

2022 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities

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Highlights

The following are highlight from the 2022 findings:

- No fewer than 83 cases, 24 fatal and 59 non-fatal,¹ involving agricultural confined spaces were documented in 2022, representing a 40.7% increase over the 59 cases in 2021
- There were no fewer than 42 grain related entrapments in 2022 representing a 44.8% increase over 2021. This was the highest number of grain entrapments in over a decade. The balance of 41 cases involved livestock waste handling facilities, entanglements inside confined spaces, falls from confined space structures, and grain dust explosions or fires
- Eight incidents involved more than one victim
- Eleven cases involved livestock waste storage pits or lagoons, eight of which were fatal
- Three grain dust explosions resulting in 18 non-fatal injuries were documented². Fifteen of these injuries were attributed to a single incident in Iowa.
- One female case was documented in 2022, which occurred inside a cotton module builder
- 29% (24) of 2022 cases were fatal compared to 59% historically
- Iowa reported the most cases, 24, including those relating to fires and explosions (fifteen of these cases resulted from a single explosion incident), followed by Indiana (6), Minnesota (6) and Ohio (6)
- Iowa reported the most grain-entrapment cases in 2022 (9). Indiana, Iowa, Minnesota and Illinois, in that order, have historically recorded the most grain entrapment cases

¹ A case refers to one individual victim. Some incidents involve multiple victims or cases.

² Grain dust explosion related cases are included in the data being reported in this summary.

- OSHA Regions 5 and 7 have historically accounted for 67.9% 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. In 2013, with support from a U.S. Department of Labor Susan Harwood Training Grant, the effort was expanded to document additional types of incidents. The expanded data collection included 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 both tower and horizontal bunk forage storage silos, liquid storage tanks, livestock waste storage facilities and transport vehicles. In addition, explosions caused by grain, other agricultural dusts, or combustible gases are now included in the database. By definition, an explosion requires containment (involving some type of confined space), along with fuel, heat, and oxygen to occur. Data has been coded using a standardized coding process, 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 consistent for multiple years.

As of the end of 2022, the PACSID contained information on 2,323 U.S. cases, documented between 1962 and 2022,³ that resulted in an injury, fatality, or required emergency extrication by first responders. Of those cases, 1,355 (59%) were fatal. Grain storage and handling facilities, and/or grain transport vehicles were involved in 72% of the total cases.

The total number of cases published in previous annual summaries may not match as additional cases are being added as they are identified. There is also a discrepancy with earlier years due to the prior focus only on identifiable confined spaces. Later years have included an expanded list of incident types as noted above, including fires and explosions involving confined spaces.⁴

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

⁴ Historically, explosions were not included, and are generally considered as rare events. The incident in Iowa with 15 injuries is considered a statistical outlier.

The most significant contributing factor to the enhanced documentation of incidents has been access to reports or media releases published on the Internet. Earlier efforts were largely based upon hard copy news reports obtained from subscription services. Now the majority, but not all, cases are identified by electronic searches.

As noted in previous summaries⁵, 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 being included in the database. Furthermore, there is no accurate accumulative public record of these incidents due to the fact that there are still no comprehensive or mandatory incident/injury reporting systems for most of agriculture. 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 (Riedel and Field, 2013).

This report summarizes cases documented in 2022 and provides an updated historical perspective, including trends. Specific attention is given to incidents 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, evaluates the adequacy of safety training for workers and emergency first responders, and highlights the growing size of financial fines and settlements resulting from civil litigation associated with these occurrences.

The reasons for annually releasing these summaries are: decreasing the frequency and severity of such incidents by keeping stakeholders focused on the issue; aiding in the design of more effective prevention and injury reduction methods based on evidence; and giving direction to policymakers and engineering organizations in developing improved safety and health regulations and standards for worker protection.

⁵ See www.agconfinedspaces.org for earlier summaries.

2022 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2022, there were a total of 83 cases documented that fit the selection criteria, including 42 grain entrapments, 4 falls into or from grain storage structures, 7 asphyxiations due to deficient oxygen levels or toxic environments, 7 equipment entanglements (such as those involving in-floor and sweep augers) that occurred while working inside agricultural confined spaces, and 18 cases involving grain handling facility fires or explosions (Figure 1). The 83 cases represented a 40.7% increase from the number of cases documented in 2021, when 59 were recorded. The increase is largely due to the 15 non-fatal injuries that occurred during a single grain facility explosion in Iowa. The number of 2022 cases was more than both the 5-year average (66.8 cases/year), and the 10-year average (63.6 cases/year) (Figure 2). Despite the significant resources being devoted to addressing the issue, the number of reported cases continues to be a cause for concern. However, as previously mentioned, factors that have contributed to the rise in the yearly frequency are enhanced documentation of incidents due to more extensive surveillance initiatives, increased availability of case details via the Internet, and the inclusion of a wider range of types of confined space-related incidents, including those related to the storage of livestock waste and caused by fires and explosions.

