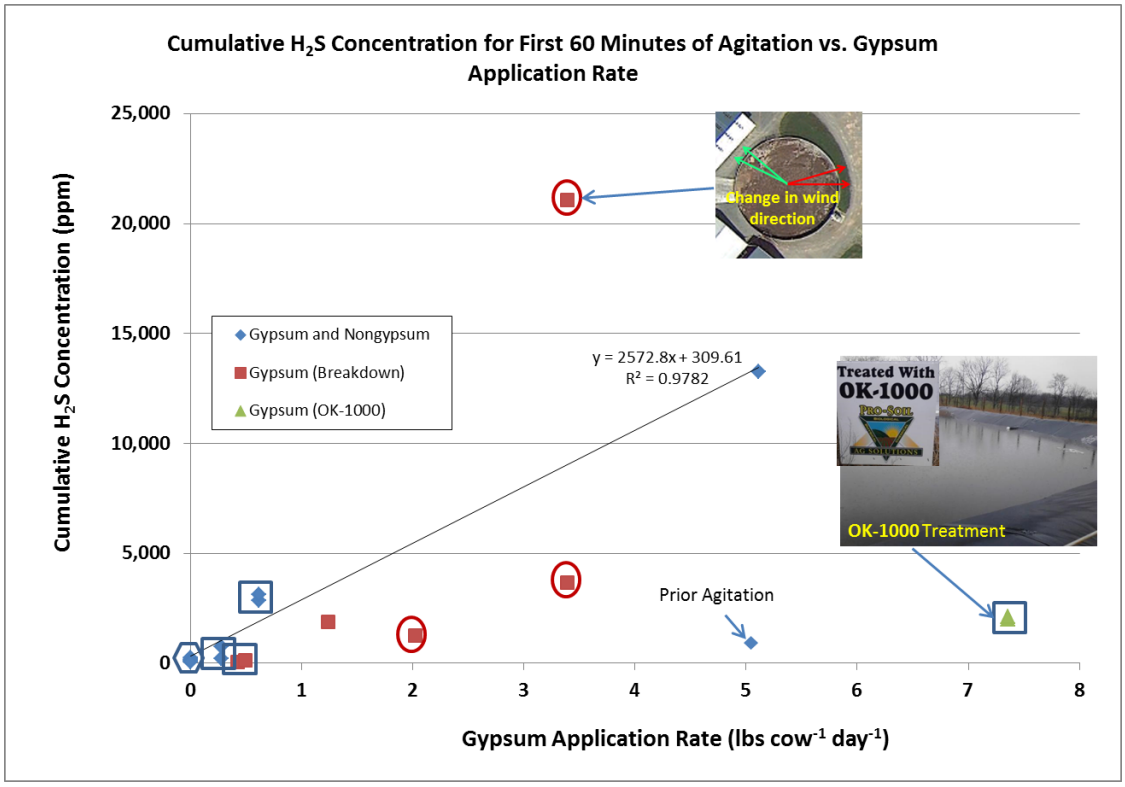

Figure 5-2: Cumulative H_2S concentration for first 60 minutes of agitation vs. gypsum use.

Gypsum and non-gypsum farms are represented by the diamonds. Gypsum and non-gypsum categories are grouped together because non-gypsum farms have a gypsum use of zero. The observations depicted by the squares represent farms that use Vital™ Breakdown (Homestead Nutrition), an amendment reported to reduce H_2S emissions. One of the farms observed, also identified in Figure 5-2 by the triangles, uses OK-1000 (Pro-soil Ag Solutions) as a manure additive.

A trend line, represented by the solid black line, was drawn through the observations associated with farms that use gypsum with no manure amendment and the observations represented by farms that do not use any gypsum (at 0 gypsum use). Note that one of the farms was agitated two weeks prior to our observation collection. It is hypothesized that H_2S gas escaped during the initial agitation that was not available for monitoring during collection date two weeks later. Thus, this observation ("prior agitation" in Figure 5-2) was not used as part of the trend line for the gypsum and non-gypsum observations. The octagon near the origin of axes encloses five observations superimposed on each other at this resolution. These five non-gypsum farms exhibited concentrations below 20 ppm over the duration of manure agitation and thus resulted in low cumulative H_2S cumulative concentrations. These observations show that lower gypsum use results in lower cumulative H_2S concentrations in the absence of amendments.

Each of the four squares surround two observations conducted at the same farm during one fall collection event and one spring collection event. Notably, H_2S concentrations recorded during different seasons were very similar for the same farm sites (Figure 5-2). Hence, seasonal variation did not appear to play a substantial role in H_2S generation or cumulative concentrations for these farms.

One exception is a farm where three observations were collected, these three observations are circled in Figure 5-2. The Bl farm changed their gypsum bedding use, which explains the offset in the two observations below 5,000 ppm in Figure 5-2. Additionally, as shown in Figure 5-3, the wind direction in fall 2014 differed substantially from fall 2013 and spring 2014. Two observations with <5,000 ppm cumulative H_2S were recorded during the fall 2013 and spring 2014 agitation events during prevailing wind direction ranging from 73 to 90 degrees (azimuth), out and away from the farmstead. The observation called out in Figure 5-2 by a photo showing the change in wind direction is plotted above 20,000 ppm recorded a wind direction ranging from 322 to 352 degrees from North during the fall 2014 agitation, which is directly into an adjacent heifer barn. This likely provided a barrier to H_2S dissipation by wind. Based on these observations, it appears that wind direction obstructed by nearby farm structures affect H_2S concentrations found near the storage during agitation. These observations suggest wind direction and physical obstructions can have a dramatic effect on H_2S build-up in nearby areas.

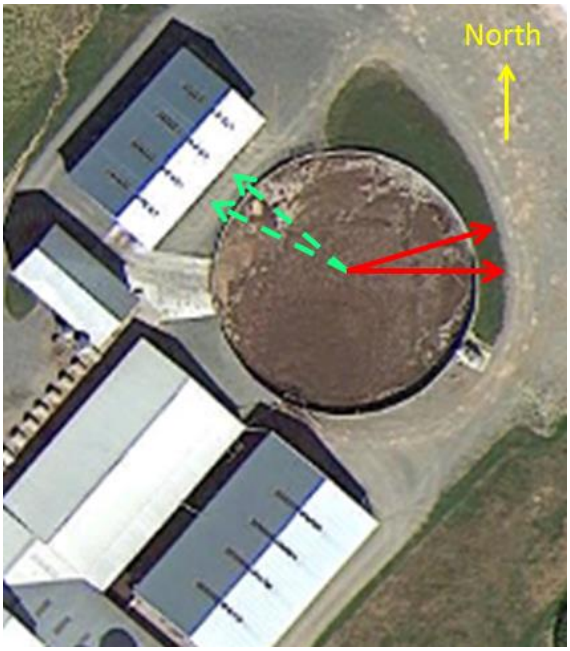

Figure 5-3: Changing range of wind directions at Bl farm impacted H_2S exposure via trapped gas emission near buildings from manure storage agitation. The solid arrows (pointing right) represent range of wind direction during both the fall 2013 and spring 2014 agitation events. The dashed arrows (pointing left) represent the wind directions during fall 2014 agitation event with high H_2S conditions.

Figure 5-4 shows trends for gypsum farms (non-gypsum) as well as farms that use manure amendment plotted against gypsum use. Farm categories were compared to distinguish if there were any significant effects among farms that do not use amendments and farms that use Vital™ Breakdown. It appears from Figure 5-4 that the farms using Vital™ Breakdown reduced cumulative H_2S concentrations. However, statistical analysis indicates that Vital™ Breakdown did not significantly (alpha = 0.05) reduce cumulative H_2S concentrations during 60 minutes of agitation. More observations may help confirm the significance among farms that use Vital™ Breakdown and those that do not in regards to cumulative H_2S concentrations. Because only one farm used OK-1000 as an amendment, the significance of this treatment could not be determined. It is notable that when both amendments were combined for analysis there is a significant reduction in cumulative H_2S concentration, suggesting that H_2S emissions may be decreased using manure amendments.

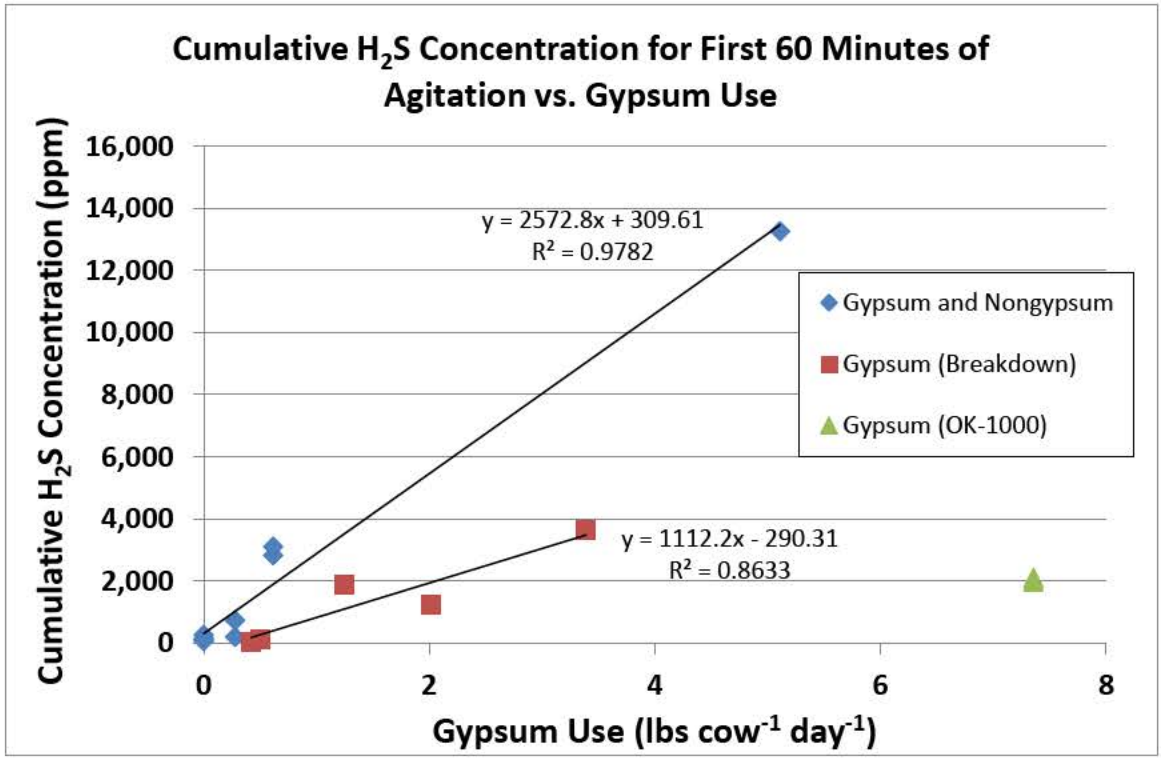

Figure 5-4: General linear model regression line through cumulative H_2S concentrations vs. gypsum use for all farms observed except for two farms that were outliers due to pre-agitation and wind direction.

Recall that two farm observations (Wr farm observed in spring 2014 and Bl farm observed in fall 2014) were excluded from the linear model findings in Figure 5-4. One farm had agitation prior to our field collection date. Because this was outside of the research protocol, and known to reduce subsequent emissions, this observation set was

excluded from the general linear model. Additionally, one of the farms that used gypsum with a manure amendment was not included in this analysis because it was found the wind direction shifted into the direction of closely adjacent structures causing limited dissipation of the H_2S plume resulting in elevated cumulative H_2S concentrations close to the storage.

5.2 Operator Exposure

Personal monitors provided a way to measure operator exposure to H_2S during the observed 60 minutes of agitation. Recall that H_2S exposure should not exceed 20 ppm during an 8-hour period (U.S. Department of Labor, 1997) although exposure may exceed 20 ppm, but not more than 50 ppm, for a single time period up to ten minutes US DL 1997). Hydrogen sulfide is considered an immediate danger to life and health (IDLH) at 100 ppm.

Fifteen of the 19 observations showed exposure below 20 ppm as shown in Figure 5-5. Figure 5-6 shows four sets of observations that reach above 50 ppm of H_2S during agitation. Operators that were considered safe, therefore not exposed to over 20 ppm H_2S, controlled the agitator hydraulics from within the cab of the tractor elevated from ground level as shown in Figure 5-7.

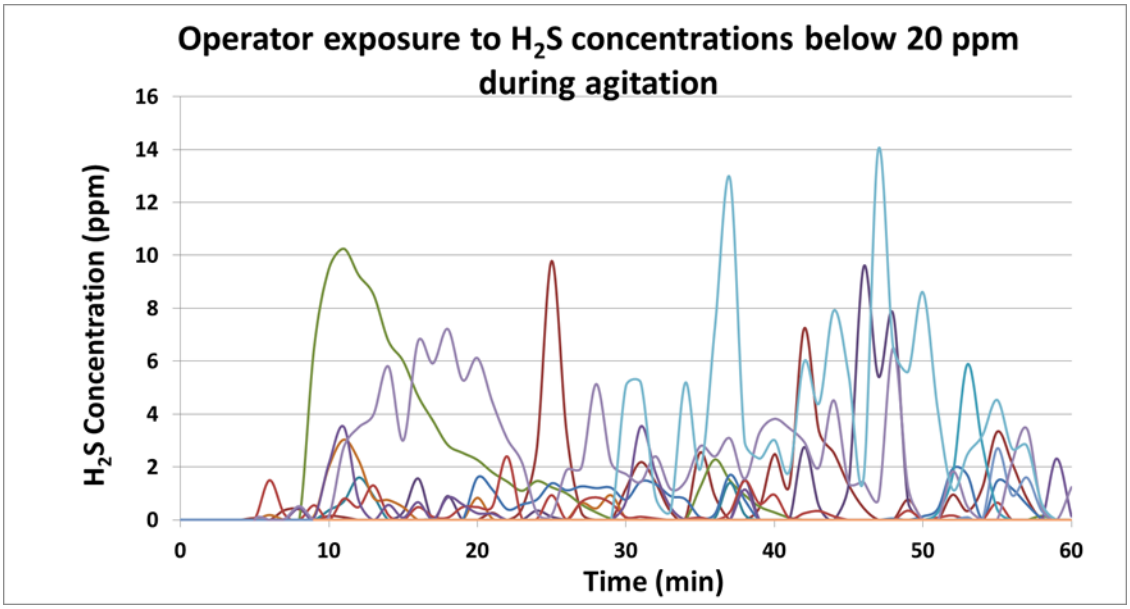

Figure 5-5: Fourteen (of nineteen) operators were able to manage manure agitation equipment in relative safety while exposed to less than 20 ppm H_2S during agitation.

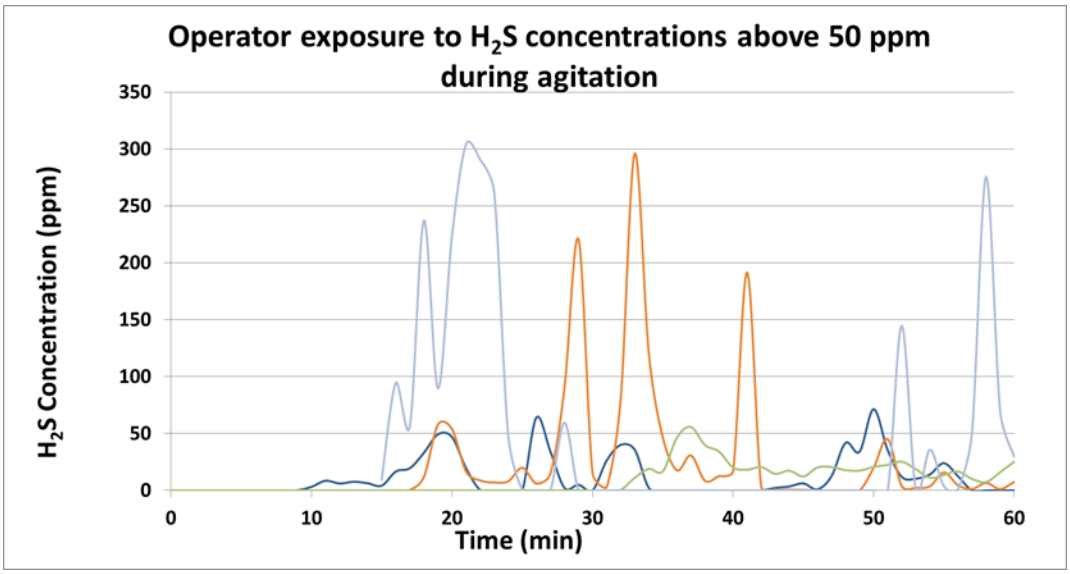

Figure 5-6: Four operators were periodically exposed to over 50 ppm H_2S (above safe labor standards) during manure storage agitation, with some exposures above the IDLH level of 100 ppm.

Figure 5-7: Operator controlling agitator hydraulics from within an elevated, enclosed tractor cab had reduced exposure to hydrogen sulfide release.

Three of the four higher exposures (above 20 ppm H_2S) were associated with operators positioned over the rim of the storage as shown in Figure 5-8 and Figure 5-9. One operator who controlled the agitator hydraulics from within the tractor cab was exposed to over 20 ppm for a total of 12 minutes, much less than the other three operators in close proximity to the manure storage.

Figure 5-8: Operator manually positioning nozzle was exposed to high gas concentrations over rim of storage.

Figure 5-9: Operator inspecting drive chain was exposed to high gas concentrations over rim of storage.

Awareness limits exposure to H_2S even when a dangerous environment exists. Use of personal gas monitors is demonstrated to raise awareness of conditions that might not be immediately obvious during toxic gas exposure. It is evident from this study that use of gypsum bedding on a dairy farm can create a toxic environment near agitated manure. High-risk avoidance should be practiced when working in the vicinity of known danger.

5.3 Downwind Concentrations

A profile of high and low meters was positioned 10 m (33 ft.) downwind from the manure storage perimeter. "Downwind" direction was based on the prevailing wind direction recorded by the portable weather station (Kestrel®) during measurement collection events for each farm. The object was to quantify the exposure to H_2S proximate to the storage. Table 5-1 lists maximum H_2S exposure 10 m (33 ft.) away from the manure storage for each observation event. Recall that OSHA recommends that exposure not exceed 20 ppm. Note that none of the non-gypsum farms exhibited observations of H_2S concentrations above 5 ppm downwind of the manure storage. Eight of 14 farms that used gypsum (including the farms that use a manure amendment to reduce H_2S emissions) showed downwind conditions above 20 ppm H_2S.

Table 5-1: Maximum H_2S concentrations 10 meters (33 ft.) from manure storage.

Category	Farm	Gypsum Use	Maximum Downwind Exposure	Notes
			10 meters from storage	
		(lbs cow^{-1} day^{-1})	(ppm)	
Non-gypsum (NG)	Ht F13 NG	0.0	0	
	Cp F13 NG	0.0	3	
	Cp S14 NG	0.0	5	
	Ht S14 NG	0.0	3	
	Sh S14 NG	0.0	3	
Gypsum (G)	Wr F13 G	5.1	45	
	Wr S14 G	5.1	11	prior agitation
	We S14 G	0.6	72	
	Sr S14 G	0.3	0	
	We F14 G	0.6	88	
	Sr F14 G	0.3	42	
Gypsum with treatment (GT)	Bl F13 GT	2.0	64	
	Bl S14 GT	3.4	31	
	Br S14 GT	0.4	7	Multi-stage Manure Transfer
	Cy S14 GT	1.2	11	Slurry Store™
	Hr S14 GT	7.4	5	liquid manure, no crust
	Hr F14 GT	7.4	170	liquid manure, no crust
	Br F14 GT	0.5	2	Multi-stage Manure Transfer
	Bl F14 GT	3.4	1000	

Notes: Codes for sampling seasons are F13 = fall 2013, S14 = spring 2014 and F14 = fall 2014.
Codes for treatment groups are NG = non-gypsum, G = gypsum and GT = gypsum with treatment.

Six farms that use gypsum had maximum H_2S concentrations under 20 ppm 10 m downwind from the manure storage. Five of these can be explained by farm characteristics. Both the Sr and Br farms had relatively low gypsum use. The Sr farm had one elevated H_2S concentration of 42 ppm confirming anecdotal reports that some farms using gypsum bedding experience no problems with H_2S levels, but at other times encounter hazardous conditions. It seemed that frequent movement decreased H_2S emission risk at any one manure movement event. Manure at the Br farm is transferred through two sumps. Dairy barn manure is scraped into a pit at the end of the barn and from there is transferred weekly to another sump beneath the heifer barnyard before being pumped into the long-term concrete manure storage once every two weeks. It is thought that H_2S generated during transfer is lost to the atmosphere before reaching the long term concrete storage structure, thus reducing H_2S available for emission during storage agitation. Recall that the Wr storage had been agitated within two weeks prior to the agitation monitoring event during spring 2014 resulting in greatly reduced emission in subsequent agitation.

The Cy farm differs from other participating farms in that the manure storage is a metal structure 6.1 m (20 ft.) above grade, as shown in Figure 5-10. All the other farms used subgrade concrete structures or earthen storages. Hydrogen sulfide plumes may not have reached the gas monitors offset 10 m from storage at ground-level by the time H_2S escaped over the edge of the storage. Note though that H_2S at 10 m distant was measured at 11 ppm for the Cy farm during the spring 2014 agitation.

Figure 5-10: Manure storage for Cy farm was 20 ft. above-grade steel structure.

These results measuring H_2S 10 m (33 ft.) away from the manure storage provide additional support for concluding that gypsum promotes greater risk of H_2S exposure. Though these concentrations are not as dangerous as the levels measured right at the perimeter, it shows that exposure can still occur downwind from the storage. Animals, children and other workers downwind are susceptible to H_2S exposure even if they do not

have direct involvement with manure agitation tasks immediately adjacent to the manure storage.

5.4 Manure Handling Practices and Farm Characterization

Not all dairy farms that use gypsum products have safety incidents. Moreover, farms that do incur problems with elevated H_2S concentrations do not have these issues every time the manure storage is agitated.

