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Consequence analysis of ammonia accidental release in risk assessment

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ABSTRACT

Ammonia is a vital chemical feedstock, with global production reaching 200 million tonnes in 2023—a more-than 40% increase since 2010. Given its strategic role in emerging energy sectors, such as hydrogen carriers and carbon-free fuels, ammonia demand is projected to rise significantly, potentially reaching 500 million tonnes annually by 2050 under the Net Zero Emissions (NZE) scenario, with an estimated yearly increase of over 10 million tonnes. However, the frequency of major ammonia-related incidents has escalated since the 1990s, with release amounts ranging from small leaks to several thousand tonnes. Notable examples include the 1992 Dakar accident, which released 22 tonnes of pressurised ammonia and resulted in hundreds of fatalities and thousands of injuries, and the 1994 Iowa incident involving the release of approximately 5,700 tonnes of anhydrous ammonia.

Although ammonia is less flammable than hydrogen or methane, it is acutely toxic, with a threshold limit value of 25 ppm. Injuries and fatalities near release sites are primarily due to direct skin contact, cold burns, and inhalation, while those farther away are mostly caused by exposure to high concentrations of ammonia gas. A significant concern during accidental releases of ammonia is its dispersion behaviour. In humid conditions, released ammonia can form an ammonia–water fog (NH₃·H₂O), which behaves as a heavier-than-air cloud, despite ammonia gas alone being lighter than air (0.59 times the density of air). This fog can travel considerable distances near ground level in both downwind and crosswind directions.

To investigate this phenomenon, a computational fluid dynamics (CFD) model was developed incorporating subroutines to account for ammonia–water fog formation. The model was validated using experimental data from published literature. A comprehensive parametric study was conducted, examining the influence of ambient conditions (e.g., temperature, wind speed, and relative humidity), leak characteristics (e.g., pressure, temperature, and release rate), and terrain effects (e.g., open tank farms and indoor environments). The findings contribute to a deeper understanding of ammonia dispersion dynamics and provide valuable insights for risk management in ammonia storage and handling.

KEY WORDS

Ammonia gas dispersion, accidental release, dense gas, risk assessment

BIOGRAPHY

Dr. Biao Sun is a lecturer at Curtin University with expertise in process risk management and consequence modelling. His PhD research focused on “*Numerical Simulation of Dense Gas Dispersion and Fire Characteristics following Liquefied Natural Gas Release*,” where he developed advanced modelling techniques for predicting hazardous outcomes. Since 2019, he has been teaching the unit “Process Safety and Risk Management,” contributing to both undergraduate and postgraduate education in chemical engineering. His research has since broadened to include safety assessments and risk analysis in emerging energy sectors, particularly involving hydrogen and ammonia processes, with a focus on sustainable and low-carbon technologies.

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