Literature Review: Industrial Accident (Explosion/Fire)

Synopsis

This qualitative risk assessment of the Industrial Accident-Explosion/Fire hazard suggests that the risk of such incidents occurring is likely holding steady. It primarily assesses the risk of an Industrial Accident-Explosion/Fire, of any size, occurring. Accidents that are so catastrophic as to require Federal support in its response are a small percentage of the overall occurrence of an Industrial Accident-Explosion/Fire event. However, new technologies and emerging risks may create more complex disasters that require more complex preventive measures and responses; and we may see an increase in frequency of requests for Federal assistance in response to Industrial Accident-Explosion/Fire incidents.

Within the scientific literature reviewed, new methodologies are being developed to better understand the domino effects of industrial explosions as well as the emerging risk of incidents triggered by natural hazards, which are called by the European Commission NaTech[292] disasters. Such methodologies should allow Federal, state, and local planners to better evaluate risks and enact prevention and protection mechanisms to reduce the risk, or at least the impact, of explosions in the future.

During the review of a draft of this paper, the Department of Labor's Occupational Safety and Health Administration identified additional sources of literature[293] which address the multi-causal nature of major industrial accidents, and provide quantitative and semi-quantitative risk assessment tools. A limitation of this literature review was the inability to access and review these sources within the time constraints of the project. Future iterations of the SNRA should review these sources.

Several recent incident reports were reviewed, and the literature suggests that more needs to be done to reduce the risks of Industrial Accidents-Explosions/Fires. Current efforts in the Executive and Legislative branches may result in significant changes in the regulation landscape for the first time in decades. If proponents are correct, implementation will reduce risks of industrial accidents. It is too early to tell whether such changes will be enacted or what their ultimate effect on risk reduction will be.

Literature Review – Industrial Accident-Explosion/Fire

Introduction

Event Description

Industrial Accident-Explosion/Fire[294] is a technological accident of an industrial nature, involving an industrial site or production facility (e.g., factories), that results in an explosion and/or fire.[295,296,297,298]

[292] Natural Hazard Triggering Technological Disasters (NaTech)

[293] The Occupational Safety and Health Administration recommended reviewing publications by the Center for Chemical Process Safety (CCPS), which can be found at http://www.wiley.com/WileyCDA/Section/id-291237.html

[294] This paper was originally developed with a scope of Industrial Accident-Explosion. Based on feedback provided during review of the drafts of this working paper, Fire was added to the scope because there have been many incidents where the investigations could not determine whether

Event Background

Explosions[299]

The National Fire Protection Association (NFPA) asserts that historically the term explosion has been difficult to define precisely.[300] Depending on the focus of the standard, NFPA uses different definitions for an explosion. The broader definition is the sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gases under pressure, or the release of gas under pressure. These high-pressure gases then do mechanical work such as moving, changing, or shattering nearby materials.[301,302]

Within that broad definition, there are two major types of explosions: mechanical and chemical.[303] Sub-types of these explosions are differentiated by the source or mechanism by which the blast overpressure is produced.[304]

- Mechanical Explosion: The rupture of a closed container, cylinder, tank, boiler, or similar storage vessel resulting in the release of pressurized gas or vapor. The pressure within the confining container, structure, or vessel is not due to a chemical reaction or change in chemical composition of the substances in the container.[305]
    - The most common sub-type of mechanical explosion is known as a BLEVE—boiling liquid expanding vapor explosion. These are explosions involving vessels that contain liquids under pressure at temperatures above their atmospheric boiling points. The liquid need not be flammable. A BLEVE can occur in vessels as small as disposable lighters or aerosol cans and as large as tank cars or industrial storage tanks. While the initiating event can be caused by vessel failure, the explosion and overpressure associated with a BLEVE is due to expansion of pressurized gas or vapor in the ullage (vapor space) combined with the rapidly boiling liquid liberating vapor.[306]

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the incident was a flash fire or explosion. Future SNRA iterations on this topic should study the fire aspects of this risk, as most of the literature reviewed for this paper was primarily focused on explosions.

[295] For purposes of coordinating with the Strategic National Risk Assessment's (SNRA) Quantitative Analysis, the categorization of this topic is based on the EM-DAT's categorization and sub-typing. Since a Qualitative Assessment does not require comparison of numbers across the spectrum of potential disasters, the threshold used by the EM-DAT (e.g., 10 or more reported fatalities) is not included in this scope to allow for a more nuanced understanding of the risk posed to the U.S. by Industrial Accidents-Explosion and Fire.

[296] EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium) [official citation]. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université Catholique de Louvain located in Brussels, Belgium (http://www.emdat.be/frequently-asked-questions), and is supported by the Office of US Foreign Disaster Assistance (OFDA) of USAID (http://transition.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/).

[297] The EM-DAT's other types of industrial accidents are chemical spill, collapse, fire, gas leak, poisoning, radiation, and other.

[298] Explosions caused by terrorism attacks, armed assault, nuclear weapons, pipeline failures, and combustible/flammable rail cargo incidents are addressed by separate SNRA topical assessments and are outside the scope of this assessment.

[299] This section is based on the definitions for the various explosions discussed in NFPA Standard 921, 2014, *Guide for Fire and Explosion Investigations.* National Fire Protection Association, Quincy, MA. See Chapter 23 "Explosions". Accessed March 2015: http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=921

[300] NFPA Standard 921, 2014, *Guide for Fire and Explosion Investigations.* National Fire Protection Association, Quincy, MA. P. 921-215. Accessed March 2015: http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=921

[301] A definition for "explosion" was not found in the EM-DAT's glossary.

[302] NFPA. "NFPA Glossary of Terms: 2014 Edition". (2014, September). See "Explosion" Definition for Document 921 (2014). Retrieved March 2015: http://www.nfpa.org/got

[303] NFPA Standard 921 (2014). P. 921-215.

[304] NFPA Standard 921 (2014). P. 921-215.

[305] NFPA Standard 921 (2014). P. 921-215. See section 23.2.1 Mechanical Explosions.

[306] This paragraph is a summary of NFPA Standard 921 (2014). P. 921-215-216. See section 23.2.2 BLEVEs and all sub-sections.

