Title: Modelling Environmental Consequences of Ammonia Spills from Tankers

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Ammonia is being considered as an alternative to hydrocarbon fuels and to transport hydrogen derived from water electrolysis. Ammonia is anticipated to be shipped in greater amounts and frequencies; therefore, spill risks are of great interest. Consequences of liquified ammonia spills were simulated using RPS's CHEMMAP modelling system. A worst-case discharge (WCD) of an entire tanker cargo of 54,400 tonnes (80,000 m^3) was modelled, along with a discharge of 64.4 tonnes (94.6 m^3) such as might occur from operational accidents. Trajectories were computed for an ensemble of hundreds of individual cases for each spill scenario, thus sampling the potential variability in winds and currents by starting the simulation on different dates. Results were analyzed to assess the maximum potential volumes of water exposed above thresholds of concern.

DNV's PHAST outflow, air dispersion and consequence modeling software system was used to estimate the portion of ammonia released in the atmosphere or on the water surface that would immediately form a vapor cloud, with the remaining amount spreading on the water surface and dissolving into the water column. Model results include the volume of water that might be exposed to greater than threshold concentrations for potential aquatic effects and the associated probability of this exposure. Statistics (mean, standard deviation, 5^{th} and 95^{th} percentiles) characterize the uncertainty and potential range of affected volumes and areas for use in risk assessments and emergency response planning.

Results demonstrate the considerable influence of the initial release conditions, i.e., whether a release is subsurface or on/above the surface and the duration of the release, on the exposure concentrations and volume/area exceeding thresholds for effects. The percentage of discharged ammonia dissolving into the water column versus forming the vapor cloud strongly depends on discharge flow rate, orifice size, height above or below the water surface, and environmental conditions. However, when released subsurface below a release-rate specific depth, a vapor

cloud is not expected to form, avoiding hazards from vapors but leading to higher in-water concentrations. Releases from depths such as from the bottom of a tanker would be less likely to breach the surface and form a vapor cloud than those nearer to the water surface. Dilution in the water column depends primarily on currents and turbulent mixing. Once diluted below toxic concentrations, (ionized) ammonia would be taken up by microbes and algae, some of which would oxidize to nitrite and nitrate. Localized blooms could also occur due to addition of often-limiting fixed nitrogen in marine systems.