Figure 5-2 and Figure 5-4 show that increased gypsum use results in elevated H_2S cumulative concentrations after 60 min of agitation. Table 5-2 shows other independent variables, or factors that were quantified or characterized during each field visit. These factors were investigated to see if these independent variables had any effect on cumulative H_2S concentrations.

Table 5-2: Manure characteristics, environmental parameters, manure handling practices and sulfur sources that were analyzed for effect on H_2S concentrations.

Independent Variables	
Manure characteristics	Manure surface temperature
	Oxidation-reduction potential (ORP)
	Manure temperature
	pH
Environment parameters	Ambient temperature
	Wind speed
Storage engineering	Storage volume
	Storage design
Manure handling	Manure transfer technique
	Thickness of solids on bottom of storage
	% crust cover
Sulfur sources	Copper sulfate foot bath
	DDGS grains in feed ration

None of the independent variables in Table 5-2 had a statistically significant effect on cumulative H_2S concentrations during manure agitation. Surprisingly, no temperature effect on H_2S cumulative concentration was found as this is a documented influence with greater temperature increasing H_2S gas release under controlled conditions. But as typical of field demonstrations, manure surface temperatures during Fall 2013 were not significantly different than for spring 2014 and fall 2014. There was a wide variation of manure surface temperatures collected during the fall 2013 sampling season likely due to a late start in the sampling season when temperatures were dropping rapidly.

No effect from wind speed on H_2S concentration was detected, however, it should be noted that wind direction could be a localized factor. Observation of highly elevated H_2S concentrations were documented during the third field collection event at one site (Bl farm as shown in Figures 5-2 and 5-3) where adjacent structures trapped manure storage emissions and inhibited dissipation of gases from the open-air storages.

Limiting sources of sulfate in manure storages would limit H_2S production. Observations showed that repeated movement or mixing of the manure released H_2S gas trapped beneath the storage crust, leading to reduced emission at subsequent agitations, but this was not found to be significant by statistical analysis. More measurements could support the observational findings collected with this demonstration, however, this demonstration has provided evidence that elevated H_2S concentrations occur at farms using gypsum products.

Chapter 6 Conclusions and Recommendations

Nineteen open-air, manure storage agitation events were monitored at ten dairy farms over a 14 month period. Hydrogen sulfide gas release was measured along with environment features, management practices and manure parameters thought to impact development and emission of H_2S gas. Findings include:

6.1 Conclusions

- Gypsum bedding use clearly and significantly increased H_2S release during manure storage agitation versus farms with conventional bedding materials (non-gypsum farms).

- Measurements collected before and after agitation show H_2S concentrations at gypsum bedding farms immediately begin at the start of agitation.

- Increased gypsum bedding use (amount per cow) was correlated with increasing risk of elevated H_2S gas release at manure storage agitation.

- The manure amendment Vital™ Breakdown showed a promising trend in diminishing hydrogen sulfide release, but did not significantly reduce cumulative H_2S concentrations with respect to farms that do not use manure amendments.

- Manure amendments did reduce H_2S concentrations when all farms that used products were considered together, offering hope that mitigation of risky gas levels may have some relatively simple solutions.

- Environment measurements did not significantly affect cumulative H_2S concentrations during manure agitation. These included: average ambient air temperature, average manure surface temperature, manure temperature at depth, pH, ORP and wind speed. Limited measurements and high variability in environmental conditions were challenges affecting evaluation of their effect on H_2S concentrations during the monitored events.

- Similarly, neither design parameters nor manure characterization measurements (storage design, manure transfer, crust cover, crust thickness) were found to significantly affect cumulative H_2S concentrations at agitation.

- Though statistical evidence from this research did not estimate significant environmental effects, farm observations must consider empirical analysis at each farm. Wind direction that is obstructed by proximate barns or outbuildings can cause elevated H_2S concentration near the storage during agitation.

- Awareness greatly reduces risk of H_2S exposure. Four out of 19 operators were exposed to elevated levels of H_2S at farms that used gypsum in bedding. Careful implementation to avoid dangerous plumes of manure gas can prevent exposure such as operating the agitator from an elevated, closed tractor cab. Efforts that require operators to work at the rim of the storage or lean over it are susceptible to high risk of H_2S exposure.

- Unacceptable H_2S concentrations (greater than 20 ppm) exist 10 meters away from manure storage during agitation events when gypsum bedding is used. Children, workers and animals are at risk at least 10 meters away from a manure storage that contains gypsum.

- With the bedding and agronomic benefits of gypsum, a balance exists between these rewards and the risk of H_2S gas toxicity during manure agitation.

6.2 Recommendations

Overview: Highly elevated H_2S concentrations are likely to occur in the vicinity of manure, which contains gypsum bedding, during agitation or movement. Awareness of dangerous environments is crucial to limiting risk. With awareness, safer practices can be implemented to limit risk to exposure of H_2S and reduce health hazards. Safety can be improved through awareness of conditions via personal gas monitors and, perhaps, manure amendments to lower H_2S emission during agitation. Because of this demonstration project, knowledge of the extent of risk and awareness of the types of hazards have been communicated to the agriculture community.

General Recommendations for any outdoor manure storage:

- **Access during agitation**: Keep non-essential people away during agitation, especially children who are at increased risk as H_2S is typically at higher concentration close to the ground. Nearby cattle are also at risk.
- **Secure** storage from entry: provide **rescue** and fall protection; **gas monitors** recommended.

Specific to gypsum bedding use

- **Under-barn manure storage**: Our unconditional recommendation is to <u>not</u> use gypsum bedding with under-barn manure storage. Potential is very high for release of extreme concentration of H_2S when manure is moved or mixed, resulting in harm to barn workers and confined cattle.
- **Operator position during agitation**: During any manure movement or mixing, operator must be up above the ground and away from edge of a manure storage. Particularly with manure containing gypsum bedding material, H_2S gas at lethal levels (>600 ppm) is quickly produced and undetectable by smell. Hydrogen sulfide is a heavy, ground-hugging gas.
- **Position work area** so operator:
    - Does not reach over the storage for routine practices
    - Does not work or need to adjust machinery near storage edge
    - Is not in a low-lying area
- **Wind Direction**: Hydrogen sulfide can settle in windless areas, shelterbelts or among buildings blocking airflow near a storage unit. Strong breezes will move H_2S out and away from storage, diminishing risk. Operators should be positioned upwind.
- **Access during Agitation**: Once manure storage agitation begins, no one should be in the immediate area. Encourage casual onlookers to keep well away (minimum of 50 feet). Children, pets, calves, and resting cattle are more susceptible due to lower breathing zones. Low areas accumulate H_2S so operators, other people and animals should avoid any nearby depressions.

- **Planning Layout**: Gases "throw" in the direction of a manure agitator nozzle, so be aware of dangerous impact on "downwind" animal or human occupied areas. Confined cattle in the area are at risk.
- **Confined storage**: Long ago it was discovered that confined spaces accumulated dangerous levels of manure gases (sumps; low areas; gutters; cross channels; pits; pump out access areas; underfloor manure storages). Dangerous gas levels are especially common during agitation of the manure. The addition of gypsum bedding makes this an even greater hazard with the potential for high H_2S levels.

Chapter 7 Dissemination of Information: Penn State Extension

As a demonstration project, the information learned was made available to the dairy industry in many user-friendly formats. Nationwide and international meetings provided excellent opportunity to highlight the findings of this project and communicate the potential hazards of working around manure storages that contain gypsum products. This section provides the details and references for the information sessions, conference and poster presentations, webinars and Penn State Extension documents that were conducted as a part of this demonstration project. There have been numerous media articles about project outcomes, and more continue to be made available to the farming community. At least two web pages catalog resources related to demonstration findings.

The project successfully completed all deliverables:

1. A written *document* with recommendations on how project findings may be incorporated into NRCS technical guidelines [Appendix H]
2. *Training* of NRCS engineers in safety, air quality instrument use, and environmental issues associated with open-air manure storages [Table 7.1; Appendix E]
3. A non-technical *brochure* for delivery to farmers as NRCS personnel work with them on issues associated with gypsum bedding use and manure handling [Appendix H]
4. *Events* to attend included two webinars and on-farm field day with technical findings suitable for producers and professionals [Table 7.1; Appendix E; Appendix G]

Information Sessions (deliverables 2 & 4):

Table 7-1 provides a list of information sessions during which observations from this project were communicated to producers, manure haulers and engineers. The slide set from the most recent presentation (2015 North American Manure Expo, Chambersburg, PA) is included in Appendix E. This appendix also includes field day promotion and NRCS training information.

Table 7-1: Trainings, field days and expos for technical and professional audiences.

Information Session	Date	Location	Approximate Number of Attendees
NRCS PA regional engineers technical training update	July 9, 2014	Livestock Evaluation Center - Penn State's Ag Progress days Site	20
Manure Hauler's field day	August 6, 2014	Lebanon County, PA	80
2014 North American Manure Exposition	July 8-9, 2014	Springfield, MO	30
International Society for Agriculture Safety and Health annual meeting	June 22 - 29, 2014	Omaha, NE	20
Ag Progress Days, Manure Haulers Training	August 12 and 14, 2014	Penn State Ag Progress Days site	60
On-farm Demonstration Day	August 28, 2014	Pleasant View Dairy Farms, Pine Grove, PA	70
2015 North American Manure Exposition	July 14-15, 2015	Chambersburg, PA	80

Conference Oral Presentations and Papers:

1. Hile, M. L., E. Fabian-Wheeler. R. C. Brandt, H. A. Elliott, D. A. Hill and R. J. Meinen. 2013. Hydrogen sulfide emissions from dairy manure and gypsum bedding. Presented in Altoona, Pennsylvania at Northeast Agriculture and Biological Engineering Conference.
2. Hile, M. L., E. E. Fabian, R. C. Brandt, H. A. Elliott, R. B. Bryant, C. A. Rotz. 2014. Hydrogen sulfide release from manure storages of dairy cows bedded with gypsum products. Presented in Long Beach, California at American Society of Agronomy, Crop Science Society of America, Soil Science Society of America Annual meeting. Reference No. 95-5.
3. Fabian, E. E., and M. L. Hile. 2014. Hydrogen sulfide release from manure storages of dairy cows bedded with gypsum products. Presented in Montreal, Canada at

American Society of Agricultural and Biological Engineers. Reference No. 1893752.

4. Hile, M.L. and E. Fabian-Wheeler. 2015. Gypsum bedding impact on hydrogen sulfide release from dairy manure storages. Proceedings of *Dairy Environmental Systems and Climate Adaptation Conference*. July 2015. Ithaca NY. USA. 13 pages.
5. Fabian-Wheeler, E. E., M. L. Hile and R. C. Brandt. 2015. Gypsum Bedding Impact on Operator Exposure to Hydrogen Sulfide from Dairy Manure Storages. Presented in New Orleans, Louisiana at American Society of Agricultural and Biological Engineers international meeting. Paper Number 2182514.

Conference Poster Presentations:

A poster was developed for the 2015 Waste to Worth national meeting in Seattle, Washington. This is referenced below and a copy of this poster is provided in Appendix F.

1. M. L. Hile, E. E. Fabian, H. A. Elliott, C. A. Rotz, R. B. Bryant, D. J. Murphy, R. C. Brandt, D. A. Hill and R. J. Meinen. 2015. Hydrogen sulfide production from dairy manure storages that contain gypsum bedding. Presented in Seattle, Washington at Waste to Worth national meeting. Reference No. 9543986.

Webinars (deliverable 4):

Two webinars were provided to a national audience. The references and link to these webinars are listed below. The slide set of the most recent webinar (Hile and Meinen, 2015) and overview of each webinar is provided in Appendix G.

1. Fabian, E. E., M. L. Hile, D. A. Hill and R. J. Meinen. 2015. Handling manure with gypsum bedding. Technical Tuesday dairy webinar series. Available at https://meeting.psu.edu/p65jlt7o1df/?launcher=false&fcsContent=true&pbMode=normal.
2. Hile, M. L. and R. Meinen. 2015. Gypsum bedding risks and rewards. Livestock and Poultry Environmental (LPE) Learning Center Educational Webcast Series Waste 2 Worth Preview. Available at: www.extension.org/pages/72649/waste-to-worth-preview:-gypsum-bedding-risks-and-rewards.

Written Documents (deliverables 1 &3):

Two Penn State Extension *fact sheets* were developed and are available on the Penn State Extension gypsum website (Penn State Extension, 2015) and are included in Appendix H.

1. A written *document* with recommendations on how project findings may be incorporated into NRCS technical guidelines:
   Fabian-Wheeler, E. and M. Hile. 2015a. E-70. Manure storage design and safety considerations with gypsum bedding. Penn State Extension. University Park PA. Available at: http://extension.psu.edu/business/ag-safety/confined-spaces/manure/manure-pit-safety-fact-sheets/e-70/extension_publication_file.
2. A non-technical *brochure* for delivery to farmers as NRCS personnel work with them on issues associated with gypsum bedding use manure handling:
   Hile, M. L. and E. Fabian-Wheeler. 2014. Safety risk from manure storages of dairy cows bedded with gypsum. G-112. Penn State Extension. University Park PA. Available at http://extension.psu.edu/animals/dairy/health/facilities/gypsum-bedding/safety-risk-from-manure-storages-of-dairy-cows-bedded-with-gypsum/extension_publication_file.

News Articles:

Table 7-2 lists the news articles that reference this work. Copies of these articles are also provided in Appendix I for convenient reference. Another Article has been drafted and approved for publication in a future issue of Hoard's Dairyman.

Table 7-2: Summary of news articles

Title	Newspaper	Author	Date
It's coming! Don't let it get you!	Farmshine	Dieter Krieg	9/5/2014
Manure handling field day focuses on hydrogen sulfide gas	Lancaster Farming	Dick Wanner	9/6/2014
Please be afraid of deadly hydrogen sulfide	Farmshine	Dieter Krieg	9/19/2014
Gypsum bedding—is it worth the manure safety risk?	Progressive Dairyman	Eileen Fabian-Wheeler	10/1/2014
Do not give the killer in the pit the benefit of the doubt	Farmshine	Dieter Krieg	10/10/2014
Empty it, maintain it, and above all, stay safe	Farmshine	Emily Dekar	10/17/2014
They're not just standing around!	Farmshine	Dieter Krieg	10/24/2014
Agricultural safety, sometimes forgotten	Industrial Hygiene	Mike Platek	12/1/2014
The invisible goon in the lagoon has been detected	Farmshine	Dieter Krieg	12/5/2014
This poisonous cocktail shows absolutely no mercy.	Farmshine	Dieter Krieg	12/5/2014
Gypsum linked to poison gas in manure storage	Lancaster Farming	Gruber, Philip.	2/21/2015

Given the numerous opportunities within the state of Pennsylvania and around the country, this work has been well received and has generated interest from a range of people in the industry including producers, haulers, engineers and county officials and fire departments. A nationally recognized manure management eXtension website has

early findings from this demonstration (eXtension, 2015). Continued communication of the observations collected from this project will prolong the discussion of manure storage safety, such as in articles generated from our fact sheets in farm.com (2015) and The Beef Site (2015).

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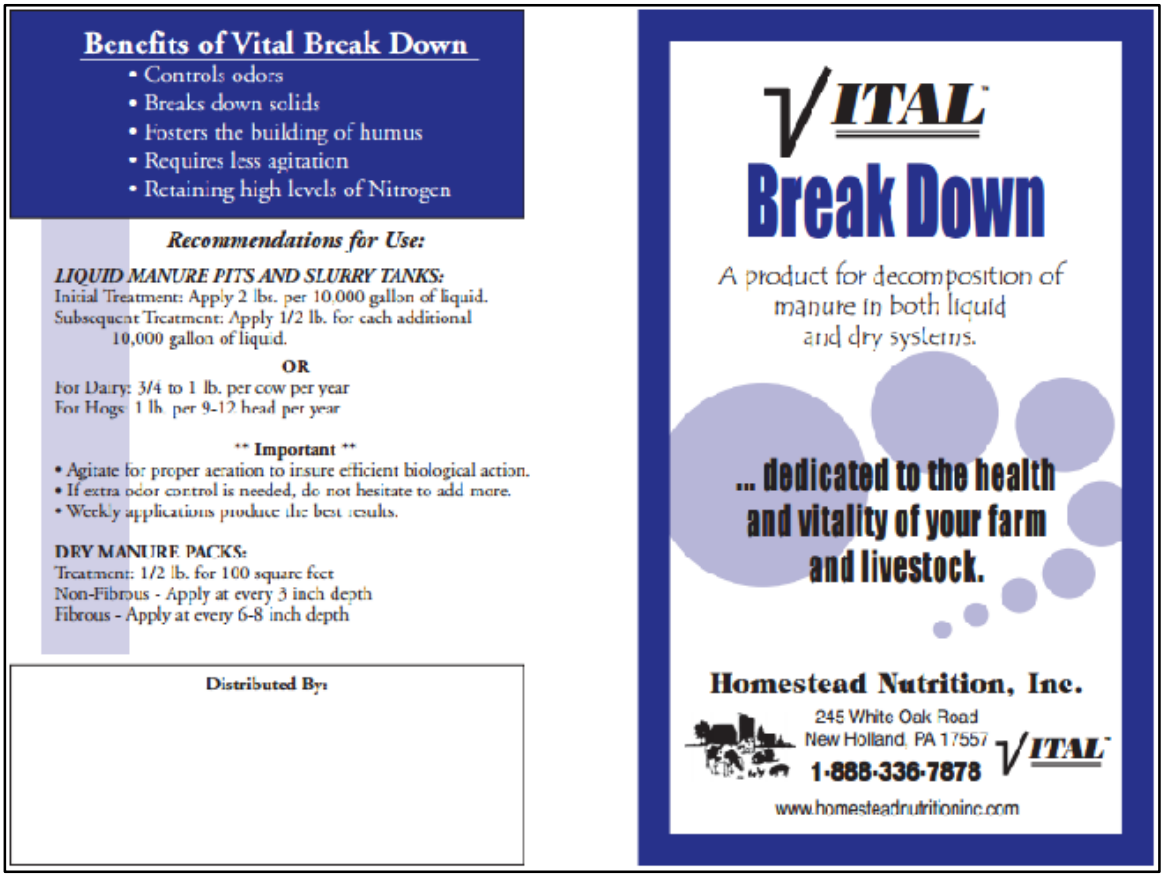
Appendix A. Manure Additives

Vital Breakdown



Benefits of Vital Break Down

- Controls odors
- Breaks down solids
- Fosters the building of humus
- Requires less agitation
- Retaining high levels of Nitrogen

Recommendations for Use:

LIQUID MANURE PITS AND SLURRY TANKS:
Initial Treatment: Apply 2 lbs. per 10,000 gallon of liquid.
Subsequent Treatment: Apply 1/2 lb. for each additional 10,000 gallon of liquid.

OR

For Dairy: 3/4 to 1 lb. per cow per year
For Hogs 1 lb. per 9-12 head per year

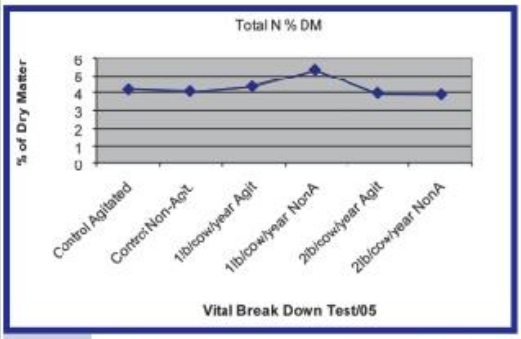
** Important **

- Agitate for proper aeration to insure efficient biological action.
- If extra odor control is needed, do not hesitate to add more.
- Weekly applications produce the best results.

DRY MANURE PACKS:
Treatment: 1/2 lb. for 100 square feet
Non-Fibrous - Apply at every 3 inch depth
Fibrous - Apply at every 6-8 inch depth

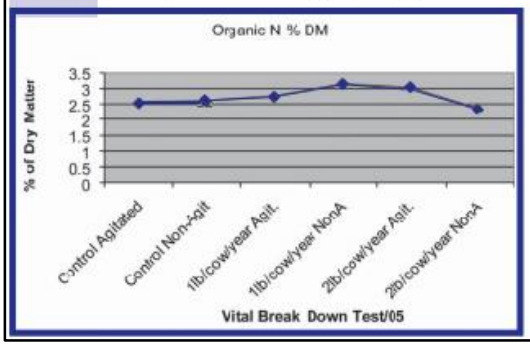
Distributed By:

VITAL
Break Down
A product for decomposition of manure in both liquid and dry systems.
... dedicated to the health and vitality of your farm and livestock.
Homestead Nutrition, Inc.
245 White Oak Road
New Holland, PA 17557
1-888-336-7878
VITAL
www.homesteadnutritioninc.com

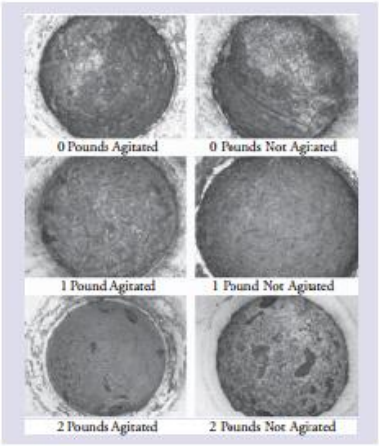


This data shows the amount of Nitrogen retained in the total dry matter of the manure after being treated with Vital Break Down. The chart reveals that the highest amount of retained Nitrogen occurred at the recommended rate of 1 lb per cow per year.

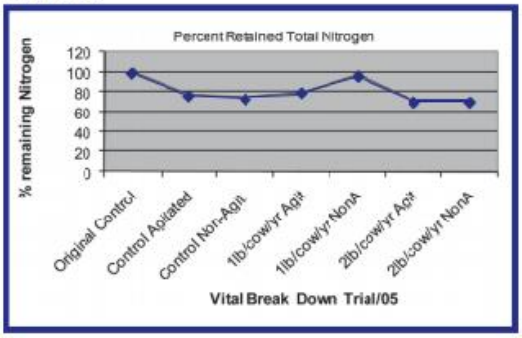
This data shows the amount of organic Nitrogen formed after treating the manure with Vital Break Down. Organic Nitrogen is a more stable form of Nitrogen. The presence of organic Nitrogen confirms the fact that humus is being built, which is a very positive thing.



