

2020 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities

Yuan-Hsin Cheng, Ph.D., Post-doctoral Research Assistant

Mahmoud Nour, Ph.D., Post-doctoral Researcher

Bill Field, Ed.D., Professor

Kingsly Ambrose, Associate Professor

Edward Sheldon, Research Associate

Agricultural Safety and Health Program

Purdue University

West Lafayette, IN

Highlights

The following are highlights from the 2020 findings:

- No fewer than 64 fatal and non-fatal cases involving agricultural confined spaces were documented in 2020, representing a 4.5% decrease over 2019
- There were no fewer than 35 grain related entrapments in 2020 representing a 7.9% decrease over 2019, with the balance of grain related incidents involving entanglements and falls
- Three incidents involved more than 1 victim
- Three incidents involved manure storage pits or lagoons
- Eight additional grain dust explosions resulting in nine non-fatal injuries were documented¹
- Three female cases were documented in 2020, two of which involved falls from storage structures
- 50% (32) of 2020 cases were fatal compared to 61% historically
- Illinois reported the most cases in 2020 (17), which was more than double the next two highest reporting states, Minnesota and North Dakota
- Illinois also reported the most grain-entrapment cases in 2020 (10). Indiana, Iowa, Minnesota and Illinois have historically recorded the most grain entrapment cases
- Six cases in 2020 involved a youth under the age of 21, none of which involved grain entrapment and one involved manure handling or storage

¹ Grain dust explosion related cases are not included in the data being reported in this summary.

- OSHA Regions 5 and 7 have historically accounted for nearly 70% of all documented agricultural confined space-related incidents
- The number of agricultural confined space-related fatalities documented exceeded the number of reported mining-related fatalities in 2020 (35 versus 29)

Introduction

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

All documented cases have been reviewed by a team of experts to ensure elimination of duplicates, assign case information to specific coding categories, and to identify potential contributing factors. Data were derived from a wide range of sources including online searches, death certificates (during early years of data collection), news clippings from local sources, work product from civil litigation, published personal accounts, and voluntary reporting. The data were coded using a standard coding process. Coded data were entered into the Purdue Agricultural Confined Space Incident Database (PACSID) allowing for summarization.

As of the end of 2020, the PACSID contained information on 2,404 cases, documented² between 1962 and 2020,³ that resulted in an injury, fatality, or required emergency extrication by first responders. Of these cases 1,442 (60%) were fatal with 1,731 (72%) involving grain storage and handling facilities, and grain transport vehicles. 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 involving falls, entanglements, drownings in manure storage lagoons, and other incidents related

² A case refers to one individual. Some incidents involve multiple victims or cases.

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

to confined spaces. The total case number (2,404) also includes additional manure handling and transportation-related cases, which were summarized recently and added to the PACSID. The addition of these cases caused a noticeable increase of total number of cases in the database from 2,181 to 2,404.

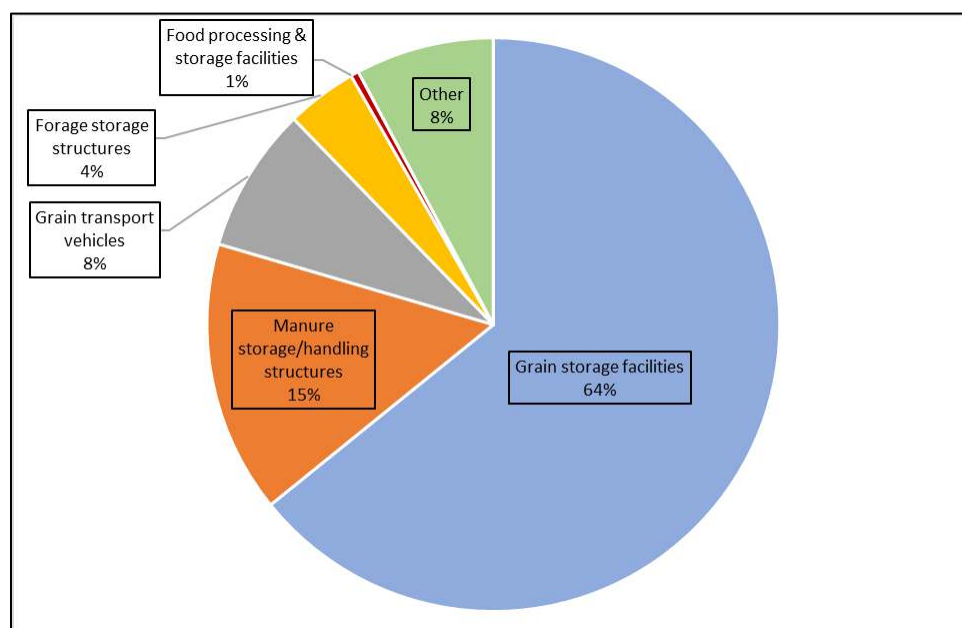


Figure 1: Documented injuries and fatalities in PACSID database based on agent category between 1962 and 2020 (N=2404)

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 2020 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 summary of the new grain bin safety standards, a brief summary of fires and explosions at grain storage and handling facilities, and observations on current safety training of workers and emergency first responders.

The purposes of publishing these findings on an annual basis are 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 in the development of more effective regulations targeting worker safety and health.

