Chemical facility risks to natural flooding hazards in the United States

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Abstract

Toxic release inventory (TRI) facilities contain chemicals, most must be kept in process equipment, otherwise leaks are possible. An analysis of the National Flood Hazard Layer and TRI facilities within ArcGIS. The national analysis included TRI facilities intersecting the 100-year floodplain based on the National Flood Hazard Layer. The frequency which TRI facilities are impacted by flooding was analyzed with federal declarations data. We were able to determine what percentage of each state’s facilities fall into the floodplain and calculate and assign a risk number to each state.

Keywords

Chemical facility; Toxic release inventory (TRI); Floodplain; Mitigation

1. Introduction

Has the emergency management field failed in solidifying the necessity of chemical facilities to be prepared in the wake of flooding disasters? The desire to have an emergency plan in place when machinery comes to blows with nature is not quixotic, rather, exceedingly pragmatic. As global warming continues on trend, the number of natural disasters, primarily...
Midwest flooding, is only expected to rise [1,2]. How chemical facilities prepare to mitigate the effects of future calamitous storms should have long been set in stone.

Explicit protocols on how chemical facilities mitigate the consequences of an unavoidable natural disaster, such as flooding, are difficult - if not impossible - to find. The common chemical facility practices involve protocols such as Spills Prevention Control and Countermeasure (SPCC) and a Stormwater Pollution Prevention Plan (SWPPP). SPCC was implemented by §311 of the Clean Water Act (CWA); SWPPP was created by the National Pollutant Discharge Elimination System (NPDES) which was implemented in 1972 by the CWA as well. SPCC regulation was established to prevent any oil from reaching waterways, their shorelines, and to, essentially, control oil containment [3]. SWPPP regulation works in a broader sense expanding to include storm water from municipal separate storm sewer systems, construction activities, and industrial activities [4]. Industrial activities are what is referenced from SWPPPs concerning the topics of this article.

There have been plenty chemical facilities impacted by natural disasters throughout history. Examples include the infamous Fukushima disaster on March 11, 2011 when an earthquake caused a tsunami that hit Japan’s Fukushima nuclear power plant [5]; and the Arkema explosions “caused” by significant flooding from Hurricane Harvey put Arkema chemical plant in Crosby, Texas up in flames on August 31 and September 1, 2017 [6]. Granted, the United States Nuclear Regulatory Commission (NRC) has reassured the nation that facilities similar to the aforementioned are able to withstand major natural disasters [7]. Even with evidence that natural disasters can devastate a chemical facility, terrorist attacks seem to be the primary focus of the NRC and its government constituents. While the information regarding the strength of chemical facility infrastructures is largely true, there is always opportunity for incident. For example, a 2011 study and analysis of natural technological, or NaTech, accidents reported evidence of industrial pipes and storage tanks as equipment most vulnerable to floods among other natural disasters. “Toxic dispersion, fire, and explosions” were all observed as a result of natural event analysis [8]. Strategies of how to mitigate such industrial facility accidents as a result of flooding and other natural disaster events was analyzed [9].

As mentioned, the discussions regarding the strength of chemical facility infrastructure generally state they are able to withstand every type of natural disaster. These types of infrastructures are meant to be built strong because, not only are they built in places which they could encounter a devastating storm, but catastrophes which could ensue as a result of a natural disaster could leave the area desolate. Each of the chemical facilities mentioned in this article house chemicals which could harm, if not ruin, their immediate and surrounding environments. The chemicals housed in these facilities, if not kept in a controlled state at all times, are probable causes for detrimental effects on future generations of humans, plants, and animals. This begs the question: Why are chemical facility emergency management plans either too narrow in scope and/or not compelling enough for sites to build the engineering safeguards to mitigate the hazards that occur during a flooding or storm surge event?
This is not to stay that general chemical facilities have zero guidelines whatsoever. The NRC Library offers an extensive list of chemical facility regulations and inspection procedures. Natural disasters are mentioned once within the explanation of regulations. The regulation states the guidelines for the transportation of materials in the event of a natural disaster. Transportation is supposed to be scheduled 24 hrs prior to said event and is elucidated further in § 73.26 Transportation physical protection systems, subsystems, components, and procedures [10]. When searched, the NRC Inspection Procedures lists only one inspection procedure regarding flooding which is Chapter 71111.06 “Flood Protection Measures” with the most current issue date being November 25, 2015. There is also an “Adverse Weather Protection” located in Chapter 71111.01, which was issued on November 28, 2017. These, however, are the only two regulatory guidelines with the keywords ‘weather’ and ‘flooding’ provided by the NRC.

