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Assessment of a Gas Monitor Distribution Program in Rural Wisconsin

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ABSTRACT

Objectives: Manure gases are deadly agricultural hazards that recently caused the deaths of two manure haulers and rural firefighters in New York in June 2024. This study had two objectives: 1) survey fire departments to learn about their use and promotion of four gas monitors in rural communities; 2) assess the Four Gas Monitor Program, a gas monitor distribution program in rural Wisconsin that targets first responders, to learn whether it is having an impact on rural community emergency preparedness.

Methods: A rapid, survey-based study was conducted in July 2024. The survey was distributed to the 81 fire departments that had members attend an Agriculture Rescue Training event, including 31 departments that had received gas monitors as a part of the Four Gas Monitor Program. The survey included questions about gas monitor use and promotion by the fire departments.

Results: Seventeen different departments responded to the survey. It was found that 16 of the 17 departments had four gas monitors, and 10 departments had received monitors from the Four Gas Monitor Program. Additionally, 13 departments informed their communities about the monitors, 3 used the monitors with farmers, and 15 departments had used monitors during an emergency response.

Conclusion: The study findings show that the Four Gas Monitor Program has successfully placed gas monitors into the hands of rural first responders, particularly in Central Wisconsin. The outcome of the Four Gas Monitor Program shows the potential for positively shaping the agricultural health and safety landscape through sustained work with first responders.

KEYWORDS

Community-based intervention; emergency preparedness; manure gases; rural firefighters; rural first responders

Introduction

Manure gases create some of the most hazardous environments on agricultural operations.[1–10] As manure decomposes, it forms and releases four gases that are hazardous to humans and animals: hydrogen sulfide (H_2S), methane (CH_4), ammonia (NH_3), and carbon dioxide (CO_2). Hydrogen sulfide is the most acutely toxic and in high concentrations it can lead to a sudden loss of consciousness and death. In addition to being invisible, hydrogen sulfide can also deaden a person's sense of smell, making detection increasingly difficult. High concentrations of the other manure gases can lead to other toxic effects that make a person very ill or cause long-term health problems. Manure gases are generally present in high levels when manure is being agitated, in confined spaces, or when ventilation systems are not functioning properly. Thus, it is possible for manure gases to be present in all manure storage areas, including pits, tanks, or other structures.

On June 13, 2024, two men, 33-year-old Nathan Doody and 29-year-old Tyler Memory, died as a result of manure gases at a farm in Clinton, New York. Doody and Memory worked as manure haulers and also served as volunteer firefighters.[11] According to WKTV, the Kirkland Police Department stated that one of the men went to retrieve a piece of equipment that had fallen into a manure tanker but became incapacitated and fell into the tanker. The second man was similarly overcome by manure gas as he tried to help the first. Workers at the farm found the men and called 9-1-1.[12]

Following the tragedy in New York, we decided to implement a rapid, survey-based project to accomplish two objectives: 1) learn about how fire departments are using and promoting four gas monitors in rural communities and 2) complete an assessment of the Four Gas Monitor Program at the National Farm Medicine Center (NFMC).[13] The purpose of the assessment was to learn about the impact of the

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program and gain actionable insights for advising agricultural health and safety colleagues about how and why they might implement a similar program in their areas. That the New York victims were volunteer firefighters increases the appropriateness of evaluating the Four Gas Monitor Program following the event. Before reporting the results of the survey, we review manure gas incidents and prevention recommendations and introduce the Four Gas Monitor Program in the context of the NFMC's ongoing work with first responders as agricultural safety advocates in rural communities.

Manure gas incidents

Extensive research has long been conducted on the harmful health effects of the toxic environments that accompany manure storage and handling work[1–6] (For a historical overview of safety research related to manure incidents, see Beaver and Field).[7] Consistent surveillance of manure-related incidents in order to inform prevention strategies, in contrast, did not occur until around 2019.[8,9] These recent and previous studies identify the toxic gases released by decomposing or agitated manure – methane, ammonia, carbon dioxide, and hydrogen sulfide, the latter being the most acutely dangerous – as the most significant hazards associated with manure-related activities. Asphyxiation is primarily cited as the cause of manure-related fatalities,[6] and a review of manure handling incidents from seven Central US States from 1975 to 2019 revealed that 42% of cases stemmed from asphyxiation.[9] Importantly, Nour and colleagues report that manure-related incidents are much more common than reported in existing literature.[8,10]

