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 23 fatal and 36 non-fatal cases[1] involving agricultural confined spaces were documented in 2021, representing a 7.8% decrease over the 64 cases in 2020
- There were no fewer than 29 grain related entrapments in 2021 representing a 17.1% decrease over 2020, with the balance of 30 involving livestock waste handling facilities, auger entanglements and grain dust explosions or fires
- One incident involved three fatalities, and two involved two victims each
- Eight cases involved livestock waste storage pits or lagoons, seven of which were fatal
- Six additional grain dust explosions resulting in seven non-fatal injuries were documented[2]
- Two female cases were documented in 2021, one involved a grain entrapment and the other an auger entanglement
- 39% (23) of 2021 cases were fatal compared to 59% historically
- Iowa reported the most confined space-related cases in 2021 (8), followed by Minnesota (7) and 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
- One case in 2021, an auger entanglement, involved a youth under the age of 21, which reflects 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 (23 versus 36)

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

[1] A case refers to one individual. Some incidents involve multiple victims or cases.
[2] Grain dust explosion related cases are included in the data being reported in this summary.

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, and falls from or into confined spaces; and other types of agricultural confined spaces including forage storage silos, bunk 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).

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 2,240 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 the overwhelming majority of cases and 1,331 cases (59%) were fatal.

The total number of cases published in previous annual summaries may not match as additional cases are being added to the database as they are identified. There is also a discrepancy with earlier years due to the original focus only on identifiable confined spaces. Later years have included cases involving falls, entanglements, asphyxiations and drownings in manure storage facilities, and other incidents related to confined spaces in agricultural workplaces.

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 manure 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 needs 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 standard's organizations in the development of more effective regulations and standards targeting worker safety and health.

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

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

In 2021, there were a total of 59 cases documented, including 29 grain entrapments, 2 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 or around agricultural confined spaces, 7 cases involving grain handling facility fires or explosions and seven miscellaneous cases (Figure 1). The total of 59 cases represented a 7.8% decrease (5) from the number of cases documented in 2020, when 64 were recorded. The number of 2021 cases was below both the 5-year average (61.0 cases/year), and the 10-year average (60.1 cases/year) (Figure 2). 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.

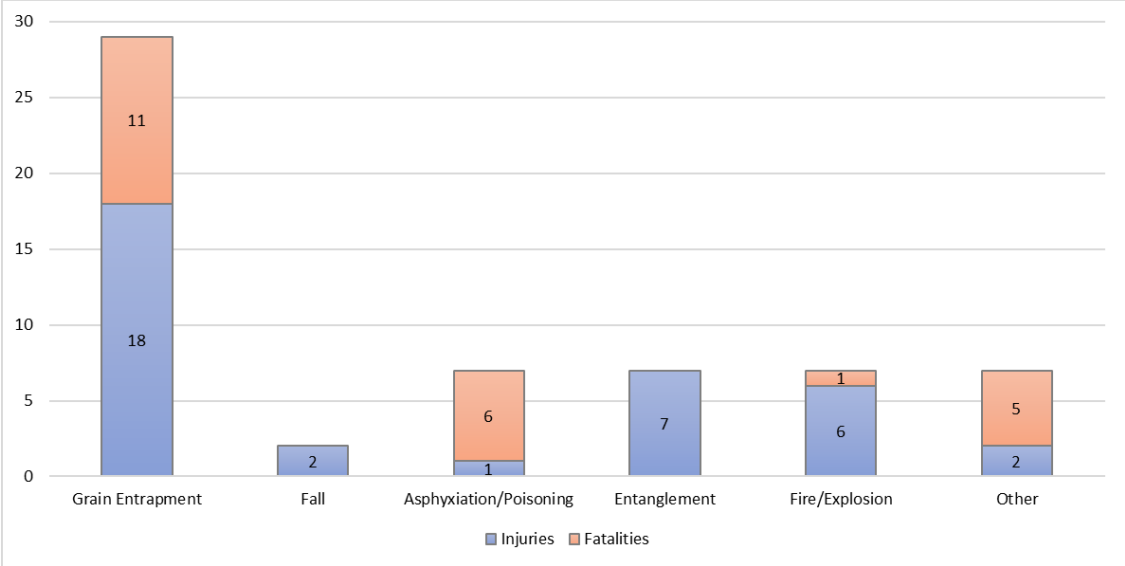

Figure 1. Distribution of all 2021 agricultural confined space-related cases by type of incident, n=59

