Development of comprehensive healthier process plants based on inherent safety concept

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ABSTRACT

Emerging from inherent safety, Inherent Occupational Health (IOH) is gaining increasing attention for its role in fundamentally mitigating potential hazards that may adversely affect worker health. Conventional IOH approaches mainly focus on hazards associated with chemical processes, with limited attention given to addressing comprehensive health hazards (e.g., noise, vibration, and ergonomic issues) that may result in occupational issues like hearing loss, musculoskeletal problems, and respiratory conditions. An implementation tool for assessing the overall healthiness of process plant alternatives is yet to be established. To address these gaps, this work developed a Process Plant Healthiness Metric (PPHM) for generating holistic inherently healthier alternatives via the proposed Health Risk Management Framework (HRMF). Firstly, a generic health index framework was established. On this basis, multidimensional health risks were identified and measured by the Residual Hazard Index and Failure Modes and Effects Analysis. Fuzzy Logic was adopted to address data sensitivity and inconsistency. Subsequently, Fuzzy Logic and Analytic Hierarchy Process were integrated into Bayesian Networks to develop the PPHM. To cope with key risk factors, the HRMF based on inherent safety concept is proposed and employed as a mind-trigger. The PPHM was validated by a case study of a methyl allyl chloride plant. The results revealed that following the implementation of HRMF-based interventions, the value of PPHM increased from 2.17 to 3.87, and the unhealthiness rate decreased from 0.0257 to 0.000558, thereby establishing a relatively healthier alternative. This work enables a holistic identification, assessment, and mitigation of comprehensive health risks within process plants during the design phase. It facilitates a shift in the inherently safer design ideology from process health to plant health.

1. Introduction

In process industries, process-related health hazards (e.g., chemical exposure, high temperatures, and high pressure) pose significant threats to the health and well-being of workers. However, from a plant perspective, the pervasive presence of health hazards (e.g., noise, ergonomic issues, and volatile organic compounds) within production processes, labor procedures, and the working environment may result in worker susceptibility to various illnesses such as hearing impairments, musculoskeletal disorders (Morabito et al., 2021), and building-related illnesses (Crook and Burton, 2010), thereby adversely impacting workers' health, quality of life, and work efficiency. Therefore, a comprehensive scrutiny and evaluation of these hazards are imperative to establish a healthier plant. The health hazard assessment of a process