Relating to first responders, the issue of manure storage facility incidents received treatment in the influential manual, *Farm Accident Rescue* by Baker and colleagues,[14] see also Worsing R., Rural Rescue and Emergency Care.[15] In that publication, the authors mention that initial incidents are often compounded because bystanders, coworkers, and even first responders often attempt rescues without proper consideration of the environment, leading them to become secondary victims. Comparably, 22% of the manure-related fatalities identified by Beaver and Field from 1975 to 2004 were people attempting rescues.[7]

Manure gas incident prevention

Many recommendations for manure gas incident prevention involve engineering and design changes to manure waste storage structures.[4,7,16,17] While these changes would no doubt be the most effective, their practical impact is limited because many agricultural operations lack the means of investing in engineering fixes.[18] Path dependency, the *sunk cost fallacy*, and market constraints that deter pushing costs downstream to consumers may also influence farmers' hesitancy toward these solutions. Further, most of these recommendations only consider manure structures, not manure transport equipment or activities like manure pumping, agitation, or application. It is important to note that manure storage and transport entities in the U.S. are already classified as confined spaces and may require a permit for entry (For additional information on confined spaces in the U.S., see Occupational Safety and Health Administration (OSHA). Confined Spaces[19] and the additional resources on that page). In these cases, we strongly suggest following all relevant state and federal regulations. Confined space regulations pertaining to manure storage and transport systems may differ by country and should be consulted accordingly. Other commonly recommended changes are to treat all manure storage and transport entities as confined spaces – regardless of classification status – meaning that their atmospheres should be tested prior to and during entry, positive-pressure ventilation systems should be used, personal protective equipment – including portable multi-gas monitors – should be worn, and hazard warnings should be applied on or near manure storage and transport apparatuses. Each of these recommendations ultimately rest on changing the behavior of farmers, farm workers, and other manure-handling persons.

The primary approach adopted by agricultural health and safety interventionists for initiating behavior change among the agricultural community involves educational campaigns and the creation of informational materials. This approach has many merits and may lead to an increased consciousness of agricultural hazards among the target population. However, there are several obstacles to this approach, namely that the agricultural population is geographically dispersed, wary of "experts," and largely exempt

from regulatory governance. An additional challenge is that there simply are not enough agricultural safety personnel present in rural areas to reach the farmer, rancher, or other agricultural worker directly. Thus, interventions that depend on direct interfacing between agricultural safety personnel and members of the agricultural community are expensive and limited in reach.

Given these obstacles to direct consciousness-raising, researchers at the National Farm Medicine Center (NFMC) have found an "indirect route" to the agricultural worker to be expedient. Utilizing an approach influenced by the Social Ecological Model, we completed a study to determine which person in rural communities would be best positioned to function as an agricultural safety advocate.[20] The key criteria were that the person had to be highly trusted by farmers, capable of providing them with safety advice, and working with them to develop risk mitigation strategies for their operations. Rural firefighters and first responders emerged the best option. Thus, we have been working closely with rural fire departments to promote agricultural health and safety since 2016. This work has involved training in hazard assessment, agricultural emergency preplanning, farm first-aid, strategies for building relationships with farmers, and various components of agricultural technical rescue through the Rural Firefighters Delivering Agricultural Safety and Health (RFDASH) and Ag Rescue Training (ART) programs.[20–26] To date, these programs have trained over 350 rural first responders in various components of agricultural health, safety, and emergency response. However, NFMC connections with rural first responders go back even further, to farm rescue training events in the 1980s. Our longstanding connections with first responders are the foundation and cause of the positive impacts of the Four Gas Monitor Program at NFMC.

