When Small-Scale Meets High Risk: Quantitative Risk Assessment of a Fischer-Tropsch Academic Experimental Setup

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Ensuring safety in research laboratories and pilot plants represents a critical and evolving challenge in chemical engineering. Despite operating at reduced scales, these experimental infrastructures can exhibit risk levels comparable to, or even exceeding, those of industrial facilities, often underestimated and exacerbated by high variability in operating conditions, limited standardization, and the significant influence of human factors. Current approaches to laboratory safety often rely on qualitative sporadic assessments or simplified analyses, lacking systematic integration with quantitative risk methodologies widely adopted in industrial contexts.

This study proposes a structured application of Quantitative Risk Assessment (QRA) techniques — including Hazard and Operability Analysis (HAZOP), Fault and Event Tree Analysis (FTA, ETA), Layers of Protection Analysis (LoPA) and consequence modeling — to an academic pilot plant dedicated to Fischer-Tropsch synthesis. The research addresses the gap between laboratory-scale risk management and industrial safety standards, demonstrating how quantitative methods can be effectively adapted to the constraints and peculiarities of research environments.

The analysis highlights the potential for major accident scenarios, such as flammable gas accumulations and toxic exposures, even under seemingly controlled experimental conditions. It further reveals the limitations of manual interventions and conventional ventilation systems, underscoring the need for automated safety barriers and enhanced procedural frameworks. By modeling accidental releases and evaluating the robustness of safety systems, the study provides a quantitative basis for redesigning experimental operations towards higher resilience and sustainability.

Positioned within the broader field of chemical engineering, this work seeks to contribute to the ongoing advancement of safety science by extending the principles of risk-based design and management to academic research settings. It promotes a paradigm shift towards more rigorous, data-driven safety practices in experimental infrastructures, supporting the development of safer and more sustainable engineering solutions for chemical and environmental systems.

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