VITAL BREAK DOWN TRIAL

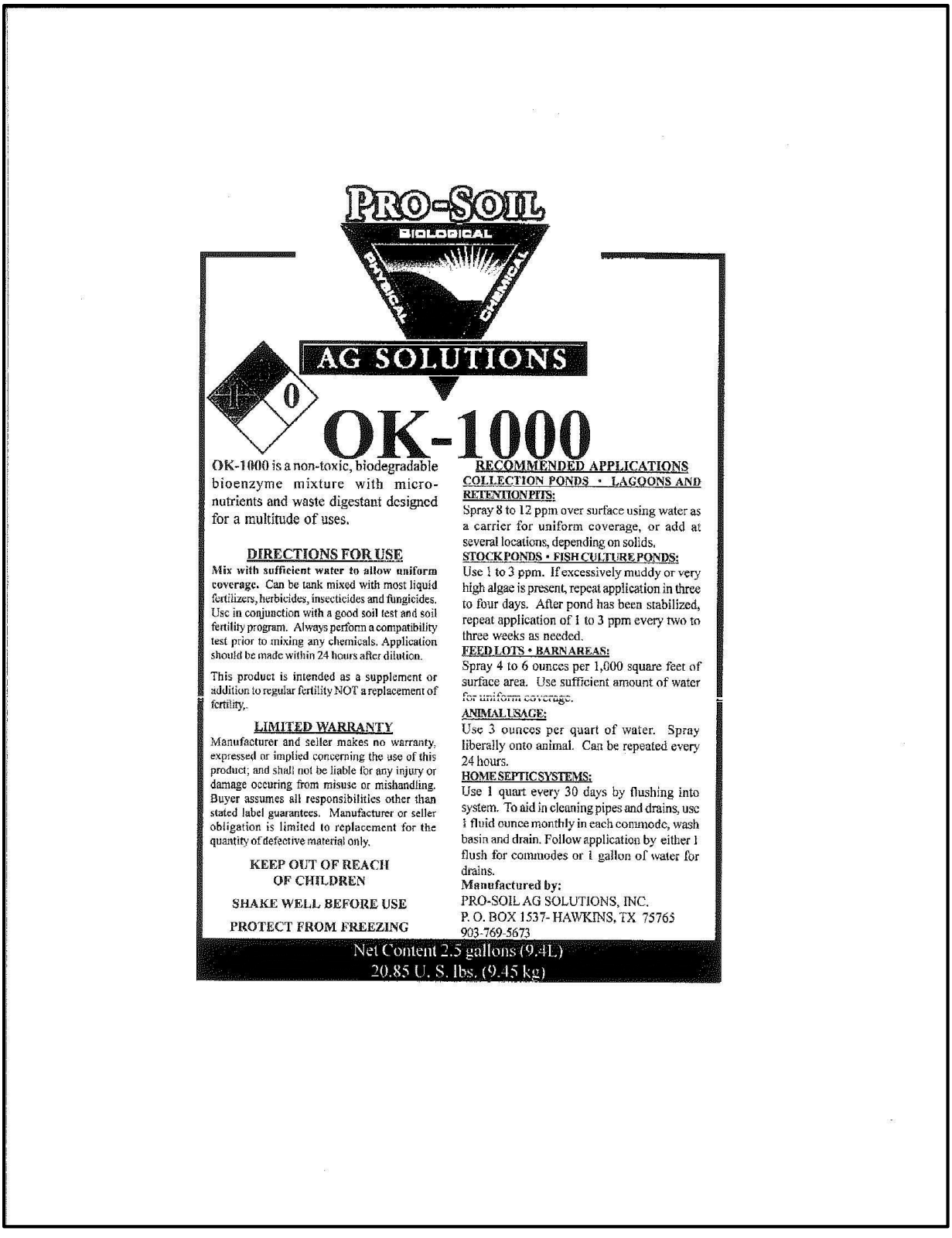


This chart compares the amounts of total Nitrogen, organic and non-organic, after the application of Vital Break Down. Again, the best results were obtained from applying the 1 pound rate, which is our suggested rate of application.



Pro Soil OK-1000

OK-1000 is a product that is designed to abate mal-odors and reduce solids for animal waste byproducts. This technology uses a proprietary enzymatic process that works through the acceleration of the natural biodegradation process and includes enzymes and biological catalyst as well as specific micronutrients all of which are non hazardous, non toxic and environmentally friendly. This process molecularly transforms mal-odors into benign species. In waste byproducts, mal-odors are generated by the anaerobic digestion of biomass. Hydrogen sulfide and mercaptans, which are generated as by-products of anaerobic digestion, are strong correlants to the mal-odor industry. OK-1000 enzyme mal-odor abatement protocol proceeds in three stages. In the first stage, the mal-odor species generated by the decaying of biomass are captured. This is facilitated by the enzymes and bio-chemical reactions with a number of the micro constituents in the catalyst solution. The second stage,involves the aerobic respiration of the insitu and added microbes. This process consumes the Biomass, releasing carbon dioxide, water and energy. The third stage, involves the propagation and growth of the microbial populations. Mal-odor and toxic emmissions species, such as hydrogen sulfide,mercaptans,ammonia,amines and other nitrogen or sulfur hetero-atom containing organic materials are converted into a benign species, becoming part of the building blocks of new cell structure. Hydrogen sulfide are suppressed by the use of the product. When hydrogen sulfide is present, this proprietary bio catalyst enzyme captures the hydrogen sulfide and cleave the sulfhydryl group. The sulfhydryl group winds up in a sulfur containing amino acid or mercaptans when incorporated into animal manure or municipal sludge that is maintained aerobically. It is also effective in treating solid waste streams and waste water, both the insitu and air to air phases. Ammonia emissions are suppressed by a bioenzyme/catalytic process. Any ammonia captured is bound into the enzymatic process. The ammonia is then used to build amino acids, pricipally aspartic. These then support the healthy propagation of the aerobic bacteria populations. Instead of the ammonia winding up in the air, the nitrogen source stays contained in the biomass, organically bound and enhances the fertilizer value of the manure. Recommended application rates are 1 gallon to 326,000 gals of manure.


PRO-SOIL
BIOLOGICAL
PHYSICAL
CHEMICAL
AG SOLUTIONS
0
OK-1000
OK-1000 is a non-toxic, biodegradable bioenzyme mixture with micro-nutrients and waste digestant designed for a multitude of uses.
DIRECTIONS FOR USE
Mix with sufficient water to allow uniform coverage. Can be tank mixed with most liquid fertilizers, herbicides, insecticides and fungicides. Use in conjunction with a good soil test and soil fertility program. Always perform a compatibility test prior to mixing any chemicals. Application should be made within 24 hours after dilution.
This product is intended as a supplement or addition to regular fertility NOT a replacement of fertility.
LIMITED WARRANTY
Manufacturer and seller makes no warranty, expressed or implied concerning the use of this product; and shall not be liable for any injury or damage occuring from misuse or mishandling. Buyer assumes all responsibilities other than stated label guarantees. Manufacturer or seller obligation is limited to replacement for the quantity of defective material only.
KEEP OUT OF REACH OF CHILDREN
SHAKE WELL BEFORE USE
PROTECT FROM FREEZING
RECOMMENDED APPLICATIONS
COLLECTION PONDS • LAGOONS AND RETENTION PITS:
Spray 8 to 12 ppm over surface using water as a carrier for uniform coverage, or add at several locations, depending on solids.
STOCK PONDS • FISH CULTURE PONDS:
Use 1 to 3 ppm. If excessively muddy or very high algae is present, repeat application in three to four days. After pond has been stabilized, repeat application of 1 to 3 ppm every two to three weeks as needed.
FEED LOTS • BARN AREAS:
Spray 4 to 6 ounces per 1,000 square feet of surface area. Use sufficient amount of water for uniform coverage.
ANIMAL USAGE:
Use 3 ounces per quart of water. Spray liberally onto animal. Can be repeated every 24 hours.
HOME SEPTIC SYSTEMS:
Use 1 quart every 30 days by flushing into system. To aid in cleaning pipes and drains, use 1 fluid ounce monthly in each commode, wash basin and drain. Follow application by either 1 flush for commodes or 1 gallon of water for drains.
Manufactured by:
PRO-SOIL AG SOLUTIONS, INC.
P. O. BOX 1537- HAWKINS, TX 75765
903-769-5673
Net Content 2.5 gallons (9.4L)
20.85 U. S. lbs. (9.45 kg)

Appendix B. Dairy Farm Background Characterization

NRCS CIG Demo Gypsum, Additives & Dairy Manure Gas
Farm Name or Owner

Date and note taker name: _____ _____

Farm contact person
Phone #s
Email
Address

Driving Directions

Type of dairy for our demonstration: ___gypsum; ____ with additive; ___no gypsum

Barn Description(s) that contribute manure to storage
General: # stall rows; feeding aisle; shape

Primary barn dimensions (L, W, H) and description (natural ventilation, bedded pack; freestall; etc.):

2nd barn dimensions (optional):

Site plan sketch (on back) with compass north
House age and builder
Cleanliness/ condition of note

Barn Manure Management
Type of handling system (slurry, liquid, etc.)

Barn cleanout schedule (daily-approx. time; 2xdaily, etc.)
Cleanout technique (scraper, skid steer, gutter cleaner, etc.)

General conditions
(temperature, odor, moisture, quantity of feed waste, water spill, etc.)

Type and use of manure additives

Notes:

Manure Storage Description

Geometry and maximum manure depth
Design and construction contractors
Size (dimensions, gallons, etc.)
Material (concrete, steel, earthen)
Intended capacity (6 months, etc.)
Loading design (push off onto top, bottom, etc.)

Unloading design

Notes relevant (% buried; surface water encroachment, etc.)

Manure Storage Management

Agitation schedule
Type (top discharge; tractor PTO, etc.)
Frequency/ duration
Notable criteria

Manure and other materials (check-off and estimated amounts, where available)

Dairy manure	Y / N
Heifer manure	Y / N
Dry cow manure	Y / N
Silage leachate	Y / N
Milkhouse washwater	Y / N
Barnyard runoff	Y / N
Other additions	Y / N

Notes:

Cow Management

Milk supplied to _____
Milk cow population _____ Breed _____
Groups (hi, lo)
Average cow weight
Milk production
Number milking/day
Population contributing to manure storage
Heifers
Dry cows
Other animals contributing to manure storage

Feeding Schedule, type of feeders, total tonnage, daily feed consumption
Lighting Schedule, type and amount
Type of waterers; consumption if available
Feed analysis (get papers from nutrition consultant?)
DDGs fed?
Special Production strategies (cooling for feed consumption etc.)

Notes:

Bedding

Type
Amount
Cost
Amendment (description and amount)
Gypsum use(d)
Amount
Cost

Notes:

****

Site visit #1 Farm Name/owner _____

Date
Personnel present
Observations today:
Temperature range
Humidity
Wind velocity and direction
Precipitation
Weather-clouds etc.
Notes

Manure storage
Crust? Depth & description
Last agitation. Date and describe

Notes:

****

Site visit #2 Farm Name/owner _____

Date

Personnel present

Observations today:

- Temperature range
- Humidity
- Wind velocity and direction
- Precipitation
- Weather-clouds etc.
- Notes

Manure storage today

- Crust? Depth & description
- Last agitation. Date and describe

Notes:

Table A-1: Farm characterization summary

Sampling Season	Farm	Cumulative H_2S Concentration	Gypsum Application Rate	Storage Structure	Manure Transfer	Storage size	Thickness of Bottom Solids	Surface Crust		Sulfur Sources (Aside from Gypsum)		Somatic Cell Count
		60 min	lbs cow-1 day-1							Copper Sulfate Foot Baths	Distiller's Grains[1]	
						(gal)	(inches)	(%)	(inches)	(gal 6 month^{-1})	(% DM)	
Fall 2013 (F13)	Bl F13 GT	1250.8	2.0	Subgrade Concrete	Scrape - Topload	1,100,000	36	45	12	0	0	225,000
	Wr F13 G	13261.7	5.1	Subgrade Concrete	Scrape - Topload	415,000	12	100	12	2400	0	150,000
	Ht F13 NG	150.2	0.0	Subgrade Concrete	Scrape - Topload	365,000	48	100	36	0	0	60,000
	Cp F13 NG	145.7	0.0	Subgrade Concrete	Scrape - Topload	290,000	36	100	36	480	1.319	140,000
Spring 2014 (S14)	Cp S14 NG	262.7	0.0	Subgrade Concrete	Scrape - Topload	290,000	12	100	30	480	1.319	140,000
	Ht S14 NG	91.4	0.0	Subgrade Concrete	Scrape - Topload	365,000	36	100	36	0	0	60,000
	Sh S14 NG	66.5	0.0	Subgrade Concrete	Scrape - Topload	1,500,000	24	100	12	0	0	100,000
	Wr S14 G	982.9	5.1	Subgrade Concrete	Scrape - Topload	415,000	36	55	12	2400	0	150,000
	We S14 G	2828.8	0.6	Subgrade Concrete	Scrape to Sump - Gravity Flow	850,000	6	100	2	600	5.07	200,000
	Sr S14 G	203.0	0.3	Earth Lagoon	Scrape - Topload	160,000	NA	100	12	0	NQ	200,000
	Bl S14 GT	3645.4	3.4	Subgrade Concrete	Scrape - Topload	1,100,000	60	35	12	0	0	225,000
	Br S14 GT	60.6	0.4	Subgrade Concrete	Scrape to sump - Two Transfer Sump Pumps	370,000	12	50	0	1040	NQ	225,000
	Cy S14 GT	1888.2	1.2	Abovegrade Steel	Scrape to Sump - Tranfer Pump to Bottom of Storage	380,000	80	100	12	0	7.914	170,000
	Hr S14 GT	2102.3	7.4	Lined Earth Lagoon	Scrape to Sump - Gravity Flow	250,000	NA	0	0	150	0	150,000
Fall 2014 (F14)	We F14 G	3104.3	0.6	Subgrade Concrete	Scrape to Sump - Gravity Flow	850,000	60	100	12	600	5.07	200,000
	Sr F14 G	737.5	0.3	Earth Lagoon	Scrape - Topload	160,000	NA	100	12	0	NQ	200,000
	Hr F14 GT	1984.1	7.4	Lined Earth Lagoon	Scrape to Sump - Gravity Flow	250,000	NA	0	0	150	0	150,000
	Br F14 GT	127.2	0.5	Subgrade Concrete	Scrape to sump - Two Transfer Sump Pumps	370,000	24	100	2	1040	NQ	225,000
	Bl F14 GT	21076.5	3.4	Subgrade Concrete	Scrape - Topload	1,100,000	24	80	12	0	0	100,000

Notes: Season codes are F13 = fall 2013, S14 = spring 2014 and F14 = fall 2014
Treatment codes are NG = non-gypsum, G = gypsum and GT = gypsum with treatment
[1]NQ = Distiller's grains are used in diet but were not quantified

Appendix C. Gas monitor information sheets

MX6 iBrid Brochure and specification sheet (Industrial Scientific, Pittsburgh, PA)

Don't Buy Gas Detectors

Subscribe to Gas Detection as a Service

It gives you help from The Gas Detection People.

Let us handle your gas detection program. Gas d etection is probably not core to what you do. But, it's all that we do. It's what we love to do.

It gives you a safer workplace.

On average, gas detectors go into high alarm once every ten days. How many high alarms did your facility have? iNet gives you information and tools to fix problems before they happen.

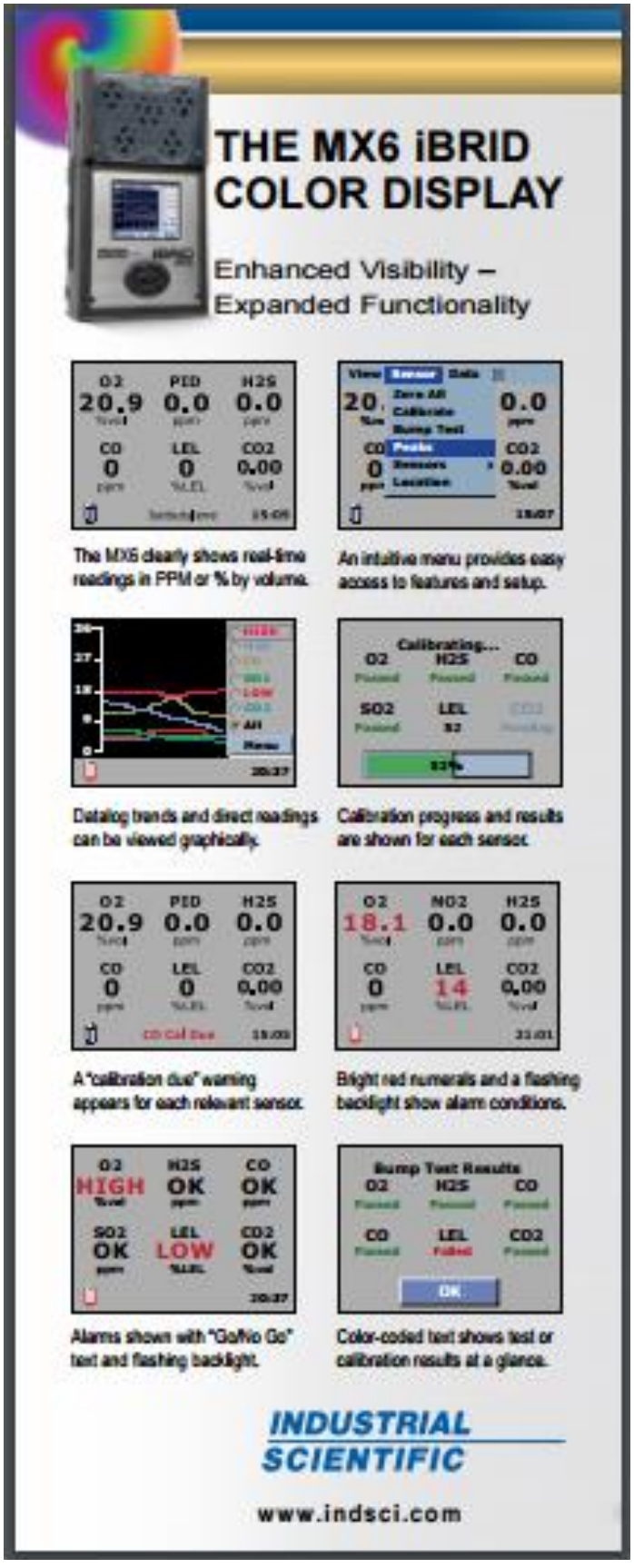
It gives you cost savings.

The list price is only part of a gas detector's total cost. You have to maintain it. You have to wait for it to be serviced. iNet eliminates unnecessary ownership and maintenance costs.

iNet Compatible for Increased Safety, Cost Savings and Productivity

iNet is a software-based service that manages your fleet of gas detectors. iNet solves the most common gas detection problems. For example, iNet keeps people safe by providing visibility into alarms, exposure and usage. It keeps gas detectors working without costly and time-consuming maintenance. And with iNet, you won't have to buy the MX6. So why do it?

How Does iNet Work?


THE MX6 iBRID COLOR DISPLAY
Enhanced Visibility – Expanded Functionality
The MX6 clearly shows real-time readings in PPM or % by volume.
An intuitive menu provides easy access to features and setup.
Datalog trends and direct readings can be viewed graphically.
Calibration progress and results are shown for each sensor.
A "calibration due" warning appears for each relevant sensor.
Bright red numerals and a flashing backlight show alarm conditions.
Alarms shown with "Go/No Go" text and flashing backlight.
Color-coded text shows test or calibration results at a glance.
INDUSTRIAL SCIENTIFIC
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ORDERING INFORMATION

MX6 BASE UNIT	SENSORS OPTIONS	BATTERY OPTIONS	VERSION OPTIONS	AGENCY CERTIFICATIONS	LANGUAGE OPTIONS	
Supplied with monitor: Universal charger, nylon carrying case, belt clip, calibration cup, wrist strap, manual, quick start guide, dust filter/water stop (with pump), sample tubing (with pump).	Combustible Gases: LEL (Pentane) LEL (Methane) CH_4 IR (0-100% vol.) CH_4 (0-5%) Hydrocarbons IR (0-100% LEL) Volatile Organic Compounds: PID Toxic Gases: H_2S O_2 NO_2 CO COH_2S NH_3 Cl_2 ClO_2 PH_3 CO High SO_2 HCl HCN H_2 PH_3 High NO COH_2 low interference CO_2 IR	Li-ion	Diffusion	UL/CSA	English	Portuguese
		Li-ion/Ext. Range	Pump	ATEX/IECEx	French	Indonesian
		Alkaline		MSHA/NIOSH	Spanish	Russian
				GOST-R	German	Polish
				INMETRO	Italian	Czech
				KOSHA	Dutch	
				China EX		
				China CPC		

Build and price your MX6 online with the MX6 instrument builder.
www.indsci.com/MX6builder.aspx

COMMON INSTRUMENT CONFIGURATIONS

PART NO.	DESCRIPTION
MX6-K1230081	MX6 - LEL (Pentane), CO, H_2S, O_2, Ext. Li-Ion
MX6-K123R111	MX6 - LEL (Pentane), CO, H_2S, O_2, PID, Li-Ion, Pump
MX6-L1230111	MX6 - LEL (Methane), CO, H_2S, O_2, Li-Ion, Pump
MX6-M1030211	MX6 - Methane, CO, O_2, CO_2 IR, Ext. Li-Ion, Pump
MX6-MDH34211	MX6 - Methane, NO, CO high range, O_2, NO_2, Ext. Li-Ion, Pump
MX6-K1235111	MX6 - LEL (Pentane), CO, H_2S, O_2, SO_2, Li-Ion, Pump
MX6-KJ835101	MX6 - LEL (Pentane), COH_2S, NH_3, O_2, SO_2, Li-Ion
MX6-MH2303201	MX6 - Methane, CO high range, H_2S, O_2, CO_2, Ext Li-Ion

COMMON INDUSTRY CONFIGURATIONS

MX6-KJ53R211	MX6 - LEL, COH_2S, O_2, SO_2, PID, Extended Li-Ion, Pump Petroleum Refining
MX6-K1033211	MX6 - LEL, CO, O_2, CO_2, Extended Li-Ion, Pump Brewing/Bottling/Wineries
MX6-KJ835101	MX6 - LEL, $COH2S$, O_2, SO_2, ClO_2, Li-Ion Pulp/Paper
MX6-K873R211	MX6 - LEL, O_2, NH_3, Cl_2, PID, Extended Li-Ion, Pump Hazmat
MX6-M1030401	MX6 - CH_4 (%), CO, O_2, Li-Ion (MSHA/AUS) Mining
MX6-M1034401	MX6 - CH_4 (%), CO, O_2, NO_2, NO, Li-Ion Extended (MSHA/AUS) Mining (Diesel Applications)

DSX DOCKING STATION

The DSX™ Docking Station easily maintains the gas detectors that keep your people safe in hazardous environments.