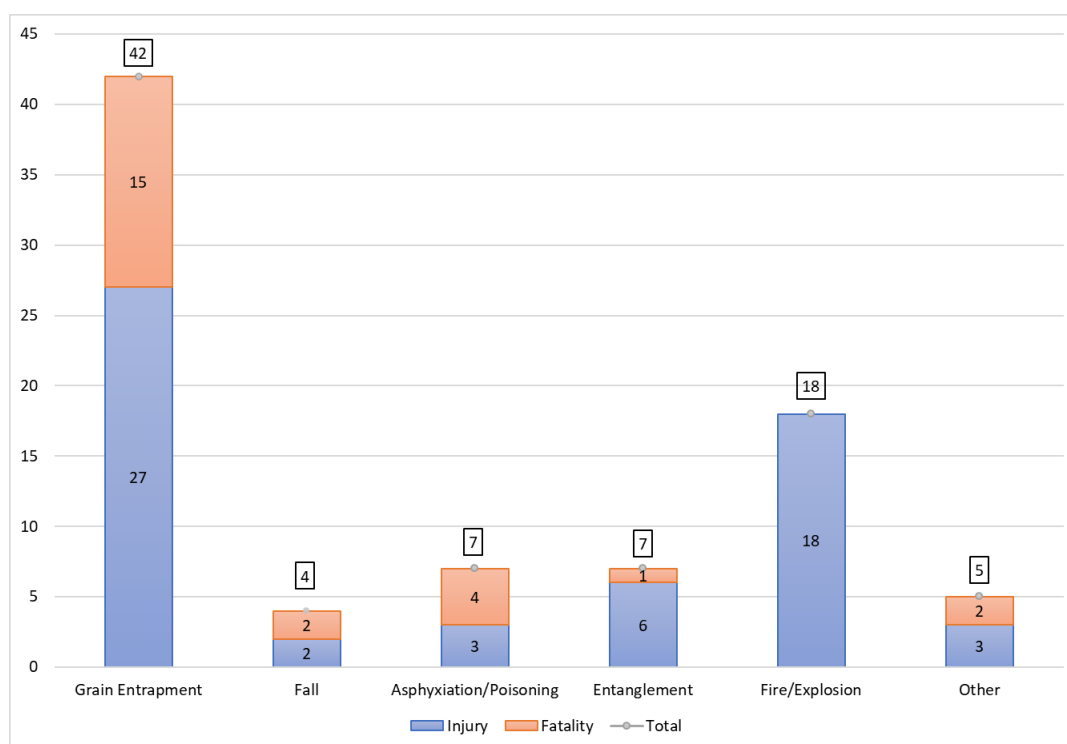


Figure 1. Distribution of all 2022 agricultural confined space-related cases by type of incident, n=83

During 2022 there were more non-fatal cases documented than fatal (Figure 2). In 2022 the number of fatal cases (24) was well below the 5 and 10-year averages of 29 and 27.9 cases/year respectively. The 59 non-fatal cases documented is substantially higher than the five-year average of 37.8. Over the long-term, however, there have been considerably more documented fatal cases than non-fatal cases, further suggesting earlier under-reporting of non-fatal incidents. Another possible factor contributing to the increasing proportion of non-fatal injuries is the increased level of training taking place for emergency first responders on more effective rescue strategies. It appears, however, that the overall frequency of these incidents, even though it has leveled off over the past six years, is reflecting little significant improvement from current prevention efforts.

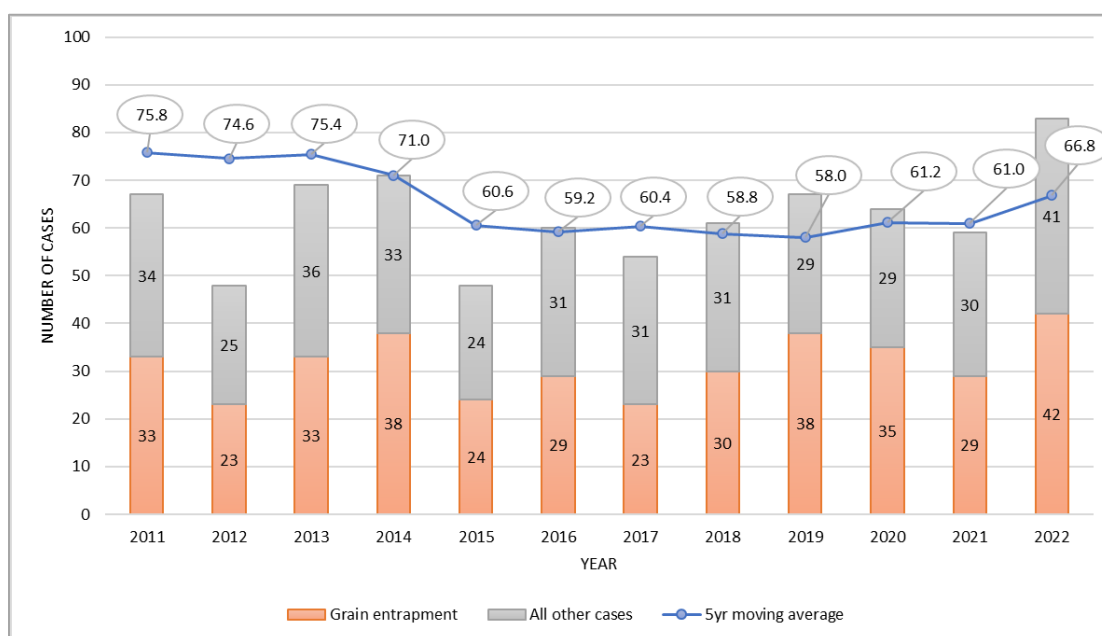


Figure 2. Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2011 to 2022

During 2022, incidents were documented in 22 states. Figure 3 illustrates both the geographic distribution of all documented cases in the PACSID and those documented in 2022. The states with the most documented confined space cases of all types in 2022, including fatal and non-fatal, were Iowa (24), Indiana (6), Minnesota (6), and Ohio (6). The four states with the largest number of cases, historically, have been Iowa (288), Indiana (238), Minnesota (225), and Illinois (218). As noted earlier, it is estimated that the current surveillance effort could potentially underreport cases by up to 30%, mainly due to inadequate reporting mechanisms. Additionally, it is believed that Indiana’s high ranking in the number of total cases is the result of

more proactive surveillance measures implemented for all confined spaces-related cases over the past four decades.

