Comparison of Accident Databases and Analysis of Past Industrial Accidents in the Chemical Process Industry

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Abstract-Despite India being home to some of the worst chemical industry disasters, there is no proper accident reporting and analysis mechanism. The National Informatics Centre of the Ministry of Environment and Forest (MoEF) presented an online accident database called CAIRS to assist Past Accident Analysis (PAA). This paper compares CAIRS with major accident databases widely used by safety professionals. The parameters considered for compassion are scope, accessibility, method of data collection, quality, and the frequency of reporting. Past accident analysis showed that the total number of reported events is more or less steady and the number of major accidents is decreasing marginally in European countries, whereas in India only a few states report accidents using the CAIRS platform. The analysis raised serious concerns about the monitoring of reported information in the Indian database. At present, the information available in this database is not reliable and any conclusion based on this information can be misleading. Suggestions are offered to enhance the efficacy of the Indian accident database.

Keywords-Past Accident Analysis (PAA); chemical process industry; accident database; CAIRS; eMARS

I.   INTRODUCTION

Industrial accidents cause losses to human life, environment, and property. A critical examination of these events can bring valuable information on accident morphology, and lessons learned from past accidents can prevent similar events in the future [1, 2]. Accident investigation and follow-up of the results are vital in safety management systems. Learnings from past incidents can help us anticipate hazards and mitigate the associated risks by reducing the frequency and/or the consequences of the event. With the help of accident investigation, the root cause of the accident can be identified and with corrective and preventive actions, associated risks can be mitigated and make the workspace safer. To anticipate, recognize, and control accidents in the industry we need to collect and review past incident information. It is well documented that the reasons for accidents in many cases are repeated [3, 4]. If we can find out reasons or patterns which are frequently repeating, such accidents can be avoided in the future, and this is the basic objective of Past Accident Analysis (PAA).

When processes are carried out at extreme temperatures and pressures, the probability of occurrence and the severity of any undesired event is higher. By properly analyzing the information obtained from past accidents, one can get to know the probable causes of failures and accidents in the chemical industry. Major accidents in the process industry are caused due to loss of containment due to process failures or due to natural events such as earthquakes, lightning, and floods, which are also called Natech events. Unlike process equipment failure accidents, Natech events can trigger accidents in the entire plant. Most of the time the response against these events is delayed due to the lack of communication or the non-availability of personnel leading to the escalation of the accidents [5, 6]. Although we can't completely safeguard against natural disasters, we can find the most vulnerable parts of the system and can add additional layers of protection for such installations. After identifying the vulnerable units/areas we can develop the system in such a way that it will have the least effect on such critical/vulnerable installations [6]. The repeated disruption in a process industry can be an indication of a major fault that can lead to an accident. If these disruptions

are more frequent, they raise questions about the safety controls in the organization. Authors in [7] analyzed industrial accidents from the FACTS database and concluded that repeated disruption can be considered a precursor to accidents, which indicates the failures in the control mechanism of the organization. By analyzing the past incident information it will become much easier to predict the common accident precursor in chemical process industries by looking at factors like the chemicals used, chemical release modes, etc. [8].

Unlike other branches of science and technology, where experimental and analytical data are used, in accident analysis, performing experiments to forecast an accident is a cumbersome task. The data we get from past accidents can be used to identify the root causes, which would help prevent similar accidents in the future. So, it is important to analyze past accidents and learn from them, so that the same situation will not be repeated [9-11]. PAA is possibly the most powerful and frequently utilized activity for gaining insight into the reasons accidents happen. PAA gives important "intelligence of knowing the past" and techniques to forecast hazardous events or mitigate the effects of incidents [3, 12-14]. Active research is being carried out in the field of accident analysis with the help of management tools and machine learning, incorporating data management tools such as Business Intelligence (BI) in past accident analysis, which can provide valuable insight to develop business strategy and tactics [15-18].

In the past, India has been home to several chemical industrial accidents including the world's worst industrial disaster, the Bhopal gas tragedy. To collate the accident data systematically, the National Informatics Centre of the Ministry of Environment and Forest introduced a web-based accident reporting platform called Chemical Accident Information Reporting System (CAIRS). This paper compares the functionality of this database with other well-known accident databases and its efficacy by performing PAA.