- Know that your gas detectors are ready for use every day, every shift, without the burden of manual maintenance routines.
- Stop worrying about calibration gas and let the DSX monitor and order replacement gas cylinders when you need them.
- Effortlessly manage your fleet, data, and software updates from any web-enabled device.

ACCESSORIES

PART NO.	DESCRIPTION
MX6KIT-0000R211	MX6 kit - PID, Extended Li-Ion, with pump
MX6KIT-K1230211	Confined space kit, 4-gas with pump
MX6KIT-K123R211	Confined space kit, 4-gas/PID with pump
18108329-ABC -ABC	DSX™ Docking Station for MX6 A – DSX Mode: 0 = DSX Standalone 1 = DSX Cloud-connected 2 = DSX-L Local Server B – Number of Gas Inlet Ports: 3 = 3 Ports 6 = 6 Ports C – Power Cord Type: 0 = None, 1 = North America, 2 = EU, 3 = AUS, 4 = UK
18106765	SPS motorized sampling pump module
18107886	MX6 datalink assembly – software included
18106971	MX6 replacement battery charger
18107894	MX6 battery charger/datalink, universal
18107811	MX6 battery charger, 12V
18107136	MX6 battery charger, 5-Unit
18107343	MX6 truck-mount charger, 12V
18107250	MX6 truck-mount charger, (hard-wired)
17131838-1	Rechargeable Li-Ion battery pack, UL/CSA/ATEX/IECEx/GOST-R/KOSHA
17131838-2	Rechargeable Li-Ion extended battery pack, UL/CSA/ATEX/IECEx/GOST-R/KOSHA
17131838-4	Rechargeable Li-Ion battery pack, MSHA/AUS
17131838-5	Rechargeable Li-Ion extended battery pack, MSHA/AUS
17131846-3	Alkaline battery pack, UL/CSA/ATEX/IECEx/GOST-R/KOSHA
17131846-6	Alkaline battery pack, MSHA/AUS
18106856-0	MX6 without pump, hard leather carrying case
18106856-1	MX6 without pump, hard leather case, no display window
18106880-0	MX6 with pump, hard leather carrying case
18106880-1	MX6 with pump, hard leather case, no display window
18106831	Nylon carrying case, supplied with MX6 without pump
18106864	Nylon carrying case, supplied with MX6/SPS with pump
17095746	MX6iTX maintenance tool
17128489	MX6 Calibration cup
17153749	MX6 screen protector, 10 pack
17153760	MX6 screen protector, 100 pack

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SP6 MOTORIZED SAMPLING PUMP
CHARGER / DATALINK
· Instantly download event logs and datalog data while instrument battery charges
· Quickly and easily configure instrument settings
MULTI-UNIT CHARGER
CHARGER
TRUCK MOUNT CHARGER
LEATHER CASES
MX6 CONFINED SPACE KIT
Cylinder shown with iGas Card Reader
Choice of MX6 monitor, universal charger, nylon carrying case, belt clip, calibration cup, wrist strap, maintenance tool, manual, quick start guide, calibration tubing, dust filter/water trap (with pump), calibration fitting (with pump), sample tubing (with pump), calibration gas (appropriate mix) with regulator, spare replaceable cell alkaline battery pack, rugged Pelican® case.

iBRID™ MX6

SPECIFICATIONS*

INSTRUMENT WARRANTY:
Warranted for as long as the instrument is supported by Industrial Scientific Corporation

CASE MATERIAL:
Lexan/ABS/Stainless Steel w/protective rubber overmold

DIMENSIONS:
135 mm x 77 mm x 43 mm (5.3" x 3.05" x 1.7") – without pump
167 mm x 77 mm x 56 mm (6.6" x 3.1" x 2.2") – with pump

WEIGHT:
409 g (14.4 oz) typical – without pump
511 g (18.0 oz) typical – with pump

DISPLAY/READOUT:
Color Graphic Liquid Crystal Display

POWER SOURCE/RUN TIMES:
Rechargeable Lithium-ion (Li-ion) Battery Pack (24 hours) – without pump
Rechargeable, Extended-Range Lithium-ion (Li-ion) Battery Pack (36 hours) – without pump
Replaceable AA Alkaline Battery Pack (10.5 hours) – without pump

OPERATING TEMPERATURE RANGE:
-30°C to 55°C (-4°F to 131°F)

OPERATING HUMIDITY RANGE:
15% to 95% non-condensing (continuous)

MEASURING RANGES:

SENSOR	RANGE	RESOLUTION
CATALYTIC BEAD		
Combustible Gas	0-100% LEL	1%
Methane	0-5% vol	0.01%
ELECTROCHEMICAL		
Ammonia	0-500 ppm	1
Carbon Monoxide	0-1,500 ppm	1
Carbon Monoxide (High Range)	0-9,999 ppm	1
Carbon Monoxide/Hydrogen low	0-1,000 ppm	1
Chlorine	0-50 ppm	0.1
Chlorine Dioxide	0-1 ppm	0.01
Carbon Monoxide/	CO: 0-1,500 ppm	1
Hydrogen Sulfide (CO/H)	H2S: 0-500 ppm	0.1
Hydrogen	0-2,000 ppm	1
Hydrogen Chloride	0-30 ppm	0.1
Hydrogen Cyanide	0-30 ppm	0.1
Hydrogen Sulfide	0-500 ppm	0.1
Nitric Oxide	0-1,000 ppm	1
Nitrogen Dioxide	0-150 ppm	0.1
Oxygen	0-30% vol	0.1%
Phosphine	0-5 ppm	0.01
Phosphine (High Range)	0-1,000 ppm	1
Sulfur Dioxide	0-150 ppm	0.1
INFRARED		
Hydrocarbons	0-100% LEL	1%
Methane (% vol)	0-100% vol	1%
Methane (% LEL)	0-100% LEL	1%
Carbon Dioxide	0-5% vol	0.01%
PHOTOIONIZATION		
VOC	0-2,000 ppm	0.1

CERTIFICATIONS:

UL:	Class I, Groups A,B,C,D T4; Class II, Groups F,G; AEx ia d IIC T4
CSA:	Class I, Groups A,B,C,D T4; Ex d ia IIC T4
MSHA:	CFR30, Part 22, Intrinsically safe for methane/air mixtures
ATEX:	Ex ia IIC T4 Ga / Ex ia I Ma; IP64; Equipment Group and Category: II 1G / I M1 (I M2 w/IR sensor)
IECEx:	Ex ia IIC T4 Ga / Ex ia I (Ex ia d I w/IR sensor)
ANZEx:	Ex ia a Zone 0 I; IP64; Ex ia a Zone 0 IIC T4
INMETRO:	Ex ia IIC T4 Ga
GOST-R:	PBExiadI X / 1ExiadIICT4 X
KOSHA:	Ex d ia IIC T4
China Ex:	Ex ia d IIIC T4
China CPC:	Metrology Approval

*These specifications are based on performance averages and may vary by instrument

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AMERICAS
Phone: +1-412-788-4353
1-800-DETECTS (338-3287) North America
Fax: +1-412-788-5353
info@indsci.com

ASIA PACIFIC
Phone: +65-6561-7377
Fax: +65-6561-7167
info@ap.indsci.com

EMEA
Phone: +33 (0)1 57 32 92 61
Fax: +33 (0)1 57 32 92 67
info@eu.indsci.com

Tango TX1 specification sheet (Industrial Scientific, Pittsburgh, PA)

TANGO™ TX1

SINGLE GAS MONITOR

ORDERING INFORMATION

PART NO.	DESCRIPTION
INSTRUMENT CONFIGURATIONS	
TX1-1	Tango TX1, CO
TX1-2	Tango TX1, H_2S
TX1-4	Tango TX1, NO_2
TX1-5	Tango TX1, SO_2
TX1-G	Tango TX1, CO/H_2 low
ACCESSORIES	
18108330-A0C -A0C	DSX™ Docking Station for Tango™ TX1 A – DSX Mode: 0 = DSX Standalone, 1 = DSX Cloud-connected, 2 = DSX-L Local Server B – Number of Gas Inlet Ports: 3 = 3 Ports, 6 = 6 Ports C – Power Cord Type: 0 = None, 1 = North America, 2 = Europe, 3 = Australia, 4 = UK
17154367	Replacement battery
18109171	Soft nylon case, Black
18109259	Soft nylon case, Orange
18109218	Dust barrier kit, 5 pack
18109258	Water barrier kit, 5 pack
18109238	CalCup and tubing kit
17103908	Belt clip
17154915-0	AlarmAmp™, Black
17154915-1	AlarmAmp™, Safety Orange
17154916	Black nameplate
17154917	Green nameplate
17154918	Yellow nameplate
17154919	Blue nameplate
17154920	White nameplate

SPECIFICATIONS

INSTRUMENT WARRANTY:
Three year warranty which does not include battery, sensors and filters.*
CO and H_2S sensors are warranted for 3 years from the initial purchase date.
All other sensors are warranted for 2 years from the initial purchase date.

DISPLAY:
Segment liquid crystal display (LCD)

KEYPAD:
Two buttons

CASE MATERIALS:
Case top: Polycarbonate with a protective rubber overmold
Case bottom: Conductive polycarbonate

ALARMS:
Three strobe-emitting visual alarm LEDs (two red; one blue)
100 decibel (dB) audible alarm at a distance of 10 cm (3.94"); Vibration alarm

DIMENSIONS:
99 x 51 x 25 mm (3.9" x 2.0" x 1.4")

WEIGHT:
126.0 g (4.4 oz.)

TEMPERATURE RANGE:
-40°C to +50°C (-40°F to +122°F)†

HUMIDITY RANGE:
15%-95% Non-condensing (continuous)

SENSORS:
CO, COR/H_2, H_2S, NO_2, SO_2 - Electrochemical sensor technology

SENSOR MEASURING RANGES:

Carbon Monoxide (CO):	0 to 1,000 ppm in 1 ppm increments
Carbon Monoxide (CO/H_2 low):	0 to 1,000 ppm in 1 ppm increments
Hydrogen Sulfide (H_2S):	0.0 to 200.0 ppm in 0.1 ppm increments
Nitrogen Dioxide (NO_2):	0.0 to 150.0 ppm in 0.1 ppm increments
Sulfur Dioxide (SO_2):	0.0 to 150.0 ppm in 0.1 ppm increments

BATTERY:
3.6 V Primary lithium-thionyl chloride (Li-SOCl2); 1.5Ah, 2/3AA; replaceable; non-rechargeable; always on; 3 year run time depending on operating conditions

DATALOGGING:
3 months at 10-second intervals

EVENTLOGGING:
60 alarm events

CERTIFICATIONS

INGRESS PROTECTION:
IP68; IP67

-40°C to +50°C (-40°F to +122°F)

ATEX	Ex ia I Ma Ex ia IIC T4 Ga Equipment Group and Category: I M1 and II 1G
CSA	Ex ia IIC; Class I, Groups A B C D; T4
IECEx	Ex ia I Ma Ex ia IIC T4 Ga
UL (C-UL)	Class I, Groups A, B, C, and D; Class II, Groups E, F, and G; T4; Exia Class I, Zone 0, AEx ia IIC T4
INMETRO	Ex ia IIC T4 Ga; Ex ia I Ma

-20°C to +50°C (-4°F to +122°F)

China Ex	Ex ia IIC T4 Ga
KOSHA	Ex ia IIC T4

These specifications are based on performance averages and may vary by instrument.

* The Tango is warranted to be free from defects in material and workmanship under normal and proper use and service for 3 years from the initial purchase date.

† Operating temperatures above 50°C (122°F) may cause reduced instrument accuracy. Operating temperatures below -20°C (-4°F) may cause reduced instrument accuracy and affect display and alarm performance.

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AMERICAS
Phone: +1-412-788-4353
1-800-DETECTS (338-3287) North America
Fax: +1-412-788-4353
info@indsci.com

ASIA PACIFIC
Phone: +65-6561-7377
Fax: +65-6561-7757
info@ap.indsci.com

EMEA
Phone: +33 (0)1 57 32 92 61
Fax: +33 (0)1 57 32 92 67
info@eu.indsci.com

Appendix D. Manure Characterization and Environmental Parameters

NRCS CIG Demo Gypsum, Additives & Dairy Manure Gas

On-Farm measurements

Manure surface temperature: IR thermometer
Manure sample ORP (oxidation reduction potential): hand-held meter (starting spring 2014)
Gas concentration:
- Hydrogen sulfide
- Ammonia
- Carbon dioxide
- Carbon monoxide
- Methane (%LEL)

Oxygen
Weather (one location):
- Air temperature
- Relative humidity
- Wind velocity
- Wind direction

Manure analysis from Ag and Analytical Services Lab (Penn State)

3 Samples drawn: *Before* agitation, near *top* and near *bottom* of storage and *After* agitation.

Solids %
Total Nitrogen (N)
Ammonium N (NH4-N)
Calculated organic N
Total Phosphate (P2O5)
Total Potash (K2O)
Total Calcium (Ca)
Total Magnesium (Mg)
Total Sulfur (S)
Total Copper (Cu)
Total Zine (Zn)
Total Manganese (Mn)
Total Iron (Fe)
Total Sodium (Na)
Total Aluminum (Al)
pH
Ash %
Volatiles %
P Source Coefficient

Table A-2: Summary of field measurements

Sampling Season	Farm[1]	Ambient Temperature[2]	Manure Temperature				Oxidation-Reduction Potential (ORP)			pH			Average Wind Speed[4]
			Surface Before Agitation[3]	1 Foot Below Crust Before Agitation	Bottom Before Agitation	Middle After Agitation	1 Foot Below Crust Before Agitation	Bottom Before Agitation	Middle After Agitation	1 Foot Below Crust Before Agitation	Bottom Before Agitation	Middle After Agitation	
		deg C	deg C	deg C	deg C	deg C	(mV)	(mV)	(mV)				m s^{-1}
Fall 2013	Bl F13 GT	14.8	13.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5
	Wr F13 G	14.7	7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.6
	Ht F13 NG	18.0	16.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5
	Cp F13 NG	4.1	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.0
Spring 2014	Cp S14 NG	12.5	9.5	15.2	14 8	15.1	23	22	28	6.46	6.42	6.38	0.0
	Ht S14 NG	6 8	4.3	7.2	11 5	10.5	19	10	2	6.65	6.82	6.77	2.0
	Sh S14 NG	19.7	8.3	16.4	12.7	16.4	-39	-57	-23	7.71	8.02	7.45	3.2
	Wr S14 G	0 3	-5.6	0.1	1.2	6.1	-13	-11	-21	7.31	7.2	7.39	0.8
	We S14 G	10.1	-2.7	2.8	5.4	6.6	18	17	11	6.67	6.69	6.79	0.4
	Sr S14 G	3.4	-0.8	8.8	8.0	11.0	-4	-10	7	6.69	6.83	6.75	0.2
	Bl S14 GT	7 5	2.7	4.9	7.0	5.5	-3	-7	-6	7.08	6.95	6.89	3.2
	Br S14 GT	16.7	15 5	9.1	8.6	9.0	-13	-7	-11	7.24	7.14	7.2	N/A
	Cy S14 GT	21.8	15 3	11.7	14.6	14.0	-13	7	-8	7.24	6.88	7.16	0.0
	Hr S14 GT	3.6	1.6	7.1	6.8	6.8	-37	-2	-3	7.67	6.96	7.06	0.9
Fall 2014	We F14 G	20.9	19 5	20.9	20 8	22.3	19	24	22	6.52	6.47	6.47	2.9
	Sr F14 G	13.3	20 5	20.0	21.0	20.5	16	-3	-17	6.6	7.01	7.19	N/A
	Hr F14 GT	14.4	18 5	17.8	18.6	17.5	5	9	11	6.85	6.72	6.67	N/A
	Br F14 GT	17.9	20.0	21.7	21.7	21.8	-28	-28	-34	7.42	7.38	7.49	0.7
	Bl F14 GT	6.7	15 2	14.7	13.6	16.2	14	12	8	6.62	6.67	6.71	0.5

Notes: [1]F13, S14 and F14 represent Fall 2013, Spring 2013 and Fall 2014, respectively

[1]NG, G and GT represent non-gypsum, gypsum and gypsum with treatment, respectively

[2]Ambient temperature was averaged from Kestral wetaher station data.

[3]Surface temperature were averaged from measurements collected using an infrared thermometer

[4]Wind Speeds were average over first 60 mins of agitation from data collected from Kestral™ weather station at one location

N/A cells represent dates that kestral data was not measured or recovered. MX1 meter
Fall 2013 Observation did not include manure temperature, pH or ORP at depth because the field meter was not available for these field collection dates
Temperature for shaded cells are from

Table A-3: Summary of laboratory analytical results

Sampling Season	Farm	Cumulative H_2S Concentration	Gypsum Application Rate	pH			PSC			Solids (% dry weight)			Total Nitrogen (% dry weight)			Sulfur (% dry weight)			Calcium (% dry weight)		
		60 min	lbs cow^{-1} day^{-1}	Surface	Bottom	Agitated	Surface	Bottom	Agitated	Surface	Bottom	Agitated	Surface	Bottom	Agitated	Surface	Bottom	Agitated	Surface	Bottom	Agitated
Fall 2013	Bl F13 GT	1251	2.0	7.18	7.12	7.3	0.22	0.11	0.2	2.96	11.48	6.43	20.8	2.6	4.4	3.7	2.0	2.3	5.2	3.9	5.9
	Wr F13 G	13262	5.1	7.5	7.38	7.51	0.19	0.15	0.16	4.72	10.47	8.95	5.7	3.1	3.7	3.2	2.0	2.3	7.9	7.2	15.7
	Ht F13 NG	150	0.0	7.88	7.96	7.82	0.35	0.24	0.32	9.32	5.81	8.29	3.9	5.4	4.3	0.5	0.5	0.5	2.3	1.9	4.0
	Cp F13 NG	146	0.0	7.8	7.86	7.88	0.25	0.31	0.31	9.51	3.2	5.58	2.8	6.2	3.9	0.3	0.9	0.4	2.0	3.5	3.4
Spring 2014	Cp S14 NG	263	0.0	7.02	7.12	7.13	0.36	0.36	0.37	8.8	8.82	9.2	3.2	3.7	3.5	0.4	0.4	0.4	1.9	1.8	4.6
	Ht S14 NG	91	0.0	7.33	7.41	7.38	0.33	0.39	0.52	14.81	12.54	12.58	3.2	3.4	3.7	0.4	0.5	0.4	26.6	1.6	5.9
	Sh S14 NG	66	0.0	7.52	7.82	7.43	0.36	0.34	0.35	13.09	8.82	10.73	4.0	4.4	3.7	0.3	0.3	0.3	1.9	1.9	5.1
	Wr S14 G	983	5.1	7.79	7.69	7.89	0.29	0.17	0.16	5.58	10.72	9.99	5.3	4.1	4.3	3.1	3.0	3.0	4.4	5.9	12.7
	We S14 G	2829	0.6	7.01	6.73	6.93	0.7	0.64	0.66	2.8	5.53	5.41	6.5	4.4	4.3	1.1	0.8	0.8	3.3	2.6	3.2
	Sr S14 G	203	0.3	7.19	7.09	7.42	0.64	0.65	0.62	10.69	10.65	10.62	4.1	3.9	4.3	0.6	0.6	0.6	3.0	2.8	7.7
	Bl S14 GT	3645	3.4	7.57	7.42	7.31	0.42	0.15	0.18	1.83	6.97	7.95	11.9	2.8	2.9	5.1	2.4	2.2	5.2	4.6	10.8
	Br S14 GT	61	0.4	7.56	7.66	7.76	0.48	0.45	0.48	7.39	7.61	7.83	4.0	3.8	3.7	0.6	0.5	0.5	1.7	1.5	2.9
	Cy S14 GT	1888	1.2	7.65	7.44	7.12	0.3	0.32	0.3	10.08	7.82	8.85	3.9	4.4	4.0	1.5	1.8	1.6	3.6	3.9	7.7
	Hr S14 GT	2102	7.4	7.49	7.59	7.62	0.29	0.43	0.3	1.31	1.33	1.97	5.4	7.9	5.5	2.7	5.6	5.8	4.8	7.1	2.8
Fall 2014	We F14 G	3104	0.6	6.89	6.8	6.81	0.54	0.59	0.57	2.8	3.4	5.23	7.2	6.0	4.2	1.1	0.9	0.7	3.5	3.2	3.1
	Sr F14 G	737	0.3	7.43	7.25	7.44	0.39	0.46	0.41	9.7	9.27	10.28	3.9	3.9	4.2	0.6	0.6	0.7	2.9	3.0	7.5
	Hr F14 GT	1984	7.4	7.53	7.46	7.48	0.11	0.12	0.1	7.28	5.55	7.86	3.0	8.0	2.7	1.8	2.2	2.0	8.2	8.6	31.0
	Br F14 GT	127	0.5	7.83	7.83	7.98	0.29	0.29	0.311	6.77	6.89	6.7	4.2	4.1	4.0	0.6	0.6	0.6	2.1	2.2	3.6
	Bl F14 GT	21076	3.4	7.32	7.26	7.26	0.13	0.1	0.11	7.38	7.71	7.71	2.2	2.9	2.9	1.6	1.6	1.9	3.1	4.3	14.4

Notes: [1]F13, S14 and F14 represent Fall 2013, Spring 2013 and Fall 2014, respectively

[1]NG, G and GT represent non-gypsum, gypsum and gypsum with treatment, respectively

Appendix E. Example Oral Presentation Slides

Hile, M. L. 2015. Hydrogen sulfide production in manure storages at Pennsylvania dairy farms that use gypsum bedding. North American Manure Expo. Chambersburg, Pennsylvania.