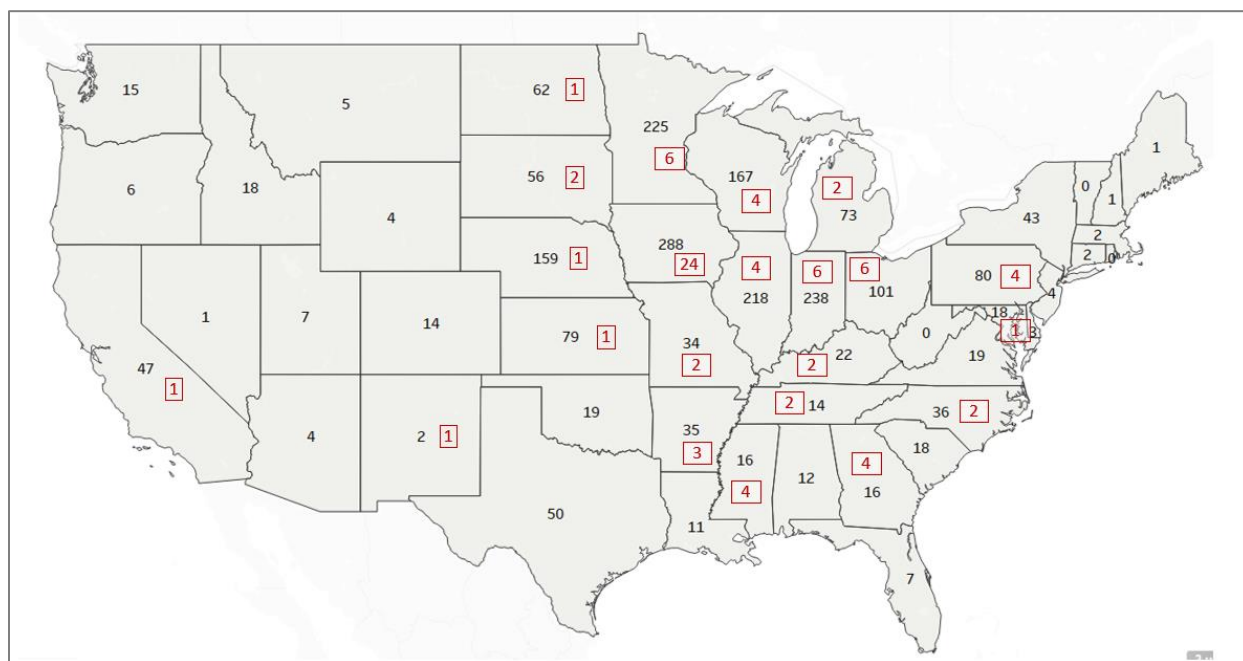


Figure 3. Geographic distribution of all agricultural confined space cases for 2022 and previous years (n=2253 excluding 70 with an unknown location)

A specific age was known for 32 of the 83 victims in 2022, with the oldest victim being 75 and the youngest 4 years old. Seven cases (of those with known ages) involved children or youth under the age of 21, as shown in Figure 4. Those over the age of 60 accounted for 7 (22%) of the cases where age was known, reflecting the increasing average age of farmers (57.5 years old) in the U.S.⁶ As shown in Figure 4, most cases were documented (51) without the specific age of the victim. Based upon a review of the case reports, it was concluded that in nearly all cases the victims, in which an age could not be ascertained, were adults. This determination was due to the lack of identifiers such as “child” or “youth”. There was one female case documented in 2022, which took place inside a cotton module builder.

⁶ 2017 Census of Agriculture [2017Census Farm Producers.pdf \(usda.gov\)](https://www.nps.gov/2017Census_Farm_Producers.pdf)