The Four Gas Monitor Program

Scholars have noted that gas monitors are a viable option for mitigating incidents involving hazardous atmospheres on the farm.[27] As Park and colleagues note: "Identification of potential hazards in an unpredictable environment using a gas monitor is important to prevent [manure gas] incidents."[6] It is important to note that four-gas monitors alone do not guarantee an individual's safety when working with manure. Thus, four-gas monitors should always be used in conjunction with other prevention measures, including: proper ventilation (e.g., positive-pressure ventilation system or a windy day); use of a breathing apparatus and harness when entering a manure pit; removal of persons and animals from building where manure is being agitated; consideration of proper storage conditions; clear signage to denote hazardous areas and exclusion zones as well as fencing around manure lagoons; and an operation-level written protocol for entering permit-required confined spaces.[4,28–31] Portable four-gas monitors (also referred to as multi-gas monitors) should be worn when pumping, agitating, removing, or applying manure and can also be used in manure tanks or pits to test the atmosphere prior to entry and to perform continuous monitoring while working in the confined space.[31] In such scenarios, other confined measures (detailed previously) should also be in place.[19,31] Similarly, first responders can use four-gas monitors along with other proper precautions, such as a breathing apparatus, when responding to manure gas incidents or performing rescues from incidents involving manure.

Four gas monitors are capable of simultaneously monitoring multiple hazardous gases as well as detecting whether an atmosphere is oxygen deficient.[32] The gases monitored by a four-gas meter are hydrogen sulfide (H_2S), carbon monoxide (CO), oxygen (O_2), and combustible gases. The combustible gas sensor is non-specific and can detect a variety of gases, including methane (CH_4) and ammonia (NH_3). Thus, four-gas monitors are ideal for situations involving manure, where simultaneous exposure to any or all of hydrogen sulfide, methane, ammonia, and carbon dioxide (CO_2) is possible. Four-gas monitors typically do not directly detect carbon dioxide, but this gas is minimally toxic on its own. The primary problem with carbon dioxide is that it displaces oxygen, so in high concentrations it can lead to asphyxiation. The four-gas monitor measures

oxygen levels, ensuring that the oxygen in an environment has not been displaced by carbon dioxide or another gas. Single-gas monitors are cheaper than four-gas monitors and are also an option for individuals working with manure. However, these monitors are restricted to monitoring only a single gas – usually hydrogen sulfide, carbon monoxide, or oxygen. Manure generates multiple harmful gases (as described above), so while using a single-gas monitor is better than no monitor at all, a four-gas monitor is recommended for situations where exposure to manure gas is possible.

One benefit to gas monitor distribution is that it is a site-agnostic intervention – the impact is applicable across manure activities associated with storage tanks, ponds/lagoons, or haulers as well as manure pumping, agitation, removal, or application. Recent technological developments have also greatly decreased the cost of sensors of various kinds and farmers are progressively integrating different kinds of monitoring into their operations (e.g., herd health, environmental factors, etc.), increasing the viability of sensor-based interventions for preventing manure gas incidents.[33] However, a survey of manure applicators in Minnesota revealed that 90% of 145 respondents did not regularly use gas monitors, despite 37% of 90 respondents reporting symptoms of manure gas exposure during application work.[28] A similar lack of best safety practices has been reported for operations with manure storage structures.[29] Two possible barriers to gas monitor adoption are that the monitors often require calibration after use and the sensors, especially the sensor for hydrogen sulfide, expire after 2–4 years.[32]

Building on the approach exemplified by the Agriculture Rescue Training (ART) and Rural Firefighters Delivering Agricultural Safety and Health (RF-DASH) programs, the Four Gas Monitor Program leverages the position of fire departments as agents of change in rural communities, instead of attempting to work directly with individual agricultural operations. The program provides a free gas monitor to fire departments when three or more department members participate in the annual ART event. The ART event has taken place each year since 2020, and gas monitors started being distributed in 2021. To date, 33 gas monitors have been distributed to 31 different fire and emergency response departments. When the meters are distributed, fire departments are advised to inform their communities about the gas monitors and work with farmers, encouraging them to contact the department about using the gas monitor for relevant activities and for advice about hazard mitigation or emergency pre-planning.[13] They are also informed about gas monitor calibration and lifespan. The Four Gas Monitor Program was established with support from the Mike Biadasz Farm Safety and Education Memorial Fund. On August 15, 2016, Mike Biadasz was agitating an outdoor manure pit when he was fatally overcome by hydrogen sulfide.[34] Mike's family established the memorial fund and supports the Four Gas Monitor Program to help prevent other families from enduring the same kind of tragedy.