Dairy Manure-gas Agitation Risks-Field Day

Thursday August 28, 2014
10:30 AM – 12:30 PM

2.0 Continuing Education Credits (CECs) for Act 49 Haulers and Brokers
No Registration. No Charge. No meal provided.

Penn State Extension, in conjunction with USDA-NRCS, is conducting an educational program at an actual manure gas measurement event at a dairy farm. This one event is part of a larger project that is exploring Hydrogen Sulfide emissions during agitation at a number of manure storage structures. A number of recent dangerous or deadly incidents related to toxic gas levels at dairy farms has increased interest in working safely around manure storages. Farms participating in the study either bed with gypsum, bed with gypsum but use a manure pit additive, or do not gypsum for bedding.

Educational discussions and presentations will include: manure storage practices and risks; safety instruments and protective gear; emergency response actions; gases released at agitation; gypsum bedding benefits and risks; observations of agitation during field demonstration. Personal safety gas monitors will be available to try. Supplier of instruments available for questions.

Wolfe Dairy
181 Wolfes Road
Pine Grove, PA 17963

10:30-Explore the demonstration site of gas monitors surrounding the manure storage with Extension researchers
11:00 - Agitation begins
Actions for safe mixing.
Impact of stall bedding, including gypsum.
Gas level detection instruments for personal use.
Safety tips.
12:00 - Field day discussion of dairy manure storage agitation with instruments and safety practices demonstrated.
Actions useful in an emergency response.
Observation of gas monitor changes during agitation of both stationary monitors and those worn by workers.
12:30 Finish

NRCS Safety & Air Quality Training
Penn State Extension
July 9, 2014 9:30 AM – 1:30 PM
114 Agricultural Engineering Building, University Park campus

1. Welcome & introductions

2. Environmental issues associated with open-air manure storages
    a. Toxic gas levels observed during data collection-Mike Hile/Eileen Fabian
        i. Measurement and observation results
    b. Makeup of "normal" air and factors that affect the air we breathe-Mike Platek
        i. Chart of oxygen levels
        ii. H2S-Source and levels
        iii. NH3-Souce and levels
        iv. CO2-Source and levels
        v. CH4-Source and levels
    c. Using instruments to measure unsafe atmospheres-Mike Platek
        i. Selection, use, calibration and care of gas detection equipment

3. Creating and encouraging a safety culture with manure storages-Dave Hill
    a. Restricted areas during agitation
    b. Training of family & employees
    c. Signage & barriers
    d. PPE
    e. Developing an on-farm manure storage safety program-farm info kit

4. Next steps and discussion

5. Adjourn

PENNAG INDUSTRIES ASSOCIATION
MANURE HAULER/APPLICATOR FIELD DAY

Wednesday, August 6, 2014

Lebanon Convention Expo Center & Fairgrounds

80 Rocherty Road, Lebanon, PA 17042 (Enter through Main Expo Building Doors)

FIELD DAY PARTICIPATION = 2 NUTRIENT MANAGEMENT CREDITS AND 4 MANURE HAULER/BROKER CREDITS

Preliminary Agenda:

8 a.m. - 9 a.m.	Registration
9 a.m. - 10 a.m.	Manure Gas Emissions / Gypsum Research Update / Monitoring Instruments Demo Eileen Fabian, Mike Hile ~~& Dan Hofstetter, PSU~~
10 a.m. - 10:30 a.m.	Regulatory Review Mike Aucoin, SCC & Robb Meinen, PSU
10:30 a.m. - 11 a.m.	Recordkeeping Mike Aucoin, SCC
11 a.m. - 12 p.m.	Application Compliance – Roundtable Discusion Mike Aucoin SCC, Steve Taglang DEP, Robb Meinen PSU & others
12 p.m. - 1 p.m.	Lunch
1 p.m. - 2 p.m.	Live Action Spill Response Demonstration – Discussion and Demonstration
2 p.m. - 2:30 p.m.	Council Meeting

NOTE: RSVP by emailing (mfleetwood@pennag.com), calling (717-651-5920) or faxing (717-651-5926) the below information. **Registration fee will be collected at event. *Cash or check only.***

Questions? Contact Mindy Fleetwood at mfleetwood@pennag.com or 717-651-5920.

2014 MANURE HAULER/APPLICATOR FIELD DAY REGISTRATION

Registration Fee: $15 PennAg Members, $25 Non-Members

(Registration includes presentations and lunch. Registration fee will be collected at event. Cash or check only.)

Name(s): _____

Company: _____

Address: _____

_____

Phone: _____ Email: _____

COMPLETE AND RETURN (OR CALL 717-651-5920) BY WEDNESDAY, JULY 23 TO GUARANTEE LUNCH RESERVATION.

PennAg Industries Association • 2215 Forest Hills Dr., Suite 39 • Harrisburg, PA 17112
Phone 717.651.5920 • Fax 717.651.5926 • mfleetwood@pennag.com • www.pennag.com

Hydrogen sulfide production in manure storages at Pennsylvania dairy farms that use gypsum bedding

July 2015

Michael Hile
Graduate Assistant of
Agricultural Engineering

Penn State **Extension**

GYPSUM BEDDING Introduction Benefits and Use

- Gypsum – uses and benefits in agriculture
- Hydrogen sulfide (H_2S) – cause for concern
- Demonstration – H_2S concentrations and exposure
- Safety tips when working around manure storages

Penn State **Extension**

What is Gypsum

Calcium Sulfate
- $CaSO_4 2H_2O$ (Hydrous)
- $CaSO_4$ (Anhydrous)

Naturally occurring mineral and coal plant byproduct

Penn State **Extension**

Manufacturing And Construction Waste

Gypsum is used to produce drywall for construction. Manufacturing rejects and construction waste is collected and recycled.

Penn State **Extension**

Manufacturing And Construction Waste Is Processed And Sold For Use In Agriculture

Penn State **Extension**

Agricultural benefits – improves soil

Improves soil structure (opens tight soils)
- Water is more mobile in soil
- Improves root development

Improves soil nutrients
- Reduces phosphorus runoff
- Retains plant available nitrogen
- Provides source of secondary crop nutrients (Ca and S)

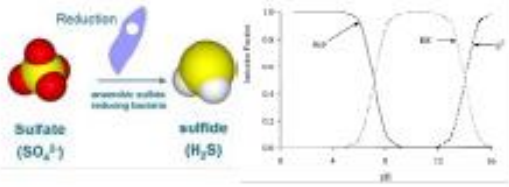
Penn State **Extension**

Agricultural benefits – ideal bedding for dairy cows

As bedding
- Moisture absorption
- Low bacteria counts
- Neutral pH

Penn State **Extension**

Gypsum bedding provides a sulfate source within the manure storage that reduces to form H_2S



Penn State **Extension**

Hydrogen Sulfide Creates A Dangerous Environment Heavier Than Air

Exposure Limit	H_2S Concentration (ppm)
Permissible Exposure Limit (PEL) or Ceiling	10
Immediately Dangerous to life and Health (IDLH)	100

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Manure gases escape during agitation

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Numerous reports of:

- REALLY strong smell
- Dead livestock
- Employees/workers overcome
- Some haulers would not haul from gypsum farms

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Child Found Unresponsive Here (2011)

Penn State **Extension**

May 2012 –
3 PA Workers Die In MD Manure Storage

Farm bedded with Gypsum

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Dairy Farmer's Boys Have Close Call With Manure Gas

Penn State **Extension**

Unresponsive but breathing
500-600 ppm H_2S

150 ppm H_2S

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Barn 30 feet away-(30-60 ppm H_2S)

Penn State **Extension**

50 feet away (50 ppm H_2S)

Inside free stall (35 ppm)

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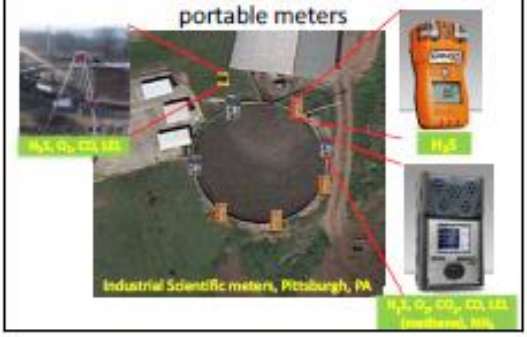
METHODS: Three farm categories were observed in the fall and spring:

1. Gypsum
2. Gypsum with treatment
3. Non-gypsum

Penn State **Extension**

METHODS: H_2S concentrations were measured during agitation events using portable meters



METHODS: Temperature, wind speed and wind direction were recorded during data collection

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METHODS: Manure was characterized

Field and Lab Analysis

- Samples were collected and analyzed for % solids, Ca, S, Total N, pH, ORP, PSC and temperature.

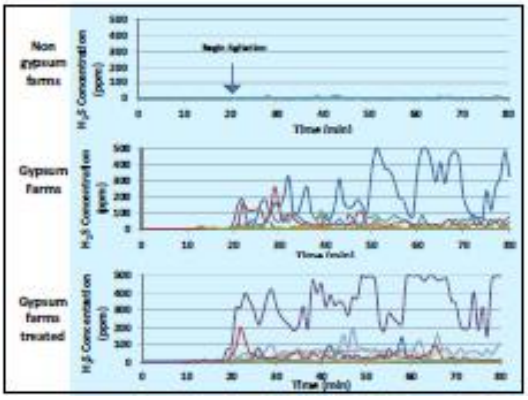
Physical Characteristics

- Crust thickness, Bottom sediments,

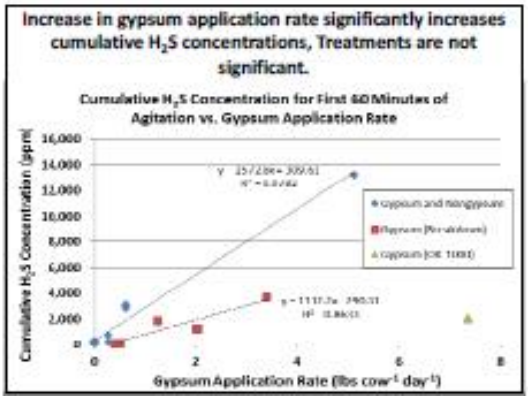
METHODS: Farm practices were documented

- Storage Design
  - Type of structure, volume

- Manure Handling
  - Loading, sulfate inputs



Increase in gypsum application rate significantly increases cumulative H_2S concentrations, Treatments are not significant.



Change in wind direction increased H_2S concentrations

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Personal monitoring devices provide effective awareness of exposure

Penn State **Extension**

Best management practices lower exposure risk

Penn State **Extension**

Operators with two highest H_2S readings were close to agitation

Penn State **Extension**

Concentrations 10 meters away from storages were measured

Elevated H_2S concentrations **(50 to >500 ppm)** were observed at farms that use gypsum

Penn State **Extension**

Conclusions: H_2S Concentrations

- Increased gypsum use increases cumulative H_2S concentrations.
- Treatments did not significantly reduce cumulative H_2S concentrations, but more research could show otherwise.
- Manure moving-mixing-agitation creates safety concerns related to high gas levels.
- Safety practice's lower risk of exposure.
- Risk of exposure present even at 10 meters downwind from storages that contain gypsum.

Penn State **Extension**

Open Air Manure Storage Safety

- Non-enclosed manure storages can still meet the definition of a ***confined space*** in terms of occupational safety and health:
  - Is large enough that a worker can enter and perform work;
  - Has limited or restricted means for entry or exit; and
  - Is not designed for continuous human occupancy

"Easy in. Hard to get out!"

Penn State **Extension**

Confined Spaces

- Do not enter them!!
- Gases can cause loss of consciousness and death.
- Always assume there are gases present.

Invest in the Insurance of a Monitor

Test atmosphere
- Oxygen deficiency
- Combustibles
- Toxic gases

Multiple gas vs single gas—cost and ease of use will be a factor

Own or lease

Most reliable way of *"seeing"* the invisible

Penn State **Extension**

Observed gas behavior

Gases *'throw'* in the direction of manure agitator nozzle, so be aware of dangerous impact on 'downwind' animal- or human-occupied areas

Penn State **Extension**

Operator Position – up and away

Position operator work area so that a person…
- Does **not** reach over the storage for routine practices
- Does **not** work or need to adjust machinery near storage edge
- Is **not** in a low-lying area. (Remember H_2S is a heavy, ground-hugging gas)

Choose up-wind position

Penn State **Extension**

Gypsum bedding should **not** *be used with under-barn manure storage*

Unconditional recommendation **against** under-barn manure storage when gypsum bedding is used.

Penn State **Extension**

Penn State **Extension**

Body Alarms!!!

- Dizziness
- Wobbly knees
- Feeling hot and clammy
- Lack of attention to details
- Loss of motor skills/ fatigue
- Anxiety
- Severe eye irritation/ decrease in sight
- Irregular/fast heartbeat
- Headaches
- Nausea/Vomiting
- Shortness of breath
- Panting
- Pausing/Stopping of breath
- Respiratory tract irritation/Coughing
- Tightness of chest
- Acute bronchitis
- Asphyxiation
- Loss of consciousness

Pay attention to your body. Take action if there are signs of gas exposure. Get to fresh air!

Penn State **Extension**

Acknowledgment and Thank You to the supporters of this project.

Penn State Investigators

- Eileen Fabian-Wheeler, Michael Hile, Davis Hill, Dennis Murphy, Robin Brandt, Hershel Elliot, Robert Meinen

USDA Natural Resources Conservation Service
United States Department of Agriculture

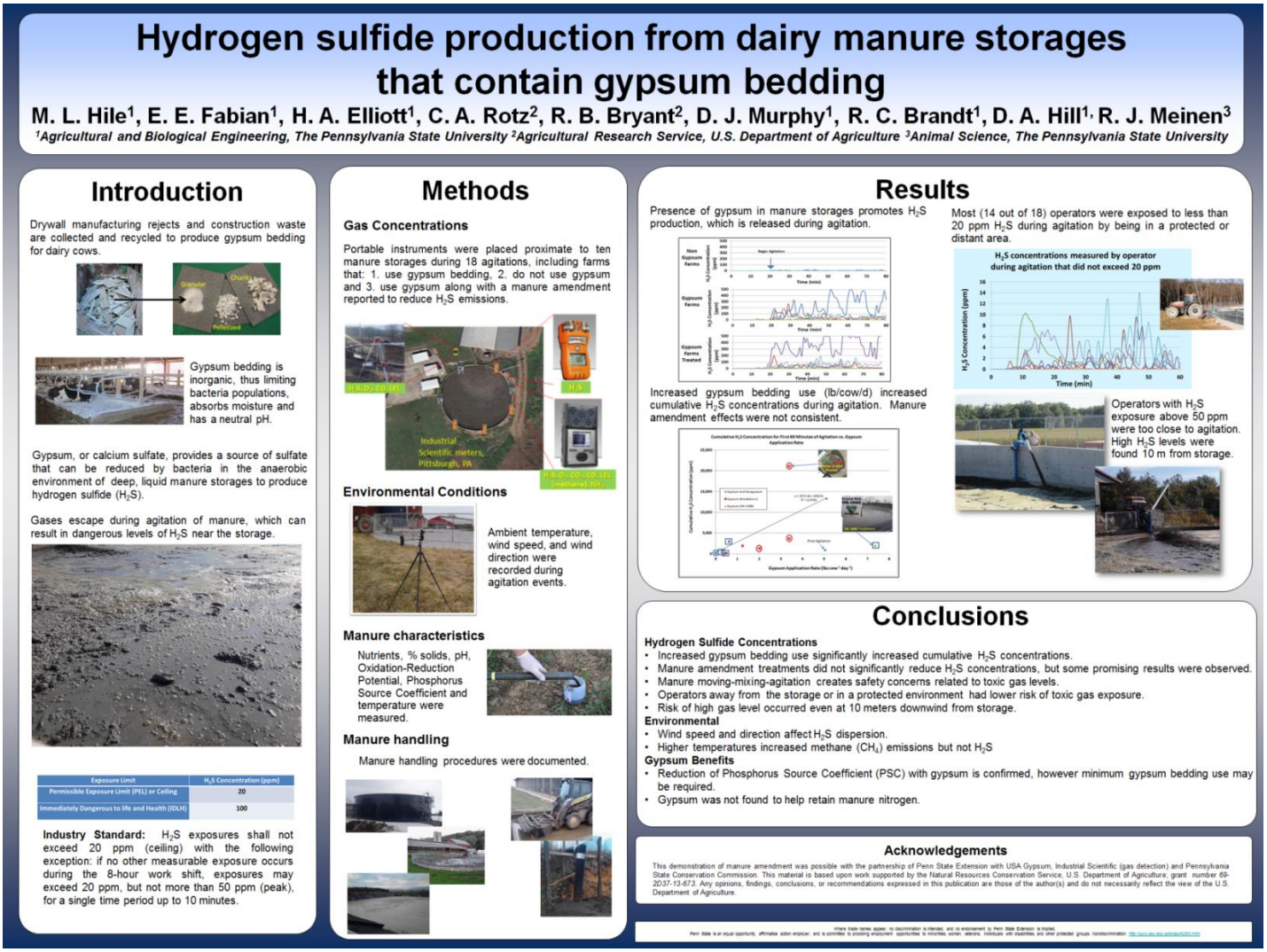
INDUSTRIAL SCIENTIFIC
The Gas Detection People

Questions

Penn State **Extension**

Appendix F. Poster

M. L. Hile, E. E. Fabian, H. A. Elliott, C. A. Rotz, R. B. Bryant, D. J. Murphy, R. C. Brandt, D. A. Hill and R. J. Meinen. 2015. Hydrogen sulfide production from dairy manure storages that contain gypsum bedding. Presented in Seattle, Washington at Waste to Worth national meeting. Reference No. 9543986.



Appendix G. Example Webinar Slides (deliverable)

Hile, M. L. and R. Meinen. 2015. Gypsum bedding risks and rewards. Livestock and Poultry Environmental (LPE) Learning Center Educational Webcast Series. Waste 2 Worth Preview.

Livestock and Poultry Environmental (LPE) Learning Center
Educational Webcast Series
http://www.extension.org/animal+manure+management

Waste to Worth Preview:
Gypsum Bedding Risks and Rewards
February 27, 2015
2:30 pm (eastern), 1:30 pm (central), 12:30 pm (mountain), 11:30 am (pacific)

A preview of the useful topics that will be discussed and presented via posters and informational sessions at the Waste to Worth Conference in Seattle, a group of professors and extension professionals present about the use of gypsum in dairy bedding. Gypsum recycled from dry wall is used to supplement traditional bedding materials with agronomic, milk quality, and cow health benefits. But once in the manure storage, gypsum bedding is a source of sulfur that leads to increased hydrogen sulfide gas production. This toxic gas is commonly found at deadly levels in enclosed manure pits, though dangerous levels are found even around outdoor open-air storages during agitation of gypsum manure. *An application for continuing education credit for Certified Crop Advisors (CCAs) and members of the American Registry of Professional Animal Scientists (ARPAS) has been submitted.*

Robb Meinen is a Senior Extension Associate in the Department of Animal Science at Penn State University. His main duty is to coordinate education for the PA Commercial Manure Hauler and Broker Certification Program. Additional duties include education in Nutrient and Odor Management and service to the swine industry. Meinen co-instructs the Nutrient Management course at Penn State. He is involved in long-term Manure Expo planning and is Co-Chair of the 2015 North American Manure Expo in Chambersburg, PA on July 14-15. Be sure to attend the Manure Expo. It promises to provide *Manure than you can Handle*.
Phone: (814) 865-5986. Email: rjm134@psu.edu

Dr. Joe Harrison is a faculty member of the Department of Animal Sciences at Washington State University and has been conducting research and demonstration projects related to feed management and whole farm nutrient management since the early 2000's. His projects include: precision nitrogen feeding, effect of potassium on milk fat in the early lactation cow, capture of phosphorus for off-farm transport, and efficiency of capture of manure nitrogen in crops as affected by manure source and method of application. Phone: (253) 445-4638; Email: jhharrison@wsu.edu

Mike Hile is a Ph. D. Candidate in the Department of Agricultural and Biological Engineering at Penn State University. His research focuses on gas emissions from manure storage, processing and handling in the agricultural industry. As one of the members of the Penn State Odor Assessment Laboratory (PSOAL), Mr. Hile has evaluated the efficacy of manure additives and technological solutions to reducing odors for biosolids and animal manures. Field and laboratory experience enables Mr. Hile to be a key member of projects that involve measuring greenhouse gases, ammonia and hydrogen sulfide.
Phone: (814) 865-1783. Email: mlh144@psu.edu

How Do I Participate?
On the day of the webcast, go to www.extension.org/58813 to download the speaker's power point presentations and connect to the virtual meeting room. First time viewers should also follow the steps at: www.extension.org/8924.

For More Information
* Waste to Worth - http://wastetoworth.org/
* Gypsum Bedding – Risks and Recommendations for Manure Handling - www.extension.org/67660
* Gypsum bedding: Is it worth the manure safety risk? - http://www.progressivedairy.com/dairy-basics/manure/12719-gypsum-bedding-is-it-worth-the-manure-safety-risk

The LPE Learning Center is a project dedicated to the vision that individuals involved in public policy issues, animal production, and delivery of technical services for confined animal systems should have on-demand access to the nation's best science-based resources. See our website at: http://www.extension.org/animal+manure+management.