- Chemical Explosion: The generation of overpressure is a result of exothermic reactions wherein the fundamental chemical nature of the fuel is changed. Chemical reactions of the type involved in an explosion usually propagate in a reaction front away from the point of initiation.[307]
  - The most common sub-type of chemical explosion is the combustion explosion, caused by the burning of combustible hydrocarbon fuels, and frequently characterized by the presence of a fuel with air as an oxidizer. A combustion explosion may also involve dusts. In combustion explosions, overpressures are caused by the rapid volume production of heated combustion products as the fuel burns. [308]

Combustion explosions are classified as either deflagrations (sub-sonic blast pressure wave) or detonations (blast pressure wave propagates at a velocity faster than the speed of sound). Several sub-types of combustion explosions can be classified according to the types of fuels involved. The most common are flammable gases, vapors of ignitable liquids, combustible dusts, smoke and flammable products of incomplete combustion (backdraft explosions), and aerosols.[309]

Industries Commonly Affected by Industrial Accident-Explosion/Fire

Industries affected by Industrial Accident-Explosion/Fire are wide and varied, including the following examples:[310]

- Chemical manufacturing
- Oil and gas industry—drilling and refineries
- Grain-handling
- Coal mines
- Lumber and wood products
- Food product
- Metal
- Plastic

Table 14: Table of Large Scale Industrial-Accident Explosions from 1989-2013[311]

Start	Location	Plant Name	Killed	Injured	Cause
10/23/1989[312, 313, 314]	Pasadena, Texas	Phillips 66 Company polyethylene plant	23	314	Instantaneous release of >85,000 lbm of flammable material to the atmosphere that ignited during routine maintenance.

[307] NFPA Standard 921 (2014). P. 921-216. See section 23.2.3 Chemical Explosions.
[308] NFPA Standard 921 (2014). P. 921-216. See section 23.2.3 Chemical Explosions.
[309] This paragraph is a summary of NFPA Standard 921 (2014). P. 921-216. See 23.2.3.1 Combustion Explosions and all sub-sections.
[310] List of industries pulled from The Chemical Safety and Hazard Investigation Board. Combustible Dust Hazard Study. Report No. 2006-H-1 (2006, November). Retrieved March 2015, from http://www.csb.gov/assets/1/19/Dust_Final_Report_Website_11-17-06.pdf.
[311] Incidents were identified from EM-DAT, CSB Reports, and Subject-Matter Experts who reviewed drafts of this paper. This table is not exhaustive. It is intended to provide the reader a broad overview of major events involving explosions at industrial sites over the past 25 years. See footnotes for each event for the specific citations for the details listed for each incident.
[312] U.S. Department of Labor, OSHA, September 24, 1991, Federal Register #56:48133.

Start	Location	Plant Name	Killed	Injured	Cause
07/05/1990[315]	Channelview, Texas	Atlantic Richfield Company (ARCO) petrochemical plant	17		Failed oxygen analyzer allowing excessive oxygen in a vapor space of a wastewater storage tank causing an explosion.
09/03/1991[316]	Hamlet, North Carolina	Imperial Foods processing plant	25	54	Failure in a hydraulic line that powered a conveyor belt supplying the deep fat fryer vat spewing hydraulic fluid onto the vat gas-fired burners. Contributing to the deaths was the locked shut fire doors that prevented workers from escaping the fire.
09/10/1997[317]	Columbus, Ohio	Georgia-Pacific Resin plant	1	4	Explosion may have been triggered by adding all the ingredients to the resin kettle (reactor) at one time instead of sequentially.
09/23/2001[318]	Brookwood, Alabama	Jim Walter Resources #5 Coal Mine, Blue Creek coal seam	13	3	The first explosion most likely caused by a scoop battery that was damaged by a roof fall that short circuited and ignited methane gas. This was followed by a more powerful second explosion 55 min. later.
02/28/2004[319, 320]	50 miles off Virginia coast	MT Bow Mariner, Owner: Odfjell ASA of Bergen, Norway; Operator: Ceres Hellenic Shipping Enterprises Ltd. Of Piraeus, Greece	21	6	Ignition of a fuel/air mixture either on deck or in the cargo tanks, that was within its flammable limits. Ignition source could not be precisely determined.
03/23/2005[321]	Texas City, Texas	British Petroleum Texas City Refinery	15	180	Raffinate splitter tower was overfilled; pressure relief devices opened, resulting in a flammable liquid geyser from a blowdown stack that was not equipped with a flare. This release led to an explosion and fire.
01/02/2006[322]	Tallmansville, West Virginia	Wolf Run Mining Company, Sago Mine	12	1	Lightning strikes observed in the area at the time of the explosion. Lightning most likely ignition source that caused the accumulated methane behind a sealed section of the mine to ignite and explode. All other possible ignition sources discounted.

[313] Explosion and Fire at the Phillips Company Houston Chemical Complex, Pasadena, Texas, Chemical Engineering Department, Texas Tech University, Lubbock, Texas 79409.
[314] U.S. Fire Administration/Technical Report Series, Phillips Petroleum Chemical Plant Explosion and Fire, Pasadena, Texas; USFA-TR-035/October 1989.
[315] ARCO Spells Out Cause of Channelview Blast, Oil& Gas Journal, Vol. 89, Issue 2; January 14, 1991.
[316] U.S. Fire Administration/Technical Report Series, Chicken Processing Plant Fires, Hamlet, North Carolina and North Little Rock, Arkansas; USFA-TR-057/June/September 1991.
[317] The Liaisons, Booth et al. v. Georgia Pacific Resins, Inc.; Final Report of Liaison's Investigation Georgia-Pacific Resins, Inc., Columbus, Ohio; October 2005.
[318] United Mine Workers of America Report: Jim Walter Resources #5 Coal Mine Disaster.
[319] United States Coast Guard Investigation Into The Explosion And Sinking Of The Chemical Tanker Bow Mariner In The Atlantic Ocean On February 28, 2004 With Loss Of Life And Pollution; December 14, 2005.
[320] Tanker carrying ethanol explodes, then sinks off Virginia, claiming 21 lives, six rescued. Professional Mariner, February 2007.
[321] Investigation Report Refinery Explosion and Fire BP Texas City March 23, 2005; U.S. Chemical Safety and Hazard Investigation Board; Report No. 2005-04-I-TX, March 2007.
[322] Report of Investigation Fatal Underground Coal Mine Explosion January 2, 2006, Sago Mine, Wolf Run Mining Company, Tallmansville, Upshur County, West Virginia; U.S. Mine Safety and Health Administration, Coal Mine Safety and Health; ID No. 46-08791, May 9, 2007.

