

2021 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities

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Highlights

The following are highlights from the 2021 findings:

- No fewer than 56 fatal and non-fatal cases¹ involving agricultural confined spaces were documented in 2021, representing a 12.5% decrease over the 64 total cases in 2020
- There were no fewer than 29 grain storage and handling related entrapments in 2021 representing a 17.1% decrease over 2020, with the balance of 27 cases involving livestock waste handling facilities, falls, entanglements in confined spaces, and grain dust explosions or fires
- Three incidents involved more than 1 victim, including two involving 3 victims each
- Four cases involved livestock waste storage pits or lagoons, all of which were fatal
- Seven grain dust explosions resulting in one fatal and seven non-fatal injuries were documented²
- Two female cases were documented in 2021, one involved a grain entrapment and the other involved an auger entanglement
- 38% (21) of 2021 cases were fatal compared to 59% historically
- Iowa and Minnesota reported the most confined space-related cases of all types in 2021 (7), followed by Illinois (5)
- Illinois reported the most grain-entrapment cases in 2021 (5). Indiana, Iowa, Minnesota and Illinois, in that order, have historically recorded the most grain entrapment cases

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

² Grain dust explosion related cases are not included in the data being reported in this summary.

- One case in 2021, an auger entanglement, involved a youth under the age of 21 entanglement, reflecting a significant decline from the six cases in 2020 involving younger workers
- OSHA Regions 5 and 7 have historically accounted for 68.1% of all documented agricultural confined space-related incidents
- The number of agricultural confined space-related fatalities documented were less than the number of reported mining-related fatalities in 2021 (21 versus 36)

Introduction

Since the 1970's, Purdue University's Agricultural Safety and Health Program 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, livestock waste storage facilities and transport vehicles. Data has been coded and stored in the Purdue Agricultural Confined Space Incident Database (PACSID).

For additional information on how the data was identified, documented and coded for this report see the 2020 Summary posted at www.agconfinedspaces.org. The methodology used has remained the same for several years.

As of the end of 2021, the PACSID contained information on 2,460 cases, documented between 1962 and 2021,³ that resulted in an injury, fatality, or required emergency extrication by first responders. Grain storage and handling facilities, and/or grain transport vehicles were involved in 72% of the total cases. Of the 2,460 documented cases, 1,463 (59%) were fatal. Figure 1 provides a distribution of all cases by agent category.

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 focus only on identifiable confined spaces. Later years have included cases

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

involving falls, entanglements, asphyxiations and drownings in livestock waste storage facilities, and other incidents related to confined spaces in agricultural workplaces.

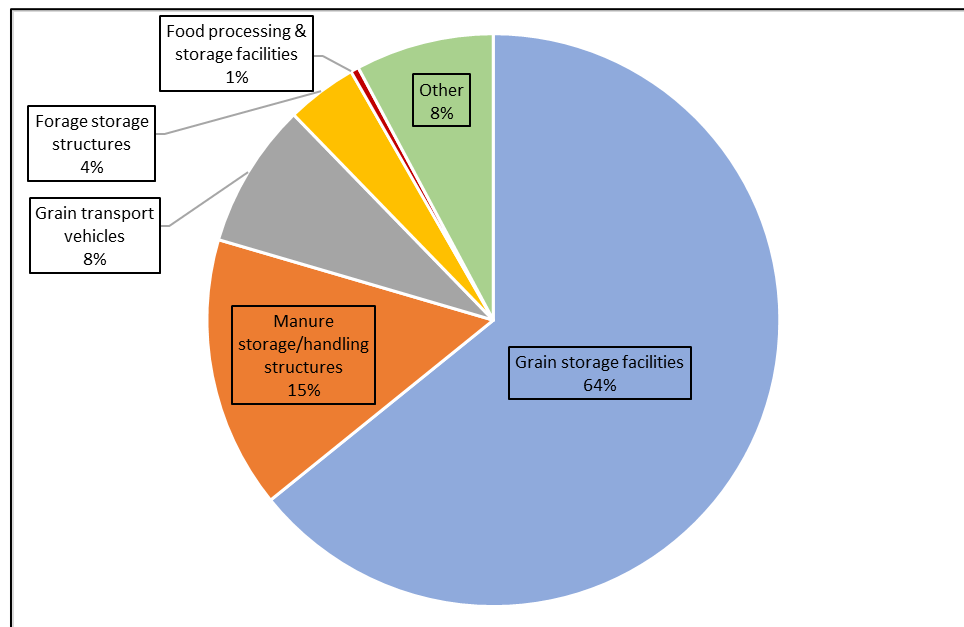


Figure 1: Documented injuries and fatalities in PACSID database based on agent category between 1962 and 2020 (N=2460)

As noted in previous summaries, 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 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 2021 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 livestock waste storage and handling operations, the second largest category of incidents. In addition, the report includes a brief summary of fires and explosions at grain storage and handling facilities, observations on current

safety training of workers and emergency first responders, and the increasing size of financial settlements from civil litigation related to these incidents.