GYPSUM BEDDING

RISKS AND REWARDS

FEBRUARY 2015

Penn State **Extension**

GYPSUM BEDDING Introduction Benefits and Use

Penn State **Extension**

GYPSUM BEDDING Introduction Benefits and Use

What is gypsum and where does it come from

Uses in agriculture and benefits

Risk in manure storages – demonstration results

Penn State **Extension**

What is Gypsum

Calcium Sulfate

- $CaSO_4$ $2H_2O$ (Hydrous)
- $CaSO_4$ (Anhydrous)

Naturally occurring mineral and coal plant byproduct

Penn State **Extension**

Manufacturing And Construction Waste

Gypsum is used to produce drywall for construction. Manufacturing rejects and construction waste is collected and recycled.

Penn State **Extension**

Manufacturing And Construction Waste Is Processed And Sold For Use In Agriculture

Penn State **Extension**

Agricultural benefits – improves soil

Improves soil structure (opens tight soils)
- Water is more mobile in soil
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Improves soil nutrients
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Penn State **Extension**

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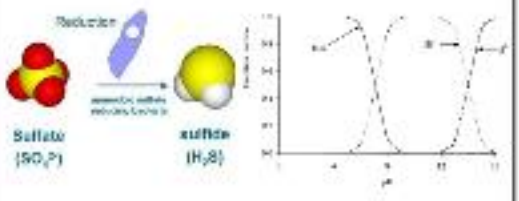
Penn State **Extension**

Gypsum bedding provides a sulfate source within the manure storage that reduces to form H_2S



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Hydrogen Sulfide Creates A Dangerous Environment Heavier Than Air

Exposure Limit	H_2S Concentration (ppm)
Permissible Exposure Limit (PEL) or Ceiling	20
Immediately Dangerous to Life and Health (IDLH)	100

General Industry: 29 CFR 1910.1000 Z-2 Table – Exposures shall not exceed 20 ppm (ceiling) with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes.

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Manure gases escape during agitation

Penn State **Extension**

Numerous reports of:

- REALLY strong smell
- Dead livestock
- Employees/workers overcome
- Some haulers would not haul from gypsum farms

Penn State **Extension**

Child Found Unresponsive Here (2011)

Penn State **Extension**

May 2012 –
3 PA Workers Die In MD Manure Storage

Farm bedded with Gypsum

Penn State **Extension**

Dairy Farmer's Boys Have Close Call With Manure Gas

Penn State **Extension**

Unresponsive but breathing
500-600 ppm H_2S

150 ppm H_2S

Penn State **Extension**

Barn 30 feet away-(30-60 ppm H_2S)

Penn State **Extension**

50 feet away (50 ppm H_2S)

Inside free stall (35 ppm)

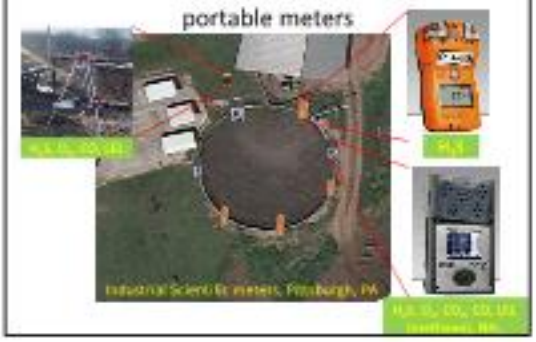
Penn State **Extension**

METHODS: Three farm categories were observed in the fall and spring:

1. Gypsum
2. Gypsum with treatment
3. Non-gypsum

Penn State **Extension**

METHODS: H_2S concentrations were measured during agitation events using portable meters



METHODS: Temperature, wind speed and wind direction were recorded during data collection

Penn State **Extension**

Penn State **Extension**

METHODS: Manure was characterized

Field and Lab Analysis

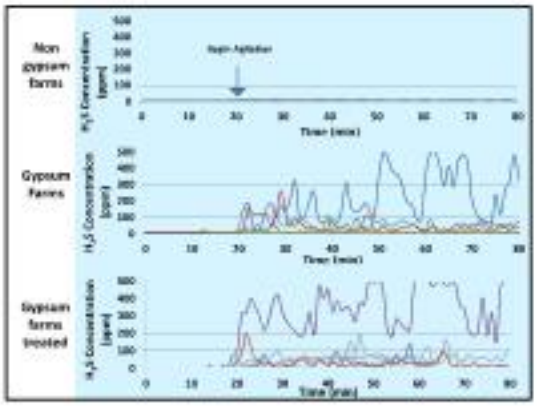
- Samples were collected and analyzed for % solids, Ca, S, Total N, pH, ORP, PSC and temperature

Physical Characteristics

- Crust thickness, Bottom sediments,

METHODS: Farm practices were documented

- Storage Design
  - Type of structure, volume
- Manure Handling
  - Loading, sulfate inputs



Change in wind direction increased H_2S concentrations

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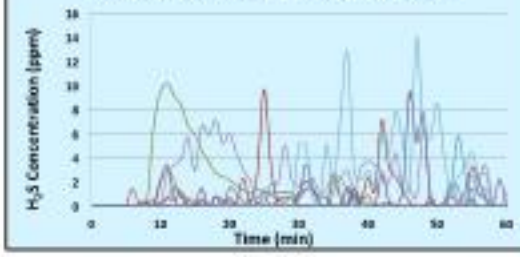
Personal monitoring devices provide effective awareness of exposure

Penn State **Extension**

14 out of 18 operators did not exceed 20 ppm H_2S exposure

H_2S concentrations measured by operator during agitation that did not exceed 20 ppm

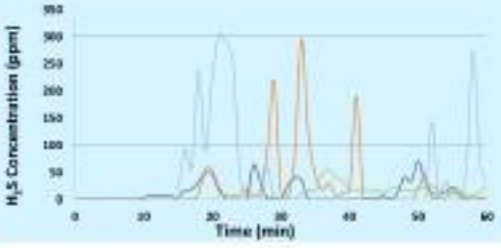


Best management practices lower exposure risk

Penn State **Extension**

4 out of 18 operators were exposed to H_2S above 20 ppm

H_2S concentrations measured by operator during agitation that exceeded 20 ppm



Penn State **Extension**

Operators with two highest H_2S readings were close to agitation

Penn State **Extension**

Concentrations 10 meters away from storages were measured

Elevated H_2S concentrations were observed at farms that use gypsum

Penn State **Extension**

Conclusions: H_2S Concentrations

- Increased gypsum application rate significantly increases cumulative H_2S concentrations.
- Treatments did not significantly reduce cumulative H_2S concentrations, but more research could show otherwise.
- Manure moving-mixing-agitation creates safety concerns related to high gas levels.
- Safety practice's lower risk of exposure.
- Risk of exposure present even at 10 meters downwind from storages that contain gypsum.

Penn State **Extension**

Conclusions: Environmental Effects

- Wind speed and direction affect H_2S
- Temperature affected CH_4 but not H_2S.

Penn State **Extension**

Conclusions: Gypsum Benefits

Users and manufacturers claim gypsum retains plant available nitrogen – however measurements did not confirm this claim.

Phosphorus retention increases with increasing gypsum application rate, but not at bedding rates less than ½ lb gypsum per cow per day.

PSC=Phosphorus source coefficient

Penn State **Extension**

Additional Project Findings

Low concentrations of methane were observed at non-gypsum and gypsum farms during manure agitation.

Corrosion of metal fences and building components was observed at multiple farms that used gypsum.

Gypsum storages were reported by some users to have increased odors.

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SUMMARY
On-Farm Demonstration Study

QUESTIONS?

Penn State **Extension**

Practical Thoughts for Manure Handlers

Robert Mulrow
Senior Extension Associate
Penn State Department of Animal Science
University Park, PA
rjm23@psu.edu
(814) 865-5986

Penn State **Extension**

Penn State **Extension**

Gypsum and Liquid not needed

- *All manures are organic material in a state of microbial degradation.*
- *Gases are a by-product of microbial respiration.*

H_2S

- Many people can detect it <1 ppm
- Can deaden sense of smell at 100 ppm
- Deadly 600 ppm

Exposure Level	Effects or Symptoms
Dizziness	
10 ppm	Irritation
20 ppm for more than 8 hours	Irritation to eyes, nose & throat
50–100 ppm	Vomiting, nausea, diarrhea
50 ppm for 1 hour	Dizziness, nausea, nystagmus, decreased mental capability, poor muscle coordination
50 ppm for 30 min	Nausea, sleeplessness, excessive salivation
100 ppm	Rapid death
Unconscious	
250 ppm, exposure considerable	Fear of light, loss of appetite, nervous tension
500 ppm	Possible pulmonary edema, loss of consciousness and possible loss of consciousness and death

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Gases

- Some are odorless
- Most (all) are colorless
- Some are explosive
- Some sink (e.g. H_2S)
- Some rise

Open Air Manure Storage Safety

- Non-enclosed manure storages can still meet the definition of a ***confined space*** in terms of occupational safety and health:
  - Is large enough that a worker can enter and perform work;
  - Has limited or restricted means for entry or exit; and
  - Is not designed for continuous human occupancy

"Easy in. Hard to get out!"

Penn State **Extension**

Confined Spaces

- Do not enter them!
- Gases can cause loss of consciousness and death.
- Always assume there are gases present.

What is your responsibility?

Everyone has an obligation to design, supply, buy, operate and maintain manure storage and handling systems that are safe for workers, visitors and children.

Invest in the Insurance of a Monitor

Test atmosphere

- Oxygen deficiency
- Combustibles
- Toxic gases

Multiple gas vs single gas—cost and ease of use will be a factor

Own or lease

Most reliable way of *"seeing"* the invisible

Penn State **Extension**

Open Air Manure Storage Safety

Safety tips include:

- No horseplay
- No smoking, open flames or sparks
- If equipment malfunctions shut it off and remove it before servicing
- If *feeling unsure or uncomfortable*, step back, contact someone and review the situation before proceeding.
- Be prepared to call 911 if an emergency happens.
  - accurately describing the incident, number of victims, and giving specific directions to the site of the emergency

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Tips for Operators

- Use a monitor.
- Observe agitation from a distance. Consider remote control kill switches.
- The first hour of agitation is probably the worst, but *never* let your guard down.
- H_2S is a heavy gas – higher is better.
- Remember health of nearby livestock.
- This is one time when the Agricultural Work Ethic can backfire!

Observed gas behavior

Gases *'throw'* in the direction of manure agitator nozzle, so be aware of dangerous impact on 'downwind' animal- or human-occupied areas

Penn State **Extension**

Operator Position – up and away

Position operator work area so that a person...

- Does **not** reach over the storage for routine practices
- Does **not** work or need to adjust machinery near storage edge
- Is **not** in a low-lying area. (Remember H_2S is a heavy, ground-hugging gas)

Choose up-wind position

Penn State **Extension**

Gypsum bedding should **not** *be used with under-barn manure storage*

Unconditional recommendation **against** under-barn manure storage when gypsum bedding is used.

Penn State **Extension**

New NRCS Warning Sign

Penn State **Extension**

Penn State **Extension**

Body Alarms!!!

- Dizziness
- Wobbly knees
- Feeling hot and clammy
- Lack of attention to details
- Loss of motor skills/ fatigue
- Anxiety
- Severe eye irritation/ decrease in sight
- Irregular/fast heartbeat
- Headaches
- Nausea/Vomiting
- Shortness of breath
- Panting
- Pausing/Stopping of breath
- Respiratory tract irritation/Coughing
- Tightness of chest
- Acute bronchitis
- Asphyxiation
- Loss of consciousness

Pay attention to your body. Take action if there are signs of gas exposure. Get to fresh air!

Learn More at the North American Manure Expo

- Data collection demonstrations (July 14 Tour Day)
- Highlighted education on manure gas issues

Chambersburg, PA
- Tour Day - July 14
- Main Event - July 15

manureexpo.org

Penn State **Extension**

Manure Gas Risks Associated with Gypsum Bedding at Dairy Farms

Penn State Investigators

- Eileen Fabian-Wheeler, Mike Hile, Davis Hill, Dennis Murphy, Robin Brandt, Hershel Elliot, Mike Platek, Robert Meinen

USDA Natural Resources Conservation Service
United States Department of Agriculture

INDUSTRIAL SCIENTIFIC
The Gas Detection People

Acknowledgment and Thank You to the supporters of this project.

www.manurepitsafety.psu.edu

Video Presentations:

- Reducing Entry Risk: Solid Floor Storages
- Reducing Entry Risk: Slotted Floor Storages

Fact Sheets:

- E 51: Confined Space Manure Storage Hazards
- E 52: Confined Space Manure Gas Monitoring
- E 53: Confined Space Manure Storage Ventilation System Design
- E 54: Confined Space Manure Storage Emergencies
- Open Air Manure Storage Safety Tips

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More information on issues surrounding handling manure with gypsum bedding

- Agricultural Safety web site
  - extension.psu.edu/business/ag-safety
- Gypsum bedding and manure handling
  - abe.psu.edu/news/2014/gypsum-bedding...is-it-worth-the-risk
- Commercial Manure Hauler and Broker Certification Program
  - www.agriculture.state.pa.us
- North American Manure Expo
  - manureexpo.org

Penn State **Extension**

SUMMARY
Practical Thoughts for Manure Handlers

QUESTIONS?

Penn State **Extension**

Appendix H. Fact Sheets (deliverables)

Written document for NRCS *technical guidelines* & non-technical *brochure* for NRCS personnel

Penn State **Extension**

SAFETY RISK FROM MANURE STORAGES OF DAIRY COWS BEDDED WITH GYPSUM

Michael Hile and Eileen Fabian-Wheeler, Agricultural and Biological Engineering G-112

Human and cattle deaths have prompted investigation into what is causing dangerous conditions during otherwise routine manure handling procedures on farms. This brochure provides background and findings from on-farm monitoring of dairies using gypsum as stall bedding where a link has been found to highly toxic levels of hydrogen sulfide gas during manure movement and agitation.

GYPSUM – ANIMAL WELFARE AND AGRONOMIC IMPROVEMENT

Gypsum recycled from manufacturing and construction waste provides a bedding source for the dairy industry. Gypsum can be used as 100% of the bedding or as a bedding additive to traditional bedding materials. Advantages to its use include the following:

Bedding

- Absorbs moisture
- Low bacteria
- Neutral pH
- Improved udder health

Soil

- Low carbon
- Adds sulfur
- Adds calcium
- Reduced phosphorus runoff

GYPSUM AND MANURE GAS HYDROGEN SULFIDE

Gypsum is calcium sulfate ($CaSO_4 \cdot 2H_2O$) so it provides a source of sulfate, which under anaerobic conditions can be microbially converted to hydrogen sulfide (H_2S) gas. Anaerobic conditions (without oxygen) exist in dairy manure slurry within many short-term and most long-term storages. Hydrogen sulfide is heavier-than-air. It therefore settles in low areas such as in pits, near storages, and in the breathing zones of calves and children. When present, H_2S is released in bursts that are dangerous to nearby humans and cattle during manure movement or agitation.

Hydrogen sulfide is immediately dangerous to life and health above 100 ppm. Lower concentrations of 10 to 20 ppm can be tolerated for periods of time, such as a part of a workday. Hydrogen sulfide gas has a familiar "rotten egg" odor to a healthy human nose. Unfortunately, this distinctive odor goes undetected at dangerous levels or after extensive exposure. Because of this, instruments are needed to detect H_2S concentrations to avoid dangerous conditions.

PERSONAL MONITORING TO SAVE LIVES

Portable gas instruments detect and indicate hazardous situations. Audible, vibration, and visual alarms are set to alert the user of dangerous gas concentrations that are not otherwise detectable. ***It is recommended that farm operators working around manure storages with gypsum bedding wear a hydrogen sulfide personal gas monitor.*** Single gas monitors (right) are about the size of a cell phone and cost under $300. Units can provide multi-year battery life, display of gas level, and a second backup sensor. For professional dairy manure haulers a four-gas monitor offers additional safety from *methane*, low *oxygen* level in a confined space, *carbon monoxide* (exhaust) from equipment operation, in addition to *hydrogen sulfide* protection for gypsum-using farms.

Photo Source: Industrial Scientific

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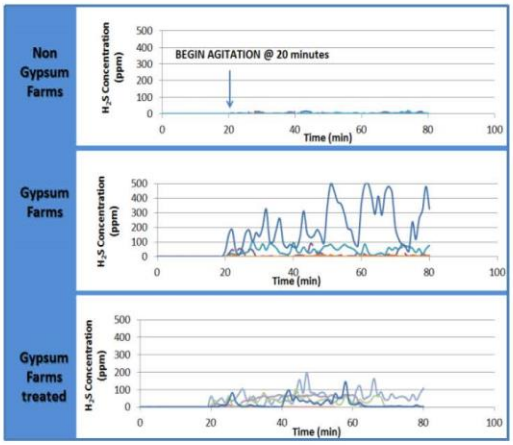
MONITORING MANURE AGITATION GAS RELEASE

Three types of farms were monitored based on their bedding management: 1) conventional dairy stall bedding; 2) gypsum bedding, and 3) gypsum bedding with a manure additive treatment. Instruments placed around the perimeter of the outdoor open-air manure storages recorded gas concentration immediately prior to and for up to two hours after manure agitation began. Findings are from ten farms during 19 events.



- The use of gypsum bedding increased H_2S gas release during manure agitation to levels that were dangerous near the storage (see graphs).
- Almost no H_2S was found near the non-gypsum dairy manure storages.
- Some additive-treated manure and crust-free manure reduced H_2S emissions during agitation.
- Operators with highest H_2S exposure were very close to agitation.
- The first 30 to 60 minutes of agitation is the most dangerous even near open-air outdoor manure storages.

REDUCING RISKS FROM GYPSUM-MANURE STORAGE

1. Gypsum bedding adds sulfur to manure that can lead to dangerous levels of hydrogen sulfide gas emission at agitation; but not all farms with gypsum bedding have safety problems.
2. Keep non-essential people away during agitation, especially children who are at increased risk as H_2S is typically at higher concentration close to the ground. Nearby cattle are also at risk.
3. Secure storage from entry; provide rescue and fall protection; gas monitors recommended.
4. Manure moving-mixing-agitation creates highest gas levels for the first hour. Leave the area.
5. Crust-free manure and additives seem to allow continuous H_2S release lowering agitation risk.
6. Gypsum benefits for cow bedding and agronomic values must be balanced against the potential gas hazard.

ACKNOWLEDGEMENTS: We are thankful that this demonstration of manure amendment is possible with the partnership of Penn State Extension with USA Gypsum, Industrial Scientific (gas detection) and Pennsylvania State Conservation Commission. This material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture; under number 69-2037-13-673. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

Additional Information: Mike Hile 814-865-1783; mlh144@psu.edu. Eileen Fabian (Wheeler) 814-865-3552; fabian@psu.edu

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Penn State **Extension**

Manure Storage Design and Safety Considerations with Gypsum Bedding

Eileen Fabian-Wheeler, Professor of Agricultural Engineering
Mike Hile, Post-Doc, Agricultural and Biological Engineering

E – 70

Surprise! Open-air, outdoor manure storages pose dangers even with all that fresh air around. A number of recent human tragedies in the vicinity of mixing and cleanout of outdoor manure storages raised concern. A series of investigations by farmers, manure haulers, Penn State Extension personnel and industry leaders identified that gypsum-laced manure was capable of creating deadly levels of gas emissions, specifically hydrogen sulfide gas [H_2S]. The gypsum, a.k.a. calcium sulfate, was a residual in the manure from its use as a beneficial bedding material in the dairy barn. This fact sheet outlines practical design considerations of manure storages and management for safely working during manure agitation events on dairy farms using gypsum bedding.

Under-barn Manure Storage

Our unconditional recommendation is to not use gypsum bedding with under-barn manure storage. Potential is very high for release of extreme concentration of H_2S when manure is moved or mixed, resulting in harm to barn workers and confined cattle.

Operator position during agitation

During any manure movement or mixing, operator must be up above the ground and away from edge of a manure storage. Particularly with manure containing gypsum bedding material, H_2S gas at lethal levels (>600 ppm) is quickly produced and undetectable by smell. Hydrogen sulfide is a heavy, ground-hugging gas.

Position work area so operator:

- Does not reach over the storage for routine practices
- Does not work or need to adjust machinery near storage edge
- Is not in a low-lying area

Wind Direction

Hydrogen sulfide can settle in windless areas, shelterbelts or among buildings blocking airflow near a storage unit. Strong breezes will move H_2S out and away from storage, diminishing risk. Operators should be positioned upwind.

Access during agitation

Once manure storage agitation begins, no one should be in the immediate area. Encourage casual onlookers to keep well away (minimum of 50 feet). Children, pets, calves, and resting cattle are more susceptible due to lower breathing zones. Low areas accumulate H_2S so operators, other people and animals should avoid any nearby depressions.

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Planning Layout

Gases "throw" in the direction of a manure agitator nozzle, so be aware of dangerous impact on "downwind" animal or human occupied areas. Confined cattle in the area are at risk.

Confined Manure Storage

Long ago it was discovered that confined spaces accumulated dangerous levels of manure gases (sumps; low areas; gutters; cross channels; pits; pump out access areas; underfloor manure storages). Dangerous gas levels are especially common during agitation of the manure. The addition of gypsum bedding makes this an even greater hazard with the potential for high H_2S levels.

Take home points are:

1. **Manure movement and mixing** will almost certainly cause dangerous level of H_2S gas release from manure that contains gypsum bedding.
2. **Avoid** being anywhere near the manure storage during agitation events and consider impact on occupants of nearby surroundings.
3. **Up and away.** Operators positioned above surrounding topography and at a distance from the storage are at reduced risk for experiencing dangerous H_2S gas levels versus operators positioned nearby at ground-level. Operators should be positioned upwind.

