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Research Article

Hazardous Chemical Incidents in the United States: A Five-Year Public Health Surveillance Study

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ABSTRACT

Study objectives: Hazardous chemical accidents include unintentional spills, leaks, explosions, or exposures to toxic, flammable, or otherwise harmful substances that threaten public health. These events occur at industrial facilities, during transportation, at storage sites, or after natural disasters affecting chemical plants. We analyzed the occurrence, causes, and consequences of hazardous chemical incidents across the United States from 2021 through 2025.

Methods: We retrospectively collected and cross-referenced incident data from six publicly available sources: the Coalition to Prevent Chemical Disasters, the Environmental Protection Agency, the Pipeline and Hazardous Materials Safety Administration, the National Response Center, the Chemical Safety Board, and the Occupational Safety and Health Administration. Using a standardized abstraction form, reviewers collected data on location, released substances, injuries, and community consequences. We summarized variables using descriptive statistics. Interrater reliability was assessed using Cohen's kappa on a random sample of incident records.

Results: During the study period, 137,927hazardous chemical incidents occurred nationally, causing more than $1.8billion in damages. Of these, 1,368(1.0%) met inclusion criteria as public health-threatening incidents. Annual counts increased from 191in 2021to a peak of 339in 2023. Texas accounted for 12.6%of incidents, followed by California, Ohio, Louisiana, and Pennsylvania. The most involved sectors were plastics and petrochemical manufacturing (41.7%), oil and gas extraction and transportation (12.2%), and miscellaneous manufacturing (11.6%). Incidents resulted in 1,516injuries, 309hospitalizations, 63first-responder injuries, and 91deaths. Smoke inhalation was the most reported acute symptom (34.9%). Evacuations occurred in 390communities (28.5%), shelter-in-place orders in 377(27.5%), road closures in 198incidents (14.5%), and documented water contamination in 117communities (8.6%). Weather-related events represented only 3.5% of incidents. Interrater reliability was excellent (Cohen's κ=0.78).

Conclusions: Hazardous chemical incidents remain a substantial and potentially growing public health threat in the US. Most were linked to potentially preventable factors, including human error and equipment failure. Enhanced equipment maintenance,

stronger safety regulations, and comprehensive workforce training may reduce injuries, deaths, and community harms.

Keywords: Cross-sectional study, surveillance, hazardous chemical incidents, chemical accidents, industrial accidents, chemical exposure injuries, environmental contamination, smoke inhalation

Introduction

Emergency physicians and first responders are increasingly called to manage the consequences of hazardous chemical incidents - uncontrolled releases of toxic, flammable, or reactive substances that can injure workers, surrounding communities, and responders alike. These events span a wide range of scenarios, including explosions at industrial facilities, spills during rail or highway transport, leaks from chemical storage sites, and toxic releases triggered by natural disasters[1]. Health consequences can be immediate and severe or develop slowly after an undetected "silent" release[2,3].

Between 2021 and 2023, the Coalition to Prevent Chemical Disasters documented more than 825 such incidents across the United States, including fires, explosions, and toxic releases that led to nearly 200 community evacuations[4,5]. Data from the National Toxic Substances Incidents Program (NTSIP), a federal surveillance system operated by the Agency for Toxic Substances and Disease Registry (ATSDR), identified 22,342 toxic substance incidents across nine states from 2010 to 2014 alone, resulting in 6,635 injuries and 190 deaths[6].

Despite the frequency and severity of these events, national surveillance remains fragmented across multiple federal agencies - including the Environmental Protection Agency (EPA), the Department of Transportation (DOT), the US Coast Guard, and the Chemical Safety Board (CSB). There is no unified reporting system. As a result, no single agency has the full picture, and policymakers, emergency planners, and clinicians work with incomplete data[6-8]. To better characterize this burden, we analyzed publicly available federal and nonprofit databases to document the frequency, geographic distribution, industrial-sector involvement, and health consequences of hazardous chemical incidents in the United States from 2021 through 2025.

Methods

Study design

This retrospective, cross-sectional study used secondary data analysis to characterize the frequency, distribution, and health consequences of hazardous chemical incidents in the United States from January 1, 2021, through December 31, 2025.