The purposes of publishing these findings on an annual basis have remained the same: to contribute towards the reduction in the frequency and severity of these incidents by keeping public attention on the problem; assist in developing more effective, evidence-based prevention and injury mitigation strategies; and, to provide guidance to public policy makers and engineering standards organizations in the development of more effective regulations and standards targeting worker safety and health.

2021 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2021, there were a total of 56 cases documented, including 29 grain entrapments, 2 falls into or from grain storage structures, 4 asphyxiations in livestock waste storage facilities due to deficient oxygen levels or toxic environments, and 7 equipment entanglements (such as those involving in-floor and sweep augers) that occurred while working inside or around grain storage structures. There were also 7 cases involving grain handling facility fires or explosions, and seven incidents involving other agricultural confined spaces (Figure 2). The total of 56 represented a 12.5% decrease (8) from the number of cases documented in 2020, when 64 cases were recorded. The number of 2021 cases was below both the 5-year average (60.4 cases/year), and the 10-year average (59.8 cases/year) (Figure 3). The 5-year running average continues to decline from its peak in 2011 of 75.8 cases/year. 2019 had the lowest reported five-year average (58.0 cases/year) since 2008. Regardless, the frequency of documented cases remains a concern considering the substantial resources being invested in solving the problem. As noted earlier, a significant contributing factor in the earlier increase in the annual frequency can be attributed to better documentation of incidents due to more aggressive surveillance efforts, increased access to case information via the internet, and broadening the array of confined space-related incident data being captured, such as those involving livestock waste storage.

During 2021 grain entrapments accounted for 29 (51.8%) of all documented cases, a lower proportion than the historical average reflecting, again, more aggressive recent efforts to identify other types of confined space incidents (Figure 3). In 2021, there were more non-fatal cases documented than fatal. Historically, however, there have been considerably more documented fatal cases than non-fatal cases, further suggesting under-reporting of non-fatal incidents.

(Another factor is the increased level of training taking place for emergency first responders on more effective rescue strategies.) The 5-year average for non-fatal cases was 32.0 cases/year and 28.4 annually for fatal cases. In 2021 the number of fatal cases (21) was well below the 5 and 10-year averages of 28.4 and 27.3 cases/year. It appears, however, that the frequency of these incidents, even though it has leveled off over the past six years, is reflecting little significant improvement from current prevention efforts.

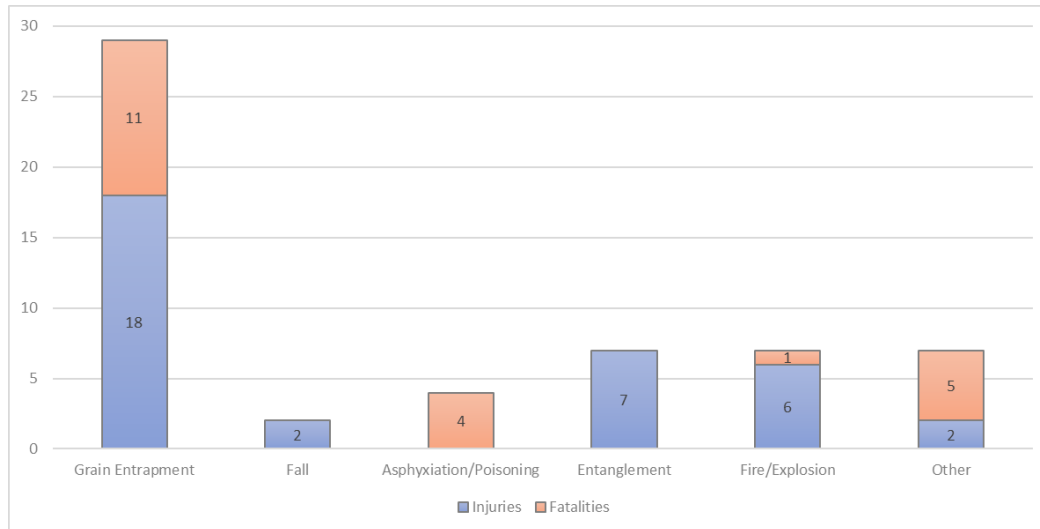


Figure 2: Distribution of all 2021 agricultural confined space-related cases by type of incident, N=56