During 2021 grain entrapments accounted for 29 (49.2%) 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 2). 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 to consider 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 32.2 cases/year and 28.8 annually for fatal cases. In 2021 the number of fatal cases (23) was well

below the 5 and 10-year averages of 28.8 and 27.5 cases/year respectively. 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.

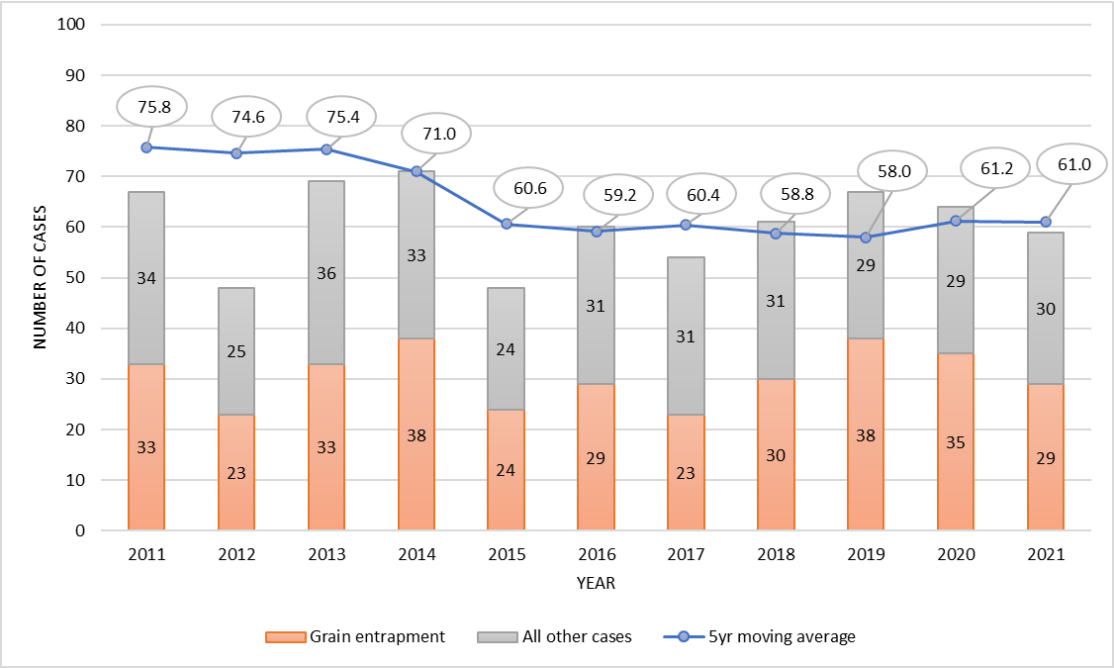

Figure 2. Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2011 to 2021

During 2021, the states with the most documented confined space cases of all types, including fatal and non-fatal, were Iowa (8), Minnesota (7), Illinois (5), Ohio (4) and Wisconsin (4). There were three cases documented in each of Nebraska, Texas and Washington. Overall, incidents were documented in 25 states in 2021, and Figure 3 illustrates the geographic distribution of all documented cases in the PACSID and those documented in 2021. The total does not include 70 cases where the state was unidentified because the site of the incident may have varied from the state where the victims were declared dead. The four states with the largest number of cases, historically, have been Iowa (264), Indiana (232), Minnesota (219), and Illinois (214). As noted in previous summaries[4], it is estimated that this surveillance effort underreports cases by as much as 30% due to the lack of adequate reporting mechanisms, especially for non-fatal incidents. It is also believed that Indiana has such a high ranking because of more aggressive surveillance efforts over the past 40 years.

