2024 Summary of U.S. Agricultural Confined Space-related Injuries and Fatalities

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Highlights

The following are highlights from the 2024 Summary of injuries and fatalities associated with agricultural confined spaces:

- No fewer than 51 cases involving agricultural confined spaces were documented, including 22 fatal and 29 non-fatal cases[1], representing a 38.6% decrease over the 83 cases in 2022, and a 7% decrease since 2023.
- There were no fewer than 34 grain related entrapments in 2024 representing a 25% increase from 2023, with the balance of 17 involving livestock waste handling facilities, entanglements and falls in and around the grain handling facilities
- Four incidents involved more than one victim
- Three cases involved livestock waste storage pits or lagoons, resulting in three fatalities and one injury
- Nine additional grain dust explosions at commercial facilities resulted in no fatal injuries[2]
- One case involved a female in 2024, involving a fall from an abandoned grain elevator unrelated to agricultural production activity
- 43% (22) of 2024 cases were fatal compared to 58% historically
- Indiana and Missouri both experienced the most confined space-related cases in 2024 (5), followed by Illinois, Nebraska, and Wisconsin, each experienced 4 cases each.

[1] A case refers to one individual. Some incidents involve multiple victims or cases.
[2] Grain dust explosion related injuries are not included in the data being reported in this summary.

- Indiana reported the most grain-entrapment cases in 2024 (5). Iowa, Indiana, Minnesota, Illinois and Nebraska, in that order, have historically recorded the most grain entrapment cases
- Vertical or tower forage silo incidents accounted for four fatalities and three non-fatal cases
- OSHA Regions 5 and 7 have historically accounted for 67.8% of all documented agricultural confined space-related incidents

Introduction

Since the 1970's, Purdue University's Agricultural and Biological Engineering Department has been documenting and investigating incidents involving grain storage and handling facilities at both commercial and on-farm locations. Beginning in 2013, the effort was expanded with support from a U.S. Department of Labor Susan Harwood Training Grant, to include incidents involving grain transport vehicles (trucks, wagons, railcars); injuries occurring inside of confined spaces due to exposure to powered mechanical components, such as augers; falls from or into confined spaces; and other types of agricultural confined spaces including forage storage silos, liquid storage tanks, manure storage facilities and transport vehicles. Data has been coded and stored in the Purdue Agricultural Confined Space Incident Database (PACSID).

To learn more about the process of identifying, documenting, and coding the data for this report, please refer to the previous summaries available at www.agconfinedspaces.org. The methodology employed has remained largely consistent for multiple years.

As of the end of 2024, the PACSID contained information on 2,429 cases, documented between 1962 and 2024,[3] that resulted in an injury, fatality, or required emergency extrication by first responders. In the database, 58.9% of documented cases were reported as grain-related entrapments, making it the leading cause of agricultural confined space-related incidents. Approximately 58% of all documented cases have historically resulted in fatality.

The total number of cases in previous summaries may differ as additional cases are identified. Also, earlier years of surveillance focused only on grain storage and handling-related confined spaces, while later years have included incidents like falls, entanglements, asphyxiations, and drownings in manure storage facilities and other agricultural confined spaces.

[3] There is one case in the database that occurred in 1956.

As noted in previous summaries[4], there is no claim that the data presented accounts for all incidents involving agricultural confined spaces. The early focus on grain-related incidents has resulted in the disproportionate number of these cases included in the database. Furthermore, there is no accurate accumulative public record of these incidents due to the fact that there is still no comprehensive or mandatory incident/injury reporting systems for most agricultural workplaces. In addition, there has been reluctance on the part of some victims and employers to report "near-misses" or non-fatal confined space-related incidents, especially those occurring at farms, feedlots and seed processing operations not covered by federal OSHA injury reporting requirements. Based upon earlier research, it is estimated that approximately 30% of cases go unreported or undocumented using current surveillance strategies. (Riedel and Field, 2013).

This report summarizes cases documented in 2024 and provides an updated historical perspective, including trends. Specific attention is given to cases involving grain storage and handling facilities (which accounted for most cases), and manure storage and handling operations, the second largest category of incidents. Furthermore, the report provides a brief overview of the fires and explosions that have occurred at grain storage and handling facilities, a summary of incidents involving bunk silos, observations regarding the adequacy of safety training for workers and emergency first responders, highlights the growing size of financial settlements resulting from civil litigation associated with these occurrences, and a preliminary summary of incidents involving vertical or tower silos used to store silage and other forages.

The reason for annually releasing this incident data has remained unchanged. The primary aim is to reduce the frequency and severity of such incidents by keeping the public aware of the issue, contributing to the development of more effective, evidence-based, prevention and injury reduction methods, and giving direction to policymakers and engineering organizations in developing improved safety and health workplace regulations and engineering standards for future construction of related facilities.

[4] See www.agconfinedspaces.org for earlier summaries.