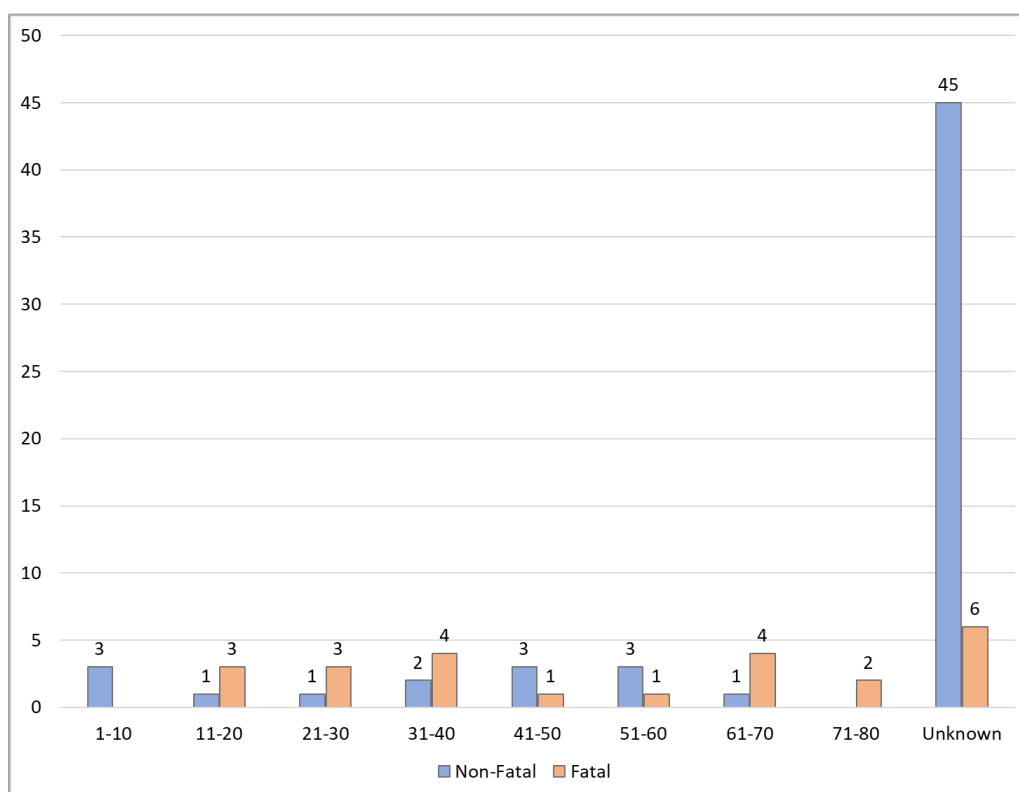


Figure 4. Age distribution of 2022 agricultural confined space incident victims (n=83)

During 2022, in 81 of the 83 cases the exemption status⁷ of the facility with respect to OSHA regulations was known. Forty cases (49.4%) occurred on farms or other locations currently exempt from regulatory enforcement under the OSHA Grain Handling Facilities Standards (29 CFR 1910.272) or Confined Space Standards (29 CFR 1910.146), while 41 (50.6%) 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 have been OSHA exempt.

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

Agricultural confined space-related cases have occurred in every OSHA region but tend to be concentrated in regions 5 and 7 (Figure 5). Region 5 has accounted for 43.8% of all agricultural confined space cases (1,017), with 58.3% of those cases being grain entrapments, and 12.6% being falls. Region 7 accounted for 560 cases (24.1% of the U.S. total) with grain entrapments,

⁷ 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.

asphyxiation and entanglements representing 83.2% of those cases. Region 1 represented the region with the smallest number of grain entrapments while region 6, interestingly, represented the region with the highest percentage of total documented cases being grain entrapment cases (71%).

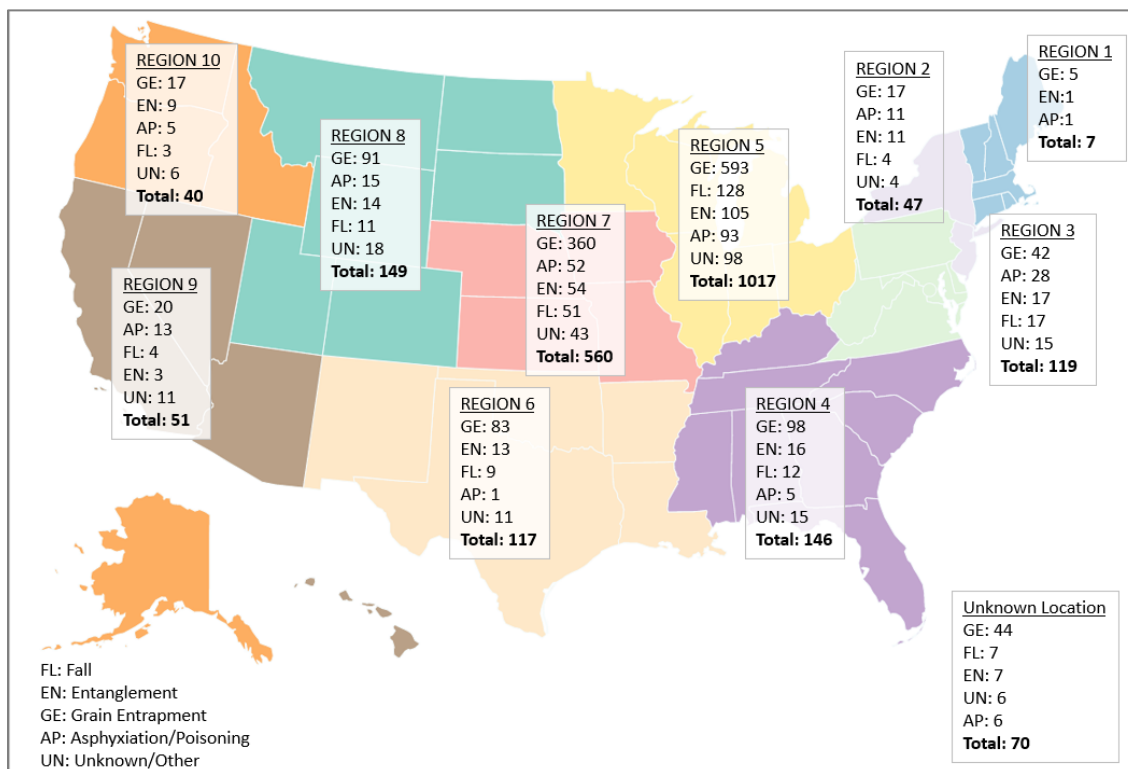


Figure 5. Agricultural confined case distribution by OSHA region from 1962-2022. The total number of cases and most frequent type of case is listed for each region (n=2253)