Start	Location	Plant Name	Killed	Injured	Cause
02/07/2008[323]	Port Wentworth, GA	Imperial Sugar Company, Manufacturing Facility and Sugar Refinery	14	38	The recently installed steel cover panels on the belt conveyor allowed explosive concentrations of sugar dust to accumulate inside the enclosure. An unknown source ignited the sugar dust, causing a violent explosion. The explosion lofted sugar dust that had accumulated on the floors and elevated horizontal surfaces, propagating more dust explosions and fires throughout the buildings and fires. The pressure waves from the explosions heaved thick concrete floors and collapsed brick walls, blocking stairwell and other exit routes.
04/20/2010[324]	Mississippi Canyon Block #252, Gulf of Mexico	British Petroleum, Macondo Well, Deepwater Horizon Rig	11	17	Well blowout during the mothballing of the well resulting in hydrocarbon fluid under pressure rising to the drilling platform contacting with an ignition source resulting in an explosion and fire.
04/05/2010[325]	Montcoal, West Virginia	Performance Coal Company/Massey Energy, Upper Big Branch Mine-South	29	2	Accumulated methane ignited by longwall shearer causing a massive coal dust explosion.
1/31/2011[326]	Gallatin, TN	Hoeganaes Corp – produces atomized steel and iron powders	5	3	Two Iron Dust (Combustible Dust) Flash Fires and One Hydrogen Explosion which also resulted in iron dust flash fires.
3/21/2011[327]	Louisville, KY	Carbide Industries – produces calcium carbide	2	2	Electric Arc Furnace Explosion
10/09/2012[328]	East Rutherford, NJ	US Ink	0	7	Combustible Dust Flash Fires and Explosion
04/17/2013[329, 330]	West, TX	West Fertilizer Storage and Distribution Facility[331]	15	~200	Fire in wooden warehouse where approximately 20-30 tons of Ammonium Nitrate were stored. CSB and ATF investigations are still pending, but it is believed that the explosion yield was less than 30 tons.[332] 200 homes damaged or destroyed, nursing home, 2 schools, and an apartment complex were demolished. Estimates that damages are $230 million.

[323] U.S. Chemical Safety and Hazard Investigation Board. "Investigation Report: Sugar Dust Explosion and Fire, Imperial Sugar Company" Report No. 2008-05-I-GA. September 2009. Retrieved May 2015: http://www.csb.gov/assets/1/19/Tanks_Safety_Study_FINAL.pdf. http://www.csb.gov/assets/1/19/Imperial_Sugar_Report_Final_updated.pdf

[324] Investigation Report Volume 1 Explosion and Fire at the Macondo Well Deepwater Horizon Rig, Mississippi Canyon Block #252, Gulf of Mexico, April 20, 2010; U.S. Chemical Safety and Hazard Investigation Board; Report No. 2010-10-I-OS, June 6, 2014.

[325] Report of Investigation Fatal Underground Mine Explosion, April 5, 2010, Upper Big Branch Mine-South, Performance Coal Company, Montcoal, Raleigh County, West Virginia; U.S. Mine Safety and Health Administration, Coal Mine Safety and Health; ID. No. 46-08436.

[326] U.S. Chemical Safety and Hazard Investigation Board. "Case Study: Hoeganaes Corporation: Gallatin, TN Metal Dust Flash Fires and Hydrogen Explosion". Report No. 2011-4-I-TN. December 2011. Accessed April 2015: http://www.csb.gov/assets/1/19/CSB_Case_Study_Hoeganaes_Feb3_300-1.pdf

[327] http://www.csb.gov/assets/1/19/Final_Report_small.pdf.

[328] U.S. Chemical Safety and Hazard Investigation Board. ""Board Voting Copy of Case Study: Ink Dust Explosion and Flash Fires in East Rutherford, New Jersey" Report No. 2013-01-I-NJ. January 2015. Accessed April 2015: http://www.csb.gov/assets/1/19/US_Ink_Case_Study_Draft__Board_Vote_Final_RevI.pdf

[329] Accessed April 2015: http://www.csb.gov/assets/1/19/West_Preliminary_Findings.pdf.

[330] Texas State Fire Marshal's Office. "Firefighter Fatality Investigation: Abbott Volunteer Fire Department, Bruceville-Eddy Volunteer Fire Department . . .". Investigation FFF FY 13-06. May 2014. Accessed May 2015: http://www.tdi.texas.gov/reports/fire/documents/fmloddwest.pdf

[331] http://www.nfpa.org/newsandpublications/nfpa-journal/2014/march-april-2014/features/nfpa-400.

[332] OSHA subject-matter experts.

Start	Location	Plant Name	Killed	Injured	Cause
6/13/2013	Geismar, LA	Williams Olefins Petrochemical Plant Explosion and Fire	2	114[333]	Still under CSB investigation: Equipment Failure. "Catastrophic failure involving a heat exchanger and associated piping which broke loose from a distillation tower."[334]

Federal Government Roles

The **U.S. Chemical Safety Board (CSB)**[335] is an independent Federal agency charged with investigating industrial chemical accidents. Headquartered in Washington, DC, the agency's board members are appointed by the President and confirmed by the Senate. The CSB conducts root cause investigations of chemical accidents at fixed industrial facilities. Root causes are usually deficiencies in safety management systems, but can be any factor that would have prevented the accident if that factor had not occurred. Other accident causes often involve equipment failures, human error, unforeseen chemical reactions, or other hazards. The agency does not issue fines or citations, but does make recommendations to plants, regulatory agencies such as the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA), state and local governments, industry organizations, and labor groups. Congress designed the CSB to be non-regulatory and independent of other agencies so its investigations might, where appropriate, review the effectiveness of regulations and regulatory enforcement.

The **Occupational Safety and Health Administration (OSHA)**, Department of Labor, has the authority to set and enforce safety and health standards, which includes the ability to inspect worksites and levy fines.[336] The Process Safety Management (PSM) standard is the OSHA standard that addresses the management of hazards associated with processes using highly hazardous chemicals. The requirements are addressed in specific standards for general and construction industries.[337,338] OSHA is currently in the process of revising the PSM standard in response to the findings from the CSB and the President's 2013 Executive Order on Improving Chemical Facility Safety and Security (E.O. 13650), which directed OSHA and other Federal agencies to modernize policies and regulations.