2020 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2020, there were a total of 64 cases documented, including 35 grain entrapments, 7 falls into or from grain storage structures, 4 asphyxiations due to deficient oxygen levels or toxic environments, and 12 equipment entanglements (such as those involving in-floor and sweep augers) that occurred while working inside or around agricultural confined spaces (Figure 2). Three cases involved manure storage facilities. The total of 64 represented a 4.5% decrease (3) from the number of cases documented in 2019, when 67 were recorded. However, the number of this year's total confined space-related cases was well above the 5-year average (61.2 cases/year), and above the 10-year average (60.9 cases/year) (Figure 3). The 5-year running average, however, for all cases has substantially decreased 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. The five-year average started to steadily increase in 2002 from 36.8 cases per year to a peak of 75.8 cases in 2011. A significant contributing factor in the earlier increase in the frequency was 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 incidents being captured, such as those involving manure storage.

During 2020 grain entrapments accounted for 35 (54.7%) of all documented cases, a lower proportion than the historical average likely reflecting, again, more aggressive recent efforts to identify other types of confined space incidents (Figure 3). In 2020, the number of fatal and non-

fatal cases was the same. Historically, however, there have been considerably more documented fatal cases than non-fatal cases, further suggesting under-reporting of non-fatal incidents. The 5-year and 10-year averages for non-fatal cases were 31.0 and 33.3 cases/year respectively. In comparison, the 5-year and 10-year averages for fatal cases were 30.2 and 27.6 cases/year respectively. In 2020 the numbers of both fatal (32) and non-fatal cases (32) were above average for the metrics. It appears that the frequency of these events has leveled off over the past six years reflecting little improvement from current prevention efforts.

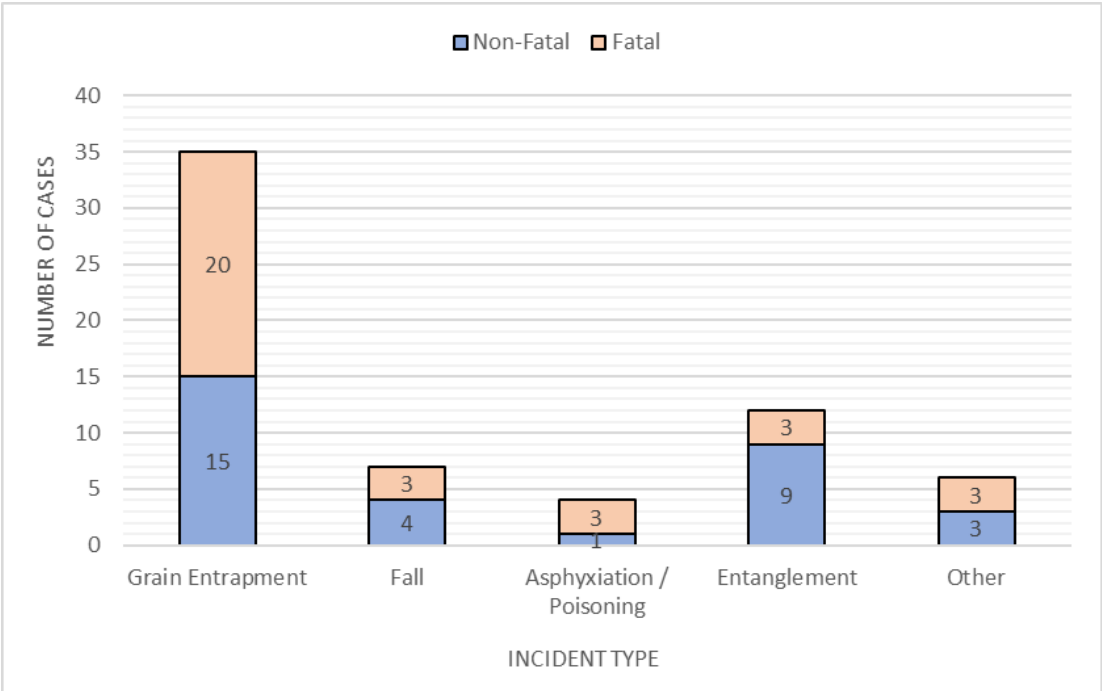


Figure 2: Distribution of all 2020 agricultural confined space-related cases by type of incident, N = 64