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

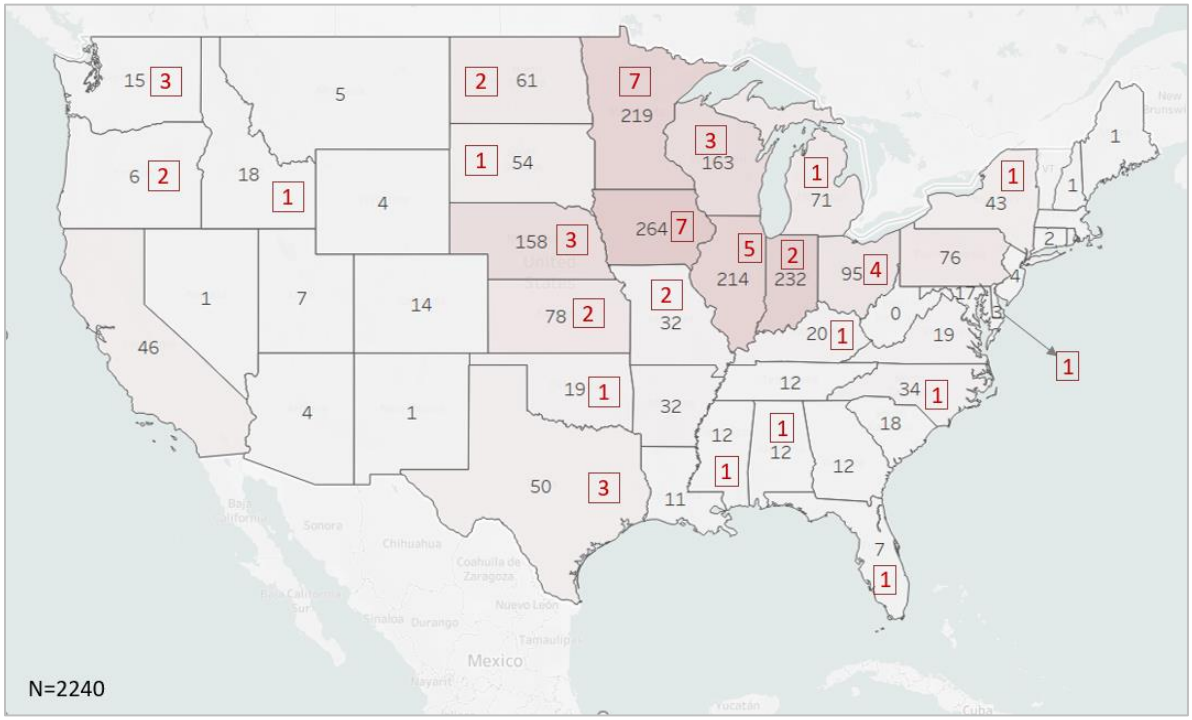

Figure 3. Geographic distribution of all agricultural confined space cases for 2021 and previous years (n=2240)

In 2021, only one cases involved a child or youth under the age of 21, as shown in Figure 4. A specific age was known for 20 of the 59 victims in 2021, with the oldest victim being 79 and the youngest 16 years old. The average age was 49.5 years old, and the median age 46.5 which is substantially younger than the average age of U.S. farmers. Those over the age of 60 accounted for 7 (35%) of the cases where age was known. As noted, a large number of the cases were documented (39) 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 due to the lack of identifiers such as “child”, “youth”, or “parent”. There were two female cases documented in 2021; one was a grain entrapment, and the other an auger entanglement.