The **Environmental Protection Agency's (EPA)** mission is to protect human health and the environment, and they do so by developing and enforcing environmental regulations.[339] Pertaining to this topic, the EPA administers the Risk Management Plan (RMP)[340] rule, which requires facilities that use extremely hazardous substances to develop an RMP. EPA is currently reviewing the chemical hazards covered by the Risk Management Program and determining if it

[333] This number includes those hospitalized due to the subsequent Chemical Spill. See http://www.nola.com/environment/index.ssf/2013/06/geismar_eplosion_and_fire_rele.html.
[334] http://www.csb.gov/testimony-of-rafael-moure-eraso-phd-chairperson-us-chemical-safety-board-before-the-us-senate-committee-on-environment-and-public-works-june-27-2013/.
[335] Adapted from the CSB website. Accessed March 2015: http://www.csb.gov/about-the-csb/.
[336] Adapted from OSHA Website: https://www.osha.gov/about.html.
[337] 29 CFR 1910.119 for General Industry, and 29 CFR 1926.64 for Construction.
[338] See www.osha.gov/SLTC/processsafetymanagement.
[339] http://www2.epa.gov/aboutepa/our-mission-and-what-we-do.
[340] Established by Section 112(r) of the 1990 Clean Air Act.

should be expanded to address additional regulated substances and types of hazards (E.O. 13650).[341]

The **Department of Homeland Security (DHS), National Protection and Programs Directorate, Office of Infrastructure Protection (IP),** coordinates national programs and policies on critical infrastructure security and resilience. The office conducts and facilitates vulnerability and consequence assessments to help critical infrastructure owners and operators and state, local, tribal, and territorial partners understand and address risks to critical infrastructure.[342] **DHS IP's Infrastructure Security Compliance Division** is responsible for implementing the Chemical Facility Anti-Terrorism Standards (CFATS),[343] the Nation's program to regulate security at high-risk chemical facilities and prevent the use of certain chemicals in a terrorist act on the homeland through the systematic regulation, inspection, and enforcement of chemical infrastructure security requirements. Under CFATS, facilities that have been determined by DHS to be high-risk are required to develop and implement Site Security Plans (SSPs) or Alternative Security Programs (ASPs) that meet applicable risk-based performance standards (RBPS).[344]

Theme 1: Scientific and Academic Literature on Risk Methodologies for Industrial Accidents

There are a number of scientific and technological papers devoted to the study of explosions. The vast majority are extremely technical—delving into the physics of explosions and mechanisms that can help prevent, detect, or suppress an explosion—and are targeted at the scientific community, the owners and operators of industrial facilities, or the fire fighters that may have to respond to an explosion (or a fire that might lead to an explosion). Standards and regulations, as discussed below, continue to evolve and be strengthened, which leads to additional literature on the effectiveness of those standards.

A Journal of Risk Analysis and Crisis Response article, "The Assessment of Risk Caused by Fire and Explosion in Chemical Process Industry: A Domino Effect-Based Study" by Farid Kadri, E. Chatelet, and Patrick Lallement, develops a quantitative risk assessment of domino effects[345] caused by heat radiation and overpressure on industrial sites.[346] The Europe-based study notes that accidents caused by domino effects are those that cause the most catastrophic consequences. The quantitative method developed in the study allows for the evaluation of the failure probability for each subsystem. The study defines three areas—zone of certain destruction, zone of possible destruction, and safety zone—that may be useful in the choice of safe distances between industrial equipment. The study concludes with the assertion that more quantitative assessment of risk and damage with probabilistic and deterministic modeling is needed.

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[341] http://www2.epa.gov/rmp?_ga=1.184772905.122873663.1395699540.

[342] Adapted from the DHS, IP website: http://www.dhs.gov/office-infrastructure-protection.

[343] DHS leads national implementation of the CFATS. In October 2006, Congress passed Section 550 of the DHS Appropriations Act of 2007, Pub. L. 109-295, authorizing and requiring the DHS to regulate security at chemical facilities that DHS determines are high-risk. To implement this authority, DHS issued the CFATS in 2007.

[344] Adapted from the ISCD website: http://www.dhs.gov/iscd.

[345] The authors note that the term "domino effect" does not have a generally accepted definition in the context of accidents in industrial plants. They define it as an accident in which a primary event propagates to nearby equipment (units), triggering one or more secondary events resulting in overall consequences more severe than those of the primary event. (see page 67, section 1.1)

[346] Kadri, Farid, Chatelet, E., Lallement, Patrick. The Assessment of Risk Caused By Fire and Explosion in Chemical Process Industry: A Domino Effect-Based Study. Journal of Risk Analysis and Crisis Response, 2013, 3 (2), pp.66-76.

Kadri, Chatelet, and Lallement cite other recent research including R.M. Darbra, Adriana Palacios, and Joaquim Casal's study, "Domino effect in chemical accidents: Main features and accident sequences" published in the Journal of Hazardous Materials in November 2010,[347,348] which evaluated 225 accidents involving domino effects. The study showed that:

- Storage areas are the most probable starters of a domino effect (35%), followed by process plant (28%);
- The most frequent accident sequences are explosion-fire (27.6%), and fire-explosion (27.5%) and fire-fire (18%);
- The most frequent causes are external events (31%) and mechanical failure (29%);
- Flammable materials were involved in 89 percent of accidents, the most frequent of which was Liquefied Petroleum Gas (LPG).

Another European-based study published in 2011 examines the threat of natural hazards impacting chemical facilities and infrastructures. The authors, Krausmann, Cozzani, Salzono, and Renni, outline the ongoing efforts in the development of new concepts and tools for Natural Hazard Triggering Technological Disasters (NaTech) hazard and vulnerability ranking, risk assessment, risk-based design, and emergency planning and early warning. NaTech accidents are industrial accidents triggered by natural events, such as earthquakes, floods, and lightning.[349,350] Krausmann, Cozzani, Salzono and Renni suggest that NaTech accidents will be exacerbated by climate change and is an emerging risk issue.

The Krausmann study found that a key challenge of NaTech accidents is that standards for industrial accident preventions do not explicitly address NaTech risk, nor do typical methodologies and tools for the assessment of risk. Their study proposes a risk methodology for NaTech. This new methodology for risk appraisal and characterization provide an approach for the ranking and the quantitative assessment of NaTech risk. These capabilities contribute to risk-based design, emergency planning, and early warning.

While there may not be industry standards for NaTech risks, the current U.S. regulations address these risks in part through the PSM standard, which requires process hazards analyses for foreseeable natural disasters such as floods and lightning strikes.

A 2004 study by the European Commission and United Nations, entitled "State of the Art in NaTech Risk Management"[351] examined seven countries' NaTech Risk Management, including the U.S. Though the date of the study, places it out of the time frame for this Literature Review, it is notable for its examples of NaTech incidents in the United States and summary of the U.S.'s mitigation efforts, including describing the roles and responsibilities of various U.S. agencies. The study found that there is "an increasing trend in this type of emergency" in the United States.

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[347] Darbra, R.M., Palacios, Adriana and Casal, Joaquim. "Domino Effect in Chemical Accidents: Main Features and Accident Sequences." *Journal of Hazardous Materials* 183.1-3 (2010): 565–573. Elsevier. Web. 1 Mar. 2015. http://www.ncbi.nlm.nih.gov/pubmed/20709447.

[348] Full access to this article was not available. Information was obtained from the available abstract.

