

Management of Process Plant and Territories: Resilient Strategies for Loss of Containment and Early Warning Systems

Abstract

This doctoral thesis addresses the topic of industrial resilience through an integrated approach to technological risk management, with particular attention to loss of containment, material degradation, NaTech risk, and the safety of hydrogen as an energy carrier. The objective is to develop resilient strategies and operational tools to improve the ability of industrial plants to prevent and manage critical events, in line with the regulatory requirements of the Seveso Directive, which requires more frequent inspections and the preparation of safety plans for facilities at risk of major accidents. However, the Directive does not provide systematic operational tools to address these issues.

To fill these gaps, the research proposes a holistic, data-driven approach based on the systematic analysis of 3,830 industrial events collected from international databases, complemented by quantitative models and predictive tools for risk management, to identify the most recurring relationships between the process industry and material degradation.

Through the study of a real-world case, the Otterburne pipeline explosion, the bidirectional vulnerability between latent structural defects and extreme natural events is demonstrated.

An innovative methodology for dynamically monitoring hydrogen leaks using drones equipped with concentration sensors is also proposed, supported by numerical simulations using PHAST software.

To support the assessment of the explosive consequences of hydrogen, the simplified methods proposed by the Center for Chemical Process Safety were applied. The TNO method proved to be the most valid for the preliminary estimation of overpressures and safety distances, with good agreement with experimental data.

The thesis offers operational recommendations for regulatory updates, the adoption of risk-based inspections, and the implementation of advanced technologies for early detection. This work contributes to strengthening the resilience of industrial plants and the safety of the energy transition, offering a replicable model for risk management in multifactorial scenarios.