May 2015

Contact Information

Department of Agricultural and Biological Engineering
249 Agricultural Engineering Building
University Park, PA 16802

ACKNOWLEDGEMENTS: An evaluation of conditions for farms using and not using gypsum bedding was possible with the partnership of Penn State Extension with USA Gypsum, Industrial Scientific (gas detection) and Pennsylvania State Conservation Commission. This material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture; under number 69-2D37-13-673. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Appendix I. News Articles

Krieg, Dieter. It's coming! Don't let it get you! Farmshine - September 5, 2014.

Warner, Dick. Manure handling field day focuses on hydrogen sulfide gas. Lancaster Farming - September 6, 2014.

Manure Handling Field Day Focuses on Hydrogen Sulfide Gas

DICK WANNER
Reporter

PINE GROVE, Pa. — It was almost like standing next to a pond full of spring peepers. Peep-peep-peep.

But the noise wasn't coming from tiny frogs. It was coming from hydrogen sulfide monitors hanging from a chain-link fence encircling a 12-foot-deep liquid manure pit on Eric and Amy Wolfe's dairy farm here in Schulykill County.

Many of the 50-or-so observers wandering around the pit were also wearing monitors that contributed to the din.

The Wolfes were the hosts for a liquid manure handling field day designed to emphasize the need for safety awareness around manure pits.

The demonstration project was also expected to provide some insight into the effectiveness of additives that might reduce the presence of hydrogen sulfide — H_2S — in liquid manure.

The project was the result of an

More *FIELD DAY*, page *A3*

Photo by Dick Wanner

A tractor-powered agitator drew material from the bottom of the 12-foot-deep pit and sprayed it through a nozzle onto the top.

Field Day

Continued from A1

unusual alliance of government, academia and industry, according to Eileen Fabian-Wheeler, a Penn State professor of agricultural and biological engineering.

It was also one of the few manure projects to ever receive a hefty grant from the USDA's Natural Resources Conservation Service. Here's the way Fabian-Wheeler described that alliance:

NRCS sponsored Penn State doctoral candidate Mike Hile's demonstration project with a $70,000 grant. Matching support of the same amount came from Penn State, USA Gypsum, the Pennsylvania State Conservation Commission and Industrial Scientific.

Terry Weaver, president of USA Gypsum, covered the field day expenses for snacks and beverages, fuel and time for the Wolfes.

Penn State Extension coordinated the 10 farms used in Hile's project, and prepared and presented the program at the Wolfe farm.

Industrial Scientific donated about $15,000 worth of gas monitors to the project, and those monitors will continue to be used in other demonstrations, Extension education and research.

Aug. 28, the day of the program, was clear, windy and on the cool side of normal for late summer. It was a perfect day for agitating a manure pit before hauling the contents out to the field for spreading.

But the Wolfes weren't planning on spreading. They just agreed to stir up their pit so folks could watch and see what happened.

About 11 a.m., Eric Wolfe climbed into the seat of a tractor hooked up to an agitator that took material from the bottom of the pit and blew it onto the crust that had formed on the top.

A nozzle swayed from side to side, distributing stirred-up material evenly across the surface. About 11:05, the monitors started beeping.

Mike Hile, a doctoral ag engineering candidate at Penn State, is shown with two H2S monitors, one mounted near the ground, one at chest level. That difference in height can mean the difference between a safe and deadly level of the heavier-than-air gas.

Fabian-Wheeler said some of the monitors were designed to detect multiple gases, hydrogen sulfide among them. Others were designed for H_2S alone.

Hydrogen sulfide in the air at 100 parts per million is considered an immediate threat to life and health. A concentration of 20 ppm is considered safe. The field day monitors were set to go off at 10 ppm.

It was possible to track the position of the agitator nozzle by the monitor beeps. As the nozzle swung across the surface, it created a plume of gas with considerably elevated concentrations of H_2S.

Hydrogen sulfide smells like rotten eggs, and it can be deadly. And insidious. It is heavier than air, which has a molecular weight, when dry, of about 29 grams per mole. Hydrogen sulfide weighs in at 34 g/mole.

It can creep out of a manure pit and hug the ground in an invisible, deadly carpet a foot or two thick, where a farmer's kids can be riding their tricycles, while the farmer is breathing good air several feet above the ground.

This actually happened two years ago in Montour County, and fortunately, the boys' father dragged them to safety just in time.

Mike Hile's doctoral thesis will focus on the effectiveness of additives intended to reduce the presence of hydrogen sulfide in manure pits. The additive used on the Wolfe farm is Vital Breakdown, a limestone-rich formulation made by Homestead Nutrition in New Holland, Pa.

"We have seen some promise for additives under these uncontrolled conditions and in some previous controlled lab-scale work," Fabian-Wheeler said.

Weaver's interest in Hile's work was sparked by the fact that gypsum bedding can dramatically increase the amount of hydrogen sulfide in liquid manure. His company, US Gypsum, is a major supplier of gypsum bedding, which is made from recycled wallboard and other gypsum-rich building products.

"My interest is in safety of farm families," Weaver said. "We have had a handful of tragic incidents in the past few years, some involving gypsum, some not."

Fall protection is first and foremost a safety issue for manure pits, Weaver said. If a person slips and falls into a manure pit, the presence or absence of hydrogen sulfide is pretty much academic.

Photos by Dick Warner

Amy and Eric Wolfe are happy with their clean, healthy and productive gypsum-bedded mixed breed herd of 180 milkers.

Although gypsum bedding can increase the presence of deadly H_2S, he said, farmers have to know how to deal with numerous toxic chemicals — footbaths for dairy cows was one example he used — on a daily basis.

Terry Weaver

Weaver liked the setup on the Wolfe farm, especially the fact that the gates on the chain-link fence could be snugged up against the tractor wheels to prevent intrusion into the pit.

"Too often," he said, "a farmer will open the gates and leave them open while he's emptying the pit. Sometimes, they'll be open for days."

Eileen Fabian-Wheeler

Weaver said the Wolfes' setup was about as good as you're going to see on a dairy farm.

Eric and Amy Wolfe are fully aware that their bedding practices can result in the production of hydrogen sulfide. But, as Weaver pointed out, they had their practices, enclosure and monitors in place before they even started their participation in the Penn State study.

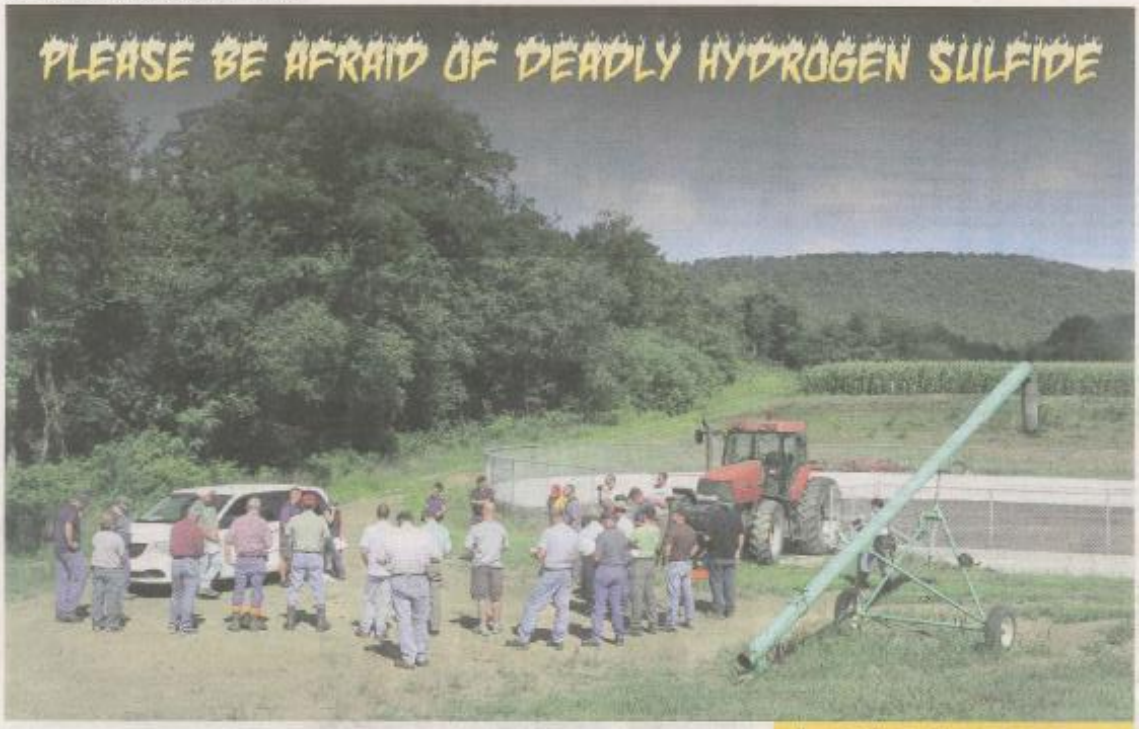
Hydrogen sulfide is something they have to be careful about — like footbath solutions — but they say they feel the advantages of gypsum bedding far outweigh what they see as a moderate risk.

They milk about 180 head of mostly Holsteins with a few Brown Swiss, Linebacks, Guernseys and one lone Jersey.

"The cows are clean and dry. They're comfortable. Our somatic cell count has dropped from 400,000 to 200,000 since we switched to gypsum bedding. Our mastitis is way down and our production is up," Eric Wolfe said. "We're going to stick with gypsum."

Krieg, Dieter. Please be afraid of deadly hydrogen sulfide. Farmshine - September 19, 2014.

PLEASE BE AFRAID OF DEADLY HYDROGEN SULFIDE



Never mind (for now) all the scientific data that was collected around Eric Wolfe's manure lagoon on August 28th. Arguably one of the most extensive efforts ever undertaken in the U.S. to measure deadly manure gases, the only statistic you need to remember for now is that even just one person being overcome by manure gases is one too many. The danger is very real and that's what this field day in Schuylkill County, Pa. was all about. The corn harvest has begun and with it comes the emptying of manure pits. Hydrogen sulfide (H_2S) gas has been identified as the most lethal of all manure pit gases when it comes to rendering people unconscious. It's a proven killer and you are hereby reminded to take extreme care when working around your manure pit. Especially when agitation is taking place. Only the most essential two or three people should be present. Make sure the pit is secured so that no one can fall in. A personal gas monitoring device is highly recommended. More detailed information will follow in upcoming editions of Farmshine.

Photo by Dieter Krieg

Fabian, Eileen. Gypsum bedding: Is it worth the manure safety risk? Progressive Dairyman – October 1, 2014.

Gypsum bedding: Is it worth the manure safety risk?

Eileen Fabian-Wheeler for *Progressive Dairyman*

Gypsum bedding offers benefits to cow comfort, milk quality and agronomic features, but its use should be weighed against the risk of elevated levels of hydrogen sulfide gas in manure storages.

Photo by Robert Mellen, Penn State Extension

Recent deaths of farmers and cattle have raised awareness of the all-too-common dangers of working around manure storage facilities. People "being overcome" or feeling dizzy around manure storage areas happens too often. Headlines often list the reason as asphyxiation or toxic gas. Many times, the toxic gas is hydrogen sulfide, with most deaths associated with below-ground, enclosed storages. More recent investigations indicate that hydrogen sulfide is also present in outdoor open storages, particularly on dairy farms where gypsum is used as bedding material.

Recent measurements at 10 dairy farms confirm highly elevated hydrogen sulfide gas concentrations surrounding open manure storages during agitation prior to manure removal for land application. A link to gypsum bedding seems clear. A big concern is respecting the everyday risks of working near any stored manure, particularly when agitating.

Gypsum bedding has become popular in regions with an affordable supply, such as in Pennsylvania. It is obtained from recycled construction wastes, such as drywall board. Bedding products range from a floury powder to granular material to pellet-sized wall-board chunks. All versions seem comfortable to the cows, offering increased moisture absorption and low bacteria growth in the pH-neutral material, enhancing animal welfare through improved udder health and cow cleanliness.

Farmers who are fans of gypsum bedding point to the soil benefits. Manure from gypsum-bedded cows has reduced carbon to be broken down once land-applied versus wood chips and sawdust bedding. Plus gypsum-manure provides additional sulfate to soil while reducing phosphorus runoff through improved phosphorous source coefficient (PSC).

Thus, there are many good reasons for the use of gypsum as dairy cow bedding. The question now is how to raise awareness that safe manure-handling practices are just as important, if not more so, when handling manure containing gypsum as with any dairy manure.

One might ask how a bedding material choice could influence risk during manure handling months later. Gypsum is calcium sulfate ($CaSO_4$-$2H_2O$) that under anaerobic (no oxygen) conditions in manure storages is microbially converted to hydrogen sulfide gas. This makes it very likely that hydrogen sulfide will be produced in dairy manure collection pits and manure storages. Some will recognize hydrogen sulfide by its "rotten egg" smell.

Hydrogen sulfide gas is particularly tricky as it is heavier than air. It can settle in low spots near manure storage. Children breathing at their low height are more susceptible to hydrogen sulfide plumes. Equally tricky is that hydrogen sulfide overcomes the sense of smell and no longer smells like rotten eggs at dangerous levels (100 ppm). Then, at higher levels (500 ppm or more), it quickly arrests the ability to breathe properly, resulting in dizziness followed by passing out. At extremely high levels (approximately 1,000 ppm), breathing ceases quickly.

Hydrogen sulfide and other gases of concernare released in bursts during manure movement and agitation. These bursts are often accompanied by significant odor. During our measurements from a USDA Natural Resources Conservation Service-funded demonstration project, we found several features of interest. One is with gypsum-bedded cows, the manure during agitation released hydrogen sulfide levels that were immediately dangerous to life and health (at 100 ppm or higher). This raises obvious concern. Plumes of this gas have been known to be present in dangerous levels in below-ground, enclosed storages with any species of

Continued on page 133

animal manure and any dairy bedding material. But recent observations raise the need for concern even at outdoor open manure storages during agitation. A second project finding is encouraging in that use of manure additives that break down the stored manure seemed to reduce hydrogen sulfide gas levels at agitation on farms using gypsum bedding.

We also found that the first 30 to 60 minutes of manure storage agitation are the most dangerous. Stay away during this time. Or wear a gas monitor that warns of risky gas level. Personal gas monitors are barely larger than a cell phone and cost less. The farmers at our 10 demonstration sites each wore a personal gas monitor during manure storage agitation so we could observe exposure and increase their safety.

Operators with highest hydrogen sulfide exposure during our project were very close to the manure being agitated or had leaned over the storage fence line to adjust or maintain equipment. Operators who stayed in tractor cabs or were otherwise well away from gas plumes coming off the manure were at lower risk.

It is virtually impossible for an individual to get themselves out of a manure storage accident. Every recent fatal incident in the northeastern U.S. (except two young boys in Pennsylvania who were overcome by gas and found unconscious at the edge of an in-ground open storage during agitation) involved people who were found unresponsive in a manure storage with no means of rescue or recovery in place. The fatalities have involved farms using gypsum bedding and those that do not. We will never know if the people were overcome by gas or simply fell into the storage, as there were no surviving witnesses. These tragic reminders point to the importance of providing a life line (harness and rope, for example) and a plan that does not endanger those attempting rescue.

This leads to two strong recommendations for any and all dairy manure storages. One is to stay clear of manure being agitated for the first half-hour when most gas is released; more than an hour is even better. This includes not leaning over or within the storage confines. Secondly, keep non-essential people away during agitation, especially children.

Gypsum bedding offers benefits to cow comfort, milk quality and agronomic features. These benefits should be weighed against the risk of elevated levels of hydrogen sulfide gas. Hydrogen sulfide is likely to reach dangerous levels in locations in bursts even around outdoor open manure storages during agitation prior to land application when gypsum bedding is used. Be aware. **PD**

Eileen Fabian-Wheeler is an agricultural and biological engineering professor with Penn State University. Email her at efw2@psu.edu.

Three manure storage safety tips

Outdoor dairy manure storages are open to the atmosphere but still meet the definition of a confined space in terms of danger from toxic gas and drowning.

1. If you must go into the fenced area of the open manure storage, wearing a safety harness with life line attached to a safely located solid object or anchor will enhance your chances of rescue.
2. Never work alone. The second person's role is to summon help in an emergency and assist with rescue without entering the storage.
3. If you feel unsure or uncomfortable with what you are getting ready to do near the open manure pit, step back, contact someone and review the situation before proceeding.

Find more useful information in the publication from which these three tips were taken: *Open Air Manure Storage Safety Tips*. Penn State Extension. By D.J. Murphy, R. Meinen and D.E. Hill. 2014.

Platek, Mike. Agricultural safety, sometimes forgotten. Industrial hygiene – December 2014.

INDUSTRIAL HYGIENE

Agricultural Safety, Sometimes Forgotten

There must be ongoing education of farmers, their families, and hired hands on the dangers of gases on farm properties.

BY MIKE PLATEK

PENN STATE AGRICULTURAL ENGINEERING

The Agricultural and Biological Engineering group of Penn State University is currently conducting a research project on hydrogen sulfide releases from manure pits, with a focus on farms using gypsum products as bedding for dairy cows.

One industry in the United States that many people take for granted is the farming industry. Agriculture and agriculture-related industries contributed $75.8 billion to the U.S. Gross Domestic Product in 2012, a 4.8 percent share. Of that amount, American farms contributed $166.9 billion, or about 1 percent. That translates into 16.5 million full- and part-time jobs, accounting for about 9.2 percent of total U.S. employment. More than 2.6 million of those jobs are directly connected to U.S. farms.

Why all the stats? Agricultural deaths in 2012 totaled 475, making the death rate 21.2 per 100,000 full-time workers. And to make matters worse, in 2013, the number of deaths climbed to 479 and the rate increased to 22.2 deaths per 100,000 workers. These numbers shouldn't be accepted by anyone.

Having spent time on farms, I have seen several unsafe acts involving different age groups. On family farms, the "young ones" are always helping out, from driving tractors and combines to working closely with the animals.

Of the many safety hazards that exist on a farm, the atmospheric hazards often go unaccounted for or are simply forgotten. This is due to either lack of caring or just being unaware of the potential gas hazards on a farm. Because of this, an increasing number of farmers and their family members are dying from gas exposures.

Areas in a farm that should be of concern are silos, outbuildings, barns, and manure pits. The most hazardous of these locations, by far, is manure pits. Some of the gases that can be found on a farm are hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), methane (CH_4), chlorine (Cl_2), and ammonia (NH_3). In addition to these hazardous gases, another threat is the depletion of oxygen (O_2), which is a very common problem. The areas where these gases appear on a farm's property are numerous. For example, ammonia is used as a fertilizer, while nitrogen dioxide can be found when corn and other crops along with silage are stored in silos, while methane and hydrogen sulfide are present in manure pits. The list goes on.

Manure Pit Gas Hazards

As mentioned, the most hazardous area on a farm is the manure pit. Look at any fatality report regarding farming, and you'll see that the manure pit generally gets top billing as one of the most dangerous locations. Why are manure pits so dangerous? A typical dairy cow that produces approximately 2,000 gallons of milk per year also produces more than 7,000 gallons of liquid manure. The manure requires storing and overall managing by the farmers.

The Agricultural and Biological Engineering group of Penn State University is currently conducting a research project on hydrogen sulfide releases from manure pits, with a focus on farms using gypsum products as bedding for dairy cows. The gypsum bedding is being used for the animals' welfare in that it improves the dairy cows' living conditions. The gypsum absorbs moisture better, reducing the bacteria count, and it is pH neutral. As a result, the cows are healthier. Later, as the manure is spread on the fields, the effects on the soil are low carbon additions with added sulfur.

(This study was principally funded by a grant from the USDA-Natural Resources Conservation Service [USDA-NRCS]. It is being conducted by Mike Hile, a Ph.D. candidate at Penn State University, and overseen by Eileen Fabian Wheeler, professor, Air Quality. They are located in University Park, Pa., and can be contacted as follows: Mike Hile, *mlh144@engr.psu.edu*; Eileen Wheeler, *efw2@psu.edu*.)

Before gypsum was introduced to the dairy industry, there needed to be an understanding of the working of the manure pits and the dangers associated with them. The cow manure is moved from the barn into

a manure pit either by a built-in conveyor system or manually by the farmer, depending on the size of the dairy operation. For example, one farm included in the research study has 275 dairy cows and a 1 million-gallon manure pit. The pit is emptied twice a year, with the manure spread over the fields for fertilizer. Typically this is done in late fall after the crops have been harvested and then again in the spring before the crops are planted.

This long storage time of the manure allows it to go anaerobic (without oxygen) and allows the bacterial action to produce hydrogen sulfide. Sometimes a "crust" forms on the top of the manure, acting as a lid trapping the gases. The danger occurs when the farmer needs to "stir" the manure pit to prepare for the disposal or spreading of the manure. The stirring releases the hydrogen sulfide, along with any methane. The presence of these gases also can contribute to low-oxygen atmospheres. There are numerous accidents on record of farmers and members of their families who have been overcome by these deadly gases.

While gypsum benefits the welfare of cows, it increases the presence of hydrogen sulfide. Gypsum is a sulfur-based ore. Also known as calcium sulfate, $CaSO_4$, it provides a sulfate source within the manure storage that reduces to form H_2S. The Penn State research is focused on the use of gypsum as bedding and its contribution to the increased levels of H_2S. When farms using gypsum were studied, H_2S was detected at life-threatening levels.

OSHA has a PEL of 20 ppm that is stated as the ceiling level, with an Immediately Dangerous to Life or Health level of 100 ppm. When the manure pits containing gypsum were stirred, levels as high as 500 ppm were encountered. A breath or two at these levels could have serious effects on a farmer, including respiratory distress and/or unconsciousness, potentially leading that farmer to fall into the manure pit. This could lead to higher gas exposures, asphyxiation, and even drowning.