II.　PREVIOUS WORK

Authors in [3] analyzed 3222 major accidents in chemical process industries reported between 1926 and 1997. Their study revealed that in process industries, 49% of accidents were caused by fire and explosions and 38% by toxic releases. Their study concluded that although the number of accidents per year decreased during the '80s, the losses per accident have an increasing trend. The fatalities per accident for fire/explosion and toxic release incidents are 3.27 and 2.49 respectively. In the chemical industry, accidents often involve cascading effects, also known as domino effects. Often devastating destructions are caused by accidents involving domino effects. Predicting and forecasting a standalone accident is much easier than forecasting a domino effect by risk assessment which also requires past accident data. That is one of the reasons very little work has been carried out on managing domino accidents in process industries. PAA can provide valuable information to predict and manage domino effects in process industries [9, 19]. Authors in [20] conducted statistical research on 207 major industrial accidents from 1969 to 1998. They identified that 39% of major accidents involve domino effects. The risk of domino accidents was determined to be dependent on the type of substance involved and gaseous hydrocarbons pose more

risk (58%) of causing domino accidents than liquid fuels (49%). Authors in [9] a conducted another noteworthy study on this topic by analyzing 224 accidents involving domino effects from 1917 to 2019 and concluded that 80% of domino accidents occur in fixed installations and 20% during transportation. Domino effects are frequently associated with flammable substances, and Vapor Cloud Explosion/Fire (VCE/VCF) is the most common initiating cause of domino accidents. The analysis of reporting trends indicated that domino accidents are more rigorously reported in developed countries. Among developing countries, India reports the highest number of domino accidents (34%).

III.　CHEMICAL PROCESS INDUSTRY ACCIDENT DATABASES

The main motive of accident investigation is to learn from the mistakes or lapses that led to an accident and identify remedial measures to prevent recurrences [21]. If information of multiple accidents is clubbed in a single source, the analysts will be able to gather pictures on a bigger canvas. Accident data clubbed under one unit consist an accident database. By analyzing this information we can identify the anatomy of accidents. Inferences from such analysis are being used for making or updating legal requirements and issuing safe work guidelines for similar processes and industries. As we know, even slight negligence can lead to a major problem in chemical industries, so it becomes important to find out the reasons of such accidents. After identification of the root causes, they could be mitigated. Public sharing of the accident investigation reports can help all stakeholders who deal with similar hazards. Accident databases are a vast source of such information, so by reviewing them, both the industry and the regulators can plan proactive measures to prevent the recurrence of accidents. Generally, the accident databases are used for the following reasons:

- To gain knowledge from past incidents: to perceive what has occurred, how has it occurred, what the outcomes were, and why it occurred. By this, the designers can avoid the mistakes which have caused accidents in the past.

- Where adequate information is accessible, it might be feasible to create frequencies or probabilities of incidents, which can support risk assessment studies [22].

There are many databases that maintain past accident data of the process industry. Some of the well-known accident databases include FACTS, eMARS, MHIDAS, CAIRS, and PUPAD. These databases have their advantages and limitations: some of them are not free to use, i.e they require some kind of subscription, and some of them do not have accurate data [12]. There are very few databases freely available for PAA and those which are available are having issues with data accuracy. So, the need occurs to have such a free database in order to provide a single platform to search past accidents and work on the learnings from them in order to create a workplace as safe as possible. The focus of this paper is to review the existing literature on PAA and by analyzing the existing databases to find out their problems and propose possible solutions. The major chemical process industry accident databases and advantages and disadvantgages are briefly discussed below.

1) Major Hazard Incident Data Service (MHIDAS)

This database was launched in 1986 by Health and Safety Executive (UK), followed by the Canvey Island study, which highlighted the need for reliable data for quantitative risk assessment [22]. This database contains information on global accidents involving hazardous materials. Authors in [12] identified data discrepancies in this database. MHIDAS provides information on the incident type, origin, causes, fatalities, injuries, and losses in the UK and abroad, but it is no longer being updated.

- Advantages: Incidents can be analyzed based on activity, location and people affected. It is a huge inventory of past accidents, since it is one of the oldest databases.

- Disadvantages: A substantial fee is required to access it. It is no longer being updated.

2) eMARS- The Major Accident Reporting System

The Major Accident Reporting System, later known as eMARS was launched by the European commission in 1982, based on the recommendation of the Seveso directive [23]. This database contains information from the Major Accident Hazards Bureau (MAHB) supplied by the EU and affiliated countries and the information includes both accidents and near misses. Reporting of events categorized as major accidents by SEVESO directive III is mandatory for EU countries and voluntary for affiliated countries. In terms of categories of information, this is the most comprehensive accident database. The available information includes year-wise accidents, industry type, involvements of domino effects, Natech events, transboundary impacts, etc. [23].