Promoting the use of four-gas monitors among persons involved in manure-related work is one way to contribute to the prevention of manure gas incidents. The Four Gas Monitor Program provides a mechanism for increasing the use of these monitors in rural communities. Additionally, the program provides and incentive for fire departments to have their personnel attend our ART event, increasing agriculture emergency preparedness more broadly. In this article, we discuss the results of the assessment of the Four Gas Monitor Program in order to show the impact of this intervention and to provide our colleagues in agricultural health and safety with an example of a manure gas incident prevention intervention in light of the recent tragedy in New York.

Methods

Using RedCap, we developed a short survey to learn about gas monitor use among rural fire departments and assess the impact of the Four Gas Monitor Program. The survey was distributed via email to all fire departments that had members attend an Agriculture Rescue Training (ART) event from 2020 to 2023. The study sample included 81 total departments: 31 departments that had received a gas monitor through the Four Gas Monitor Program and 50 departments that

had not received a monitor from the program. The survey included Yes/No and multiple-choice questions with optional short answer questions to reduce the time required to complete it. The survey was first distributed on July 3, 2024, with a reminder send on July 12, 2024. The survey closed on July 15, 2024. The survey was reopened for one participant on Tuesday, July 16, 2024. The firefighter contacted us to ask whether we could reopen the survey for him as he was on vacation and did not return until that day.

Results

Seventeen different emergency response departments responded to the survey (21% of all departments). Ten of the 31 departments (32%) that received a gas monitor from the Four Gas Monitor Program and 7 of the 50 departments (14%) that did not receive a monitor responded to the survey. Sixteen of the seventeen departments in the survey sample indicated they have a gas monitor (94%). Table 1 shows the number of departments that informed members of their community about the monitor. Table 2 shows the number of departments that used their gas monitor with farmers/ranchers to detect gases on agricultural operations. While the Yes/No format may have limited the richness of the data returned, the design choice was a purposeful trade-off based on our longstanding work with volunteer firefighters, which has indicated that they are often extremely busy and that surveys that are too intensive will be received poorly.

These Yes/No questions were accompanied by optional short answer questions that prompted the respondent to describe how they used the monitor with a farmer and how they promoted the gas monitor in their communities. Survey respondents indicated they primarily informed their communities about the gas monitor in a couple of ways: 5 of the 13 departments that informed their communities did so through Facebook or another social media platform, and 4 displayed the monitors at an open house or other event. Other ways departments promoted the monitors included local newspapers, word-of-mouth through department members, and hosting agricultural safety trainings with farmers. The three departments that used their monitor with a farmer/rancher stated they demonstrated the monitor to the operator of a large farm in the area and trained them on how to use it, used the monitor with contract haulers during pit agitation, and used the monitor during bin entry with a farmer.

Only two departments responded to manure-related incidents over the last 4 years. One department responded to a single incident and received their gas monitor from the Four Gas Monitor Program. The other department responded to two incidents and did not receive their monitor from the program. Departments were also asked how many times they had utilized their gas

Table 1. Departments that informed their community about their gas monitor. Note that one department did not own a gas monitor.

	Informed Community About Gas Monitor		
Sample Subgroup	Yes	No	Total
Departments with Gas Monitor from Four Gas Monitor Program	9	1	10
Departments with Gas Monitor not from Four Gas Monitor Program	4	2	6
Total	***13***	***3***	***16***

Table 2. Departments that used their gas monitor with a farmer. Note that one department did not own a gas monitor.

	Used Gas Monitor with a Farmer		
Sample Subgroup	Yes	No	Total
Departments with Gas Monitor from Four Gas Monitor Program	2	8	10
Departments with Gas Monitor not from Four Gas Monitor Program	1	5	6
Total	***3***	***13***	***16***

Table 3. How many times departments used a monitor during an emergency response. Note that one department did not own a gas monitor.

Times Monitor Used During a Response	Departments with Gas Monitor from Four Gas Monitor Program	Departments with Gas Monitor not from Four Gas Monitor Program	*Total*
0 times	1	0	***1***
1–3 times	3	2	***5***
4–6 times	1	1	***2***
7–9 times	0	2	***2***
10 or more times	5	1	***6***
Total	***10***	***6***	***16***

monitor during an emergency response effort over the last 4 years. Results are shown in Table 3.