Grain Entrapments

The 42 fatal and non-fatal grain entrapment cases⁸ documented in 2022 represented a 44.8% increase from the 29 recorded in 2021 and was substantially higher than the 5-year average (34.8 cases/year). The total of combined fatal and non-fatal grain entrapment cases, was the highest annual frequency over the past decade. Nevertheless, the 5-year running average continues to be below its peak of 40.4 in 2011 (Figure 6). Of the reported entrapment cases in 2022, 35.7% resulted in a fatality, lower than the five-year average. In 2022, the state with the most documented grain entrapments (fatal and non-fatal), was Iowa with nine, followed by Minnesota with five, and both Indiana and Missouri with four cases. Overall, grain entrapments were documented in 16 states in 2022. The majority of grain entrapment cases occurred in the

⁸ 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.

Midwest, or Corn Belt (64.3%). Historically, 74% of previously documented cases have occurred in the Corn Belt region. Figure 7 provides a geographic distribution of all documented grain entrapment cases contained in the PACSID for which the incident location was known. Iowa has now surpassed Indiana with the greatest number of documented cases (177 vs. 175). Considering total grain production and grain storage capacity, Iowa, Illinois, and Minnesota ought to have a significantly greater number of cases than Indiana, reflecting a possible historical under counting of cases in those states.

Figure 6. Number of annual grain entrapment cases recorded between 2011 and 2022

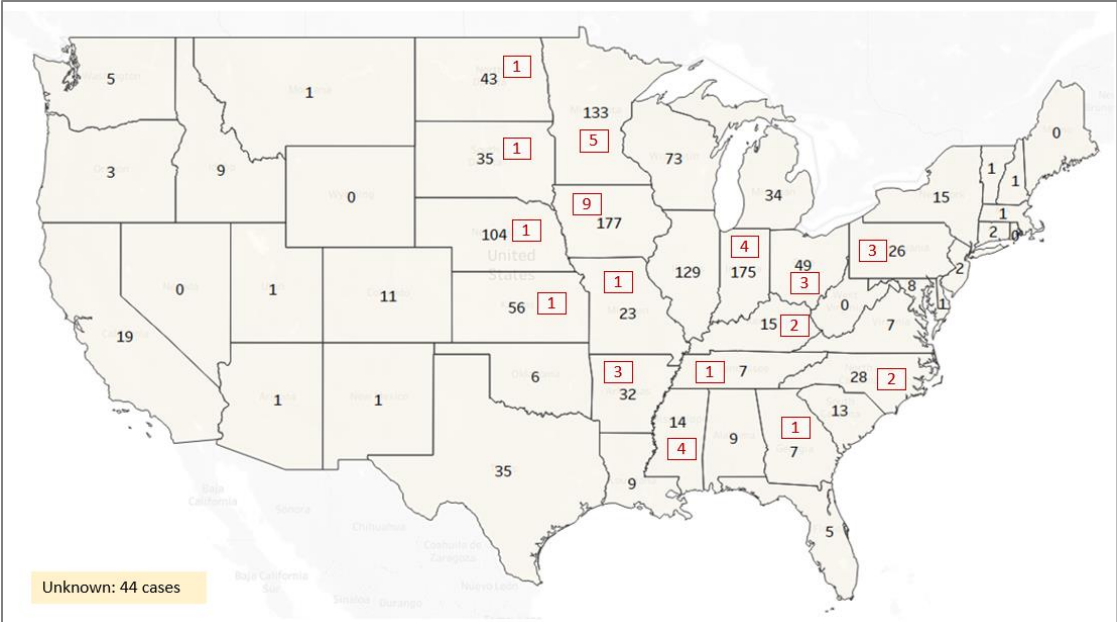
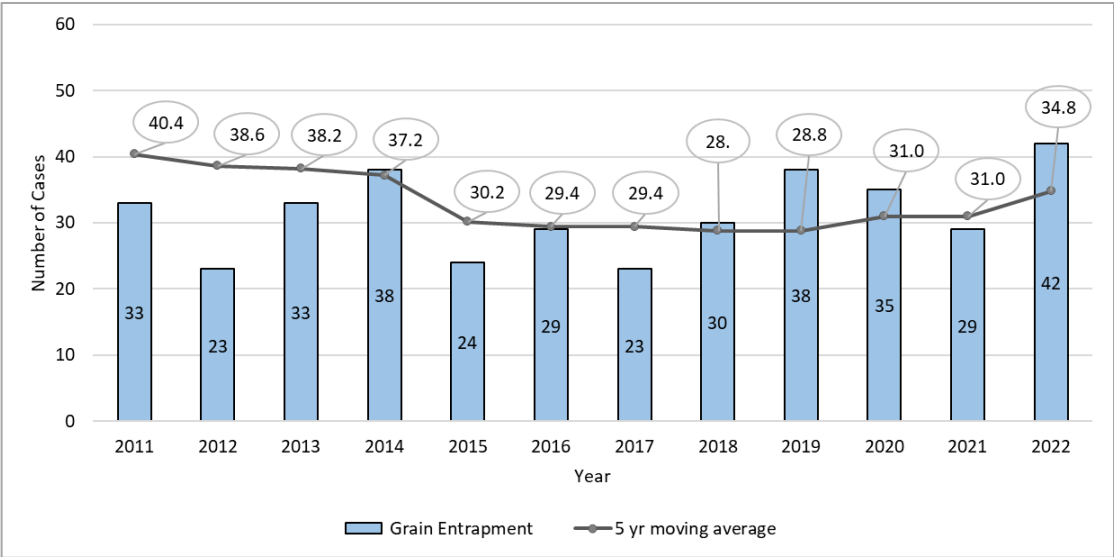


Figure 7. Geographic distribution of documented grain entrapment cases in 2022 and previous years (N=1370)

All documented grain entrapment cases in 2022 involved males. Five (12%) involved youth under the age of 21, a demographic that has represented up to 20% of cases in the past. The oldest victim of grain entrapment was 75 (figure 8). The average age was 41.3 years old and the median age 42. In over 52.4% of the cases, the specific age could not be documented, however review of the reports strongly indicates that nearly all were adults.