- Advantages: EU member states have to report into eMARS compulsorily so most of the accidents do get reported here. Companies' names and locations are not provided in the database. Data are available in two forms i.e. short report and full report [24].

- Disadvantages: As it takes almost two to three years to complete a report after proper investigation, one has to wait up to three years to access the full report.

3) Failure and Accidents Technical information System (FACTS) Database

This is a global chemical process industry accident database launched by TNO Industrial and External Safety. Nowadays, it is maintained by the Unified Industrial & Harbour Fire Department in Rotterdam-Rozenburg. As of date, this is the largest repository of chemical industry accidents containing information on over 27500 industrial incidents. FACTS database gathers information from accident reports of companies and governmental agencies [25].

Advantages: Abstract containing all important information is available for every accident (3 levels of reports). It contains information from professional sources (CSB, ARIA, MARS, ZEMA, NRC, NTSB, reports by companies and publications) so data are considered to be reliable.

Disadvantages: Only accident tables are freely accessible. A fee is required to access detailed information.

4) Chemical Accident Information & Reporting System (CAIRS)

CAIRS is an Indian chemical industry accident database developed by the Environment & Forest Informatics Division of the National Informatics, Centre Govt. of India. Here, accidents are reported by companies and are updated in the database by authorities specified under the MSHIC Rule 1989 [26, 27]. The flowchart of updating the data is illustrated in Figure 1.
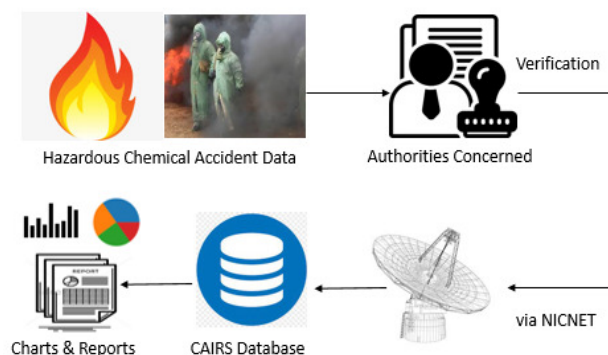

Fig. 1.   Data updating process in CAIRS.

- Advantages: Includes reports and charts that can be freely accessed. Has reports from different authorities. Losses outside the premises are reported (fatality, injury, and missing).

- Disadvantages: The root causes of most of the accidents are not mentioned, not all accidents are reported, and there are data duplicity and consistency issues.

5) Known Problems

The reported problems while performing PAA using accident databases are [12]:

- Improper accident reporting mechanism

- Record maintenance is not appropriate

- Hiding the actual cause of the accident

- The improper strategy of investigation.

Hence, it is important to consider the strengths and weaknesses of the databases before performing PAA.

IV.   PAST ACCIDENT ANALYSIS

Comprehensive past accident analyses have been performed in [3, 9, 11, 28, 29]. The last well-known PAA was performed in 2011 [9]. Since then, significant PAA research was not performed for major accidents in the chemical process industry.

In this paper, PPA was performed based on the data available in eMARS and CAIRS. The selected period analysis was from 2010 to 2021.

TABLE I.   DATABASE COMPARISON

Database	Country	Scope	Accessibility	Data updation process	No of records	Available information
MHIDAS	UK	Accidents involving hazardous materials from 1950 to 1990	Subscription required	No longer being updated. AEA technology was used to compile data from public domain sources.	8000+	• Date & location • Materials involved • No of people affected • General and special causes • Economic losses.
eMARS	EU	Major accidents and near-miss information	Free	Information provided by EU and affiliated countries under the Seveso directive.	1165	Comprehensive information, including: • Accident, site, and installation descriptions and classification. • Cause description and classification. • Consequences description and classification. • Emergency response and legal actions. • Lessons learned.
FACTS	The Netherlands	Global accidents	Accident tables are freely accessible. Subscription required for detailed reports	Accident information from professional sources.	27500+	• An accident table contains basic information about the year, country, activity, and causes of accidents. • The coded abstracts contain detailed information about location, operations, etc. • Detailed information about causes and consequences
CAIRS	India	Incidents reported by authorities in India	Free	Based on accident reports submitted to various governmental agencies.	100+	• Accidents' date and time • Company information • Chemicals involved and their type. • Causes • Number of people killed/injured within and outside the premises