2024 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2024, there were a total of 51 cases documented, including 34 grain entrapments, 3 falls into or from grain storage structures, 4 asphyxiations due to deficient oxygen levels or toxic environments, 4 equipment entanglements (such as those involving in-floor and sweep augers) that occurred while working inside or around agricultural confined spaces, and 6 cases involving miscellaneous situations (Figure 1). The total represents a 7.0% decline from 2023. The number of 2024 cases were also less than both the 5-year average (62.4 cases/year), and the 10-year average (60.2 cases/year) (Figure 2). The 5-year incident frequency has remained largely unchanged over the last few years due to the abnormally high number of cased documented in 2022. Despite the ongoing prevention efforts and increased awareness, the frequency and severity of confined space incidents should remain a concern. Earlier increases in reported cases were largely due to improved documentation through expanded on-line surveillance, greater online access to case details, and broader inclusion of incidents involving livestock waste storage and enclosed transport vehicles. In 2024, there were 22 fatal cases, which is below the 5-year average of 26. This suggests a possible slight downward trend in fatalities involving livestock waste and manure management, but adequate data is not available to confirm this change. While this decline may reflect improvements in safety awareness, equipment, or response protocols, the continued occurrence of fatal incidents highlights the need for sustained prevention efforts and targeted training—especially related to high-risk tasks such as accessing manure storage areas and transport vehicles. This pattern reinforces the importance of long-term strategies to reduce risks.

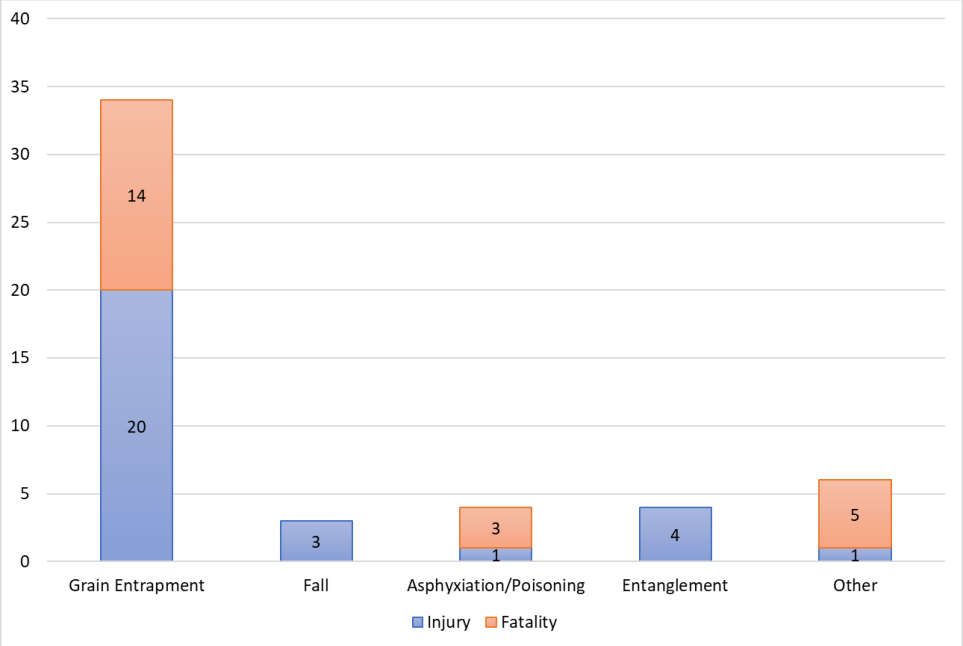

Figure 1. Distribution of all 2024 agricultural confined space-related cases by type of incident, n=51

In 2024 grain entrapments accounted for 34 cases (66%), with a greater proportion of non-fatal cases being reported (Figure 2). Historically, fatal cases have exceeded non-fatal cases, suggesting under-reporting of non-fatal incidents. Increased training for first responders may contribute to improved rescue outcomes, though no reliable research confirms a relationship between proper emergency response training and reduced frequency of fatal incidents.