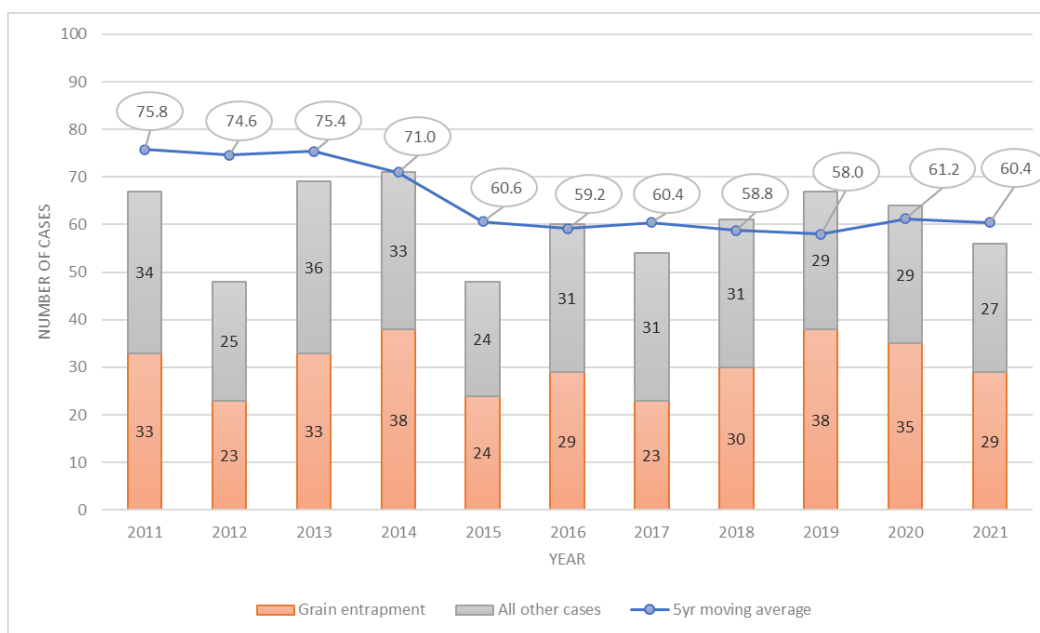


Figure 3: Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2011 to 2021

During 2021, the states with the most documented confined space cases of all types, including fatal and non-fatal, were Iowa (7), Minnesota (7), Illinois (5), and Ohio (4). There were three cases documented in each of Nebraska, Texas, Washington, and Wisconsin. Overall, incidents were documented in 25 states in 2021. Figure 4 illustrates the geographic distribution of all documented cases in the PACSID and those documented in 2021. The total does not include 70 cases where, in most cases, the state was unidentified because the site of the incident may have varied from the state where the victim died. The four states with the largest number of cases, historically, have been Iowa (263), Indiana (232), Minnesota (219), and Illinois (214). As noted in previous summaries⁴, it is estimated that this surveillance effort underreports cases by as much as 30% due to the lack of adequate reporting mechanisms. It is also believed that Indiana has such a high ranking because of more aggressive surveillance efforts over the past 40 years.