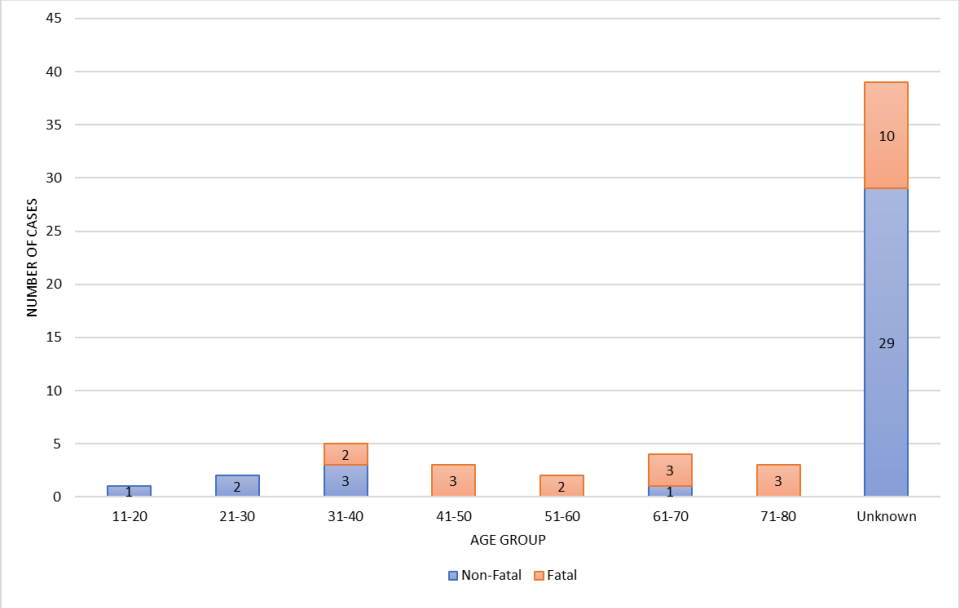

Figure 4. Age distribution of all 2021 agricultural confined space incident victims

In 2021, there were 38 cases where the exemption status[5] of the facility with respect to OSHA regulations was known. Of those cases, 25 (65.8%) 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 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.

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 mining fatalities, which is 13 more than the 23 fatalities reported for 2021 in this report. Over the past 5 years, 144 fatalities were

[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.

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

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 OSHA Regions

Nearly all of the 2,240 cases have been identified by OSHA region. Agricultural confined space-related cases have occurred in every OSHA region but tend to be concentrated in two regions, regions 5 and 7 (Figure 5). Historically, Region 5 has accounted for 44.4% of all agricultural confined space cases across the country, (994) with 58.5% of those cases being grain entrapments, and 12.6% being falls. Region 7 accounted for 531 cases (23.8% 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%).