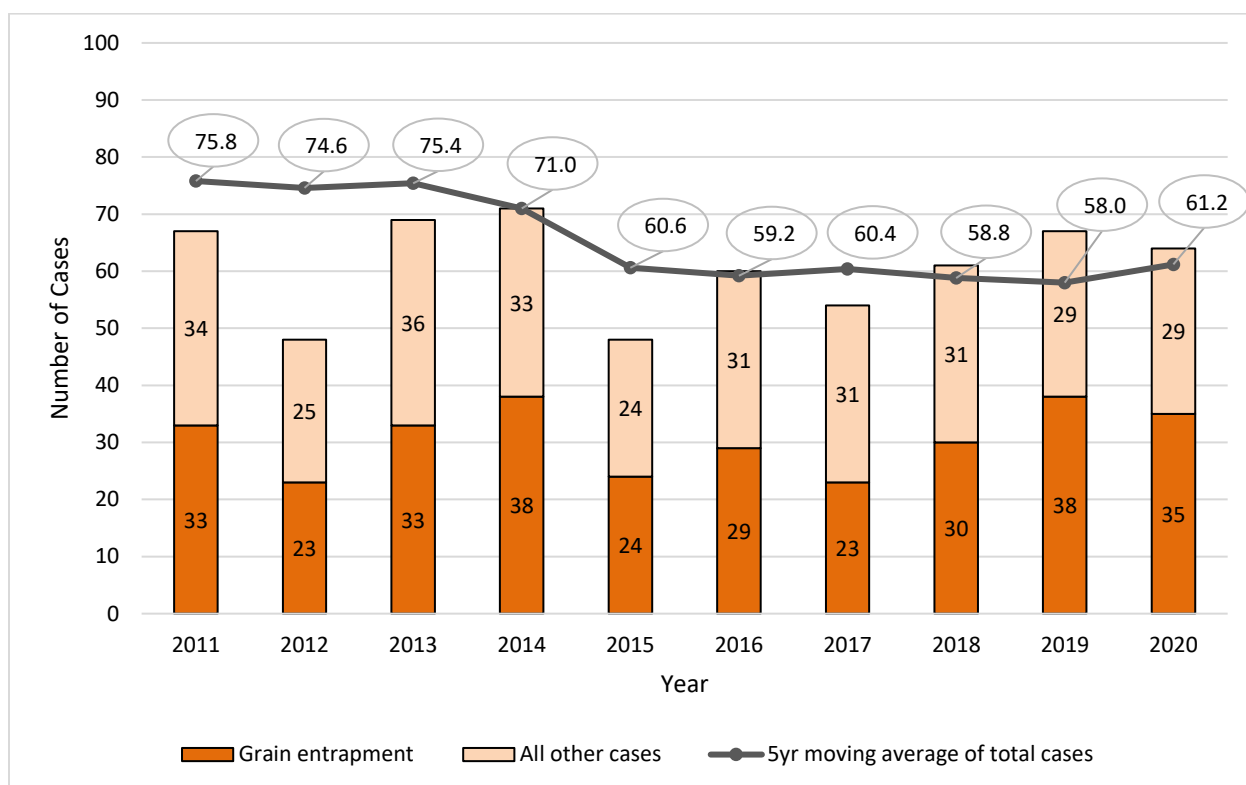


Figure 3: Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2011 to 2020

During 2020, the states with the most documented confined space cases of all types, including fatal and non-fatal, were Illinois (17), Minnesota (7), North Dakota (7), and Nebraska (5). The unusually high number of documented cases in Illinois, more than the next two states combined, was of special interest. One contributing factor may be the consequence of substantial efforts to bring attention to the problem in the state resulting in more non-fatal cases being identified. There were three cases documented in each Iowa, Indiana, Ohio and South Dakota. Overall, incidents were documented in 20 states in 2020, substantially more than the 15 states with reported incidents in 2019. Figure 4 illustrates the geographic distribution of all documented cases in the PACSID and those documented in 2020. The total does not include cases where the state was unidentified. The four states with the largest number of cases, historically, have been Indiana (270), Iowa (256), Minnesota (212), and Illinois (209). 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.

⁴ See www.agconfinedspaces.org for earlier summaries.

Distribution of Cases by State: 1962 – 2020, Confined Space (n=2181)

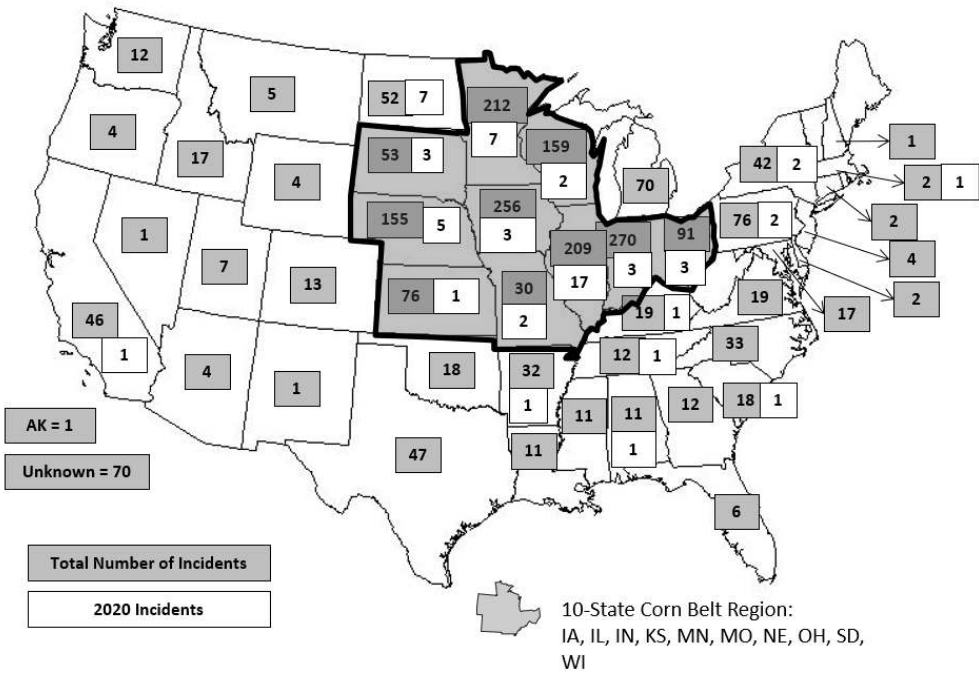


Figure 4: Geographic distribution of agricultural confined space cases for 2020 and previous years (n=2181)

In 2020, six cases (15.4%) involved a child or youth under the age of 21, as shown in Figure 5. A specific age was known for 39 of the 64 victims in 2020, with the oldest victim being 80 and the youngest 2 years old. The average age was 46.9 years old, and the median age 56. Those over the age of 60 accounted for 13 (33.3%) of the 39 cases (where age was known), reflecting the increasing average age of farmers (58 years old) in the U.S. As noted, a large number of the cases documented (25) did not include the specific age of the victim. Based upon a review of the case reports, it was concluded that most of the victims in which an age could not be documented were adults due to the lack of identifiers such as “child” or “youth”. There were three female cases documented in 2020; two of these individuals died from falls from crop storage structures.