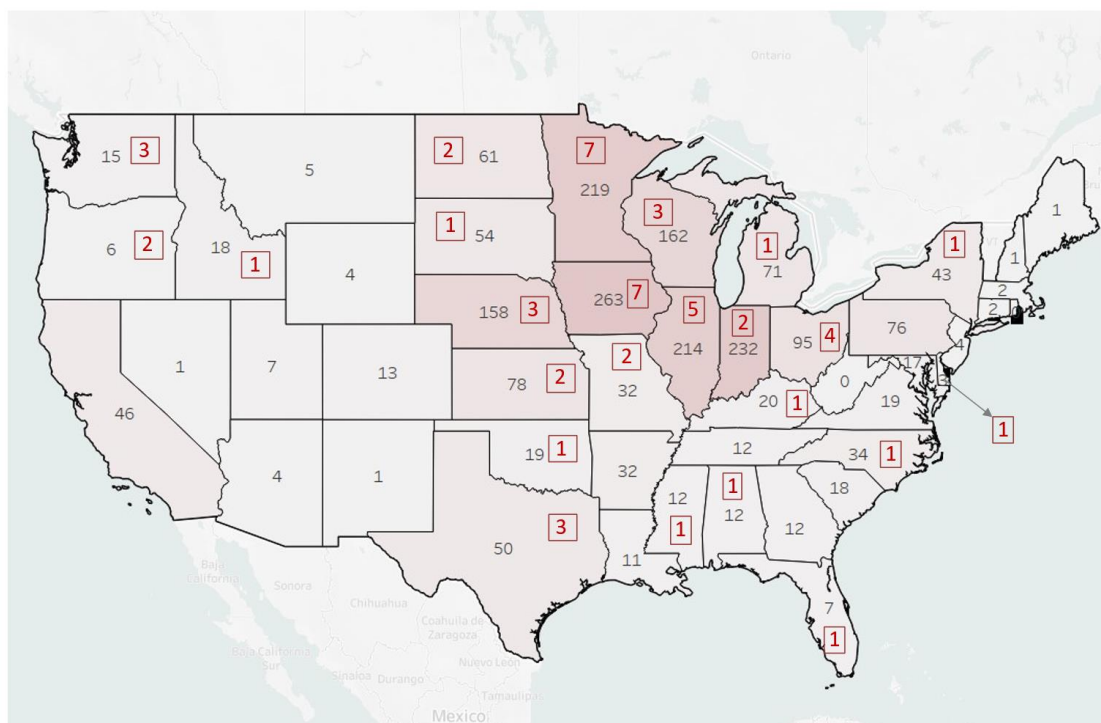


Figure 4: Geographic distribution of all agricultural confined space cases for 2021 and previous years (n=2237)

In 2021, only one case involved a child or youth under the age of 21, as shown in Figure 5. A specific age was known for 19 of the 56 victims in 2021, with the oldest victim being 79 and the youngest 16 years old. The average age was 49.8 years old, and the median age 47. Those over the age of 60 accounted for 7 (36.8%) of the cases where age was known, reflecting the

⁴ See www.agconfinedspaces.org for earlier summaries.

increasing average age of farmers (58 years old) in the U.S. As noted, a large number of the cases were documented (37) without the specific age of the victim being reported. Based upon a review of the individual case reports, it was concluded that in nearly all cases the victims, in which an age could not be ascertained, were adults due to the lack of identifiers such as “child” or “youth”, or “parents”. There were two female cases documented in 2021; one was a grain entrapment, and the other an auger entanglement.

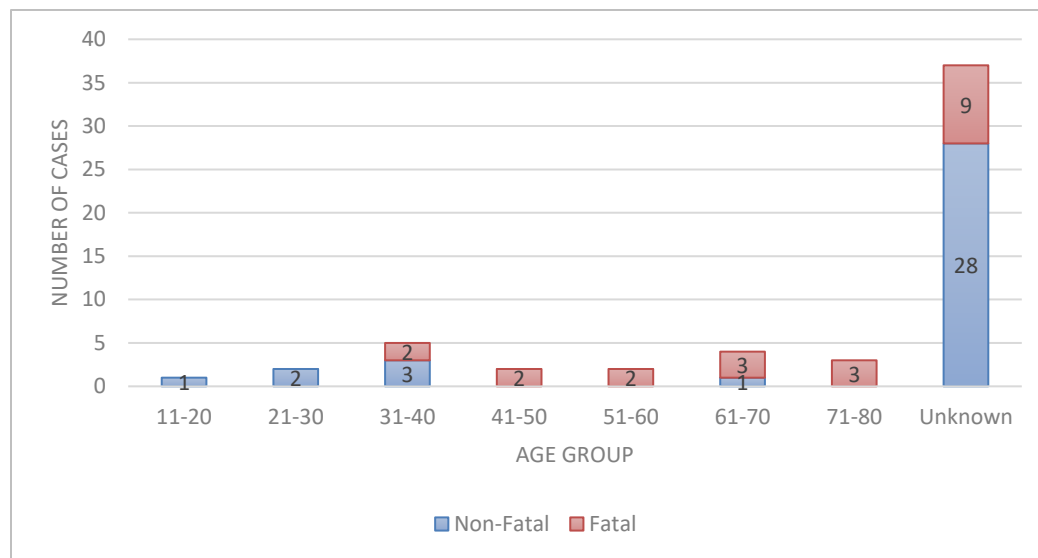


Figure 5: Age distribution of all 2021 agricultural confined space incident victims

In 2021, there were 36 cases where the exemption status⁵ of the facility with respect to OSHA regulations was known. Of those cases, 64.3% 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), with the balance of known cases, 20 (35.7%) taking place at non-exempt commercial grain facilities. Based on historical data, it is believed that the majority of the cases where OSHA status could not be determined have been OSHA exempt.