Case definition

A hazardous chemical incident was defined as any uncontrolled or unintentional release of a toxic, flammable, reactive, or otherwise harmful substance - occurring at a fixed facility, during transportation, or in storage - that resulted in death, injury, acute symptoms, community evacuation, shelter-in-place directives, or environmental contamination, as documented by a responding agency or reported in the news media. This definition aligns with those used by the ATSDR National Toxic Substances Incidents Program (NTSIP) and the EPA Risk Management Program (RMP)[6,8-11]. We excluded intentional releases (e.g., acts of terrorism) and incidents outside the United States.

Inclusion and exclusion criteria

We included incidents that occurred in the United States (including the contiguous states, Alaska, and Hawaii) between January 1, 2021, and December 31, 2025, and that were documented in at least one of the six surveillance databases. Eligible events involved an unintentional release of a toxic, flammable, reactive, or otherwise harmful chemical substance at a fixed facility or storage site, or during transportation by highway, rail, air, or water.

To meet the study definition of a public health-threatening event, incidents were required to result in either an acute injury or death among workers, first responders, or members of the public, or at least one documented off-site consequence. Off-site consequences included a community evacuation, a shelter-in-place directive, road closure, or environmental contamination extending beyond the incident site, including contamination of a community water supply. This distinction allowed us to capture injuries among on-site workers and responders while separately characterizing impacts on surrounding communities; acute chemical-incident surveillance similarly recognizes injuries among persons affected by the event and public-protective actions such as evacuation.

We excluded intentional releases, near-miss events without a confirmed chemical release, incidents outside US jurisdiction, biological or radiological events, and events with neither a documented injury nor a fatality, nor an off-site public health consequence.

Data sources

Incident data were collected and cross-referenced from the following six publicly available databases:

- **Coalition to prevent chemical disasters incident tracker:** The primary data source, maintained by Coming Clean and the Environmental Justice Health Alliance for Chemical Policy Reform (EJHA), captures incidents identified through news media surveillance[4,5].
- **US Environmental Protection Agency (EPA) Risk Management Program (RMP):** Tracks chemical incidents at regulated facilities. Facility location data and RMP coverage status were provided by Material Research, LLC[11].
- **US Coast Guard National Response Center (NRC):** Tracks chemical spills posing public health threats, including incidents not captured in news media[12].
- **US department of transportation PHMSA hazmat incident report search tool:** Tracks transportation-related chemical incidents on the nation's railroads and highways[13].
- **Chemical safety board (CSB):** An independent federal agency investigating chemical incidents to determine root cause[4].

- **Occupational Safety and Health Administration (OSHA):** Work-related Injury and Illness Database, reviewed for chemical occupational incidents[14].

The Coalition Incident Tracker served as the primary enumeration source[4,5]. We queried supplementary databases to identify incidents not captured by the news media and to augment incomplete records. Cross-database matching used the date, state, and chemical substance as linking variables; when the same incident appeared in more than one source, it was counted only once. No unique federal incident identifier exists across all six databases; therefore, trained investigators used manual matching.

Abstraction instrument

The data abstraction instrument was developed using variable frameworks from established chemical incident surveillance systems (HSEES and NTSIP) and federal reporting tools such as DOT Form F 5800.1[1,6,13]. Draft versions were iteratively refined to ensure that key domains - incident characteristics, chemical exposure details, industrial sector, and public health consequences - could be captured consistently across heterogeneous data sources. The final form included structured fields with explicit operational definitions and prespecified coding rules, supported by a brief decision manual for common edge cases (e.g., mixed-chemical releases, multi-jurisdiction events, ambiguous injury reports). Pilot testing on a sample of incidents identified unclear items and prompted adjustments to wording, ordering, and skip patterns before full deployment.

Data abstraction

Incident records were abstracted using the standardized instrument. For each eligible incident, abstractors recorded basic event characteristics (date, state, facility or transport setting, and industrial sector), key exposure details (primary chemical(s) and a brief description of the release), and public health consequences (injuries, fatalities, first responder injuries, evacuation, shelter-in-place orders, road closures, and water contamination). When available, we also documented contributing factors (e.g., equipment failure, human error, weather), EPA RMP coverage status, and weather-relatedness.

Trained medical student research assistants at Michigan State University College of Human Medicine conducted data abstraction. All abstractors completed group training sessions covering the instrument and calibration exercises using simulated incident records. A supervising investigator regularly reviewed the team's work, flagged problematic records, and brought unresolved cases to the full group for a consensus decision. We double-abstracted a random sample of incidents to assess interrater reliability.