1) Past Accident Analysis from eMARS database

During the studied period, 495 accidents were recorded in the eMARS database, and detailed reports are available for 378. The event-wise yearly trends of the reported events are illustrated in Figure 2. From the trends it can be inferred that the total number of reported events is more or less steady and the number of major accidents is decreasing marginally in Europe. This indicates that the trends identified by [9] are still prevailing in Europe. Out of these 495 accidents, 73% are major, 20% are near-miss incidents, and 7% are other events (Figure 3), meeting the criteria defined in the Seveso directive annexure [16].
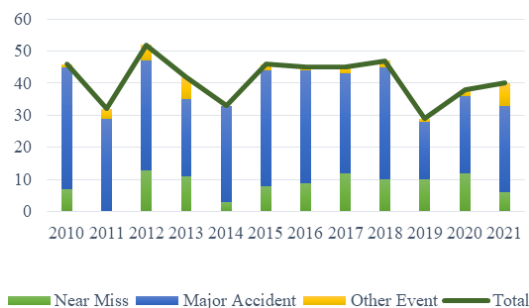

Fig. 2.   Year-wise accident reporting trends in eMARS.

Industry-wise recorded accident analysis can indicate the vulnerability of industries. The analysis, as shown in Figure 5, shows that 19% of accidents were reported in petrochemical/oil refineries followed by the general chemical manufacturing industry (10%), and the power generation, supply, and distribution (6%) industries. Interestingly, there is a drastic

reduction in the number of accidents reported in the general chemical industry during the analysis period compared to the previous decade (1998-2009), i.e. from 132 cases to 51, whereas the number of accidents in petrochemical/oil refineries increased from 84 to 93. eMARS also reports special circumstances involved with the recorded incidents such as Natech or domino events, transboundary effects, and involvement of contractors. Out of such 56 events, 54% of the cases involve contractors and 21% involve domino effects as illustrated in Figure 4.
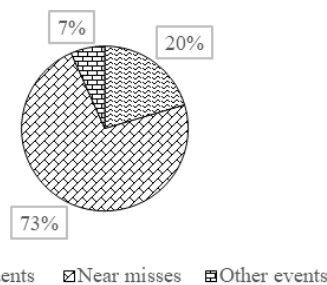

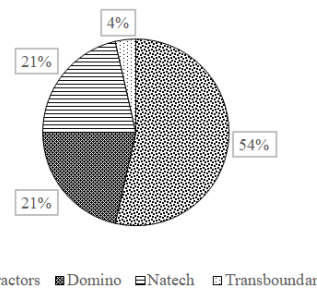Fig. 3.   Types of accidents reports in eMARS.

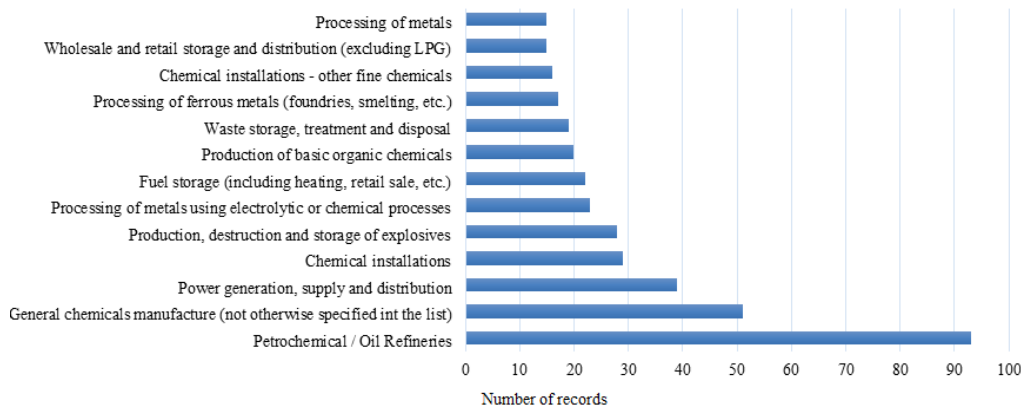Fig. 4.   Accidents involving special circumstances.

Fig. 5.   Industry-wise accidents.