[349] NaTech risk was acknowledged as an emerging risk in the European 7th Framework Programme Project iNTeg-Risk. See iNTEG-Risk: Early Recognition, Monitoring and Integrated Management of Emerging, New Technology Related, Risks, available at: http://integrisk.eu-vri.eu.

[350] NaTech is a relatively new term. It appears to have gained momentum in the mid-2000's, particularly among European policy and science leadership It is not commonly used in the United States, however, U.S. experts and leaders have participated in dialogues on NaTech.

[351] European Commission, Directorate-General, Joint Research Centre and the United Nations International Strategy for Disaster Reduction. 2004. Report No. EUR 21292 EN. Retrieved May 2015: http://www.unisdr.org/files/2631_FinalNatechStateofthe20Artcorrected.pdf

During the review of a draft of this paper, the Department of Labor's Occupational Safety and Health Administration identified additional sources of literature[352] which address the multi-causal nature of major industrial accidents, and provide quantitative and semi-quantitative risk assessment tools. A limitation of this literature review was the inability to access and review these sources within the time constraints of the project. Future iterations of the SNRA should review these sources.

While the literature indicates NaTech incidents may be increasing most of the accident examples referenced in the literature reviewed did not result in an explosion or fire. [353,354] The lone example from Table 14 above is the West Virginia, Sago Mine explosion in 2006, which is believed to have been caused by a lightning strike.

Theme 2: Recent Investigations and Calls for More Regulations, But Little Regulatory Action Thus Far

Combustible Dust

In 2003, three separate industrial explosions in the U.S. killed a total of 14 workers. The CSB investigations showed a common cause: combustible dust.[355,356] This finding prompted the CSB to conduct a larger study, eventually published in 2006.[357] The objectives of the study were to (1) determine whether combustible dust explosions pose a significant risk in general industry; (2) assess current efforts to manage those risks; and (3) recommend measures that may be necessary to reduce risks.[358]

The CSB identified 281 combustible dust incidents between 1980 and 2005 that killed 119 workers and injured 718, and extensively damaged industrial facilities. The incidents occurred in 44 states, in many different industries, and involved a variety of different materials. The CSB has concluded that combustible dust explosions are a serious hazard in American industry, and that existing efforts inadequately address this hazard.[359]

The study covered various industrial sectors (lumber and wood products, food products, chemical manufacturing) that handle and/or generate combustible dusts. But notably, the CSB excluded incidents involving grain-handling or other facilities currently regulated by the OSHA

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[352] The Occupational Safety and Health Administration recommended reviewing publications by the Center for Chemical Process Safety (CCPS), which can be found at http://www.wiley.com/WileyCDA/Section/id-291237.html

[353] Cruz, A., Katjitani, Y., and Tatano, H. "Natech Disaster Risk Reduction: Can Integrated Risk Governance Help?" *Risk Governance: The Articulation of Hazard, Politics and Ecology*. Edited by Fra.Paleo, Urbano. Springer, 2014. 441.

[354] Phillips, B., Neal, D., Webb, G. Introduction to Emergency Management. CRC Press, 2011. P.115.

[355] The CSB defines a dust explosion as a fire and/or explosion—fueled by any finely divided solid material—that harms people or property.

[356] The NFPA definition of explosions that are dust-related is the bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. This definition is the common one used for NFPA's for industry or commodity-specific dust explosions: NFPA 61, Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities; NFPA 484, Combustible Metals; NFPA 654, Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids; NFPA 655, Prevention of Sulfur Fires and Explosions; and NFPA 664, Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities. See "NFPA Glossary of Terms: 2014 Edition." See "Explosion" definition for documents 61, 484, 654, 655, 664. (2014, September). Retrieved March 2015: http://www.nfpa.org/got.

[357] U.S. Chemical Safety and Hazard Investigation Board (CSB). "Investigation Report: Combustible Dust Hazard Study." Report No. 2006-H-1. November 2006. P1.

[358] CSB. (2006). P6.

[359] This paragraph adapted from the Executive Summary, of the "Combustible Dust Hazard Study." Report 2006-H-1. Published by the U.S. Chemical Safety and Hazard Investigation Board. November 2006. P1.

Grain Handling Facilities Standard; coalmines; non-manufacturing facilities, such as hospitals, military installations, and research institutes; and transportation.

OSHA initiated a combustible dust national emphasis program (DustNEP) in October 2007.[360] The DustNEP conducts focused inspections at facilities that may handle or process combustible dust. Each OSHA Area Office randomly selects four facilities every year in which to conduct combustible dust-related inspections. Since 2007, OSHA conducted over 1,600 inspections in accordance with the DustNEP. Over 1,200 of these inspections resulted in citations and hazard abatement. OSHA considers the DustNEP to be very successful as it creates an enforcement presence in facilities handling and processing combustible dust that, without the NEP, would likely go many years without inspection.

In addition to the DustNEP[361], OSHA has been attempting to publish a comprehensive combustible dust standard since the CSB's report recommended it in 2006.[362]

A survey of literature published since the CSB report shows increased attention to the topic of combustible dust from the scientific and fire communities. Some critics argue, however, that not enough has been done to update regulations and enforcement mechanisms.[363] From 2008 to 2012, the CSB documented 50 combustible dust accidents that led to 29 fatalities and 161 injuries.[364]

Currently, the NFPA is in the process of issuing a new standard—NFPA 652—to be published in the summer of 2015. The NFPA already has five combustible dust standards specific to industries, processes, and dust types. This new, overarching standard will "establish the relationship and hierarchy between it and any of the industry or commodity-specific standards, ensuring that fundamental requirements are addressed consistently across the industries, processes, and dust types."[365]

Deepwater Horizon, New Technologies and the Petrochemical Industry's Safety Culture

On April 20, 2010, an explosion occurred on the Deepwater Horizon Oil Rig. The CSB's final report, prepared in 2014, determined that:

> The blowout preventer (BOP) that was intended to shut off the flow of high-pressure oil and gas from the Macondo well in the Gulf of Mexico during the disaster on the Deepwater Horizon drilling rig on April 20, 2010, failed to seal the well because drill pipe buckled for reasons the offshore drilling industry remains largely unaware… The blowout caused explosions and a fire on the Deepwater Horizon rig, leading to the deaths of 11 personnel onboard and serious injuries to 17 others. Nearly 100 others escaped

[360] The information in this paragraph was provided by OSHA and OSHA's DustNEP website: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=directives&p_id=3830

[361] Combustible Dust National Emphasis Program CPL 03-00-008, 3/11/2008.