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.

Comparison with Documented Mining Incidents

A comparison continues to be made between agricultural confined space incidents and U.S. mining incidents because of many similarities and the general public's perceptions of the serious hazards of mining. Historically, there have been more fatal mining incidents per year than those occurring in agricultural confined spaces. For example, in 2017, there were 28 reported fatal mining incidents and 23 fatal agricultural confined space incidents. In 2018, the number of reported fatal incidents in mining (27) equaled the fatal agricultural confined space incidents (27). In 2019, however, the trend reversed for the first time with the number of reported mining-related fatalities dropping to 24 while the number of fatal agricultural incidents increased to 39.⁶ In 2020, this trend continued with the number of reported mining-related fatalities reported as 29 while the number of agricultural confined space-related fatalities was 32. However, in 2021, the Mine Safety and Health Administration documented 36 fatalities, 15 more than the 21 documented in agricultural confined spaces. Over the past 5 years, 144 fatalities were reported in the mining industry, while there were 142 documented as involving agricultural confined spaces.

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

Of the 2,460 cases in the PACSID, 2,237 have been identified by OSHA region. Agricultural confined space-related cases have occurred in every OSHA region but tend to be concentrated in regions 5 and 7. Historically, region 5 has accounted for 44.4% of all agricultural confined space cases across the country (993), with 58.5% of those cases being grain entrapments, and 12.5% being falls. Region 7 accounted for 531 cases (23.7% of the U.S. total) with grain entrapments, asphyxiation and entanglements representing 85.3% of those cases. Region 1 represented the region with the smallest number of grain entrapments while region 6 represented the region with the highest percentage of total documented cases being grain entrapment cases (71%).

⁶ According to the U.S. Department of Labor's Mine Safety and Health Administration (MSHA), the 24 mining fatalities recorded in 2019, is the lowest number ever documented, since records were kept.

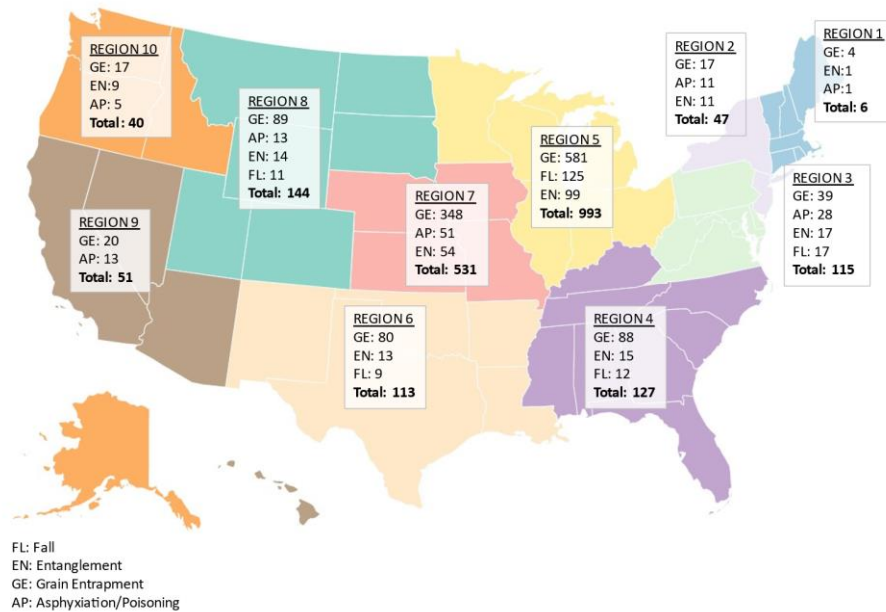
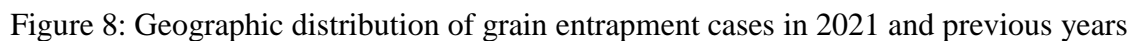