One farm visited during the study experienced a very close call related to the safety of the family's two young boys. Playing slightly downhill from the manure pit one day during a stirring process, the boys were observed by their father to be lying next to their bikes. Thinking the boys were just playing, he continued his work. A short time elapsed and he noticed the boys were in the same position. They had been overcome by hydrogen sulfide. He immediately attended to the boys and was able to revive them. No long-term damage occurred, but the younger boy was kept overnight at the hospital for observation.

There must be ongoing education of farmers, their families, and hired hands on these gas dangers on farm properties. OH&S

Mike Platek is a Gas Detection Specialist at Industrial Scientific Corporation.

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Krieg, Dieter. The invisible goon in the lagoon has been detected. Farmshine – December 5, 2014.

Krieg, Dieter. This poisonous cocktail shows absolutely no mercy. Farmshine – December 5, 2014.

MANURE MANAGEMENT SAFETY

This poisonous cocktail shows absolutely no mercy

By DIETER KRIEG
Farmshine Editor

When agitation starts, extreme danger begins.

PINE GROVE, Pa. – Hydrogen sulfide (H_2S) is a known killer. If you have a manure storage facility on your farm, the most dangerous gas of all is likely waiting beneath the murky surface. And if you're not careful, H_2S can overcome you in little more than an instant. Please heed the warning: This poisonous cocktail shows absolutely no mercy.

A field day held near here on August 28th at Eric Wolfe's farm presented all the evidence. Numerous scientists as well as others concerned with farm safety showed up to detect and measure the H_2S, which is a stress fuel of a newcomer in manure storage areas, and therefore also a bit of mystery. But one thing is sure: It's a killer. A fast killer.

Quick as hydrogen sulfide is to snuff out a person's consciousness, if the victim happens to fall into the manure pit, death is all but certain. One reason is that most (if not all) manure storage areas are considered to be a "confined space" ... meaning they're easy to get into but hard to get out of. A second reason for certain doom is that rescue attempts will likely fail unless preparations have been made ahead of time. That's why an untold number of people have been overcome by H_2S in the past several years. The fatality figure with one victim being overcome, and cada with rescuers being stricken as well.

While much remains unknown about the complex, murky chemistry that goes on inside manure pits – largely because conditions can be highly variable – the foremost reason for doing the research in the first place is safety.

"Manure safety is what this is all about," declared Mike Hile, a doctoral degree candidate at Penn State's College of Agricultural Sciences and leader of this particular research project. "Hydrogen sulfide gas is what we're looking at," he added.

Ironically, the research conducted here last summer was basically called for by someone who could potentially be hurt by its results. Terry Weaver, owner of USA Gypsum in Reamstown, Lancaster County, Pa., has been pressing for answers simply because he's so concerned about manure safety as anyone ... perhaps even more so. And while not officially on the field day's program, he's also very knowledgeable on the subject. (Please see statement from USA Gypsum, printed below, right.)

Penn State's researchers confirmed the benefits of gypsum, as did farm owner Eric Wolfe, a satisfied user of the product. "Gypsum is very absorbent and keeps the shavings in the bed longer," stated the 40-year old operator of the modern, 170-cow dairy. "Gypsum is also a great soil amendment. It has a lot of good qualities," he affirmed.

Hile, while not denying the benefits of gypsum, cautioned nevertheless that "if gypsum is introduced, there is potential for hydrogen sulfide gas emissions."

"We are collecting our data today," he explained early in the program and before Wolfe powered up his tractor to agitate the liquid manure in his 120-foot diameter by 12 foot deep pit. It wasn't long before more than a dozen strategically placed monitoring devices started their chorus of "beeps" ... in "surround sound," even.

Not surprisingly, with the demonstration going on loud and clear, everyone who had a part in the program emphasized the need for safety.

Hydrogen sulfide is a known killer, yes. But you can avoid the dangers by simply heeding the safety protocols. Again the proof was right there at the pit for everyone to see. Bumpers were off all over the place, but no one was the least bit affected by the gases, despite the fact that the amounts approached lethal levels. Simple reason? Back off! Stay away!

Wolfe sat within the relative safety of the tractor's cab. For good measure, he had a "buddy" with him to let him know what level of H_2S exposure he was being subjected to. As a custom manure hauler (in addition to being a dairyman) he understands the importance of every precaution that's prescribed and he abides by them. There's no room for errors; no reason to take chances. Safety is everything because being careful may well mean avoiding

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USA Gypsum always emphasizes safety

REINHOLDS, Pa. – Recent articles regarding hydrogen sulfide, gypsum and manure gases are misleading and are not based on science or research. There is no research data to link gypsum to hydrogen sulfide.

The safety of farm families, manure handlers and the environment is extremely important to us. Safety guidelines have been published for years from many sources and can be summed up by staying clear when agitating liquid manure and never entering a pit without safety equipment and training.

For over 20 years, multiple sources have reported manure produces dangerous gases methane, ammonia, carbon dioxide and hydrogen sulfide. From 1975 through 2004, 77 fatalities and 21 severe injuries were documented from manure handling. Recently methane explosions have destroyed buildings and injured people. In 1997 acute hydrogen sulfide (H_2S) poisoning was confirmed as the cause of death in 26 cattle weighing 1300 pounds from a load of 150 in rural Indiana while the farmer agitated the manure storage. In 1992 the American Society of Engineers reported levels of 1000 PPM during vigorous agitation. Levels above 500 PPM can be deadly.

Since 1996 (16 years), USA Gypsum has been supplying gypsum bedding additives to dairy farmers. Today, thousands of farmers add gypsum based products to their bedding on a daily basis and report that it provides a comfortable clean surface for healthy cows, which improves milk quality.

Gypsum is proven to reduce certain gases from manure. Research confirms that adding gypsum reduces ammonia and methane (greenhouse) gas release. Gypsum applied to the soil is also proven to reduce the most important pollutants to surface waters: erosion sediment, nitrogen and phosphorus.

The most complete study on gypsum dairy bedding additives was recently completed in Canada and no hydrogen sulfide was detected during agitation. However, the micro biology of manure storage is complex. Variables include type of manure storage, how long it is stored, agitation methods, water quality, nutrition, bedding type, sulfur content, waste wash water, free baths, silage leachate and other additives to manure storage. Environmental conditions such as temperature, humidity and wind are also important factors.

Because there is a lack of research, USA Gypsum, NRCS and Soil Conservation are sponsoring on-farm demonstrations which are being conducted by Penn State University to study dairy manure handling gas, how they can be reduced and new practices to keep manure handlers safe.

Manure management safety

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death.

Davis Hill, a Penn State farm safety specialist, had plenty to say at the field day. He warned that a respiratory illness (which is what H_2S inhalation causes) will affect a person quickly ... but if you can quickly get to fresh air, it will cause a quick reversal of the negative onslaught caused by H_2S.

Eric Wolfe, dairy farm owner and custom manure hauler, watches and listens as the results come in.

Hydrogen sulfide gas is heavier than air, Hill pointed out, which makes it so extremely dangerous. It's right at your level, especially if you're down. On the other hand, methane – another dangerous gas – is lighter than air and will usually vent off fairly quickly. But not so with H_2S. It stays low to the ground and if the weather is hot and humid, it's worst of all.

Rob Meinen from Penn State's Department of Animal Sciences, described the signs of lung poisoning, which include headache, dizziness and a reduced sense of smell. He referred to the symptoms as 'body alarms' and declared that anyone working with manure should be aware of the danger symptoms and pay attention to them.

"I recognize the farmer's work ethic," he noted sympathetically. "You want to get he job done even though there's pain and discomfort. But don't do it in this case. Listen to your body alarms!"

As information was being shared at a safe distance from the pit, someone would check on the monitors from time to time and report the findings. Where the PPM reading might have been 50, it had shot up to 300 and even higher as agitation of the pit's contents continual vigorously. Inside the concrete storage facility, the PPM reading shot up to 800. A level of 500 and higher is considered lethal.

The group of attendees, which kept growing throughout the event, included people from as far away as Pen Yan, N.Y. Henry Martin and his son, Daryl, were among four men from the Finger Lakes Region to make the trip. Why? They wanted answers. They wanted to see test results and above all, they're interested in manure management safety.

Don Weaver, owner of Homestead Nutrition in New Holland, was also among the visitors. Like everyone else, his main interest for being there was to help promote safety around the pit. He has a simple message: "It's like silo gas. Stay clear of it."

"Safety awareness is the big deal in all of this. The word needs to get out," concluded Penn State's Mike Hile.

More information to be shared in an upcoming edition. Please stay tuned.

W.H. "Howie" Latshaw, right, state conservation engineer with the Natural Resource Conservation Service (NRCS), noted that everyone involved in manure management needs to think of children, grandchildren and neighbors. "We need to make decisions for them," he said, explaining that the young and uninformed are often not aware of the dangers. Warning signs are available from his office. Call 717-237-2212. *Photos By Diane Kring*

Transitioning cows is topic of Technology Tuesday program

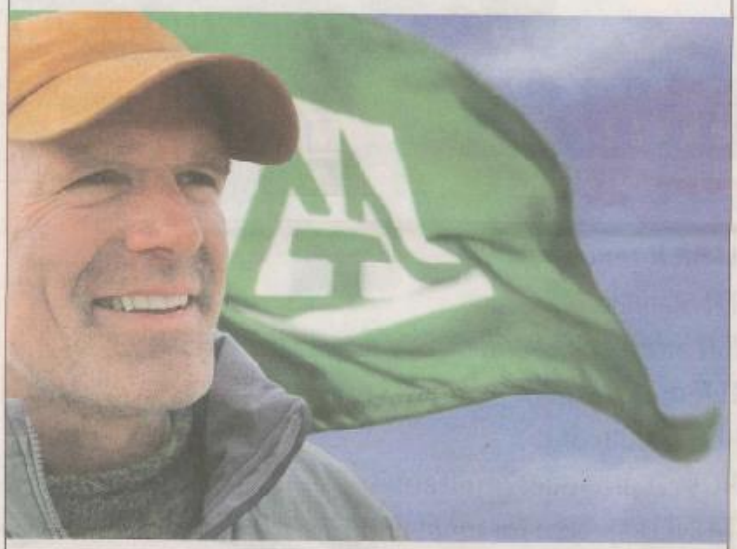
UNIVERSITY PARK, Pa. – Transitioning cows from the dry period into and through early lactation is the subject of the next "Technology Tuesdays" webinar on December 9, produced by the Penn State Extension dairy team.

Transitioning cows has a huge effect on the overall production and health of the entire herd. The way we house and manage the dry and pre-fresh cows ultimately determines the level of production she can achieve. The webinar will look at animal behavior aspects of this transition period as well as housing and management options. The discussion will be led by John Tyson, ag engineer, Penn State Extension Dairy Team.

Registration for the Technology Tuesdays Webinar Series is free of charge, but you must pre-register for the first session that you wish to attend. Pre-register online at www.surveymonkey.com/s/TechnologyTuesdays1314 no later than noon the day preceding the session. Prior to the webinar session, you will receive an email that confirms your registration and contains the webinar URL. You need only register once; the same URL is used for all sessions.

Krieg, Dieter. Do not give the killer in the pit the benefit of the doubt. Farmshine – October 10, 2014.

Do not give the killer in the pit the benefit of the doubt



The chemistry of a manure storage facility is varied, mysterious, complex, murky and deadly. You should always count on it being so. Doubting it holds no benefits.

But despite the lethal chemistry in the lagoon, avoiding the sinister killer is as easy as 1-2-3.

1. Make sure the facility is secured by fences and gates so that there's no chance of any unauthorized person entering either deliberately or accidentally.

2. Stay away from it, especially if agitation is in progress because that's when deadly gases will most likely strike.

3. Never, ever, attempt to perform any task inside the facility without being safely harnessed and a second person standing by in case of an emergency.

No matter what we do as farmers – from planting to harvesting and feeding to hauling manure – there's nothing more important about the business of farming than safety. Yet, statistics are piled on us every year about accidents and deaths. Some situations would be very difficult to avoid, such as dropping into a sinkhole that wasn't there yesterday.

But succumbing to a known danger such as silo gas or fumes from a manure pit is surely avoidable. It begins with acknowledging in your own mind that the danger is real and present. Doubting it gets you in trouble. Do not give the manure pit the benefit of the doubt. Ditto for the silo that's being filled.

There are times, we know, when a storage facility needs to be entered. When that occurs, please make sure it's done with all safety preparations and precautions in place. For the most part and for most of us, it's a simple matter of common sense. But the fact is, it's also a matter of life and death. Avoiding the deaths and accidents requires us to make everyone on the farm aware of the danger.

Please take this responsibility most seriously and make sure that every member of your family and all your employees are aware of the extreme dangers that exist not just inside the manure pit, but also within close proximity of it. Especially if agitation is taking place and the wind is blowing your way. It's a deadly breeze! Stay away!

Done right. This manure lagoon was designed and built to greatly reduce the chance of someone slipping and falling in. The gates are open for the tractor and pump/agitator, but have nevertheless been pulled back to the tractor's wheels to block the entrance.

Dekar, Emily. Empty it, maintain it, and above all, stay safe. Farmshine – October 17, 2014.

Empty it, maintan it, and above all, stay safe

EMILY DEKAR
Bradford County Conservation District

TOWANDA, Pa. – Now is the time to prepare your manure storage structure for the winter months ahead. The most important thing is to get the level down to a minimum of what will be needed to hold winter's manure production.

A manure storage facility can be your best (or worst) friend during the winter and early spring months. Not having to spread manure when it is below 0 or when fields would be torn up due to wetness is a great benefit of having a storage facility. Not emptying the storage to allow proper maintenance to be performed may require expensive and unpleasant, cold weather activities. Timely fall manure spreading can help prevent soil compaction, winter crop injury from machinery traffic, and conserve manure nutrients for next year's crops. The Conservation District is available to discuss long term management practices to prevent or alleviate soil compaction.

Manure storage levels must be low enough to allow storage through early spring months while maintaining the proper freeboard. Fall manure applications should be on sod, fall planted cover crops or fields with greater than 25% ground cover (not on bare corn stubble).

Here are some other important reminders as you prepare for winter:

1. Make needed fence repairs a priority. Safety first!
2. Take advantage of the empty storage to check and clean areas where pipes enter. It is much easier to clean now than to unplug a pipe on Christmas Eve.
3. Beware of manure gases in confined or low areas with little ventilation. Manure gases can be DEADLY!
4. Spend time agitating. A whole day is often needed. Well mixed manure will provide a more consistent nutrient application and prevent buildup of solids.
5. Maintain earthen dams.
6. Keep diversions above the storage clean and clear. More water getting to the pit means less storage and more trips with the spreader.
7. Check the perimeter drain outlet. Make sure several inches of drop from the pipe remains and that water can move away quickly.
8. Keep records of when manure is applied in the fall to plan nutrient applications in the spring. Time spent keeping records can be a good investment and is required by Pennsylvania law.
9. Maintain adequate freeboard. This is your safety net for large spring storms.
10. Contact the Conservation District with any concerns.
11. Manure analysis is a great value in allowing you to plan the best use of your manure nutrients. Understanding the nutrient content of manure from your operation can result in significant fertilizer savings. Several manure samples should be taken and put into a collection bucket as the pit is emptied. Then take a composite sample from those sub-samples and send to a laboratory to have an analysis completed. It is very important to follow shipping instruction provided by the lab. Manure sample kits may be obtained from your county Conservation District.

Well mixed manure will provide a more consistent nutrient application and prevent buildup of solids.

Krieg, Dieter. They're not just standing around. Farmshine – October 24, 2014.

16 — Farmshine, Friday, October 24, 2014

They're not just standing around!

Concern over the dangerous gases around manure pits brought several dozen people to Eric Wolf's farm in Schuylkill County earlier this fall, some coming from as far away as the Finger Lakes Region of New York State. Various industry experts were there to define and measure the hidden killers that exist in manure storage facilities, of which hydrogen sulfide is known to be the most sinister and lethal. But with safety procedures in place, the danger is all but eliminated. Every expert who took the microphone urged safety first. Please heed the warnings when you empty your manure storage facility, especially during agitation.

Photo by Dieter Krieg

Gruber, Philip. Gypsum linked to poison gas in manure storage. Lancaster Farming - February 21, 2015.

Gypsum Linked to Poison Gas in Manure Storage

PHILIP GRUBER
Staff Writer

A soft mineral that makes a good dairy bedding can also make manure storages more dangerous.

Researchers have suspected for some time that gypsum, the main material used in drywall, increases hydrogen sulfide levels in manure storages, and new research supports that belief, Penn State Extension associates said Feb. 10 during a Technology Tuesday webinar.

Gypsum, or calcium sulfate, occurs naturally and as a byproduct of burning coal. The gypsum used on farms is made using waste from drywall manufacturing, said Mike Hile, a Penn State graduate student who conducted the research.

When used as a bedding for dairy cows, gypsum absorbs moisture and helps keep bacteria low. It has a neutral pH, so "it's really an ideal bedding product," Hile said.

As a soil additive, gypsum opens tight soils, makes water more mobile and improves root development. It reduces phosphorus runoff, retains plant-available nitrogen, and supplies calcium and sulfur, Hile said.

Unfortunately, when gypsum lands in manure storage, it tends to break down and produce hydrogen sulfide, a poisonous and explosive gas that is dangerous even at low concentrations.

"Industry doesn't like to see workers exposed to above 20 parts per million," and the gas is immediately threatening at 100 parts per million, Hile said.

Most people can smell hydrogen sulfide at extremely low concentrations, said Rob Meinen, an Extension associate.

"As the concentration increases, actually your olfactory senses deaden a little bit and you all of a sudden don't recognize that rotten-egg smell, and you can actually still be in that dangerous environment without even realizing," Hile said.

Hydrogen sulfide is released when crusted-over manure is agitated, Hile said.

For years, there have been cases of farmers being overwhelmed by manure gases, but over the past few years more stories have surfaced — of "manure smelling really, really strong," dead livestock, and employees collapsing, said Davis Hill, an Extension ag safety associate.


Mike Hile

"We've heard (of) some manure haulers that have made a policy that they're refusing to haul manure from farmers that use gypsum bedding," Hill said.

In May 2012, three Pennsylvania workers died in a manure storage on a Maryland farm that used gypsum bedding.

Later that year, two little boys in Montour County were found unresponsive next to a manure storage shortly after agitation started. Their father moved them to safety just in time, Hill said.

Usually, hydrogen sulfide makes up 10-20 parts per million of the air around a manure pit during agitation, but at the Montour site the levels were 150 parts per million. The boys probably rode through a plume of 500-600 part per million on their bikes, Hill said.

Hydrogen sulfide often escapes in bursts, Meinen said.

Hill used to tell people that 30 feet was a safe distance, but even at that distance he found elevated levels of hydrogen sulfide on the Montour farm.

"Even inside the freestall barn we were kind of grabbing some samples above that 20 mark," he said.

Those findings prompted Hile to determine whether gypsum was indeed producing the deadly gas.

Hile positioned gas monitoring devices around manure pits on a number of farms to measure hydrogen sulfide levels during agitation. He also tested the manure and noted environmental conditions like wind direction.

The farms that used gypsum indeed had high levels of hydrogen sulfide. Hile found 64 parts per million even 30 feet downwind of the storage. The farms that did not use gypsum stayed under five parts per million, he said.

The farmers who agitated the manure also wore monitors, and most of them stayed below hazardous levels of exposure.

Those who were fine ran the agitator from the cab of their tractor with the doors closed. The tractor elevated them above the pit, Hile said.

Those who were exposed to more gas worked outside the tractor, often at the edge or even leaning over the storage wall, Hile said.

Some farmers reported corrosion of fences and building components, he said.

Environmental conditions can change the risks. A storm was rolling in during one agitation. The wind usually blew east on the farm, but the storm shifted the wind to the northwest — blowing the hydrogen sulfide directly into the heifer barn, where the trapped gas topped 500 parts per million.

"It was actually higher than my meters would measure," Hile said.

For now, safety precautions are the best way to reduce the risk from manure gas exposure.

Treatments claimed to reduce the hydrogen sulfide did not perform as advertised in Hile's test.

Some additives have been promising in lab research, but more farm-scale research needs to be done, Hile said.

Once agitation starts, everyone should stay at least 50 feet away from the storage, said Eileen Fabian, a Penn State ag engineering professor.

"It's helpful to be aware of who's around: even children, animals, other workers that aren't necessarily working right at the perimeter," Hile said.

Hydrogen sulfide is heavier than air and tends to stratify in the few feet above the ground. "You might be good while you're standing. When you bend over you might be in trouble," Meinen said.

Children are at particular risk because they are short enough to breathe in the hydrogen sulfide's stratum and because they are naturally curious.

Meinen remembers being at the North American Manure Expo a few years ago.

"Every time there was a hole or a confined space, the kids were the first ones to walk up and look in there and get close," he said.

Purdue University found that 10 percent of manure gas deaths were children, Meinen said.

Most manure gas deaths happen during warm months when microbial activity is greatest. August accounted for a quarter of the deaths in the Purdue study, Meinen said.

Presumably, the farmers emptied the storage in the spring, the manure accumulated while crops were growing in the summer, and they started to spread again when silage came off, he said.

It is best to have a second person to at least get help, not necessarily rescue, someone working with a manure storage. "We could avoid many deaths if we employed a buddy system," Hill said.

If help is far away, the second person may need to perform a rescue, but this is risky. "For every four people that went unconscious, another person died trying to rescue them," Meinen said.

Meinen said people near manure storages need to pay attention to their "body alarms" just as they would heed a smoke detector.

"If you feel like you just walked up three or four flights of steps and you really didn't exert yourself, that's your body calling for oxygen," Meinen said.

Meinen said a manure hauler who visited the Maryland farm said his exposure was so bad he could barely see a manure tank 20 yards away.

Carrying a gas detector can minimize your risk. "The first hour of agitation is probably the worst, but never let your guard down," he said.

Fabian, the engineer, "unconditionally recommends" that gypsum bedding not be used with underbarn manure storage. The chance of exposure is just too great, she said.

Hydrogen sulfide is only one of more than 200 manure gases, but farmers still need to weigh the hygienic value of gypsum bedding against the danger of the gas it creates later.