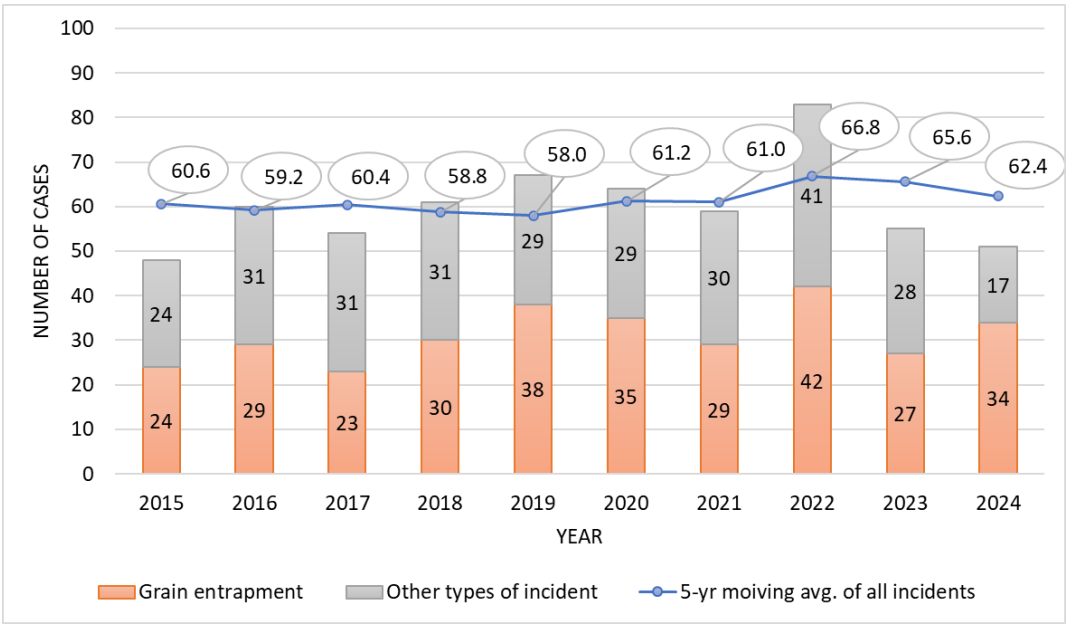

Figure 2. Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2015 to 2024

During 2024, incidents were documented in 20 states as illustrated in Figure 3. The geographic distribution of all documented cases in the PACSID are included. The total does not include 70 cases where the state was not clearly identified because the site of the incident may have varied from the state where the victim died.

The states with the most documented agricultural confined space cases of all types in 2024, including fatal and non-fatal, were Indiana (5), Missouri (5), Illinois (4), Nebraska (4) and Wisconsin (4). Historically, the four states with the largest number of cases, historically, have been Iowa (296), Indiana (245), Illinois (234), and Minnesota (232). Current surveillance efforts may underreport cases by up to 30%, mainly due to inadequate reporting mechanisms. Additionally, Indiana likely ranks high due to proactive surveillance measures implemented over the past four decades.

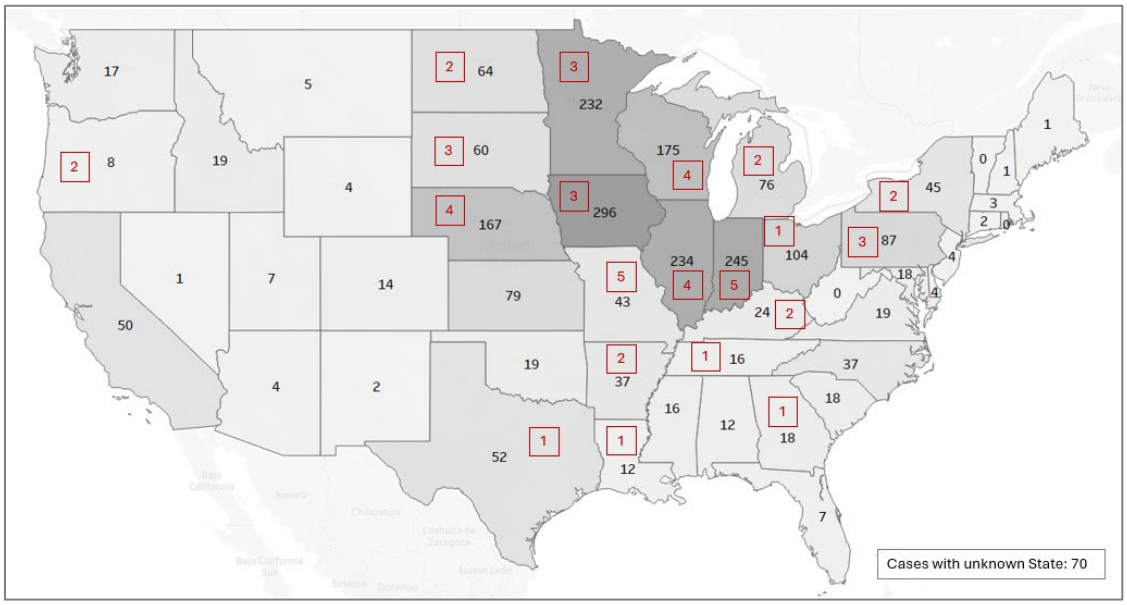

Figure 3. Geographic distribution of all agricultural confined space cases for 2024 and previous years (n=2429)

A specific age was known for 30 of the 51 victims in 2024, with the oldest victim being 94 and the youngest 13 years old. Two cases involved children or youth under the age of 21, as shown in Figure 4. Those over the age of 60 accounted for 12 (40%) of the cases where age was known, possibly reflecting the increasing average age of U.S. farmers (57.5 years old) As noted, 21 cases in 2024 were reported without the victim's specific age. Based on available details, most of these victims were presumed to be adults, as only one case was described as a "teen". Additionally, one case involved a female victim, who was severely injured after a fall from an abandoned grain elevator.