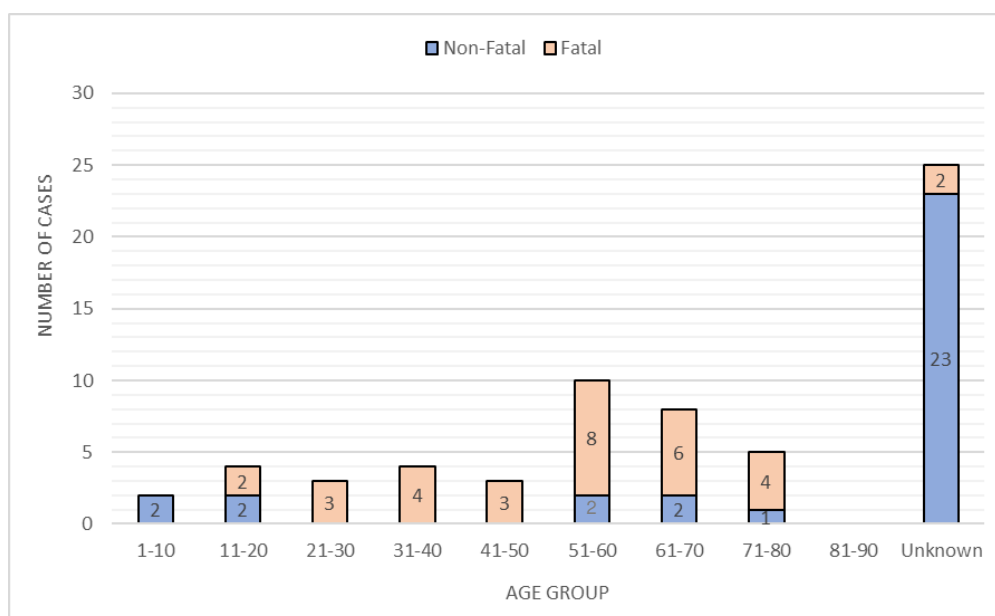


Figure 5: Age distribution of all 2020 agricultural confined space incident victims

In 2020, there were 56 cases where the exemption status⁵ of the facility with respect to OSHA regulations was known. Consistent with past trends, 51 (91.1%) of those cases occurred on farms or other locations currently exempt from enforcement under the OSHA Grain Handling Facilities Standards (29 CFR 1910.272) or Confined Space Standards (29 CFR 1910.146), with the balance of known cases, 5 (9.8%) 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 was made between agricultural confined space incidents and mining incidents. Historically, there have been more fatal mining incidents per year than those occurring in agricultural confined spaces. For example, in 2017, there were 28 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 with the number of reported mining-related fatalities dropping to 24 while the

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

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. In other words, for the past two years fatal incidents involving agricultural confined spaces have outnumbered mining-related fatalities.

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 two regions, regions 5 and 7. Historically, Region 5 has accounted for 44.5% of all agricultural confined space cases across the country, (971) with 59% of those cases being grain entrapments, and 13% being falls. Region 7 accounted for 517 cases (23.7% of the U.S. total) with grain entrapments, asphyxiation and entanglements representing 86% 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 (72%). Of the 2,404 cases in the PACSID, 2,181 have been identified by OSHA region.

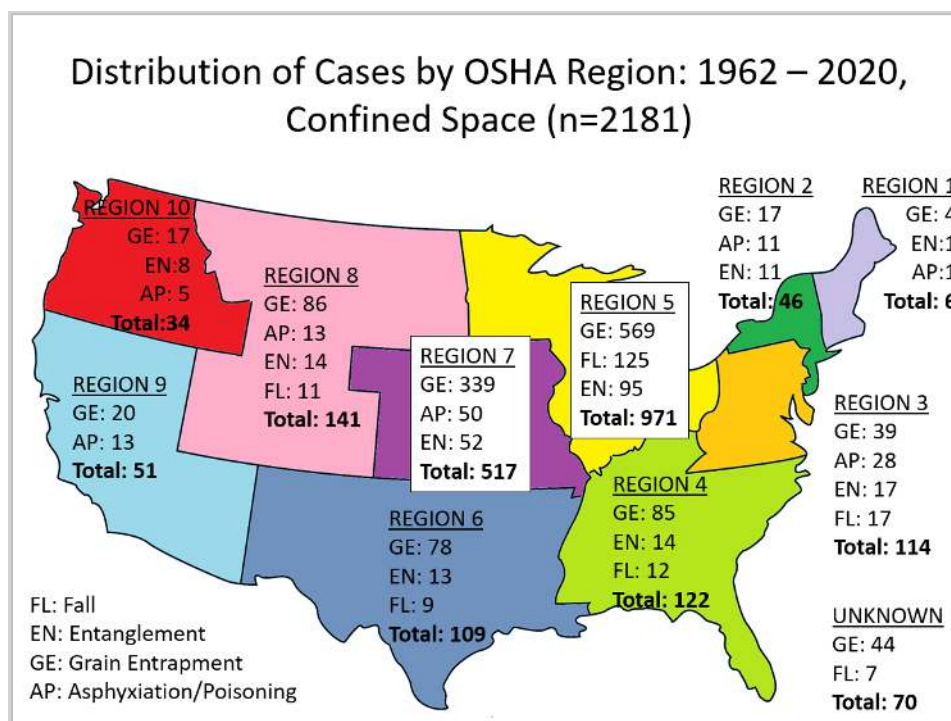


Figure 6: Agricultural confined case distribution by OSHA region from 1962-2020. The total number of cases and most frequent type of case is listed for each region (n=2181)

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.