The environment is constantly changing - even without the human impact - and it should be considered enough to worry about surviving impending natural disasters without having to then worry about surviving a chemical facility disaster as a result of the storm’s effects. A study done by the National Oceanic and Atmospheric Administration in 2013 confirmed that the warmer the atmosphere, the more water vapor it can store solidifying the probability of more frequent flooding [11]. Evidence closer to home can be found in the 2014 National Climate Assessment which stated that, relative to the average Midwest air temperature increase from 1979 to 2000, an increase of average Midwest air temperature is projected to fall between 3.8 °F–4.9 °F by mid-century depending on the consistency of global emissions [12]. Both the concentration of water vapor in the atmosphere and rising atmospheric temperature contribute to the likelihood of flooding with erosion from previous flooding playing a major part in future flooding as well.

2. Methods

To identify TRI facilities at greatest risk, a national analysis of the National Flood Hazard Layer and TRI facilities was performed. Current TRI facility data in all 50 states was downloaded from the United States Environmental Protection Agency FRS. The current National Flood Hazard Layer (NFHL) from all 50 states was downloaded from FEMA website [65]. All TRI and NFHL was uploaded within ArcGIS. Then an intersect geoprocessing technique was performed to see which TRI facilities intersected the 1% annual chance flood is also referred to as the 100-year flood. These are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30 [15].

To calculate the percentage of the number of TRI facilities impacted by 100-year flood for each state we simply took the number of facilities within that zone and divided it by the total number of TRI facilities for each state. The potential frequency which TRI facilities could be impacted by flooding, the total reported federal flood declarations were downloaded from the FEMA website [14]. The total number of flood disaster declarations for each state is depicted in Table 1. The probability was calculated by taking each state’s reported flood disasters decelerations divided by the total number of flood disaster declarations. Finally, the risk was calculated by taking the percentage of TRI facilities and multiplying it by the
calculated probability. The risk categories were split into 5 equal intervals of lowest risk, marginal risk, enhanced risk, moderate risk, and highest risk. These intervals are depicted in the Table 1.

3. Results

The results of the national TRI data analysis show that the percentage of TRI facilities located in their respective state’s flood zones range from ~1%–27%. It should be noted, that the percentage does remain worrisome due to the juxtaposition of the amount of TRI facilities in the flood zone against the general amount of TRI facilities in the respective state. In addition, the National Flood Hazard Layer is incomplete in some states. The number of TRI facilities in the 100-year flood zone is expected to grow as the National Flood Hazard Layer is further developed. It should be also noted that the 100-year flood zone changes over time with changes to land development (e.g. construction of impervious surfaces etc.).

Table 1 reveals the percentage of the TRI facilities in each state which fall into the 100-year flood zone. The number of TRI facilities in each state’s flood zone and the total number of state TRI facilities were both datasets extracted from the USEPA FRS which is available to the public through the USEPA website. Table 1 lists the results are listed in ascending order by percentage. We found that 60% of the states have over 5% of TRI facilities which are in the 100-year flood zone. We found the state of West Virginia (26.84% of their total TRI Facilities were located in the 100-year flood zone) had the most TRI facilities located in the 100-year flood zone and Minnesota to have the least (1.41% of their total TRI Facilities located in the 100-year flood zone). All 50 states had some percentage of their total TRI Facilities located in the 100-year flood zone. To further compare this to the number of floods each state has experienced we then compare to the percentage of TRI facilities to the number of Flood related Federal Declarations each state had to develop a risk internal. The risk interval is from one (1) to five (5) with one considered least at risk and five considered most at risk. The risk interval is based on each state’s flood history and number of TRI facilities located in the flood zone. The probability of TRI facility flooding ranges from 0.032 (DE) to 6.93 (IA) state to state. The risk interval based on the latter flood declaration probabilities against the percentage of TRI facilities located in each state’s flood zone range from 0.0026 (DE) to 0.8098 (WV). The states have an even dispersion with ten TRI facilities in each of the risk intervals. It is important to note that although a state may have a higher percentage of TRI facilities located in their flood zones, the percentage of FEMA flood declarations plays a huge role in determining the probability of future flooding. The top two states with the highest number of federal flooding declarations are Iowa with 641 and North Dakota with 596. In Iowa there are eighty-six listed TRI facilities; each one of these facilities are identified in either Zones A, AE, AH, or AO. In North Dakota, there are currently five updated mapped TRI facilities lying within Zone A or AE. The Midwest is relatively concentrated with enhanced, moderate, and highest risk intervals. As depicted in Fig. 1, based on the highest risk interval we found the following states most prone to Flood incidents and TRI facilities located in the 100-year flood zone: Texas, California, Kentucky, Iowa, Virginia, Montana, Pennsylvania, Nebraska, Louisiana, and West Virginia. We found the following states to be least prone to Flood incidents and TRI facilities located in the
4. Discussion

It should be widely agreed upon that safety is the paramount concern and basis for addressing the protocols and regulations of chemical facilities before, during, and after natural disasters. During a flooding event, a facility is only as safe as their preparations have determined they ought to be. This analysis is supportive of the conclusion that all of the United States TRI facilities are at some level of risk in the event of a flooding disaster.