Statistical analysis

We summarized all study variables with descriptive statistics and reported frequencies and percentages for categorical variables. We conducted all analyses using SAS version 9.4 (SAS Institute Inc., Cary, NC). We assessed interrater reliability using Cohen's kappa on a random sample of 100 incident records, with values ≥ 0.80 defined a priori as indicating excellent agreement. The Michigan State University College of Human Medicine Institutional Review Board (IRB) determined that this study was exempt from IRB review (Protocol #00011156).

Results

During the study period (January 1, 2021 - December 31, 2025), 137,927 hazardous chemical incidents occurred across the United States, causing more than $1.8 billion in damage. Of these, 1,368 (1%) met the inclusion criteria and were classified as incidents threatening public health. Incident counts rose steadily, from 191 in 2021 to a peak of 339 in 2023, dipped to 285 in 2024, and rebounded to 335 in 2025 - a net increase of 77% over the study period **(Table 1)**.

Table 1: Outcomes of Hazardous Chemical Incidents in the United States, 2021-2025.

Year	Incidents	Injuries	Hospitalizations	Fatalities	Evacuations
2021	191	63	52	18	47
2022	218	222	56	11	63
2023	339	340	63	27	100
2024	285	402	61	22	79
2025	335	489	77	22	91
Total	1,368	1,516	309	91	380

There were 1,516 injuries during the study period; 309 (20.4%) required hospitalization. Of the injured, 63 (4.2%) were first responders. There were 91 fatalities. The most frequently reported acute symptoms were smoke inhalation (n=529, 34.9%), thermal burns (n=449, 29.6%), caustic injuries (n=293, 19.3%), and injuries from falling debris (n=253, 16.7%).

During the study period, 390 communities received evacuation orders and 377 received shelter-in-place directives, representing 28.5% and 27.5% of qualifying incidents, respectively. Road closures occurred in 198 incidents (14.5%), and water contamination was documented in 117 communities (8.6%).

Geographic distribution

Texas recorded the most incidents (n=172, 12.6%), followed by California (n=103, 7.5%), Ohio (n=78, 5.7%), Louisiana (n=73, 5.3%), and Pennsylvania (n=61, 4.5%) **(Figure 1)**. Together, these five states accounted for 35.6% of all qualifying incidents. The remaining states in the top 12 were Tennessee (n=53), Illinois (n=49), Florida (n=44), Michigan (n=42), Georgia (n=38), Massachusetts (n=35), and Kentucky (n=34). Incidents were concentrated in states with high densities of petrochemical manufacturing, oil and gas extraction, and chemical transportation infrastructure.

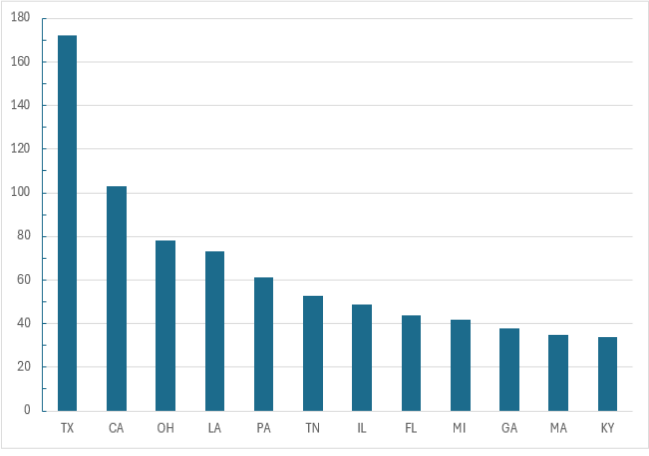

Figure 1: States with the Most Chemical Incidents.

Industrial sector distribution

Plastics and petrochemical manufacturing accounted for the largest share of incidents (n=570, 41.7%), followed by oil and gas extraction and transportation (n=167, 12.2%) and miscellaneous manufacturing and other industries (n=159, 11.6%) **(Table 2)**. The next most common sectors were food and beverage refrigeration (n=124, 9.1%), chemical transport, distribution, and storage (n=111, 8.1%), and waste and recycling (n=109, 8.0%). Together, these six sectors accounted for approximately 90.7% of all qualifying incidents. Less common sectors included metalworking, plating, and coating (n=49, 3.6%), fertilizer production and storage (n=27, 2.0%), water and wastewater treatment (n=17, 1.2%), pulp and paper (n=16, 1.2%), pesticide use and storage (n=11, 0.8%), and radioactive waste (n=8, 0.6%).