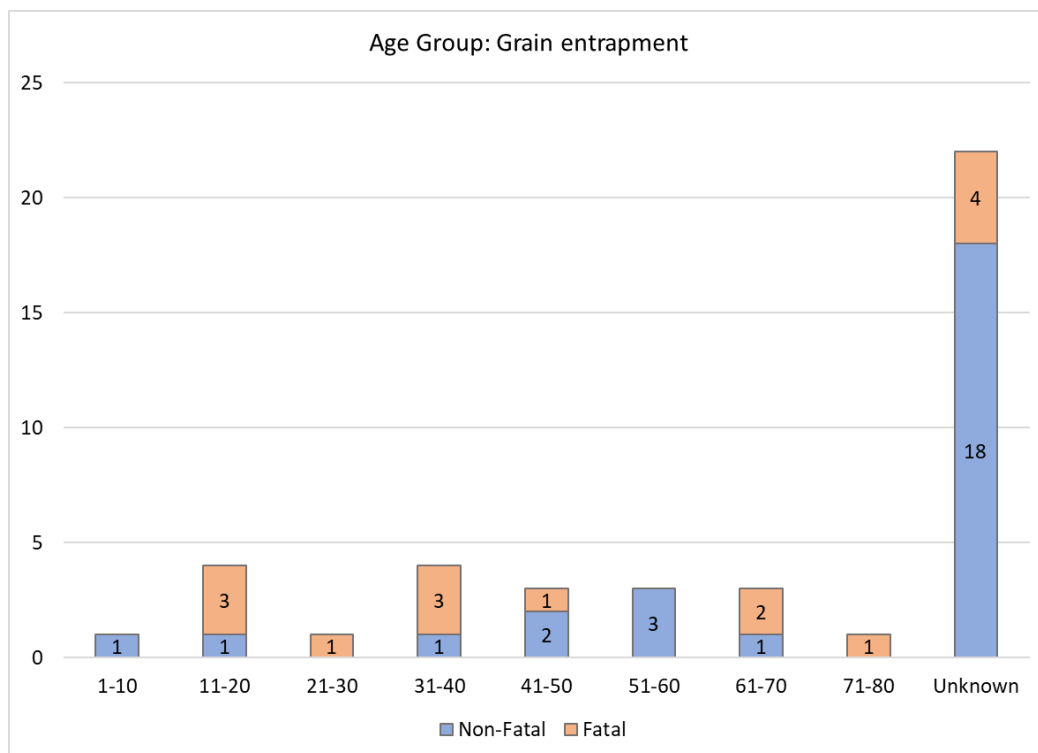


Figure 8. Age distribution of 2022 documented grain entrapment victims by number of cases recorded

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

2022 Summary of Grain Dust Related Explosions

In 2022, there were a total of 9 grain dust explosions documented. Three of those incidents resulted in non-fatal injuries, with one Iowa explosion accounting for 15 injuries. No fatalities due to grain dust explosions were documented in 2022. The ten-year average for injuries is 9.0 and 1.3 for fatalities. The explosions were in 1 ethanol plant, 2 feed mills, 2 grain elevators, 2 rice mills, and 2 grain processing plants. Dust explosions occurred in 7 different states: 2 each in

Arkansas and Louisiana, and 1 each in New Mexico, Kansas, Iowa, Illinois, and Ohio⁹. As noted above explosions require some form of containment or enclosure to occur. These spaces are generally considered confined spaces, and the resulting incidents are included as confined space related.

2022 Summary of Agricultural Waste Storage, Handling, Transport Equipment and Facility-related Incidents

Injuries and fatalities involving agricultural waste storage and handling facilities, transport equipment, and other livestock waste-related operations have been monitored as part of Purdue's Agricultural Confined Spaces-related Incident Database (PACSID). These operations include anaerobic digesters, bio-gas generators and other confined spaces used to store and process waste. Currently, approximately, 505 related fatalities or serious injuries have been documented in the PACSID.

Findings gathered between 1975 and 2021 were summarized by Nour, et al. (2021). This summary analyzed a total of 409 incidents involving 486 individuals, out of which 288 (59%) were fatal. Of the total, 85% of these victims were male. Their average age was 37, remarkably younger than the average age of U.S. farmers. This indicates that youth and less experienced farmers were more prone to agricultural waste related incidents. The most frequently identified incidents involved underground and underfloor manure storage facilities, above ground manure storage tanks, sump pits, ponds, lagoons, manure digesters, and manure transport vehicles such as portable tankers, applicators and spreaders. Fifty-three of the incidents, or approximately 11% of all cases documented involved multiple victims.

