Abstract

Accidental releases of airborne pollutants at industrial sites pose serious risks to human health and the environment. Toxic, reactive, or explosive compounds emitted during such events endanger onsite workers, emergency responders, and nearby populations. The severity of these incidents depends on whether pollutant concentrations exceed toxicity, flammability, or explosivity thresholds. Accurate estimation of concentration fields is therefore essential for emergency management and impact assessment. However, the complex geometry of industrial sites—comprising buildings, tanks, and pipes —enhances turbulence and flow irregularities, making reliable predictions of mean and peak concentrations difficult. Instantaneous peaks may exceed average levels by several orders of magnitude, representing an additional hazard.

This work experimentally investigates concentration fluctuations from a gaseous pollutant released over an idealised industrial site representative of refineries, chemical plants, and steelworks. The site includes a porous structure mimicking pipe and tank assemblies, whose effects on flow and turbulence are analysed. The experiments reveal complex recirculating and channelling patterns, with wake dynamics strongly influenced by the porous density.

Several analytical models for the one-point concentration probability density function (PDF) are evaluated. The gamma distribution best represents the midfield, while the lognormal performs better near the source; neither fully reproduces the complete experimental PDF, though both capture the high-concentration tails (95th–99th percentiles). An analytical model for threshold exceedance times offers a rapid, though approximate, tool for operational estimates.

Finally, two Lagrangian dispersion models are compared and validated against experiments. The semi-empirical PMSS model computes flow fields from adjusted meteorological profiles accounting for obstacle-induced recirculation, while SLAM (Safety Lagrangian Atmospheric Model) employs precomputed RANS simulations with a k-ε turbulence closure. Their respective advantages and limitations are discussed across varying source locations, wind directions, and site configurations.