[362] An Opinion Editorial by the Chairman of the CSB: Moure-Eraso, Rafael. "The Danger of Combustible Dust." *The New York Times* 22 Aug. 2014. The New York Times Co. Mar. 2015. http://www.nytimes.com/2014/08/23/opinion/the-danger-of-combustible-dust.html?_r=0.

[363] An Opinion Editorial by the Chairman of the CSB: Moure-Eraso, Rafael. "The Danger of Combustible Dust." *The New York Times* 22 Aug. 2014. The New York Times Co. Mar. 2015. http://www.nytimes.com/2014/08/23/opinion/the-danger-of-combustible-dust.html?_r=0.

[364] Ibid.

[365] Colonna, Guy. "Credible Risk." *NFPA Journal*. March 2015. Accessed March 2015: http://www.nfpa.org/newsandpublications/nfpa-journal/2015/march-april-2015/features/dust.

> from the burning rig, which sank two days later, leaving the Macondo well spewing oil and gas into Gulf waters for a total of 87 days…the largest in offshore history.[366]

In a January 2011 Report to the President, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling[367] included the following conclusions:

- The explosive loss of the Macondo well could have been prevented.
- The immediate causes of the Macondo well blowout can be traced to a series of identifiable mistakes made by BP, Halliburton, and Transocean that reveal such systematic failures in risk management that they place in doubt the safety culture of the entire industry.
- Deepwater energy exploration and production, particularly at the frontiers of experience, involve risks for which neither industry nor government has been adequately prepared, but for which they can and must be prepared in the future.
- To assure human safety and environmental protection, regulatory oversight of leasing, energy exploration, and production require reforms… Fundamental reform will be needed in both the structure of those in charge of regulatory oversight and their internal decision-making process.
- Because regulatory oversight alone will not be sufficient to ensure adequate safety, the oil and gas industry will need to take its own, unilateral steps to increase dramatically safety throughout the industry, including self-policing mechanisms that supplement governmental enforcement.[368]

The "systematic failures in risk management," lack of "safety culture," and need for regulatory reforms are consistent with findings from the CSB investigations into other industrial accident-explosion/fire events in the refinery and drilling industry. For example, a 2011 CSB study entitled, Public Safety at Oil and Gas Storage Facilities, found 26 explosions and fires from 1983 to 2010, killing 44 members of the public and injuring 25.[369,370] These incidents differ from those traditionally thought-of as "industrial accidents" because they are not occurring at a plant or facility where employees report to work. Rather these oil and gas production and storage facilities tend to be located in rural areas. The CSB report found that children and young adults were the most common to visit, and the primary purpose for visiting without authorization was for recreational purposes such as "socializing, hunting, and driving all-terrain vehicles."[371] Though in most cases, the members of the public would have been aware that they were trespassing, the CSB found they were "unaware of the explosion and fire hazards associated with

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[366] CSB Press Release, June 5, 2014. "CSB Board Approves Final Report Finding Deepwater Horizon Blowout Preventer Failed…" Retrieved March 2015: http://www.csb.gov/csb-board-approves-final-report-finding-deepwater-horizon-blowout-preventer-failed-due-to-unrecognized-pipe-buckling-phenomenon-during-emergency-well-control-efforts-on-april-20-2010-leading-to-environmental-disaster-in-gulf-of-mexico/.

[367] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (Commission). (January 2011). Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling: Report to the President. Retrieved March 2015: http://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/pdf/GPO-OILCOMMISSION.pdf.

[368] See page vii of the Forward. These are direct quotes from Report. There were two other conclusions that are omitted from this list because they are not relevant to this topic.

[369] Note: these explosions did not reach the level of "large scale industrial accident-explosion or fire" included in Table 14. It is referenced to demonstrate the concerns about safety culture challenges within the industry.

[370] U.S. Chemical Safety and Hazard Investigation Board (CSB). "Public Safety at Oil and Gas Storage Facilities" Report No. 2011-H-1. September 2011. Retrieved March 2015: http://www.csb.gov/assets/1/19/Tanks_Safety_Study_FINAL.pdf.

[371] Ibid. Page 21.

the tanks" and "unintentionally introduce[d] ignition sources for the flammable vapor, leading to explosions".[372] CSB found that many of the incidents occurred at unfenced facilities that "did not have clear or legible warning signs as required under OSHA's Hazard Communication Standard, and did not have hatch locks to prevent access to the flammable hydrocarbons inside the tanks."[373] There were other findings and the CSB made six recommendations when it released the study in 2011. None have been implemented.[374]

A separate example of the lack of safety culture comes from an EnergyWire review of federal labor statistics. The oil and gas industry has more deaths from fires and explosions than any other private industry (see Figure 5). It employs less than one percent of the U.S. workforce, but in the past five years it has had more than 10 percent of all workplace fatalities from fires and explosions.[375,376]

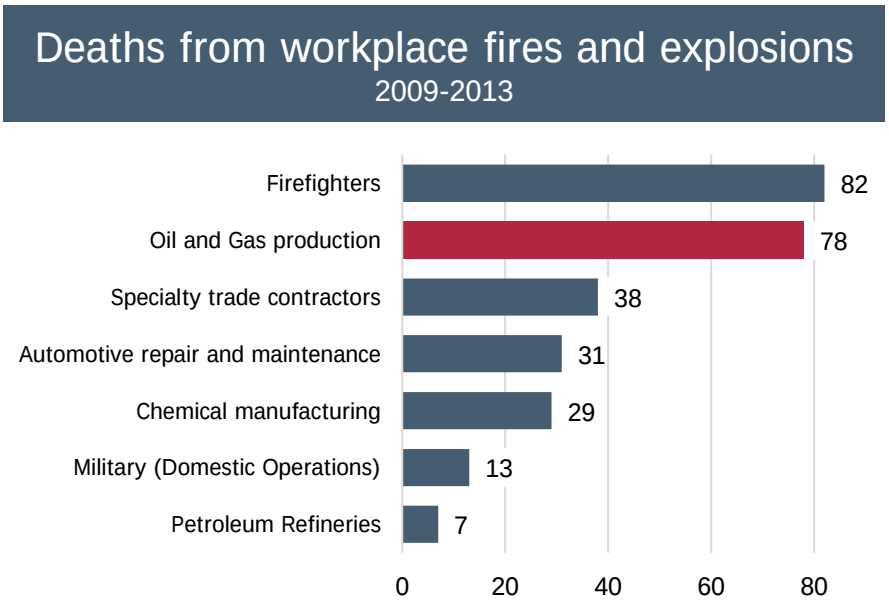

Figure 5: EnergyWire Graphic Based on Bureau of Labor Statistics[377]