Grain Entrapments

The 35 fatal and non-fatal grain entrapment cases⁷ documented in 2020 represented a 7.9% decrease from the 38 recorded in 2019, but was substantially higher 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 7). The number of non-fatal grain entrapment cases (15) was the fourth largest ever recorded after 2010 (27), 2011 (21), 2013 (21), and 2014 (20). Fifty-seven percent (57%) of the reported entrapment cases in 2020 resulted in a fatality, a rate higher than the five-year average. In 2020, the state with the most documented grain entrapments (fatal and non-fatal), was Illinois with ten cases total, followed by North Dakota (5), Minnesota (4), and Indiana and South Dakota with three cases each. Illinois represented 29% of all documented cases with a total exceeding the next two states combined. Overall, grain entrapments were documented in 11 states in 2020. 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 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.

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.

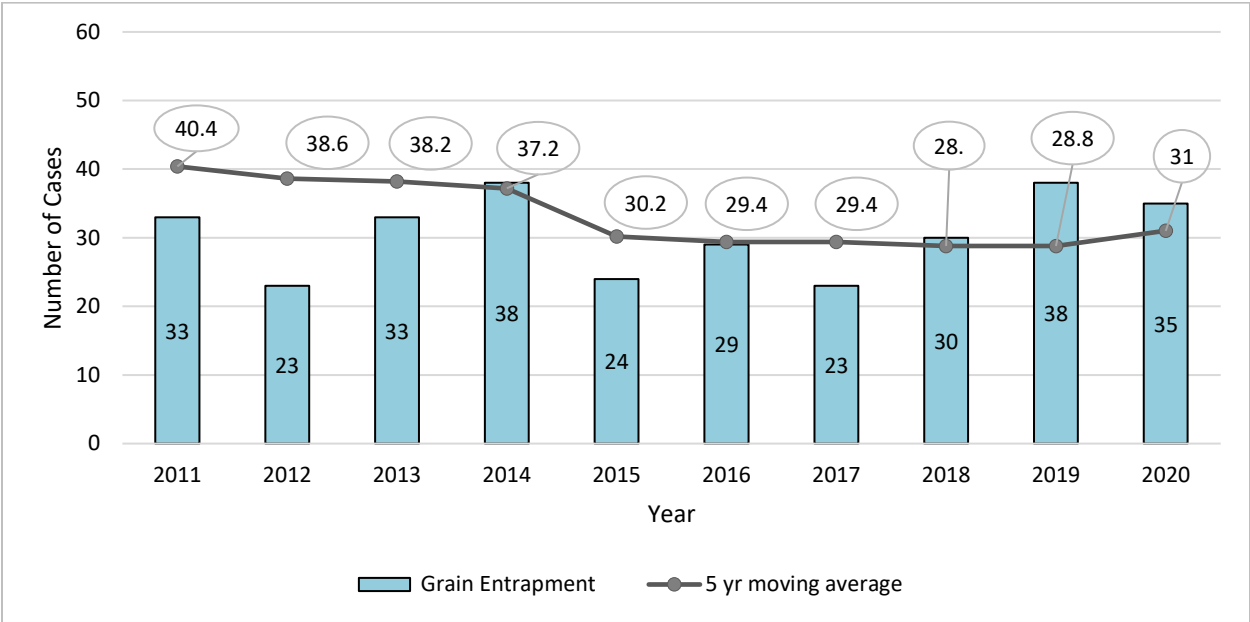


Figure 7: Number of annual grain entrapment cases recorded between 2011 and 2020

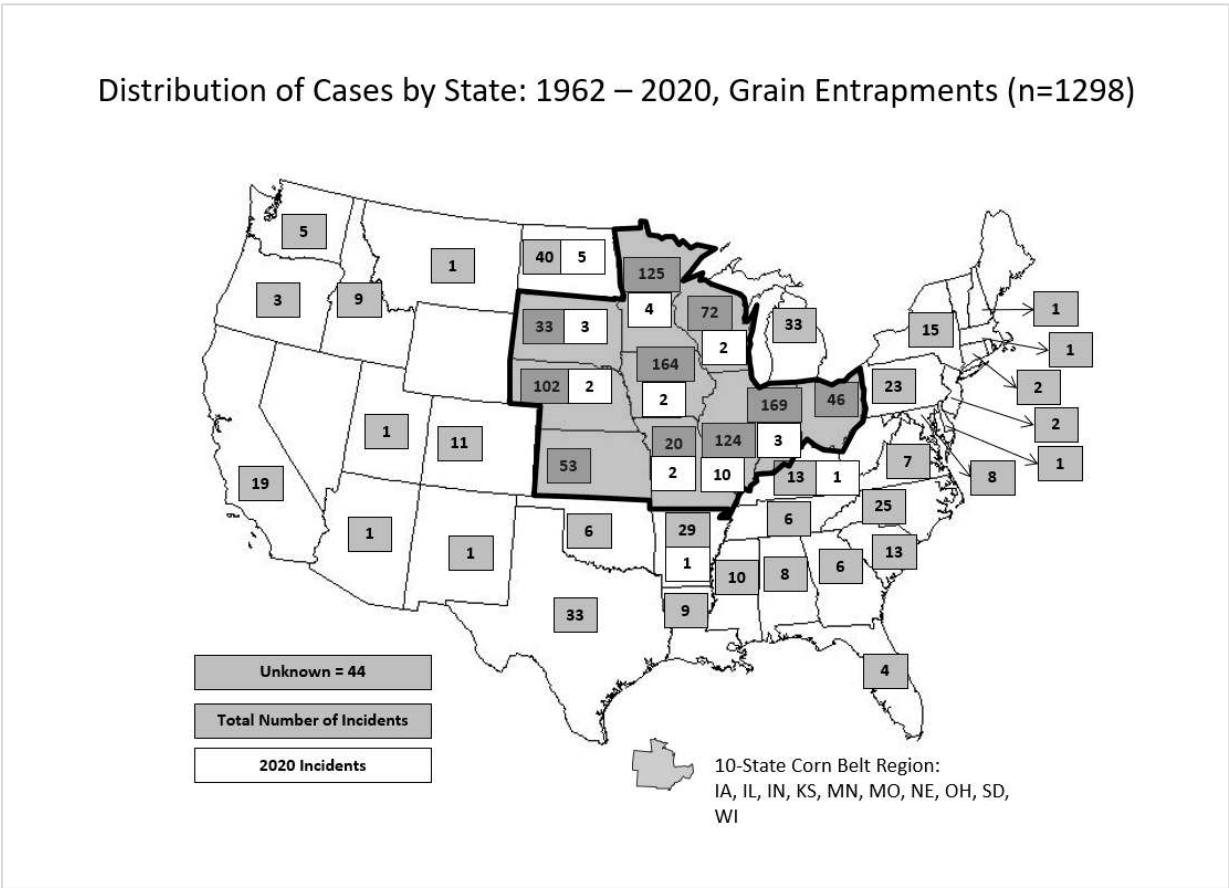


Figure 8: Geographic distribution of grain entrapment cases for 2020 and previous years (n=1298)

All the documented grain entrapment cases in 2020 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 80 (figure 9). The average age was 57.5 years old and the median age 62. In over 37% of the cases, the specific age could not be documented, however review of the reports suggests that most were adults since the terms “child”, “youth”, etc. were not used.

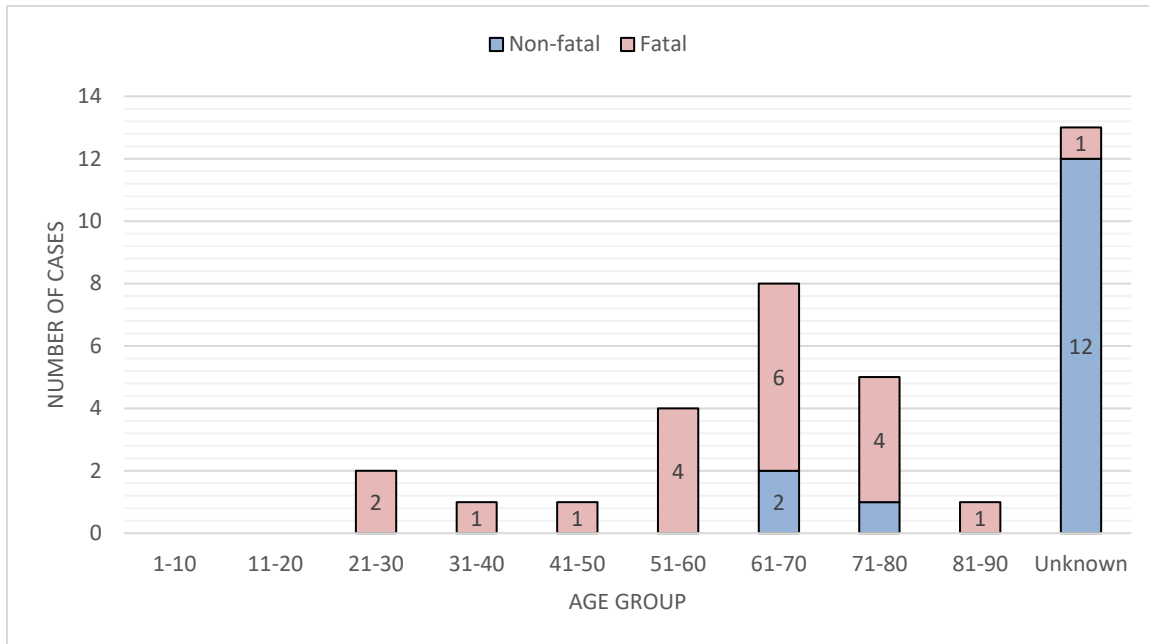


Figure 9: Age distribution of 2020 grain entrapment victims by number of cases recorded

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 incidents occurred in 2020.