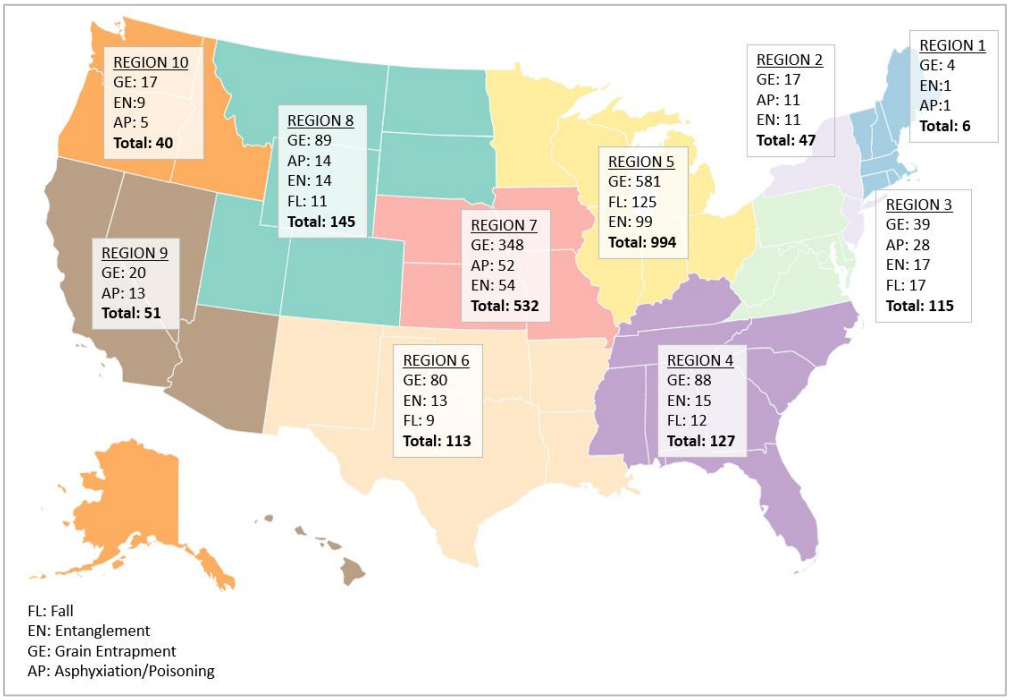

Figure 5. Agricultural confined case distribution by OSHA region from 1962-2021. The total number of cases and most frequent type of case is listed for each region (n=2240)

Grain Entrapments

The 29 fatal and non-fatal grain entrapment cases[7] 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 total was the second highest of the past six years. Nevertheless, the 5-year running average continues to drop from its peak of 40.4 in 2011 (Figure 6). 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, 11 (38%) resulted in a fatality, a rate higher than the five-year average. 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 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. As noted above, this high number more likely reflects the aggressive surveillance efforts in Indiana to document both fatal and non-fatal grain-related cases over the past 40 years rather than an actual larger number of cases. It is believed that Iowa, Illinois, and Minnesota should have a substantially higher number of cases than Indiana based on both their respective total grain production and grain storage capacity.

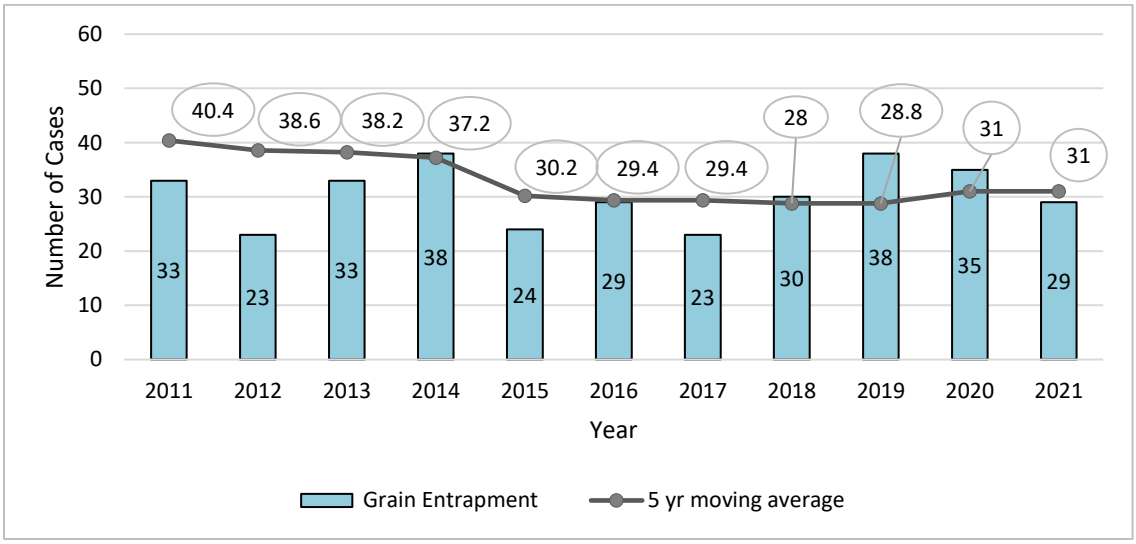

Figure 6. Number of annual grain entrapment cases recorded between 2011 and 2021

[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.