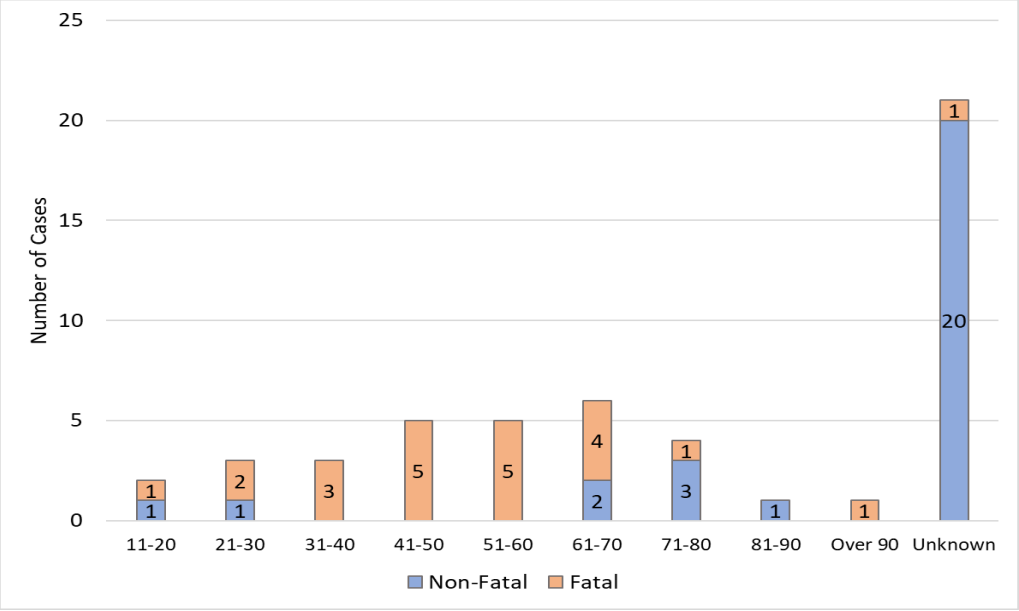

Figure 4. Age distribution of all 2024 agricultural confined space incident victims

Analysis on the Distribution of Incident Type and Facility by US and OSHA Regions.

In 2024, there were 37 cases where the exemption status[5] of the facility with respect to OSHA regulations was known. The majority of these known cases occurred on farms or other locations currently exempt from enforcement under the OSHA Grain Handling Facilities Standards (29 CFR 1910.272) or Confined Space Standards (29 CFR 1910.146). The balance of known cases, 14, took place at non-exempt commercial grain facilities. Based on historical data, it is believed that most of the cases where OSHA status could not be determined, the sites have been OSHA exempt.

A total of 2,429 agricultural confined space cases have been identified by OSHA region. While such incidents have occurred in every region, they are most concentrated in Region 5 and 7 (Figure 5). Region 5 accounts for the largest share, with 1,061 cases (43% of the national total), including 58.2% involving grain entrapments and 12.3% involving falls. Region 7 follows with 585 cases (24%), of which 65% were grain entrapments. Region 1 reported the fewest grain entrapments, while Region 6 had the highest proportion of its total cases attributed to grain entrapments (70.5%).

[5] Under the current provisions of the two OSHA workplace safety and health standards most relevant to agricultural confined spaces, agricultural worksites, including most farms, feedlots, and certain seed processing operations are exempt from compliance with confined space entry provisions and reporting requirements.