2) Indian Chemical Industry Accident Scenario

As illustrated in Figure 6, the analysis of chemical industry accidents reported to the various regulatory agencies in CAIRS, showed that out of 29 states, only 6 have reported accidents so far, pointing out the poor accident reporting culture in India. It was also found that there are duplicate data entries in CAIRS: Some of the accidents are reported multiple times, e.g. the accident in Accura Lab Pvt. Ltd, Telangana on 25th September 2013 is reported twice, one with the accident cause details and another without this information. Similarly, if an accident was involved with multiple chemicals it is reported multiple times.
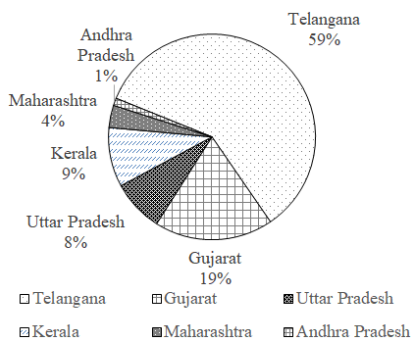

Fig. 6.   State-wise reporting of accidents.

The data collected from the CAIRS database were manually filtered to remove all duplicities, and 86 records were obtained, which were submitted to the chief inspector of factories. The year-wise reporting trends are depicted in Figure 7. As shown, there is no particular trend in the number of accidents reported in CAIRS. The maximum number of accidents was reported in 2016, while the minimum in 2014, whereas there are no available data after 2018. One of the major drawbacks of CAIRS is that the root cause of the accident is missing in most reports. Out of the 86 accidents analyzed, only 36 have their root cause mentioned, i.e. for around 58% of the accidents the root cause is not mentioned. This shows that the investigative findings of an accident are not recorded for most accidents. Figure 8 depicts the accidents with regard to their type/category. It was found that 57% of the reported cases are incidents. In some cases, accidents with fatalities are considered minor accidents or incidents, while accidents with fewer casualties may be considered as major. So, there is no

well-defined guideline or procedure to report an accident. This indicates a lack of monitoring of reported information in this database. At present, the information in this regard is not reliable and any conclusion based on this type of analysis can be misleading.
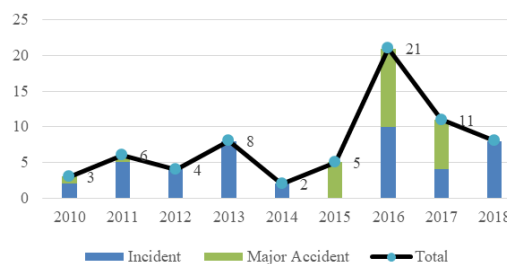

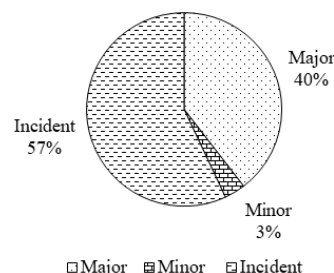Fig. 7.   Year-wise accidents reported in CAIRS.

Fig. 8.   Accidents based on category.

The conclusion of the analysis based on the available information in these two databases is that the findings of accidents are better reported in eMARS, as the root cause, and the event sequence of every accident is mentioned in eMARS, but not in CAIRS. eMARS also provides more categories of information. The Indian database CAIRS needs urgent revisions to provide more reliable and useful data.

V.   CONCLUSIONS AND RECOMMENDATIONS

This work reviewed past accidents in the chemical process industry. A comprehensive analysis of past accidents enables us to identify the recent accident trends in the industry. Accident databases aid the analysis of past accidents. Global databases were compared and their advantages and disadvantages were lsited. PAA of the accidents recorded in the European eMARS database and the Indian CAIRS database has

been performed. From the trends, it can be inferred that the total number of reported events is more or less steady and the number of major accidents is decreasing marginally in Europe. The analysis of the Indian chemical industry based on accidents reported in the CAIRS database can lead to inaccurate conclusions as accidents are not reported promptly in this database and an urgent revision to ensure data accuracy is required. Some suggestions on improving the existing databases are:

- Accident databases available in the public domain would encourage researchers to undertake active studies in this field and would also enable risk professionals and policymakers to make data-driven decisions.

- Before publishing the details in accident databases, the data entering officials need to rigorously verify all the entries, including the root causes of incidents.

- Additional information needs to be incorporated into the databases to meet the current risk assessment requirements.

- As most databases are country-specific, global collaborations are required to disseminate past accident information worldwide.

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