Figure 6: Agricultural confined case distribution by OSHA region from 1962-2021. The total number of cases and most frequent types of case is listed for each region (n=2237)

Grain Entrapments

The 29 fatal and non-fatal grain entrapment cases⁷ documented in 2021 represented a 17.1% decrease from the 35 recorded in 2020 and was lower than the 5-year average (31.0 cases/year). The 5-year running average continues to drop from its peak of 40.4 in 2011 (Figure 7). Also, the number of non-fatal grain entrapment cases (18) was the fifth largest ever recorded after 2010 (27), 2011 (21), 2013 (21), and 2014 (20). Of the reported entrapment cases in 2021, 38% (11) resulted in a fatality. In 2021, the state with the most documented grain entrapments (fatal and non-fatal), was Illinois with five, followed by Iowa with four, and Minnesota with three cases. Overall, grain entrapments were documented in 15 states in 2021. The majority of grain entrapment cases occurred in the Midwest, or Corn Belt (80%). Historically, 74% of previously documented cases have occurred in the Corn Belt region. Figure 8 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. As noted earlier, this high number more likely reflects the aggressive surveillance efforts in Indiana to document both fatal and non-fatal grain-related cases

⁷ 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.



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many as one in five cases in the past. The oldest victim of grain entrapment was 79 (figure 9). The average age was 56.7 years old and the median age 62. In over 62% of the cases, the specific age could not be documented, however, review of the individual reports strongly indicates that nearly all were adults.

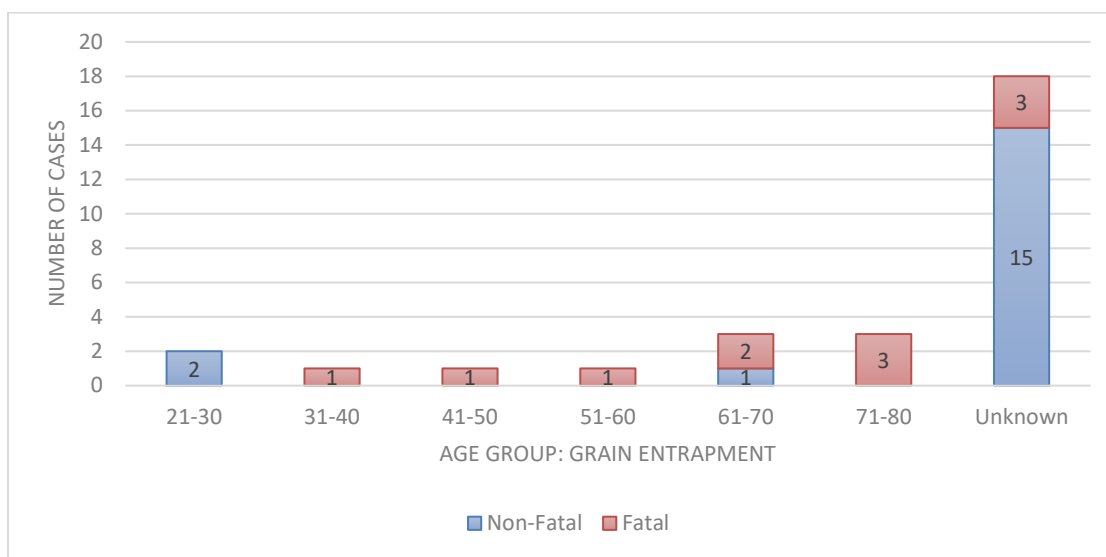


Figure 9: Age distribution of 2021 grain entrapment victims by number of cases recorded

With over two-thirds of U.S. grain storage capacity being on farms which are exempt from OSHA injury reporting requirements, this summary almost certainly does not reflect all grain-related entrapments, fatal or non-fatal, that have occurred. The low number of reports on “near misses” or self-extrication further suggests that other unreported incidents occurred in 2021.

2021 Summary of Grain Dust Related Explosions

In 2021, there were a total of 7 documented grain dust explosions, resulting in 6 injuries and 1 fatality. The ten-year average for injuries is 8.0 and 1.3 for fatalities. The fuel sources identified in the explosions involved: 5 cases of grain dust and 2 unknowns. Dust explosions occurred in 6 different states, 2 in Minnesota and 1 each in Georgia, Idaho, Indiana, Iowa, and Oregon. Four of these explosions occurred in a grain elevator and the remaining 3 in a feed mill, corn mill and an ethanol plant⁸.