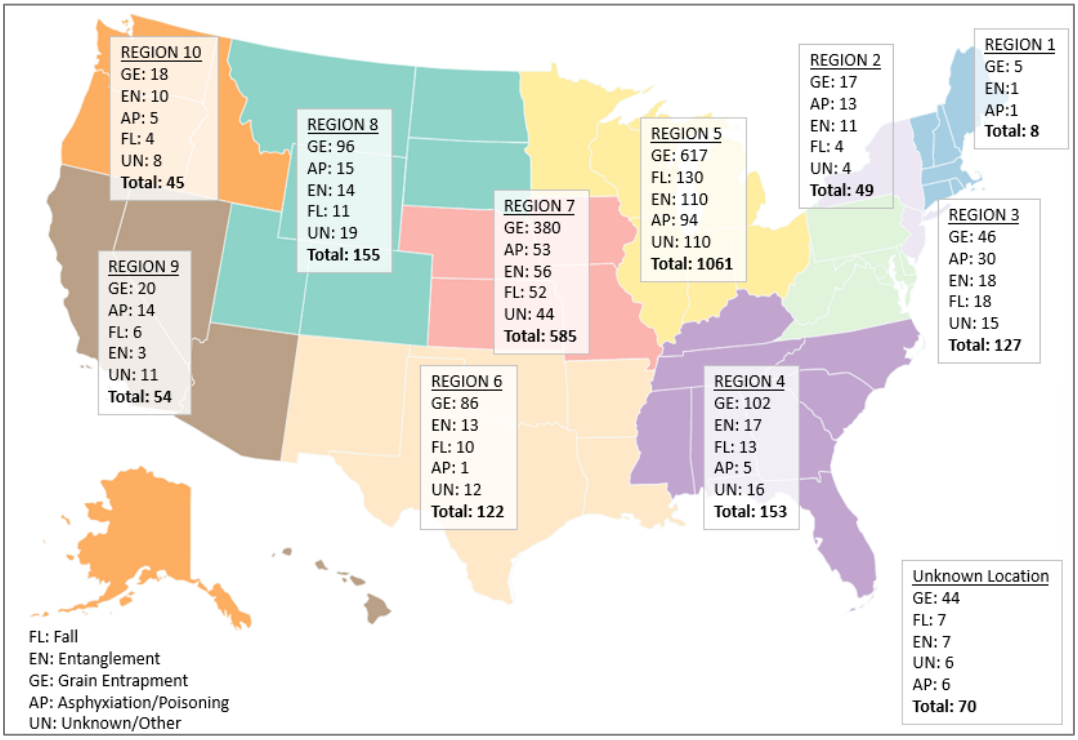

Figure 5. Agricultural confined case distribution by OSHA region from 1962-2024. The total number of cases and most frequent type of case is listed for each region (n=2429)

Grain Entrapments

The 34 fatal and non-fatal grain entrapment cases[6] documented in 2024 represented a 25.9% increase from the 27 recorded in 2023 and was slightly above the 5-year average (33.2 cases/year) (Figure 6). The long-term average has remained largely unchanged over the past decade, showing a slight increase in frequency. Of the reported entrapment cases in 2024, 41.2% resulted in a fatality, versus a five-year average of 49.7%. The state with the most documented grain entrapments (fatal and non-fatal), was Indiana with five, followed by Missouri with four, and Minnesota with three cases. The majority of grain entrapment cases occurred in the Midwest, or Corn Belt (55.9%). Figure 7 provides a geographic distribution of all documented grain entrapment cases contained in the PACSID for which the incident location was known. Indiana continues to have the highest cumulative number of documented grain entrapment cases. Considering the total grain production and grain storage capacity, Iowa, Illinois, and Minnesota ought to have a significantly greater number of case than reported in Indiana.

[6] These cases include only those cases involving entrapment or engulfment in flowing grain. They do not include fatal or non-fatal cases involving falls from grain storage structures or entanglement in grain handling equipment such as in floor or sweep augers.

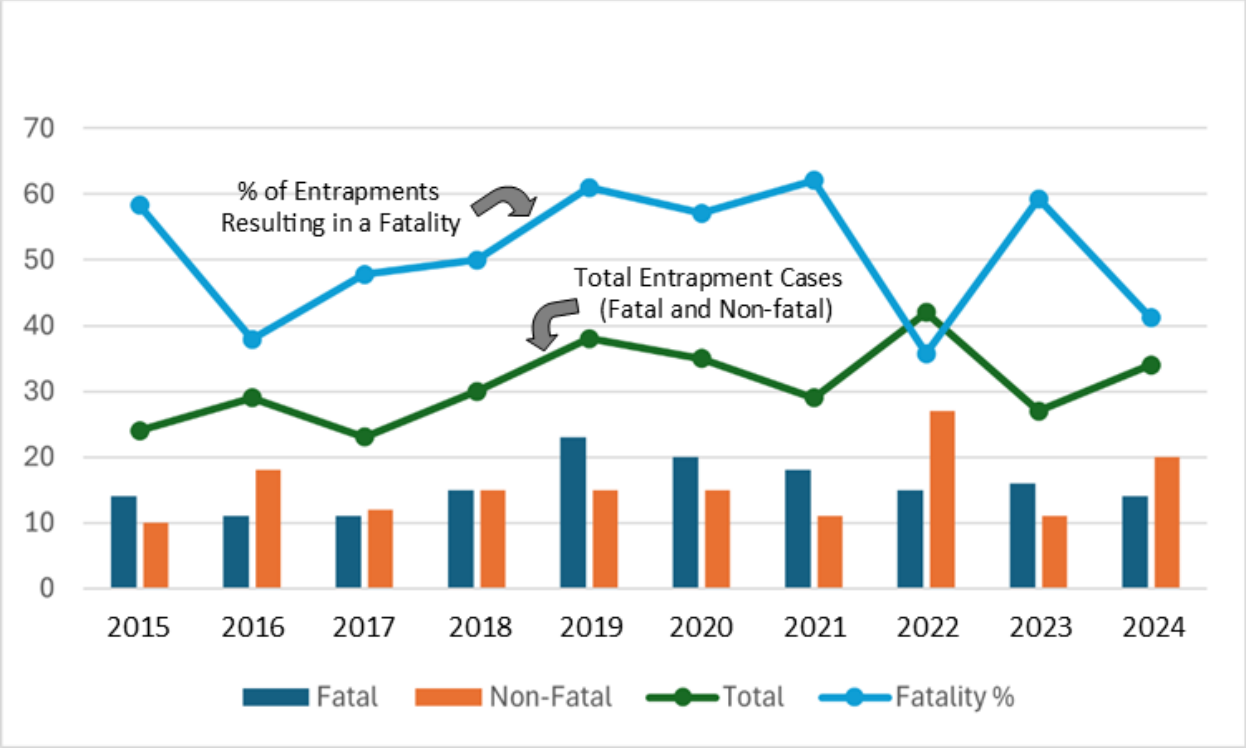

Figure 6. Distribution of fatal and non-fatal grain entrapment cases from 2015 and 2024