The concentration of high-risk intervals in the Midwest is supported by studies suggesting the Midwest will be experiencing a greater quantity of torrential storms and flooding along with the rise in average temperature come mid-century. The direct correlation between the amounts of flooding declarations of each state to the each state’s assigned risk interval is discussed; however, it is surprising to find seven out of twenty states, which fall into Risk Intervals 4 and 5, are landlocked states. Coastal states flood more often, in turn, earning them more federal flooding declarations. There is a positive relationship between flooding in landlocked states in proximity of mountain ranges and climate change due to an increase in run-off of melted snow and ice. A report by Columbia Law School found that inland states are most likely to actually lack the discussion of climate change when developing State Hazard Mitigation Plans [13].

A limitation worth noting with this analysis is that the National Flood Hazard Layer is incomplete in some states. We can expect these numbers to rise when the flood zones are updated in these areas. Future research should pursue the exact flooding protocols TRI facilities practice state-to-state. Chemical facilities operating at safer flooding standards than their state counterparts should have their standards reviewed to determine the applicability facility to facility. This would lend a hand in determining which specific protocols should be revised and improved in order to contribute to a safer chemical facility environment.

Another question which needs to then be addressed would be, “Should all chemical facilities, no matter their location on a floodplain, be operating with the highest flooding disaster protocols regardless of the possibility or probability of flooding disasters taking place in said location?” A supplemental question should read the same but with ‘general natural disasters’. Such questions suggest that even the rarest natural disaster of a location still has some percentage of taking place and that chemical facilities should be prepared.

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Fig. 1. Chemical facility flood hazard risk intervals.
Table 1
Percentage of TRI facilities in flood zone by state with risk interval.

| State | % of TRI facilities in floodplain | # of flood incidents | Risk interval | State | % of TRI facilities in floodplain | # of flood incidents | Risk Interval |
|-------|----------------------------------|----------------------|---------------|-------|----------------------------------|----------------------|---------------|
| UT    | 1.46%                            | 73                   | 1             | KS    | 5.45%                            | 186                  | 3             |
| SC    | 2.44%                            | 54                   | 1             | NM    | 6.06%                            | 95                   | 3             |
| NH    | 3.27%                            | 49                   | 1             | OR    | 6.89%                            | 117                  | 3             |
| WY    | 4.35%                            | 24                   | 1             | VT    | 7.08%                            | 87                   | 3             |
| AK    | 4.69%                            | 46                   | 1             | CO    | 7.30%                            | 146                  | 3             |
| DE    | 8.02%                            | 3                    | 1             | ND    | 3.27%                            | 596                  | 4             |
| RI    | 9.29%                            | 4                    | 1             | SD    | 4.09%                            | 324                  | 4             |
| NV    | 9.41%                            | 19                   | 1             | WA    | 4.84%                            | 239                  | 4             |
| CT    | 9.45%                            | 17                   | 1             | NY    | 6.25%                            | 208                  | 4             |
| HI    | 11.83%                           | 14                   | 1             | TN    | 7.32%                            | 205                  | 4             |
| MI    | 2.58%                            | 144                  | 2             | OK    | 7.42%                            | 215                  | 4             |
| ID    | 2.80%                            | 84                   | 2             | ARK   | 9.28%                            | 235                  | 4             |
| ME    | 2.91%                            | 96                   | 2             | MS    | 14.12%                           | 125                  | 4             |
| MT    | 3.77%                            | 93                   | 2             | NJ    | 17.39%                           | 70                   | 4             |
| AL    | 4.09%                            | 104                  | 2             | FL    | 18.39%                           | 73                   | 4             |
| NC    | 4.34%                            | 63                   | 2             | TX    | 6.51%                            | 454                  | 5             |
| MD    | 4.54%                            | 62                   | 2             | CA    | 6.91%                            | 320                  | 5             |
| AZ    | 5.04%                            | 77                   | 2             | KY    | 7.14%                            | 403                  | 5             |
| GA    | 6.10%                            | 62                   | 2             | IA    | 8.32%                            | 641                  | 5             |
| MA    | 6.61%                            | 42                   | 2             | VA    | 8.59%                            | 280                  | 5             |
| MN    | 1.41%                            | 555                  | 3             | MO    | 9.37%                            | 502                  | 5             |
| IL    | 2.53%                            | 288                  | 3             | PA    | 10.19%                           | 349                  | 5             |
| WI    | 3.77%                            | 163                  | 3             | NE    | 11.56%                           | 285                  | 5             |
| IN    | 4.04%                            | 208                  | 3             | LA    | 13.28%                           | 331                  | 5             |
| OH    | 4.40%                            | 138                  | 3             | WV    | 26.84%                           | 279                  | 5             |