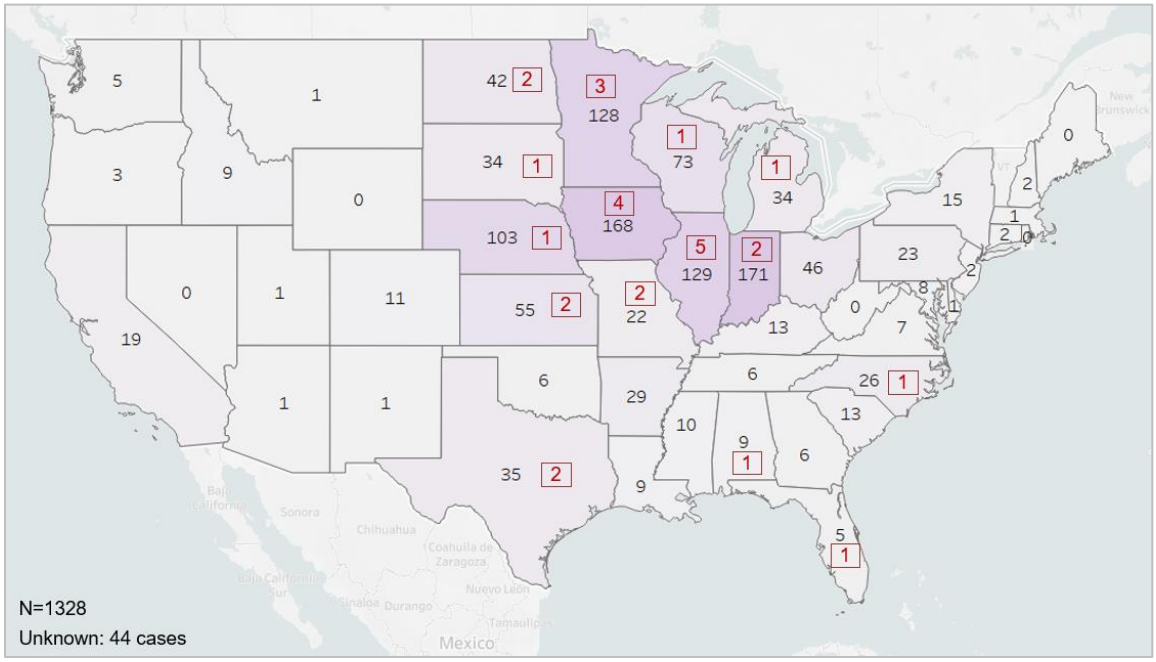

Figure 7. Geographic distribution of all documented grain entrapment cases in 2021 and previous years

All the documented grain entrapment cases in 2021 involved males. There were no grain entrapment cases involving a youth under the age of 21, an age group that has accounted for as many as one in five cases in the past. The oldest victim of grain entrapment was 79 (figure 8). 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 reports strongly indicates that nearly all were adults.

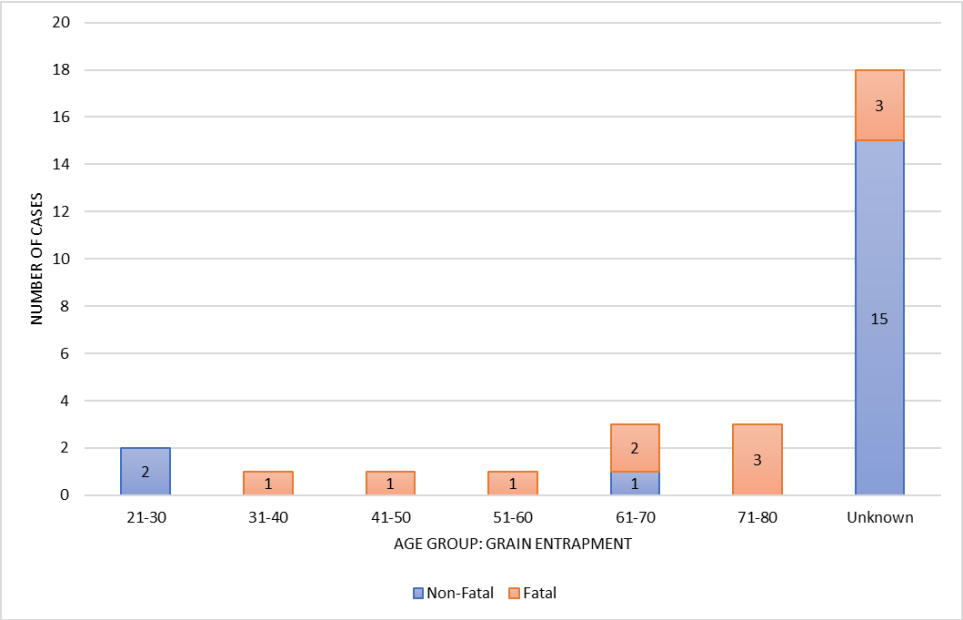

Figure 8. Age distribution of 2021 grain entrapment victims by number of cases recorded

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 plant[8].