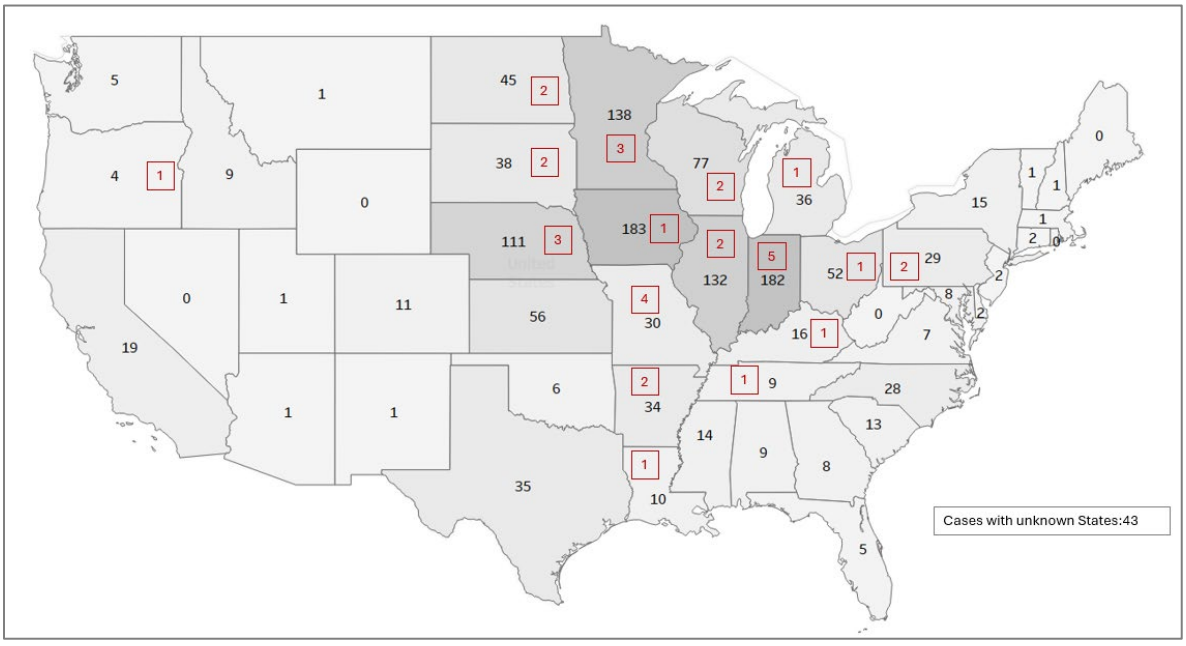

Figure 7. Geographic distribution of grain entrapment cases in 2024 and previous years (n=1430)

All documented grain entrapment cases in 2024 involved males, which has been historically the case. The oldest victim of grain entrapment was 94 (figure 8). The average age was 59.3 years old, and the median age was 62.5. In over 52.9% of the cases, the specific age could not be documented, however review of the reports strongly indicates that nearly all were adults.

Figure 8. Age distribution of 2024 grain entrapment victims by number of cases recorded (n=34)

Over two-thirds of current U.S. grain storage capacity is on farms which are exempt from OSHA injury reporting requirements, it is highly likely, as noted, that this summary does not encompass all grain-related entrapments, whether resulting in death or not.

2024 Summary of Grain Dust Related Explosions

Nine U.S. grain dust explosions in 2024 caused two injuries and no fatalities. These numbers are similar to last year's (nine explosions, 12 injuries and no fatalities) and on-par with the ten-year national average of 8.6 explosions. The explosions occurred in four feed mills, three grain elevators, one ethanol plant, and one corn processing plant. Nine different states had one explosion each: Illinois, Iowa, Kansas, Michigan, Minnesota, Nebraska, North Carolina, Tennessee, and Wisconsin.