Historically, there were 11 injuries and fatalities documented in 2020 related to livestock waste, out of which 5 (45%) were reported as fatal. The number of cases documented in 2021 jumped to 13 incidents involving 16 individuals (cases). Of these cases, 12 were fatal (75%). This doubled the number of fatalities documented in 2020.

In 2022, 11 incidents involving 11 individuals were documented. Out of the 11, 8 cases were fatal (73%). All the victims were male, including a 16-year-old youth. The ages of four of the victims were undetermined. The oldest victim was age 74. Three of these incidents occurred in Wisconsin, and two in California. Ohio, New York, Minnesota, Indiana, Maryland and

⁹ To view a copy of the full report, visit: https://engineering.purdue.edu/FFP/research/dust-explosions/Dust_Explosions_2022_Purdue.pdf

Pennsylvania each reported one case in 2022. In addition, there were 8 non-fatal roadway collision incidents involving livestock waste transport vehicles.

The most frequently identified activity causing injuries or fatalities in 2022 was performing maintenance tasks in or around manure storage structures, such as pump repairs or service. This has been the most frequent activity identified with all cases documented since 1975.

Figure 9 shows the annual distribution of all documented cases over the past 46 years which partially reflects more aggressive surveillance efforts, an increased exposure to larger capacity agricultural waste storage and handling facilities, and increased use of confined livestock production operations. The upward trend, especially the higher number of incidents after 2015 should, however, be of concern.

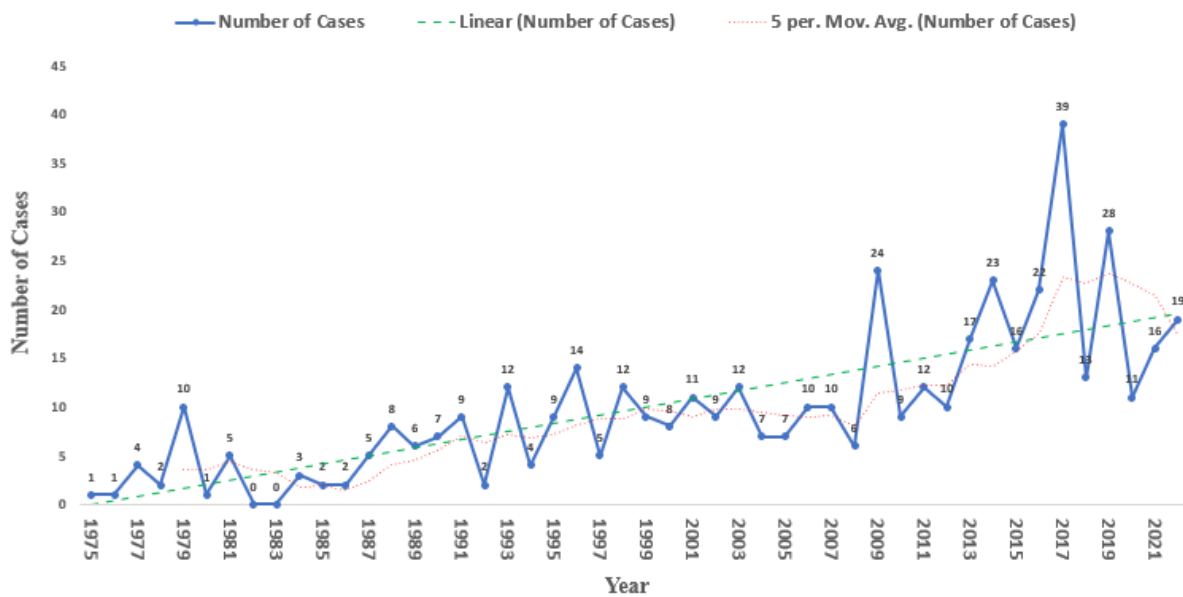


Figure 9. Distribution of Annual Frequency of Agricultural Waste-Related Incidents from 1975 to 2022 (N=505)

