Risk Assessment of Severe Accidents Involving Atmospheric Dispersion of Anhydrous and Hydrous Ammonia Mixtures

Abstract

By: Eli Stern

Accidental events involving sudden, instantaneous and/or continuous releases of anhydrous ammonia (NH_3) to the ambient atmosphere are quite hard to assess, especially when a thorough, realistic, risk assessment is required.

The thermodynamic properties of ammonia, being a major building-block and key component in the manufacture of many products, as well as being widely used as a most efficient refrigerant gas, have been extensively investigated. Thus, the behavior of ammonia during *early stages* of its emission into the atmosphere, following initial interaction with ambient air, such as evaporation from puddles, instantaneous releases during flash accidents (due to e.g. a sudden collapse of a storage tank), dual phase releases from holes in storage tanks etc., has been modelled and can be quantified relatively easily. However, the actual *environmental fate* of ammonia is determined by its dispersion characteristics, which may turn out to be quite complex. Basically, NH3, being much lighter than air (M_{NH3}=17 compared to M_{AIR}=29) is expected to undergo significant plume rise processes, prior to its downwind aerosolic diffusion/dispersion *as a gas*. On the other hand, rather vigorous hydrolysis reactions with ambient air humidity can create ammonium hydroxide (NH_4OH) liquid droplets (or solid icicles), which are expected to behave as particulate matter, i.e. as particles, deemed to either *diffusional dry deposition*, if having aerosolic mean aerodynamic diameters (AMADs) smaller than few tens of a micron, or *gravitational settling,* if having AMADs greater than, say, 50 microns. The NH_4OH particles, which can possibly be produced at very close proximities to the point/surface of release and due to their mass/volume characteristics, will remain close to the release point and start (and continue) their dispersion from rather low altitudes, compared to the light, gaseous NH_3. Thus, while due to its height of release, NH_3 does not seem to cause significant downwind air concentrations, air concentrations of NH_4OH should be carefully analyzed, due to its initial potential of "close to surface" dispersion.

In other words, from point of view of possible downwind air concentrations, determining the potential adverse health effect to public receptors (and hence, the Risks), the fractionation of anhydrous Vs. hydrous ammonia within the bulk of released material, as well as the expected heights of release of both compounds, can turn out *critical* for any risk assessment of ammonia accidents in general, and for risk-assessment-based decision making processes, in particular.

An innovative approach to overcome the above risk assessment difficulties, especially for spills on water and solid surfaces, is proposed. In this approach, (a) Rates of releases of anhydrous ammonia from puddle surfaces as function of initial ammonia temperatures as well as ambient air and surface temperatures are calculated; (b) Rates of creation of NH_4OH

close to the evaporating surface are calculated as function of relative humidity (i.e. air water content) assuming rates of reaction between NH_3 and “water in air”, up to 100% successful hit probabilities of NH_3 and H_2O molecules;(c) Plume rise and elevated dispersion of NH_3 (heights of release – a few hundred meters); (d) Dispersion of NH_4OH particles with heights of release < 20m; (e) Consideration of the *significantly different inhalation dose-effect relationships* of NH_3 as compared to those of NH_4OH; and finally (f) Fitting the atmospheric dispersion model to the relevant type of release, i.e. instantaneous or continuous, as derived, inter alia, from the accident analysis and ambient chemical/physical conditions.

Preliminary results show that conservative assumptions concerning NH_4OH creation from instantaneous “cold” NH_3 spills on water surfaces followed by consequent vigorous evaporation, do not lead to significant, life threatening, air concentrations at distances as close as 1000-2000 m from the release point; depending, *inter alia*, on prevailing meteorological stability conditions during accident occurrence.