Summary of 2024 Agricultural Waste Storage, Handling, Transport Equipment and Facility-related Incidents

Nour et al. (2021) analyzed 409 livestock waste-related incidents from 1975 to 2021, involving 486 individuals, of which 59% were fatal. The majority of victims (85%) were male, with an average age of 37, substantially younger than the current age of farm operators. Most incidents occurred in or around manure storage facilities or involved liquid manure transport vehicle. Eleven percent of the incidents involved multiple victims. In 2020, 11 incidents were

reported, with a 45% fatality rate. In 2021, 13 incidents involved 16 individuals, resulting in a 75% fatality rate. In 2022, 11 incidents resulted in 8 deaths among 11 individuals, of which 73% were fatal. (In other words, involvement in one of these incidents is most likely to result in a fatality.) Wisconsin and California recorded the highest number of cases. Non-fatal injuries primarily involved transport vehicles, affecting 8 individuals. Maintenance tasks on pumps or transfer plumbing were the leading cause of injury and death. In 2023, two fatal incidents were documented, each involving a single individual. Additionally, five roadway transport incidents led to four injuries and three fatalities.

In 2024, three incidents were documented. The first resulted in two fatalities. The second involved a child who sustained injuries but survived. The third fatality involved a male farm worker exposed to manure gases in an inadequately ventilated pig barn. These incidents underscore the continued hazards associated with livestock waste management. To enhance safety culture around agricultural livestock waste facilities, it is recommended to implement regular safety training for exposed farm workers, upgrade ventilation systems, provide appropriate personal protective equipment and toxic gas detectors, conduct routine inspections and maintenance, install clear safety signage and fences around livestock manure storage areas to warn individuals of the potential hazards.

Summary of Bunker Silo-related Incidents

Horizontal bunk silos and open silage storage have increasingly replaced traditional tower silos in dairy and beef operations due to their larger storage capacity, improved efficiency, and enhanced silage quality. These designs reduce the need to climb tall structures and enable faster filling and unloading, improving packing density and feed consistency. However, despite these benefits, several serious injuries and fatalities—though relatively rare—have drawn attention from safety professionals and regulatory agencies. A review of approximately 2,429 agricultural confined space incidents currently documented in the PACSID, and multiple on-line sources, identified 33 cases (35 individuals) involving bunk-type or silage open storage between 1962 and 2023. Most incidents were linked to silage collapse from the face of the pile, tractor rollovers during packing, and falls from silage surfaces. Victims included farm workers, and at least two veterinarians retrieving silage samples. Key prevention strategies include avoiding overfilling, prohibiting access to unstable silage faces, using safe unloading equipment that provides operator overhead protection, and restricting packing operations to vehicles with rollover

protection. While the low frequency of incidents suggests additional regulation may not be warranted, improved safety standards and signage should be considered to reduce risk.

Efforts to estimate the frequency and severity of bunker silo-related incidents are ongoing, and surveillance will continue to expand as resources permit. Additional information or documentation related to bunker silo injuries and fatalities would be greatly appreciated.

Summary of Vertical/Tower Silo-related Incidents

As part of Purdue University's on-going surveillance of agricultural confined space related incidents, cases involving vertical/ tower silos are now being identified. To better understand the safety and health issues related to these structures, data regarding documented cases are being compiled separately as a new initiative. Findings will be used to enhance the quality of current agricultural safety and health educational resources.

Historically these structures have played a significant role in the expansion of livestock-based agriculture with an estimated 500,000 units in use on farms during their peak. These facilities have consisted of primarily older wooden stave silos, tile silos concrete stave silos, poured concrete silos, and oxygen limited structures fabricated from glass coated steel. Units are designed to be filled using an external silage blower, with contents removed via top or bottom unloading systems. Currently, vertical/ tower silos are rapidly being replaced by either bunker silos, open piles of covered silage, or silage bagging operations. Many current silo structures have outlived their anticipated life expectancy and have been abandoned.

Utilizing documented cases in the PACSID and a preliminary review of online sources, no fewer than 104 incidents involving 127 individuals (cases) were documented. Of these cases, 75 % were fatal reflecting a higher proportion of fatalities than incidents involving grain storage bins. Males accounted for 92% of the cases. When the age of victims could be ascertained, the average age of all victims was 37. The most common incident types involved exposure to toxic gases, with "silo gas", "nitrogen dioxide", or "nitrous oxide" identified most frequently in 32% of cases. The next largest category, involved falls from silos, at 23%. Entanglement in silo loading or unloading equipment were associated with 17% of cases. Initially unexpected was the 9 incidents involving 6 fatalities that were caused by collapsing silo structures. States with the most frequently reported incidents were Wisconsin, Pennsylvania, Minnesota, and New York, reflecting the close association of these structures with the historic dairy industry.

In 2023, seven incidents involving vertical/ tower silos were documented with four resulting in fatalities. The average age of the victims was 44 when age could be determined. All known

victims were male. Exposure to “silo gas” leading to asphyxiation resulted in one fatality, two cases were caused by falls, two cases involved entanglement in loading and unloading equipment, and one fatal case involved a falling object within the silo.

This is the first attempt to estimate the frequency and severity of silo-related incidents and surveillance will continue to be expanded as resources allow. Information on silo-related injuries and fatalities would be appreciated.

Are We Conducting the Right Emergency Response Training?