Oil and gas production sites are not currently subject to OSHA's Process Safety Management program, and OSHA does not have an industry specific standard for oil and gas, but regulates them under a wide range of standards and their General Duty Clause.[378,379] For example, OSHA frequently cites oil and gas production facilities for 1910 Subpart S - Electrical and for Personal

[372] Ibid. Page 8.
[373] Ibid.
[374] The CSB's investigation webpage shows the number of recommendations made by an investigation report and the number that are "open" and "closed". As of March 2015, the webpage showed all six recommendations remain "open." Retrieved March 2015: http://www.csb.gov/oil-site-safety/.
[375] Soraghan, Mike. "The Drilling Industry's Explosion Problem." *EnergyWire* 20 Oct. 2014. Accessed March 2015: http://www.eenews.net/special_reports/danger_zone/stories/1060007532.
[376] The data collected by the Bureau of Labor Statistics does not offer granularity as to the cause of the fatalities. Explosions are grouped with fire related deaths. Also, while it is likely most of these incidents fall under the industrial accident umbrella, they could be caused by sabotage, work-place violence, terrorism, or other causes that are not within Industrial Accident definition.
[377] Soraghan, M. (2014). Source of data is Bureau of Labor Statistics, Census of Fatal Occupational Injuries.
[378] Soraghan, M. (2014).
[379] Smith, A. (2015).

Protective Equipment (PPE) violations.[380] Likewise, the oil and gas industry receives exemptions from certain aspects of the EPA's regulatory framework.[381] As part of the activities directed by E.O. 13650, OSHA and EPA were to look into strengthening regulations.

New technology at the "frontiers of experience," as the Deepwater Commission framed it, "involve risks for which neither industry nor government has been adequately prepared".[382] While the Commission was referring to the relatively new deepwater drilling technologies, this statement applies to other technologies, for example hydraulic fracturing and directional drilling.

Since 2008, oil production has been on the rise and is now near its 1970 record high.[383] The NFPA Journal reports that the increase is due to the "melding of two advanced drilling techniques that are used to stimulate production of oil and gas wells: hydraulic fracturing, or fracking, and directional drilling".[384] The NFPA asserts that the advanced extraction techniques are not inherently more dangerous than older drilling approaches, but the increase in drilling has increased the number of accidents.[385] Unfortunately, there is no data on the number of fires and explosions at the new drilling sites.

The challenge is that the new drilling sites are often located close to populated communities, and increasingly, communities are moving closer to drilling sites. Not only does this increase the risk of the local community, but also puts local fire fighters in harm's way. Local fire departments are more accustomed to fighting structure fires, and lack the "training, equipment, and tactical approach to handle the fire safely and effectively."[386]

NFPA does not have specific standards for oil and gas drilling sites, but some existing standards would apply. As this is an emerging and growing risk, some have suggested that NFPA write guidelines for fire officials. Separately, the American Petroleum Institute (API) sets safety standards that most states and many Federal agencies have adopted as regulations. In July 2014, the API issued new "Community Engagement Guidelines" for drilling companies.[387] It includes guidelines on engaging with emergency services and first responders.[388] The NFPA Journal article ends with a personal account of how one particular fire department is making an effort to be prepared for the new challenges. It suggests that although the new and increased drilling is increasing the risk of fires and explosions, through proper planning and training and partnering with the drill owners, the risks can be mitigated.

In addition to the drilling hazards, there is also some new evidence that oil from fracking may be more volatile than traditionally drilled oil.[389] Though outside the scope of this assessment, from

[380] Information provided by OSHA.
[381] CSB (2011). P. 42.
[382] Commission. (January 2011). Executive Summary.
[383] See U.S. Field Production of Crude Oil Annual, Historical Chart produced by the U.S. Energy Information Administration. Accessed March 2015: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS1&f=A
[384] Smith, A. "New Frontier". NFPA Journal. March 2, 2015. Retrieved March 2015 http://www.nfpa.org/newsandpublications/nfpa-journal/2015/march-april-2015/features/fracking.
[385] Smith, A. (2015).
[386] Smith, A. (2015).
[387] American Petroleum Institute (API). Community Engagement Guidelines: ANSI/API Bulletin 100-3, First Edition, July 2014. Accessed March 2015: http://www.api.org/~/media/files/policy/exploration/100-3_e1.pdf
[388] API. (2014). P 7.
[389] Sider, A. and Friedman, N. "Oil from U.S. Fracking is More Volatile Than Expected". Wall Street Journal, June 24, 2014. Retrieved March 2015: http://www.wsj.com/articles/oil-from-u-s-fracking-is-more-volatile-than-expected-1403653344

mid-February 2015 to early March, four trains hauling oil derailed in the U.S. and Canada causing spills and explosions.[390] Most were hauling Bakken crude that was extracted by fracking, which some government tests showed is more volatile than other crude oil.[391] Investigations into these incidents are ongoing, and the cause of the explosions are unknown at this time.

More Calls for Updating and Strengthening Regulations

In 2013, an explosion at a fertilizer storage facility in West, Texas, killed 15 people, injured over 200, and damaged or destroyed over 200 homes, two schools, an apartment complex, and a nursing home. West is a small town and the explosion decimated it. Two months after the explosion in West, a fire and explosion occurred at a petrochemical plant in Geismar, Louisiana, that killed two workers and injured over 100 more.

These events renewed attention to the dangers of industrial explosions. In response, the President issued E.O 13650[392] on August 1, 2013, which directed DHS, OSHA, and EPA to perform a number of tasks to improve chemical facility safety and security. Congressional hearings[393,394,395] were held and GAO issued several reports on chemical safety[396] and chemical facilities[397].

One of the tasks from the E.O. was to update chemical safety and security regulations, which have not been updated in decades. This is not an easy undertaking. A 2012 GAO study found that it took an average of seven years to develop and issue safety and health standards.[398]

Some within the chemical industry have stated their support for stronger regulatory oversight, but have less interest in promulgating new regulations.[399] Some of this may be due to what is consistently called the "patchwork" nature of the current regulatory scheme, which is further complicated by multiple agencies (DHS, EPA, and OSHA) having various regulatory responsibilities. While the various positions and nuances of the debate are outside the scope of

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[390] Lowy, J. "Recent spate of derailments in the US, Canada deepens fear of possible oil train disaster". Associated Press. March 10, 2015. Retrieved March 2015: http://www.usnews.com/news/business/articles/2015/03/10/spate-of-oil-train-derailments-raises-safety-concerns

[391] The API disagrees with this assertion.

[392] https://www.whitehouse.gov/the-press-office/2013/08/01/executive-order-improving-chemical-facility-safety-and-security.