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

Incidents involving agricultural 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 409 incidents involving 486 individuals of which 288 (59%) were fatal; 85% of the victims were male. The average age was 37, substantially younger than the average age of U.S. farmers. Incidents most frequently identified 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. Multiple victims were documented in 53 of the incidents or approximately 11% of all cases.

In 2020, there were an additional 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 jump to 13 incidents involving 16 individuals (cases). Of these cases, 12 were fatal (75%). This was more than double the number of fatalities documented in 2020.

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 states with the most documented cases, fatal and non-fatal, were Wisconsin, Ohio, Iowa, and Vermont. In Ohio, the three fatalities that occurred in one incident, were all brothers. Colorado, New York, Indiana, and Pennsylvania reported one case each in 2021.

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 the emerging use of biogas/manure anaerobic digesters to process livestock, food wastes, and other agricultural wastes into methane gas for use as fuel.

[8] To view a copy of the full report, visit:
https://engineering.purdue.edu/FFP/research/dustexplosions/2020_Grain_Dust_Explosions.pdf

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. Two of the 13 incidents involved multiple victims (5), or 31% of all victims. One of the incidents involved three victims and the other one involved two victims.

Figure 9 shows the annual distribution of all documented cases over the past 46 years which 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.

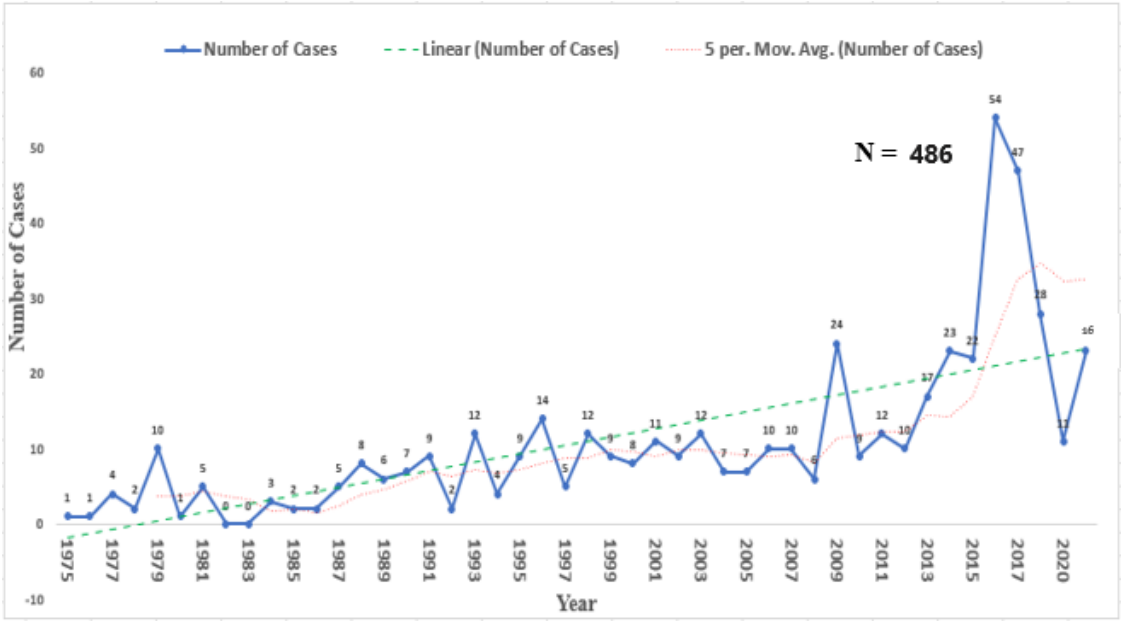

Figure 9. Distribution of Annual Frequency of Livestock Waste-Related Incidents from 1975 to 2021, n=486

Figure 10 provides a geographic distribution of the 486 cases documented between 1975 and 2021 nationwide by state. The concentration appears to parallel production levels of both dairy and swine. An earlier analysis of the data found that historically more incidents involved dairy operations than swine facilities.