Table 2: Hazardous Chemical Incidents by Industrial Sector, United States, 2021–2025.

Industrial Sector	n	%
Plastics & Petrochemical Manufacturing	570	41.67
Oil & Gas Extraction & Transportation	167	12.21
Miscellaneous Manufacturing & Other	159	11.62
Food & Beverage Refrigeration	124	9.06
Chemical Transport, Distribution & Storage	111	8.11
Waste & Recycling	109	7.97
Metalworking, Plating & Coating	49	3.58
Fertilizer Production & Storage	27	1.97
Water & Wastewater Treatment	17	1.24
Pulp & Paper	16	1.17
Pesticide Use & Storage	11	0.8
Radioactive Waste	8	0.58

Frequently identified chemicals included ammonia, vinyl chloride, benzene, 1,3-butadiene, hydrogen sulfide, chlorine, hydrofluoric acid, xylene, toluene, and sulfur dioxide, along with related petrochemical feedstocks and fuels.

Causal factors

Only 48 incidents (3.5%) were weather-related, indicating that most were preventable. Documented causal factors included human error, equipment failure, poor maintenance, corrosion, improper packaging or handling, transportation crashes, design deficiencies, permit-to-work failures, management-of-change gaps, contractor safety issues, inadequate hazard communication, and process safety lapses during startup, shutdown, or transfer operations. Prevention measures identified in incident narratives included structured inspection programs, inherently safer design, compliance with safety codes, gas detection systems, secondary containment, and strengthened emergency planning. Interrater reliability was excellent (Kappa = 0.78).

Discussion

This five-year retrospective surveillance study documented 137,927 hazardous chemical incidents across the United States. A total of 1,368 incidents met criteria for threatening public health, resulting in 1,516 injuries, 91 fatalities, and measurable community disruption in hundreds of communities. These findings reinforce prior surveillance data: hazardous chemical incidents are common, underappreciated, and, in most cases, preventable.

Geographic and sectoral concentration

The disproportionate burden in Texas, California, Ohio, Louisiana, and Pennsylvania reflects the geographic concentration of petrochemical and industrial infrastructure in those states - a pattern consistent with prior HSEES surveillance data, which identify Texas as the state with the highest frequency of hazardous substance releases[1]. Plastics and petrochemical manufacturing (41.7%) was the dominant sector, underscoring the outsized hazard risk generated by the fossil fuel supply chain and reinforcing calls for stronger EPA regulatory oversight. Food and beverage refrigeration ranked fourth (9.1%), reflecting the widespread industrial use of ammonia as a refrigerant and its well-documented hazards[5]. These findings support sector-specific regulatory inspections and targeted emergency response planning.

Temporal trend

Annual incident counts rose 77% from 2021 to the 2023 peak. This aligns with EPA data showing rising rates of evacuations, shelter-in-place orders, and chemical-related medical visits nationwide, despite industry claims of declining accident rates[11]. The 2023 spike may partly reflect heightened media and regulatory attention following the East Palestine, Ohio, train derailment in February 2023, which may have improved reporting completeness that year[15]. Incident counts remained near peak levels in 2025, suggesting 2023 was not an outlier but part of a continuing upward trend.

Health consequences and emergency preparedness

Smoke inhalation was the leading acute injury (34.9%), followed by thermal burns (29.6%), caustic injuries (19.3%), and injuries from falling debris (16.7%). This pattern aligns with prior HSEES surveillance data identifying respiratory injury as the most common health consequence of chemical manufacturing incidents[1,16]. Emergency clinicians need to recognize this injury spectrum - inhalation injury, hydrofluoric acid burns, and caustic esophageal damage - because patients often present hours after a community incident, without an obvious exposure history.