When Grain Won’t Flow

As is well documented in past annual summaries, there is a direct correlation between out-of-condition grain and an increased likelihood of worker exposure to entrapment situations. When a farmer or elevator employee has to “fight” to get the grain to flow out of the structure, there is a strong temptation to by-pass safe work practices by entering the structure in order to keep the grain flowing. In some cases, a crusted layer forms on the surface of the grain or within the grain

mass, causing a void above the outlets as grain is removed. If the crusted grain then breaks up, the chunks can block the outlets, reducing or stopping flow. In other situations, vertically crusted grain can cling to the walls of the structure or form free standing piles, possibly containing tons of grain, that can collapse without warning.

If the grain won't flow, it's already too late to debate what was or was not done to prepare the grain for safe storage, such as ensuring stored grain does not exceed 14-15% moisture content, is free of excessive foreign material or insect damage, or is protected from the elements. The issue at hand is to remove the grain without putting anyone at risk of entrapment. The following are some steps to consider. These recommendations may not be the most profitable, but are intended to keep everyone safe.

1. Never enter a bin where there is evidence of crusting on the surface or within the grain mass. If grain has been removed from the structure and the surface has not flowed toward the outlet – stay out. This is a clear sign that a large void has formed over the outlet.
2. If there is any signs that the grain is going out-of-condition, or has already done so, it needs to be moved immediately. The condition of the grain will not improve if left in storage, and will only worsen as warm weather arrives, which causes biological and insect activity to increase.
3. Perform all observations or unplugging efforts from outside the bin, at the top access hatch. Again, if there is evidence of crusting, spoilage, or excessive heating – stay out. The risk is too great. In some cases, long pipes, rebar, or other probes can be inserted into the grain mass to break up crusted grain or trash that is plugging the outlet. Watch out for overhead powerlines when handling these long probes.
4. If the grain has become so crusted, or the floor outlets become plugged, preventing grain removal according to the bin manufacturer's recommendations, contact a professional grain salvage service that has the experience and equipment to break up and remove out-of-condition grain. These services are expensive, but can save lives and salvage some of the grain. In some regions there is a market for damaged grain which helps make the salvage operation a little less costly.

Using Children and Youth in Grain Safety/Rescue Training Activities

Even after an effort to discourage the practice (Field, 2018), ongoing media surveillance efforts in 2020 continue to identify cases in which children and youth are being used as live

“victims” in safety demonstrations, grain rescue training, or recreational/educational activities. In addition, online images continue to document cases in which children and youth are intentionally being deeply buried in grain, up to their shoulders, to demonstrate the effects of entrapment and to conduct extrication training for emergency first responders. This practice is being abandoned by most informed groups, but remains more widespread than it should be. There are literally hundreds of online images showing children, including infants, being partially buried in grain. The significant hazards raised by these practices include:

- Choking and asphyxiation
- Exposure to respiratory hazards, asthma triggers
- Excessive pressure on the chest and breathing difficulties
- Claustrophobia/emotional trauma
- Injuries related to emergency extrication

An editorial was published in the April 2018 (Vol. 24 No. 2) issue of the Journal of Agricultural Safety and Health calling for an end to the use of children and youth, and others uninformed regarding the hazards of flowing grain, as “victims” in flowing grain demonstrations. There is no evidence to justify the need for or the value of placing children and youth at risk of harm, even if volunteered by a parent or guardian to participate. On the contrary, there is research to suggest that presenting a recognized hazardous activity as recreational or fun may, in fact, result in a lower appreciation of the potential risks involved. It is recommended that mannequins be used in flowing grain demonstrations and that safety professionals on-site where live “victims” are being used step up and intervene on behalf of those being placed in harm’s way. An additional concern that should be considered is the risk of being held liable if an injury were to occur.

2020 Summary of Grain Dust Related Explosions

In 2020, there were a total of 8 documented grain dust explosions, resulting in 9 injuries and 0 fatalities. The ten-year average for injuries is 8.1 and 1.7 for fatalities. A variety of grain types were involved in the explosions, including: 2 cases of corn, 2 wheat, 2 mixed feed, 1 rice and 1 dietary fiber. Dust explosions occurred in 8 different states: 1 each in Kansas, Iowa, Illinois, Ohio, Texas, Nebraska, Missouri and Arkansas. Four of these explosions occurred in a grain

elevator and the remaining 4 in a feed mill, corn mill, rice mill and grain processor for dietary fiber⁸.

Adoption of ASABE Grain Bin Safety Standard

After years of deliberation the American Society of Agricultural and Biological Engineers (ASABE) published a voluntary standard in 2019 that provides design recommendations to reduce the risk of grain entrapment in new corrugated steel grain storage bins. The standard, identified as ANSI/ASABE S624, Grain Bin Access Design Safety provides recommendations for safe bin access, anchor attachment points for lifelines, and a uniform safety decal (See Figure 10).

This standard, however, only applies to new grain storage bins. Efforts are needed to assess older facilities to identify needed upgrades, such as new signage, fall prevention features and guarding of powered components, such as in floor augers. The lack of adequate anchor points on older structures remains a significant concern when using fall restraints and during rescue operations.

For additional information on the standard contact ASABE headquarters at OrderStandard@asabe.org.