[393] Oversight of Federal Risk Management and Emergency Planning Programs to Prevent and Address Chemical Threats, Including the Events Leading up to the Explosions in West, TX and Geismar, LA: Hearings before the Full Committee on Environment and Public Works, Senate, 113th Cong. (June 27, 2013). Retrieved March 2015: http://www.epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=64099921-ffdc-075c-1328-f94f2fb7bae6.

[394] Oversight of the Implementation of the President's Executive Order on Improving Chemical Facility Safety and Security: Joint Committee Hearing of Environment and Public Works, and Health, Education, Labor, and Pensions, Senate, 113th Cong. (December 11, 2014). Retrieved March 2015: http://www.epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=b2085dfd-ecb0-3b54-db5e-d2ed8a7730eb.

[395] West Fertilizer, Off the Grid: The Problem of Unidentified Chemical Facilities: Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, Committee on Homeland Security, House, 113th Cong. (August 1, 2013). Retrieved March 2015: https://homeland.house.gov/hearing/subcommittee-hearing-west-fertilizer-grid-problem-unidentified-chemical-facilities.

[396] Moran, R. (2014). Chemical Safety: Action Needed to Improve Federal Oversight of Facilities with Ammonium Nitrate. Government Accountability Office, GAO-14-274. Retrieved March 2015, from http://gao.gov/assets/670/663293.pdf.

[397] Caldwell, S. (2013). DHS Needs to Improve Its Risk Assessments and Outreach for Chemical Facilities. Government Accountability Office, GAO-13-801T. Retrieved March 2015, from http://www.gao.gov/products/GAO-13-801T.

[398] See http://www.gao.gov/products/GAO-12-330

[399] Testimony of Timothy J. Scott, Chief Security Officer and Corporate Director Emergency Services and Security, The Dow Chemical Company, Representing The American Chemistry Council at a hearing on: West Fertilizer, Off the Grid: The Problem of Unidentified Chemical Facilities: Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, Committee on Homeland Security, House, 113th Cong. (August 1, 2013). Retrieved March 2015: http://docs.house.gov/meetings/HM/HM08/20130801/101223/HHRG-113-HM08-Wstate-ScottT-20130801.pdf

this assessment, what is germane is that there is agreement that the current regulatory system needs to be improved.

Finally, relevant to EPA's authorities, U.S. Senators David Vitter (R-La.) and Tom Udall (D-N.M.) introduced new legislation designed to fix the outdated chemical regulatory program managed by the EPA.[400] The Frank R. Lautenberg Chemical Safety for the 21st Century Act[401] would update the 1976 Toxic Substances Control Act (TSCA). It has been in development for several years and included negotiations with the industry, environmentalists, and affected communities. If enacted, it does not appear to affect OSHA or DHS's responsibilities.

It remains to be seen whether the bill will make it through Congress. The initial hearing demonstrated there are strong supporters, but also strong critics of the bill who believe it contains too many compromises.[402]

Conclusion

The Literature Review suggests that more needs to be done to improve the current regulatory scheme in order to further reduce the risks of Industrial Accident-Explosion/Fire. Current efforts in the Executive Branch (related to the implementation of E.O. 13650) and the Legislative Branch (Frank R. Lautenberg Chemical Safety for the 21st Century Act) may result in significant changes for the first time in decades. If proponents are correct, implementation will reduce risk and/or mitigate the consequences of industrial accidents. It is too early to tell whether such changes will be enacted.

Within the scientific literature reviewed, new methodologies are being developed to better understand the domino effects of industrial explosions, as well as the emerging risk of NaTech disasters. Such methodologies should allow Federal, state, and local planners to be able to better evaluate risks and enact prevention and protection mechanisms to reduce the risk or at least the impact of explosions in the future.

The Literature Review highlighted two types of potential emerging risks:

1. NaTech: The European 7th Framework Programme Project iNTeg-Risk believes NaTech is an emerging risk that will likely increase due to climate change. Thus, we may begin to see new or increasing numbers of explosions caused by natural hazards (as compared to historic trends). While explosion as a potential event caused by natural hazards is part of the NaTech definition, existing literature tends to focus on other accidents, such as chemical spills. Currently, the overwhelming majority of industrial accidents resulting in an explosion are unrelated to natural hazards. This may, however, be an area relevant for future study. Additionally, future iterations of the SNRA should review the sources provided by OSHA which address the multi-causal nature of major industrial accidents, and provide quantitative and semi-quantitative risk assessment tools.

[400] Press Release: Vitter, Udall Introduce Landmark Legislation to Protect Our Families from Toxic Chemicals. March 10, 2015. Retrieved March 2015: http://www.vitter.senate.gov/newsroom/press/vitter-udall-introduce-landmark-legislation-to-protect-our-families-from-toxic-chemicals

[401] S. 1009 text and current status can be found here: http://www.scribd.com/doc/258283745/The-Frank-R-Lautenberg-Chemical-Safety-for-the-21st-Century-Act

[402] See Transcript of Hearing: Frank R Lautenberg Chemical Safety for the 21st Century Act: Committee on Environment and Public Works, Senate, 114th Cong. March 18, 2015. Retrieved March 2015: http://www.epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_id=60d1e265-cdac-7629-3385-2d72dd8fe3eb

2. New technology at the "frontiers of experience," as the Deepwater Commission framed it, "involve risks for which neither industry nor government has been adequately prepared".[403] Techniques such as "fracking" often occur close to suburban and urban communities. Some assert in the literature that the petrochemical industry has a poor record of safety and that the safety culture remains weak. Between the increase in drilling sites, and the potential weak safety culture, an emerging risk could be explosions at fracking sites near populated communities. The literature reviewed focused specifically on the new technology within the petrochemical industry; however, it is reasonable to assume other industries, particularly the chemical industry, are developing and implementing new technologies. It will be a challenge for regulators to keep up with emerging technologies.

This literature review primarily focused on assessing the risk of an Industrial Accident-Explosion/Fire, of any size, occurring. Accidents that are so catastrophic to require Federal support in its response are a small percentage of the overall occurrence of an Industrial Accident-Explosion/Fire event. This assessment leaves frequency calculations to the Quantitative Assessment. However, this qualitative assessment suggests that new technologies and emerging risks may create more complex disasters that require more complex preventive measures and responses. Thus, we may see an increase in frequency of requests for Federal assistance in response to Industrial Accident-Explosion/Fire incidents.

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Smith, A. "New Frontier". NFPA Journal. March 2, 2015. Retrieved March 2015: http://www.nfpa.org/newsandpublications/nfpa-journal/2015/march-april-2015/features/fracking.

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