⁸ To view a copy of the full report, visit:

https://engineering.purdue.edu/FFP/research/dustexplosions/2020_Grain_Dust_Explosions.pdf

2021 Summary of Livestock Waste Storage, Handling, Transport Equipment and Facility-related Incidents

Incidents involving livestock waste storage and handling facilities, transport equipment, and other waste-related operations, such as digesters and bio-gas generators have been monitored as part of Purdue's Agricultural Confined Spaces-related Incident Database (PACSID). Findings gathered between 1975 and 2021 were summarized by Nour, et al. (2021). The summary included a total of 413 incidents involving 493 cases (individuals). Of these cases, 294 (60%) were fatal. Eighty-five percent of the victims were male, with an average age of 37. Incidents most frequently identified involved underground or underfloor manure holding facilities, aboveground manure storage tanks, sump pits, ponds, lagoons, manure digesters, and manure transport vehicles such as portable tankers, applicators and spreaders. Multiple victims were documented in 53 of the incidents or approximately 11% of all cases. This included two incidents with five fatalities in each.

In 2020, there were 11 injuries and fatalities related to livestock waste reported of which 5 or (45%) were reported as fatal. The number of cases documented in 2021 took a significant jump to 17 incidents involving 23 individuals (cases). Of these cases, 18 were fatal (78%). This was more than 3½ times the number of fatalities documented in 2020 and exceeded the number of fatalities due to grain entrapment.

All the victims were male, including a two-year old child. The ages of five of the victims were undetermined. The oldest victim was age 85.

The state with the most documented cases, fatal and non-fatal, was Iowa with five victims in three different incidents. Four cases were identified in Ohio, of which 3 fatalities occurred in one incident, all brothers. Wisconsin and Colorado each reported 3 cases.

The most frequently identified activity taking place at the time of the injury or fatality was performing maintenance tasks, such as pump repairs or service, in or around manure storage structures. Two of the cases involved biogas/manure anaerobic digesters used to process livestock, food wastes, and other agricultural wastes into methane gas for use as fuel.

Of continuing concern is the number of victims who were identified as secondary victims, or first responders who were attempting to rescue the initial victim. Three of the 17 incidents included multiple victims with two of the involving three victims each.

Figure 10 shows the annual distribution of all documented cases over the past 46 years which reflects more aggressive current 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 the number of incidents after 2015, however, should be of concern.