First responders accounted for 4.2% of all injured persons (n=63), consistent with prior national analyses identifying respiratory problems as the most common first responder injury during chemical incidents, with ammonia and carbon monoxide among the most frequently implicated agents[16,17]. The recently published Pennsylvania first responder assessment following the East Palestine derailment reinforced that specific job duties, particularly fire suppression, carry the highest exposure risk, supporting the development of role-specific protective protocols[18].

Community impact

The community burden was substantial: 390 evacuations (28.5%), 377 shelter-in-place directives (27.5%), 198 road closures (14.5%), and water contamination in 117 communities (8.6%). Water contamination is particularly concerning because it can trigger secondary public health emergencies that extend far beyond the immediate incident perimeter. Communities near chemical facilities are disproportionately low-income and communities of color[19]. When evacuation, shelter-in-place, and water contamination occur together, as they did in many of these incidents, communities with pre-planned, integrated response

frameworks are far better positioned to protect public health than those relying on improvised coordination.

Human error as the primary cause

Only 3.5% of incidents were weather-related, leaving the vast majority preventable. Documented root causes, including human error, equipment failure, permit-to-work failures, management-of-change gaps, and inadequate hazard communication, reflect failures across multiple layers of organizational and regulatory oversight[1,3,5]. No single fix will address a failure pattern this broad. A systems-level approach that includes equipment inspection, process safety management, worker and contractor training, and strengthened regulatory enforcement is necessary to meaningfully reduce incident rates[20].

Limitations

Several limitations merit consideration. Because the primary data source relies on news media surveillance, the 1,368 qualifying incidents likely represent a conservative lower bound; events in rural areas, smaller facilities, or states with lower media coverage are systematically underrepresented. Heterogeneity in how incidents are classified across six databases may introduce coding inconsistencies despite the use of a standardized abstraction instrument. Cross-database deduplication relied on date, state, and substance rather than a unique federal identifier, so residual duplicates cannot be entirely ruled out. Data completeness varies by state, which may confound geographic comparisons. Finally, the cross-sectional design precludes causal inference, and observed temporal trends may reflect changes in reporting practices as much as true changes in incident frequency. Closing this gap requires pairing media-based surveillance with the existing mandatory datasets - EPA RMP records, OSHA injury logs, PHMSA transportation reports - to build a comprehensive rather than a convenient picture.

Future Directions

This study raises several questions worth pursuing. First, the five-year upward trend in incident counts warrants explanation. Only a prospective study with mandatory, standardized reporting across all federal databases can determine whether it reflects a true increase in chemical releases, improved reporting, or both. Second, the high rates of community evacuation and water contamination in this dataset indicate an unmet need for systematic follow-up research on the downstream health effects of these events, particularly in communities with repeated exposures over time. Third, the disproportionate burden borne by Texas, Louisiana, and other petrochemical-heavy states makes a compelling case for state-level analyses linking incident data to demographic and environmental justice indicators - identifying which communities bear the greatest risk and whether regulatory enforcement is allocated accordingly. Finally, first-responder health outcomes warrant a dedicated longitudinal study. The East Palestine experience demonstrated that acute exposure data alone cannot capture the full occupational health burden of HAZMAT response[18]. A registry-based cohort design, modeled after existing firefighter health studies, would provide the long-term follow-up this population needs[17].

Future Directions

This five-year surveillance study documents the substantial and growing public health burden of hazardous chemical incidents in the United States. It reports 1,368 qualifying incidents that resulted in 1,516 injuries, 91 fatalities, and widespread community disruption, including evacuations, shelter-in-place orders, road closures, and water contamination. The 77% increase in annual incident counts between 2021 and 2023, combined with the finding that only 3.5% of incidents were weather-related, indicates that most harm stems from preventable causes-including human error, equipment failure, and process safety deficiencies. Improved equipment maintenance, stringent safety regulations in the plastics, petrochemical, oil and gas sectors, and comprehensive training for workers, contractors, and first responders are urgently needed.

Communities should not develop evacuation and water protection plans after an incident. Those plans need to exist and be practiced in advance, in close coordination with local emergency services, environmental agencies, and nearby industry. The concentration of incidents in a small number of states and industrial sectors presents a clear opportunity for targeted regulatory enforcement. Without a unified, mandatory national reporting system, the true scale of harm from chemical incidents will remain obscured, and policies meant to prevent them will be difficult to evaluate.

Conflict of interest and funding

The authors declare no conflicts of interest and that no funding was provided for this clinical study.

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