Of the 17 departments in the sample, 16 indicated that, after learning about the manure gas tragedy in New York, they planned to increase their use and promotion of gas monitors to prevent manure-related incidents in their communities. A short answer follow-up question asked how the National Farm Medicine Center might best support them in these efforts, and 11 participants provided recommendations. Most of the recommendations concerned information dissemination. Participants requested educational materials to distribute to their departments (2) and the public (3), information about gas monitors (2), assistance with locating a grant to purchase a monitor (2), and to stay informed about manure incidents (2).

Discussion

The Four Gas Monitor Program successfully places monitors capable of detecting harmful manure gases in the hands of rural Wisconsin fire and EMS departments, provides them with information about monitor use and calibration, and promotes information and resource sharing between departments and agricultural operations. The originality of the program lies less with the idea than with the implementation. Increasing first responder awareness of and equipment for dealing with manure gases is one way of mitigating the secondary victim problem that often occurs with manure gas incidents.

Results of our survey indicate fire departments with gas monitors are actively using them and these departments generally inform their communities about the monitors, regardless of whether the monitors came from the Four Gas Monitor Program. However, that half of the departments that received their monitor from an Agriculture Rescue Training (ART) event have used it more than 10 times over the last 4 years indicates the program assisted with closing a gap in emergency response preparedness in rural communities. Additionally, departments are receptive to the program's encouragement to inform their communities about the monitors, increasing risk consciousness about manure gas in those communities and informing farm workers and operators about a tool that could be useful to them. The departments that responded to our survey had less success using the monitors directly with farmers, presenting an opportunity for further relationship-building, but that some departments have done so is still a positive impact.

Departments are enthusiastic about increasing awareness of manure gas monitors in their communities following the incident in New York. There was a strong desire for educational materials about manure gas as well as gas monitors. Thus, as a further example of looping insights back through interventions, we developed and plan to disseminate ready-to-print flyers with information about manure gas hazards and four gas monitors to the departments, as well as manure gas warning stickers that link to an online manure gas info sheet. While the Four Gas Monitor Program and others like it are not capable of fully resolving the issue of manure workers not using gas monitors,[28] getting gas monitors into rural communities and making members aware of their existence is a justified first step towards this end.

Regarding the use of four-gas monitors in rural fire departments, the results of our survey are limited due to our small sample size and Central Wisconsin focus. Several departments from outside Wisconsin have received gas monitors, but they did not respond to the survey. The sample is also biased because it includes only fire departments that had members attend an ART event. The ART event includes discussions of manure gas and other agricultural hazards in a technical rescue context, so the fire departments in our sample likely have an increased awareness about manure gas and are more apt to use and promote the gas monitors in the communities. A more extensive study of four-gas monitor use among rural fire departments is possible and would include randomized sampling of rural departments across the US.

Lastly, the overall reach of the Four Gas Monitor Program is fairly limited to fire departments and agricultural communities of rural Wisconsin, limiting its overall impact. We recommend the NIOSH Centers for Agricultural Safety and Health or State Extension Services implement a similar program

in their region. Not only would this provide a valuable tool (i.e., the four-gas monitor) to rural fire departments, but it would also raise awareness about the dangers of working with manure and help to establish relations between agricultural safety personnel and rural first responders in their region. A strong relationship with local first responders could then be leveraged to implement an educational campaign about manure gas incidents and prevention measures disseminated by local first responders to farmers, ranchers, and farmworkers in their local areas. Establishing strong relations with fire departments and prompting them to disseminate agricultural safety information may seem like a challenge, but our experience with the RF-DASH program has shown that many first responders are enthusiastic about raising awareness about agricultural hazards in their communities. Importantly, members of the agricultural community are more likely to have buy-in with their local first responders than with a safety professional.[20]

Conclusion

The outcome of Four Gas Monitor Program shows the potential for positively shaping the agricultural health and safety landscape through sustained work with first responders. The landscape metaphor is apt here, because the Four Gas Monitor Program is an intervention into the social environment in which behavior takes place, rather than a direct intervention on the behavior of targeted individuals. The program assessment survey also demonstrates how relationships with first responders can function reciprocally. Rather than a one-way dissemination of information, our work with first responders involves an iterative looping of insights from the community back into research or intervention design. In the case of the Four Gas Monitor Program assessment, results of the survey can be looped back into the existing program or used to inform the development of other projects or interventions.

Declarations

The authors report there are no competing interests to declare.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

Data available upon request.

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