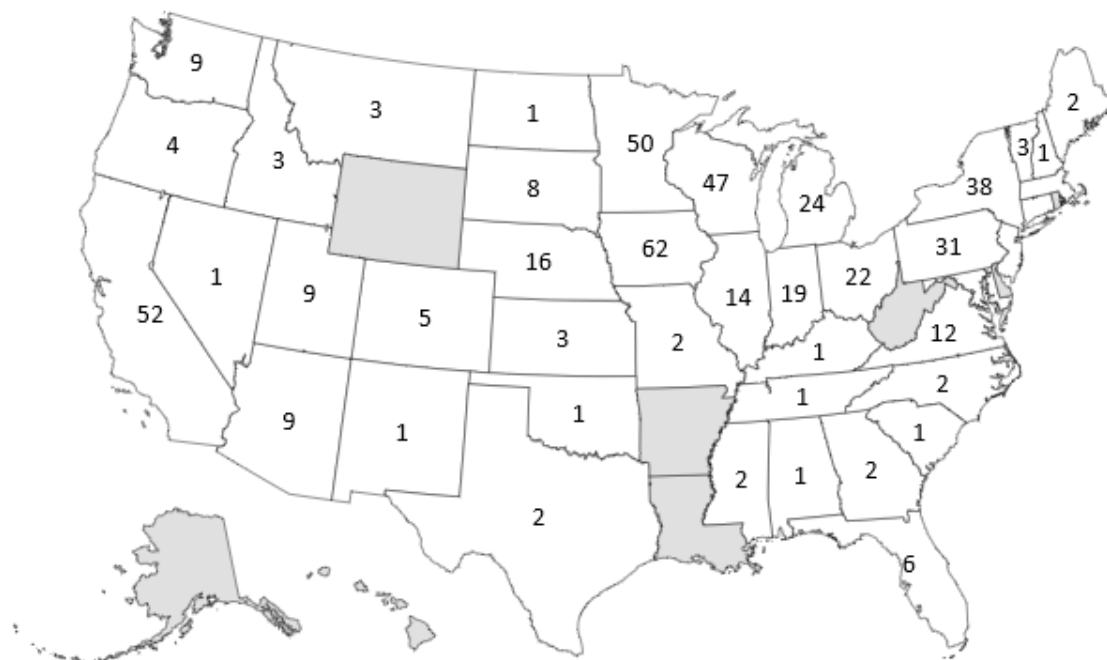


Figure 10. Geographic Distribution of Agricultural Waste-Related Incidents from 1975 to 2022
(N=505)

Figure 10 provides a geographic distribution of the 510 cases documented between 1975 and 2022 nationwide by state. The concentration closely parallels production levels of both dairy and swine. Based on a previous analysis of epidemiologic injury data, dairy operations were found to historically have more incidents than swine facilities.

In summary, continued attention should be given to the risks associated with occupational agricultural waste storage, handling, and transport injuries, including drowning, falling, suffocating, entanglement in machinery, and the potential for fires and explosions involving biogases.

Role of Out-of-Condition Grain

As found by Kingman nearly 20 years ago, there is a direct relationship between the probability of an entrapment in grain and the presence of out-of-condition, or spoiled grain. For many years the term “flowing grain” was used to identify the entrapment hazards associated with grain storage and handling, when in fact it is non-flowing grain that poses the greatest risk. Nearly all cases examined in 2022, in which adequate details were available, involved grain that was non-flowing due to spoilage. Contributing factors included attempting to store grain at

moisture content levels above 14%, improper in-bin drying practices such as rewetting grain using moist outside air, and leaks in the structure that allowed moisture to have access to dry grain. In other words, far more grain-related entrapments could have been prevented (and lives saved) by promoting proper storage techniques than could be achieved with providing training on emergency grain rescue strategies.

Are We Conducting the Right Emergency Response Training?

The topic of appropriate training needed for emergency personnel responding to confined space incidents found in agriculture has been addressed by various stakeholders. However, there remains a concern that there is a greater need to focus attention on prevention versus emergency response. There is actually little conclusive evidence indicating that current emergency management training is reducing the frequency or severity of injuries associated with agricultural confined spaces. Ongoing surveillance of the media for these incidents continues to identify a high frequency of related training activities taking place for local emergency first responders. This training is occurring across the U.S., even in areas where the probability of grain-related or agricultural waste-related entrapments are 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 coffer dams or grain rescue tubes, and high angle rescue techniques. In many cases, the training appears to be a response to a single local incident, which may have been the only such incident ever documented in the service area. Millions of dollars continue to be 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 historically over 50% have involved a victim recovery rather than a rescue.

From a public policy perspective, the following questions should be more aggressively asked: (a) Is the current level of training activities on such a narrow problem 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 in a given service area, and where should it be located for rapid deployment? Regardless, an absolutely essential priority ought to be placed on emergency first responder welfare, especially for rural volunteer fire/rescue personnel, to reduce to near zero the probability of secondary injuries.

In addition, considering the rise in the number of incidents involving livestock waste-related facilities, increased documentation of multiple victims, and the growth in the number of other

types of confined spaces found on agricultural operations, it would seem appropriate that training being offered on the hazards and strategies associated with extricating victims from related confined spaces should be more comprehensive, and in alignment with incident data. The review of current online sources found little attention being given to this gap in training.

The need for consistent evidence-based first, safety-oriented, 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 agricultural production company, insurance policies with modest coverage, Worker Compensation Insurance, or through support from the local community. With the implementation of OSHA workplace safety and health regulations, employers became exposed to the risk of much larger financial penalties for failure to provide a safe workplace. Employers have also become increasingly aware of the financial compensation granted through civil litigation in cases involving injuries or fatalities associated with agricultural confined spaces. Juries have sent a clear message that ignoring the well-being of employees will be very expensive for employers. In recent fatal incidents involving grain bins and livestock waste facilities, the OSHA fines have been relatively insignificant (\$50-100,000), compared to the multi-million dollar 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. Training material, frequently asked questions, past summaries of injuries and fatalities, and an extensive list of resources can be found at the site. Since 2019 it has hosted nearly 40,000 visitors. In 2022, the site was completely overhauled with a new look and additional resources, including an extensive glossary of confined spaces-related terms.

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 training program to present basic safety and health awareness training to youth, ages 16-21, who are employed at grain handling and storage facilities, including both exempt and non-exempt operations. The curriculum has been delivered by Purdue University staff 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 ten years over 5,575 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 lessons are supported with four 20-25 minute videos. All of these resources are available for free and are specifically designed for young and beginning workers.

Educational Resource

In 2018, Purdue's Agricultural Safety and Health Program collaborated with the Posey County Indiana Farm Bureau to produce STOP – THINK – LIVE, a video that re-enacts the actual grain bin entrapment of a Posey County farmer. Copies have been distributed to over 550 County Farm Bureau presidents, secondary agriculture education teachers, County Extension offices and many first responder agencies (It can also be viewed at www.agconfinedspaces.org). 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. 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 decade, the following articles have been published by Purdue's Agricultural Safety and Health team. Abstracts and/or 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