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Bayesian networks based laboratory retrofitting towards inherent safety: A risk-based implementation framework

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ABSTRACT

Over the years, a number of high-profile laboratory accidents involving severe injuries, fatalities, and economic losses have been reported, prompting a significant increase in efforts towards laboratory safety. However, the dominant safety measures rely excessively on add-on safeguards such as sprinklers and respirators and pay little attention to reducing the hazardous factors at their sources. This study introduced the inherent safety concept to minimize laboratory hazards and developed a dedicated implementation tool called Generic Laboratory Safety Metric (GLSM). The Traditional Laboratory Safety Checklist (TLSC) was first used to represent the safety indicators, and then the Precedence Chart (PC) and Bayesian Networks (BN) methods were used to reconcile the safety indicators to develop the GLSM. The developed GLSM was subsequently demonstrated through a case study of a university laboratory. The results revealed that the safety level increased from 2.44 to 3.52 after the risk-based inherently safer retrofitting, thus creating laboratory conditions with a relatively satisfactory safety level. This work presented a set of generic solutions to laboratory retrofitting towards inherent safety with a novel GLSM as the implementation tool. The proposed GLSM would contribute to risk quantification and identification of key risk factors for assigning targeted and fundamental safety measures to achieve inherently safer laboratories.

1. Introduction

Exploratory doings such as scientific research, experimental studies, and measurement activities in laboratories often necessitate using reactive materials, susceptible processes, and complex equipment settings. Given the circumstances, laboratory workers and facilities can be exposed to various risk agents such as chemical, biological, physical, radioactive, and ergonomic hazards (OSHA, 2022). Exposure to these risk agents has caused severe injuries, deaths, and financial losses, which have been threatening laboratory safety operations for decades (Wirth et al., 2020; Yang et al., 2019). The concerns for laboratory safety have been further strengthened by a series of grievous laboratory accidents, such as the laboratory explosion at University of Hawaii at Mānoa (Hawaii, US) (Trager, 2017), the laboratory blast at Beijing Jiaotong University (Beijing, China) (Lixin, 2018), the laboratory explosion at Israel Institute of Technology (Haifa, Israel) (Sugarman, 2019), the laboratory deflagration at Nanjing University of Aeronautics and Astronautics (Nanjing, China) (Lo, 2021), and various other laboratory accidents as reported by Ménard and Trant (2020), Yang et al. (2022), and Silver (2022). Such high-profile accidents have aroused great concerns about laboratory safety and reinforced the need for risk assessment and reduction. In practice, the dominant risk controls rely excessively on active safety systems (e.g., sprinklers and smoke detectors), administrative safety measures (e.g., standards and guidelines), and Personal Protective Equipment (PPE) (e.g., gloves and respirators) based on the assumption that the safety conditions, once established, could be maintained using these add-on protections. With the awareness of the preventive safety concept, the use of add-on protections to maintain safety is substantially complemented by the use of inherent safety to forestall hazards before they evolve into accidents and losses (Ahmad et al., 2021; Amyotte and Khan, 2021).

Inherent safety, as opposed to reactive barriers and defenses, is a

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