Figure 10: Safety decal for grain bin access

2020 Summary of Manure Storage, Handling, Transport Equipment and Facility Incidents

Building upon previous summaries of fatalities and injuries involving livestock manure storage, handling, and transport, (Nour, 2018) a total of 470 cases from 1975 to 2020 have now been documented and coded using a uniform coding system. All known cases are currently being

⁸ To view a copy of the full report visit:

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

summarized for eventual publication. A total of seven incidents resulting in 11 injuries and fatalities related to manure operations were documented in 2020. Three cases involved manure storage pits or lagoons and eight involved manure transport or hauling operations. Incidents are highlighted as follows:

- There were seven incidents involving 11 individuals (cases), of which five were fatal and six were non-fatal.
- The five fatalities documented in 2020 compared to 7 fatalities in 2019 and 16 in 2018.
- All victims were male, two of whom were children and youth under the age of 18, and one victim was age 64.
- The state with the most documented cases, fatal and non-fatal, was Michigan (4 victims in the same and only incident with multiple victims). This was followed by New York (2) and Minnesota (2). Wisconsin, Washington, and South Dakota had one case each.
- The most common pre-incident activities were tasks involving manure transport or hauling.
- The peak month for documented incidents was February.

Nour (2020) summarized cases involving children, youth, and young workers who were killed or injured while exposed to manure storage, handling, and transport. Many of these cases involved confined spaces.

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 20,000 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. Over the past eight years over 4,950 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.

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 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.

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.

Riedel, S. M., Field, W. E. Summation of the Frequency, Severity, and Primary Causative Factors Associated with Injuries and Fatalities Involving Confined Spaces in Agriculture. *Journal of Agricultural Safety and Health*, 19(2), 83-100, 2013.

Field, W. E., Heber, D. J., Riedel, S. M., Wettschurack, S. W., Roberts, M. J., Grafft, L. J. Worker Hazards Associated with the Use of Grain Vacuum Systems. *Journal of Agricultural Safety and Health*, 20(3), 147-163, 2014.

- Issa, S.F., Field, W.E., Hamm, K.E., Cheng, Y.H., Roberts, M.J., and Riedel, S.M. Summarization of Injury and Fatality Factors Involving Youth and Grain Entrapment or Engulfment in Agriculture. *Journal of Agricultural Safety and Health*, 22(1), 13-32, 2016 .
- Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Entrapment Victim Extrication Force with and without Use of a Grain Rescue Tube. *Journal of Agricultural Safety and Health*, 21:2, 2015.
- Issa, S.F., Cheng, Y.H., and Field, W.E. Summary of Agricultural Confined Space-related Cases: 1964-2013. *Journal of Agricultural Safety and Health*, 22(1), 34-45, 2016.
- Cheng, Y.H. and W.E. Field. Summary of Auger-related Entanglements Occurring Inside Agricultural Confined Spaces. *Journal of Agricultural Safety and Health*, 22:2, 2016.
- Issa, S.F., Field, W.E, Schwab, C.V., Issa, F.S., Nauman, E. Contributing Causes of Injury or Death in Grain Entrapment, Engulfment and Extrication. *Journal of Agromedicine*, 22:2, 2017.
- Issa, S.F. and Field, W.E. Determining the Pull-Forces Required to Extricate a Victim Entrapped at Various Angles in a Grain Mass. *Safety*, Accepted for publication, 2017.
- Cheng, Y.H., Field, W.E., Tormoehlen, R.L., French, B. Utilizing Secondary Agricultural Education Programs to Deliver a Grain safety Training for Young and Beginner Workers. *Journal of Agromedicine*, 22:4, 2017.
- Issa, S.F., Nauman, E., Wassgren, C., Schwab, C.V., Ahsan, Z.S., Field, W.E. Measured Spine Tensile Force Limits for Extracting Grain Entrapped Victim. Submitted to Journal of Safety.
- Field, W.E., Cheng, Y.H., Tormoehlen, R.L., Aherin, R., Schwab, C., Neenan, D., Roberts, M. Let's Stop Treating Our Youth Like Dummies. Editorial. *Journal of Agricultural Safety and Health*, 24:2, 2018.
- Issa, S.F., Nour, M.N., Field, W.E. Utilization and Effectiveness of Harnesses and Lifelines in Grain Entrapment Incident's; Preliminary Analysis. *Journal of Agricultural Safety and Health*, 24:2, 2018.
- Cheng, Y.H., Field, W.E., Issa, S.F., Kelly, K., Heber, M., Turner, R. Summary of U.S. Injuries and Fatalities Involving Entrapment and Suffocation in Grain Transport Vehicles. *Journal of Agricultural Safety and Health*, 24:2, 2018.
- Issa, S.F., Wassgren, C., Schwab, C.V., Stroshine, R., Field, W.E. Estimating Passive Stress Acting on a Grain Entrapment Victim's Chest. *Journal of Agricultural Safety and Health*, 24:3, 2018.
- Nour, N.M., Field, W.E., Ni, J.Q., and Cheng, C. Development of Methodology to Document and Code Farm-related Injuries and Fatalities Involving Manure Storage, Handling, and Transport – with Summary of 2017 Incidents. *Journal of Agromedicine*. 10.1080/1059924x2018. 1538420. 2018.
- Nour, M. M., Field, W. E., Ni, J. Q., & Cheng, Y. H. (2020). Farm-Related Injuries and Fatalities Involving Children, Youth, and Young Workers during Manure Storage, Handling, and Transport. *Journal of Agromedicine*, 1-11. doi: 10.1080/1059924X.2020.1795034

Nour, M. M., Cheng, Y. H, Ni, J. Q., Sheldon, Ed., & Field, W. E. (2021). Summary of seven central-state region injuries and fatalities involving livestock manure storage, handling, and transport operations: 1976-2019. *Journal of Agricultural Safety and Health*. (in press). (doi: 10.13031/jash.14343) @2021

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