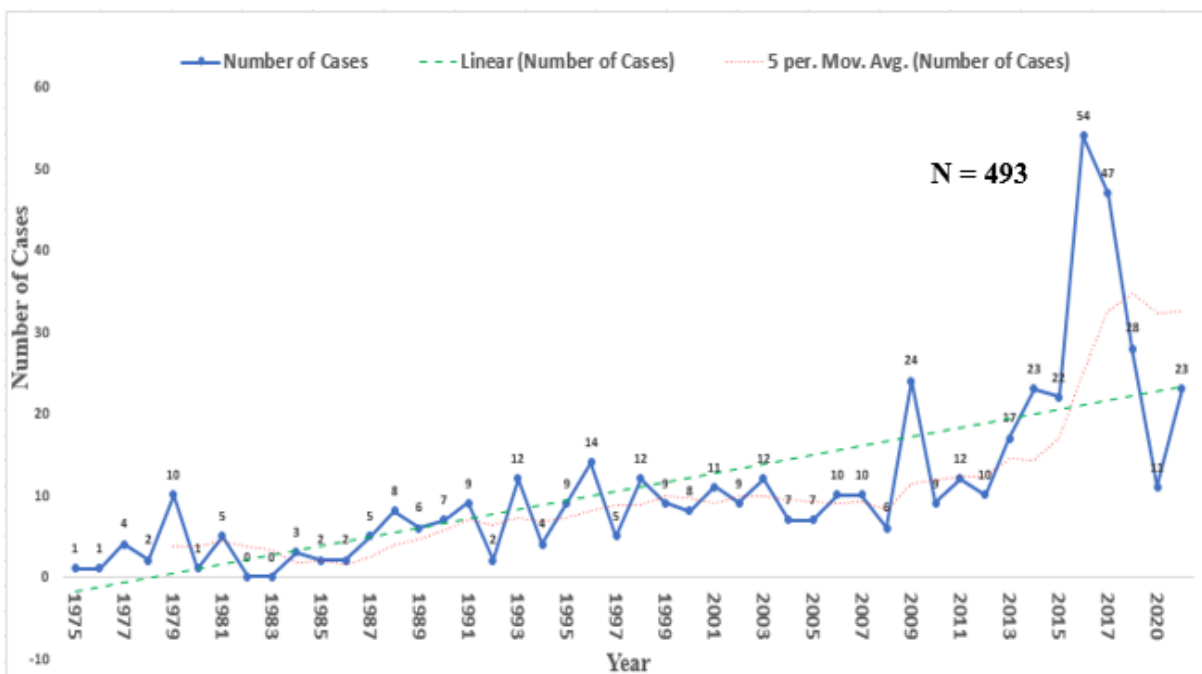


Figure 10. Distribution of Annual Frequency of Livestock Waste-Related Incidents from 1975 to 2021, N=493

Figure 11 provides a geographic distribution of the 493 cases documented between 1975 and 2021 nationwide by state. The concentration appears to correlate with production levels of both dairy and swine. An earlier analysis of the data found that more incidents involved dairy operations than swine facilities.

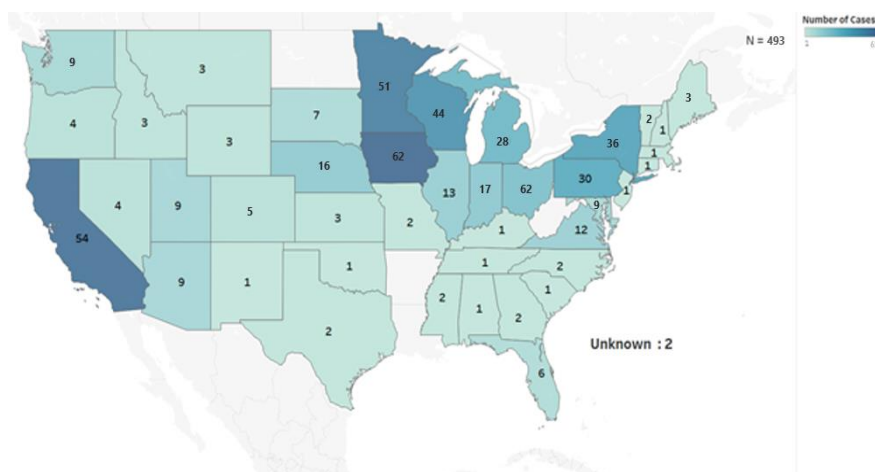


Figure 11. Geographic Distribution of Livestock Waste-Related Incidents from 1975 to 2021 (N=493)

In summary, there needs to be continued attention given to the risks associated with livestock waste storage, handling, and transport operations. The two incidents in 2021, each involving three victims, is a tragic reminder of the need for promoting safer emergency response procedures, increasing awareness about livestock waste hazards, and reducing the potential risks associated with confined spaces used in conjunction with livestock waste and handling operations.

Are We Conducting the Right Emergency Response Training?

Ongoing surveillance of the media for incidents involving agricultural confined spaces has identified a high frequency of related 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 a grain rescue tube or cofferdam. In many cases, the training appears 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.

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 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 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 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

Historically, the economic impact associated with fatalities or injuries associated with agricultural confined spaces were quite limited and often covered by the family, farm or agricultural business, modest insurance policies, Worker Compensation Insurance, or charity from the community. With the implementation of OSHA workplace safety and health regulations, employers became exposed to the risk of financial penalties for failure to provide a safe workplace. More recently, the financial awards being made as the result of civil litigation related to injuries and fatalities in agricultural confined spaces have gotten employers attention. 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. These costs are hard to ignore for even a large business.

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 materials, frequently asked questions, videos past summaries of injuries and fatalities, and an extensive list of resources can be found at the site. Since 2019 it has hosted nearly 30,000 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 training program targeting 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 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 nine years over 5,350 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. This complete agricultural safety curriculum is designed for young and beginning workers and meets many of the teaching standards for secondary agricultural education programs.

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 farmer. Copies were 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. 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 eight years, the following articles have been published. Full text for some of these articles are available at www.agconfinedspaces.org.

Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Effort Required to Insert a Rescue Tube into Various Grain Types. *Journal of Agricultural Safety and Health*, 18:4, 2012.

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For additional information on this report, contact Professor Bill Field at 765-494-1191 or field@purdue.edu. In addition, refer to these sources for more information on this topic:

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