



Inherent safety concept based proactive risk reduction strategies: A review

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ABSTRACT

The growing scale and complexity of process industries have brought safety, health, and environmental issues to the forefront. As a result, proactive risk reduction strategies (RRSs) are commonly employed to address these issues by reducing the frequency or mitigating the consequences of potential incidents. Among these strategies, inherent safety, which is a proactive measure of loss prevention and risk management, is considered to be the most effective method. This review aims to provide a comprehensive analysis of RRSs for achieving inherency, as well as techniques for evaluating the performance of inherent safety, health, and environmental aspects. Background information is presented, including the development and implementation of the inherently safer process design, as well as the approaches for achieving inherently healthier and environmentally friendlier processes. Subsequently, the execution approaches and practical applications of other RRSs are discussed to highlight the distinctiveness and benefits of inherent safety. Next, this study examined the characteristics of inherency assessment tools (IATs) based on available information at different process stages. Furthermore, the evaluation methods and historical development of IATs are investigated from the perspectives of safety, occupational health, and environmental considerations, followed by a statistical analysis of IATs. It is concluded that the no-chemical hazards-based IATs have not been extensively studied yet, which may improve the safety level of process plants from the perspective of comprehensive inherency risk reduction. As a way forward, future research opportunities are proposed to promote the implementation of greater optimized risk management.

1. Introduction

The growing dependence of the modern world on processed products has resulted in increased complexity of processing facilities and technologies. As a result, various industries are exploring better strategies to overcome the challenges associated with scaling up and achieve significant profit margins. Ensuring the safety of employees, facilities, and operations is crucial to maintaining economic viability. Without safety measures in place, a company may face serious financial consequences, including loss of revenue, legal fines, and damage to its reputation (Khan et al., 2015). Therefore, adopting proactive Risk Reduction Strategies (RRSs) to eliminate and mitigate hazards is not only a necessity for daily operation but also an essential component of long-term economic success (Pawolocki, 2021). The design stage, as the initial stage of process industry development, is considered the optimal phase for implementing

RRSs considering cost and sustainability (Khan and Syeda, 2022). Moreover, the lessons learned from numerous catastrophic chemical accidents, such as the Flixborough explosion incident (1974) caused by cyclohexane leakage and the Bhopal methyl isocyanate (MIC) leakage incident (1984), indicate that the extensive use and storage of hazardous substances are the root causes of accidents (Kletz, 1978, 1985). Consequently, inherently safer design (ISD), also known as inherent safety, was proposed by Professor Kletz (1978) with its main principles to eliminate and mitigate inherent hazards (e.g., flammability, explosiveness, and toxicity) at the design stage, without excessive reliance on additional engineering measures and operating procedures, which are prone to failure. Professor Trevor Kletz (1922–2013), a pioneer and leader in process safety, has significantly changed the understanding and philosophy of safety issues through his outstanding contributions in the areas of inherent safety, hazard identification, and accident prevention (Amyotte, 2020; Amyotte and Khan, 2021). After nearly 50

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