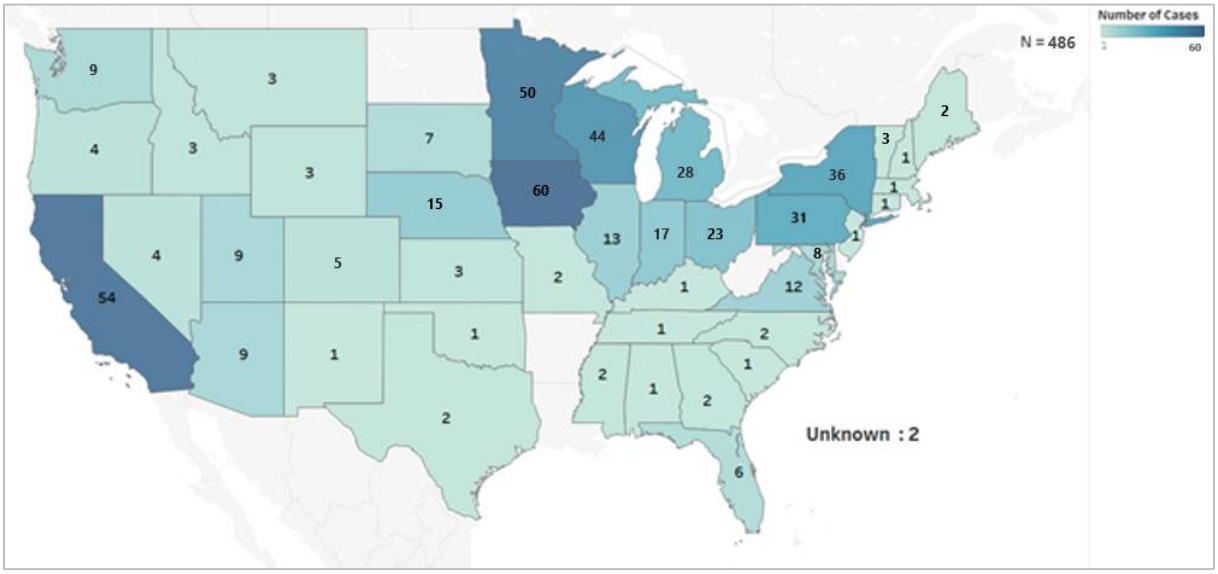

Figure 10. Geographic Distribution of Livestock Waste-Related Incidents from 1975 to 2021, n=486

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 multiple victims, is a tragic reminder of the need for promoting safety procedures, increasing awareness about hazards, and reducing the potential risks associated with livestock waste and handling operations, and confined spaces.

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 grain-related rescue training taking place for local emergency first responders. These training events are occurring across the U.S., even in areas where the probability of grain-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 grain rescue tubes or cofferdams. In many cases, the training appears to be in 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., of which approximately 60% are body recovery.

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 all forms of agricultural-confined space rescue training? and (d) How much specialized rescue equipment is actually needed in a service area, 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 and types 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 relatively modest 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. These potentially large economic penalties justify serious consideration to retrofitting current agricultural confined spaces to meet regulatory safety standards, adoption of best work practices, and, even in some cases, removing the facilities from service.

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 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 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 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. The primary focus is on ensuring first responder safety. Over the past nine years over 5,350 emergency first responders have participated in training using this 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.

Educational Resources

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-enacted an actual grain bin entrapment of a Posey County farmer. Copies were distributed to over 500 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.

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