Ongoing surveillance of the media for incidents involving agricultural confined spaces has continued to identify a high frequency of reports related to training taking place for local emergency first responders. These training events are occurring across the U.S., even in areas where the probability of a grain-related entrapment is extremely low, or historically non-existent. The primary focus of the training, as reported by the media, has been to address strategies to rescue victims from partial entrapment utilizing on-site fabricated or commercially available grain rescue tubes or cofferdams. In many cases, the training appeared to be a response to a local incident, which may have been the only such incident ever documented in the service area. Millions of dollars have been spent on these trainings and acquisition of specialized equipment, even in light of the fact that only about 30-35 such incidents occur annually in the entire U.S., and the majority of victims have died before the arrival of emergency services.

From a public policy perspective, the following questions should be asked: (a) Is the current level of training activities actually justified? (b) Who are the most appropriate first responders to receive the training? (c) What should the learning outcomes be for agricultural-confined space rescue training? and (d) How much specialized rescue equipment is actually needed and where should it be located for rapid deployment?

Considering the increase in the number of incidents involving livestock waste-related facilities, increased documentation of multiple, or secondary victims, and the growth in the number of confined spaces found on agricultural operations, it would seem appropriate that training being offered on the hazards associated with extricating victims from related confined spaces should be more comprehensive, and in alignment with actual incident data. The review of current online sources found little attention being given to this gap in training. Another gap identified in current training resources is the primary emphasis being placed on the entrapped victim with little attention being given to the potential risks to, often untrained, first responders

of becoming secondary victims at the scene. It appears that greater attention needs to be giving to first responder safety.

The need for consistent evidence-based first responder training strategies for rescues from all types of agricultural confined spaces appears to be justified.

The Cost of Agricultural Confined Space-Related Incidents is Increasing

In the past, the economic consequences related to fatalities or injuries occurring in agricultural confined spaces were relatively minor and usually taken care of by the affected family, farm or agribusiness, insurance policies with modest coverage, Worker Compensation Insurance, or through support from the local community. With the recent enhanced enforcement of OSHA workplace safety and health regulations, non-exempt employers became exposed to greater risk of financial penalties for failure to provide a safe workplace. Employers, both exempt and non-exempt, have become increasingly aware of the financial compensation granted through civil litigation in cases involving injuries or fatalities in agricultural confined spaces. Juries have sent a clear message that ignoring the well-being of employees will be very expensive. In recent fatal incidents involving grain bins and livestock waste facilities, the OSHA fines have been relatively insignificant ($50-100,000), compared to the $10-17 million legal settlements that have been documented. Even for a large business, these costs are difficult to overlook.

Project Website

With support from a Susan Harwood Grant from the U.S. Department of Labor, the website (www.agconfinedspaces.org) was developed to provide resources for those conducting safety and health training in the area of agricultural confined spaces, with an emphasis on grain storage and handling hazards. This recently updated site now includes training material, frequently asked questions, past summaries of injuries and fatalities, and an extensive list of on-line resources. Since 2019 it has hosted nearly 40,000 visitors.

One of the most frequently visited resources on the website is the curriculum developed for young and beginning workers in the grain industry (**Against the Grain**). The goal of this teaching resource is to provide agricultural and safety educators with an evidence-based 3–5-hour program to present basic safety and health awareness training to youth, ages 16-21, and new

employees who are employed at grain handling and storage facilities, including both exempt and non-exempt operations. The curriculum has been delivered to over 5,100 youth in secondary school agricultural education programs, informal out-of-school settings, and college level agriculture classrooms. Pre- and post-testing have demonstrated a significant knowledge gain and instructor feedback has been very positive. The complete curriculum is available as a free download.

Another educational resource at the site is designed for use in training emergency first responders to safely and effectively respond to incidents at grain storage and handling facilities. Over the past 10 years over 5,500 emergency first responders have participated in training using this first responder material. The curriculum is also available as a free download.

Also, check out the **Gearing Up for Safety** training material at www.agsafety4youth.info which includes two educational lessons on agricultural confined spaces. These materials can be downloaded for free.

Educational Resource

In 2018, Purdue's Agricultural Safety and Health Program collaborated with the Posey County Farm Bureau to produce STOP – THINK – LIVE, a video that re-enacts the actual grain bin entrapment of a Posey County, Indiana farmer. Copies have been distributed to over 600 County Farm Bureau presidents, secondary agriculture education teachers, County Extension offices and many first responder agencies. The video includes interviews with the farmer, shows the rescue strategies used, and has short outtakes on the role of out-of-condition grain and the risk of entrapment in grain transport vehicles. The video can be viewed at www.agconfinedspaces.org or copies can be ordered for $10.00 from:

Posey County Farm Bureau
PO Box 189
30 West Main Street,
Poseyville, IN 47633-0189

Published Works

As the result of the analysis of data gathered over the past 13 years, the following articles have been published. Full text for some of these articles are available at www.agconfinedspaces.org.

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- www.agconfinedspaces.org
- http://apps.npr.org/buried-in-grain/
- www.grainsafety.org
- www.agsafety4youth.info