A NEW SAFETY RISK INDEX FOR USE IN PETROCHEMICAL PLANNING

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Abstract: Risk analysis is being used to evaluate and manage the potential of unwanted events in the chemical processing industry. The risk in this study is the risk posed by chemical plant accidents and it is presented in a simple quantitative form. A safety risk index is formulated that represents the maximum number of people that might be affected if an accident occurred that caused the release of all the plant inventory of a chemical. The index has four terms: frequency of accidents; hazardous effect of the chemical; inventory of the chemical released; size of the plant. The overall unit of the index is expressed as the number of people affected per year from the plant operation and is formed in a particularly simple manner so as to be suitable for the comparison of safety risk within a model for planning the development of the petrochemical industry.

Keywords: risk; risk index; plant accident; hazardous chemical.

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INTRODUCTION

A decisive influence on the performance of the chemical industry is the hazardous effect of the chemicals and production safety in general. The hazardous effect of chemicals is manifested in three ways: flammability, explosivity and toxicity and the first step towards greater plant safety is being aware of the potentially dangerous properties of those chemicals. The raw material, the intermediate, and the finished products present the primary independent hazard element (Ward, 2002). They are a hazard even if only in storage, with no processing. Overlooking this increasingly important factor would be to ignore one of the major forces that shape the development of the industry. The issue of safely producing hazardous chemicals is as important as the economics of producing and selling them.

An important and widely established term in the process industry is risk. The risk due to an industrial process or a technical installation is defined in the process industries as the combination of the incident probability and the magnitude of the harmful effects. Thus, this term strongly refers to probabilistic assessment. Another definition is expressed as the time related, or location related likelihood of a hazard actually resulting in an undesired event which can impose acute or chronic effect.

The objective, in this work, was to develop a simple risk index that can be used within a model for the early stage planning of chemical plants. The index needs to be easily applied, to include industrial experience and to require only general plant information for its evaluation. In many cases, early stage planning procedure requires risk evaluation and ranking for tens of plants with only limited availability of plant information. The index was structured in a form that is suitable for incorporation into optimization models for planning the development of the petrochemical industry from a safety perspective. It can be used as an objective function or as a constraint together with other planning perspectives (see Al-Sharrah *et al.*, 2006). The existing, internationally known and proven risk indices, some discussed later in this paper, are not suitable for this purpose. Most existing methods cannot be applied directly in early process design (Koller *et al.*, 2000), and some have further limitations which will be discussed later. The risk evaluated using the simplified index provides an estimate of the potential risk to people (public and workers) resulting from a chemical plant accident.

RISK TOOLS AND CONCEPTS

The chemical process industries use a wide range of process analysis tools to identify, quantify and control risk in plant operations. Risk can be described and quantified using probability (or frequency) of damage, magnitude of potential harm and by an index for the hazardous level of operation. Also, the history of chemical accidents in the process industries is a useful means of identifying sources of risk.

Probability and Frequency for Risk Assessment

Probability theory is one tool to reconstruct reality when incomplete knowledge of the initial conditions of a sequence of events in time is available (Kirchsteiger, 1999a). It helps to answer a basic risk question: how likely is it that the event will happen? Estimating a probability number for an event is based on an extensive study and data collection for that event including the failure of all its components and consequences. Probability, an essential part of risk assessment, is used in the fields of occupational risk as the probability of accidents or any undesired event. However, relating probability to frequency was used extensively due to the fact that probability was not directly available for many events, especially if these events were complicated, multi-staged or new. Cuny and Lejeune (2003) supported this and indicated that estimating the probability is more problematic; the frequency approach is the most tangible and they estimated probability using its relative frequency.

In this paper, the evaluation of risk is based on accident frequencies and some accident consequences usually available in chemical accidents databases.

Chemical Accidents Database

Accidents databases are collections of data on chemical accidents. Major accidents databases were the result of a federal law while others were produced for private institutes or companies. The law requires that certain facilities report annually their toxic releases and inventories together with any accidents that harm workers, the public, and the environment. In the past 30 years special attention has been given in designing and developing a database of chemical accident histories. As a result, there exist a number of such databases, some of them covering specific countries and some covering wider geographical areas. Statistical analysis with data processing has led to several scientific publications and technical guidelines issued by research institutes and governmental agencies. For example, Kirchsteiger (1999b) analysed data related to major accidents in the European Union and Belke (2000) analysed data for chemical accidents risks in US industry, all using accidents databases. Balasubramanian and Louvar (2002) studied seven accidents databases and concluded that, even with some existing problems in the databases, important information can be extracted and the description of accidents are both useful and educational.

One major accidents database available on the internet is the Accidental Release Information Program (ARIP) (1999) database. It is one of the most useful databases due to its size, format and public availability. ARIP is associated with industry in the United States where all facilities are required by law to report non-routine releases of certain substances when those releases exceed a reportable quantity.

Another important, and widely recognized, chemical accidents database is the Risk Management Plans database (RMP*info). It is a result of a law enacted by the US Congress to require certain chemical facilities to submit summary reports every 5 years. These reports contain significant information on each facility's accident history, accident prevention program, and the potential consequence of a hypothetical accidental chemical release. These data have been assembled into a searchable computerized database, which was originally intended to be available to the general public via the Internet. However, the chemical industry and US security agencies raised concerns that some of the data would allow terrorists to easily identify those facilities likely to cause the greatest harm to the public in the event of a release. These concerns promoted Congress to pass legislation in August 1999, that, along with subsequent federal regulations, currently restricts public access to portions of the RMP*info database.

Belke (2000) analysed the RMP*info database and presented a preliminary characterization of the database. One useful analysis was the normalized accident rates; accident rates are commonly normalized by dividing the number of incidents by some measure of the number of opportunities for an accident. This allows large and small facilities to be compared fairly over a given period. Belke (2000) used the number of processes in the facility using the chemical and the aggregate chemical quantity as normalization factors. Table 1 shows the results.

Hazard indices

The term *hazard* represents a physical or chemical characteristic that has the potential to cause harm. The selection of appropriate measures of that harm from an environmental or safety view point will depend upon the nature of the environmental concerns, the type and quantity of information available and the degree of accuracy required in the representation. Several hazard analysis indices have been developed; some of them are internationally known and proven and some have been used and developed inside companies. The data required for each index is different and also, the results produced may vary. The different

Table 1. Normalized accident rates from RMP*info chemicals (Belke, 2000).

Chemical name	Number of accidents per process per year	Number of accidents per Mlbs stored per year
1. Ammonia	0.016	0.014
2. Chlorine	0.022	0.16
3. Hydrogen fluoride	0.064	0.27
4. Flammable mixture	0.0074	0.00075
5. Chlorine dioxide	0.155	1.97
6. Propane	0.006	0.0012
7. Sulphur dioxide	0.013	0.011
8. Ammonia (aqueous)	0.017	0.018
9. Hydrogen chloride	0.060	0.25
10. Hydrogen	0.031	0.024
11. Methane	0.027	0.0064
12. Butane	0.011	0.00089
13. Ethylene oxide	0.027	0.045
14. Hydrogen sulphide	0.067	0.5
15. Formaldehyde	0.009	0.024
16. Isobutane	0.010	0.011
17. Pentane	0.013	0.0052
18. Titanium tetrachloride	0.056	0.090
19. Phosgene	0.044	2.49
20. Nitric acid	0.038	0.047
21. Ethane	0.014	0.00071
22. Oleum	0.022	0.011
23. Ethylene	0.014	0.00089
24. Vinyl chloride	0.042	0.0051
25. Trichlorosilane	0.034	0.10