Assessing environmental impacts of ammonia spills in the marine environment

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ABSTRACT

Ammonia has been identified as an alternative fuel for reducing greenhouse gas emissions from maritime transportation. Accidental spills of ammonia into the marine environment may occur during production (operational or storage tank failures), during transportation through vessel collisions or grounding, or through pipeline bursts. When spilled in the marine environment, ammonia will undergo various physical and chemical processes. When released close to the sea surface, a substantial fraction may volatilize. In water, ammonia readily dissolves, forming ammonium ions (NH_4^+), a process dependent on water temperature, salinity, pH, and turbulence.

Release of ammonia into the marine environment may have significant ecological impacts, including toxicity to marine life. Ammonia may cause toxicity to marine organisms through damaging respiratory surfaces (gills), disruption of ion regulation, cause neurological effects, and immobilization and mortality. Establishing concentration thresholds for ammonia toxicity in the marine environment is important to understand the environmental risk of ammonia spills. We explored marine effects of ammonia using a combination of an experimental ecotoxicology and a modelling approach.

First, we assessed the acute and sub-lethal toxicity of ammonia to Atlantic cod (*Gadus morhua*) embryos. Atlantic cod embryos were exposed for 4 days starting 3 days after hatch, and after exposure, the embryos were transferred to clean sea water until 3 days post hatch. Survival and hatching were monitored daily, and at the end of the experiment, larvae were imaged for assessing larvae morphometry and potential deformations. Ammonia caused acute toxicity to cod embryos; however, no indications of delayed toxicity were observed. No additional mortality was observed during the recovery period, and the surviving larvae displayed no deformations. Based on these experimental data, ecotoxicity thresholds for ammonia toxicity were determined and compared to available literature data using species sensitivity distributions (SSDs) to estimate predicted no-effect concentrations (PNEC).

Second, we simulated an acute ammonia spill using the Dose-related Risk and Effects Assessment Model (DREAM) to predict spreading and estimate the risk of toxicity to pelagic marine organisms. Model simulations suggests that most of the ammonia reached the surface and evaporated, but some spreading of ammonia as ammonium generated a plume which displayed concentrations exceeding PNEC. To put the impact of an ammonia spill into a comparative

context, we compared the environmental risk of ammonia spill with identically simulated spills of different fossil fuels, namely marine gas oil (MGO), very low sulphur fuel oil (VLSFO) and heavy fuel oil (HFO). The environmental fate of MGO and ammonia spills were, to some extent comparable; spreading into the water column, however, substantial fractions of both also evaporated. Since PNEC for MGO was lower than for ammonia, the total volumes of water containing concentrations exceeding the PNEC was higher for MGO than ammonia. Due to their high viscosities, most of the HFO and VLSFO ended up on the surface and were carried by waves towards shorelines, and very little ended up in the water column. Thus, insignificant volumes of water exceeded PNEC for VLSFO and HFO.

This work highlights the need for tools to understand the environmental risks of ammonia spills, which can be used as input to development of prevention, preparedness, and response measures, including effective spill response plans, to mitigate the risks associated with ammonia spills and protect marine environments.

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