AEA Webinar: Ammonia at Sea

The Maritime Decarbonisation Hub

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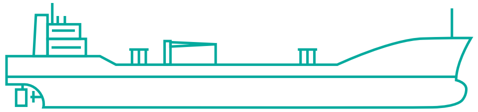
Modelling ammonia spills to water

- Ongoing QRA – assessment of three reference designs: Containership, Bulker, Tanker
- Consequences of unintended releases of ammonia on-board – risk of fatality

Containership
Storage condition: fully refrigerated

Bulker
Storage condition: pressurised



Tanker
Storage condition: semi-refrigerated

- What if there is a leak into the sea? Two scenarios identified for modelling:
  - Bunker station leak
  - Failure of tank resulting from collision or grounding of vessel

Modelling ammonia spills to water

How does ammonia behave when spilled onto water?

- Literature review found that there is limited data on the analysis of ammonia maritime spills
- US Coast Guard recognised need to understand large accidental spills due to increase in transport of liquefied ammonia
- Test spills were conducted in a laboratory, swimming pool and lake

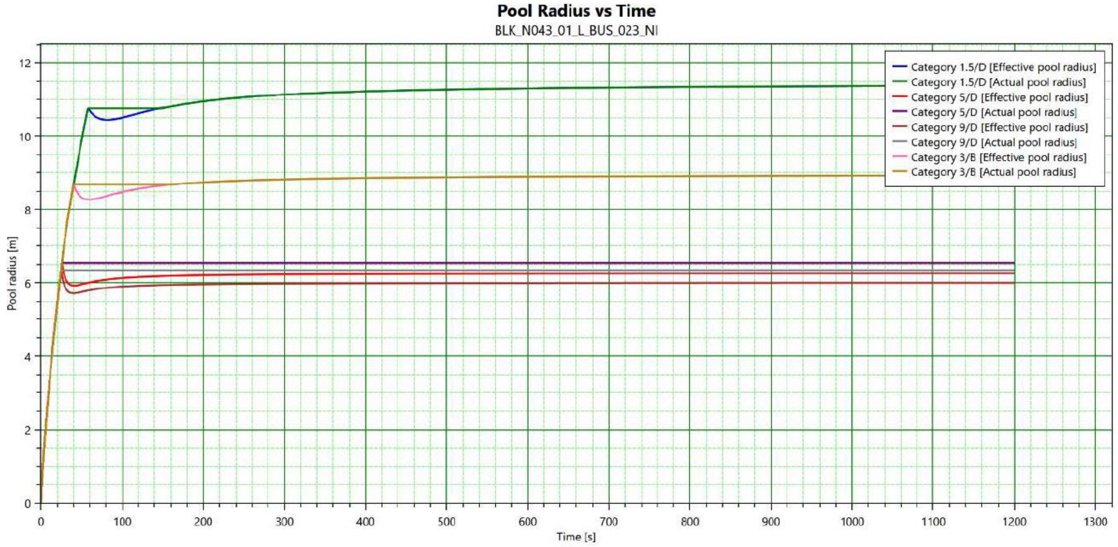
$$NH_{3(aq)} + H_2O_{(l)} \leftrightarrow NH^+_{4(aq)} + OH^-_{(aq)}$$

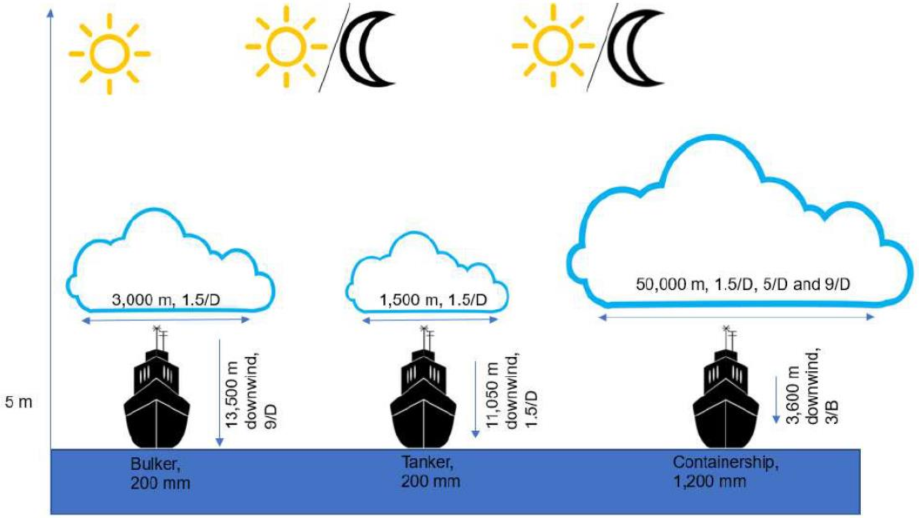
- When spilled directly onto water a spreading pool of liquid, boiling ammonia forms on the surface and approximately 70% dissolves in the water
- Equilibrium is influenced by pH, temperature and salinity of the water

Modelling ammonia spills to water

Modelling process

- Modelling was carried out using industry recognised Process Hazard software PHAST, with Raj and Reid model for ammonia and water interaction
- Scenarios modelled for each vessel type under various weather conditions, including gas cloud dispersion
- Scenarios also modelled with MGO for comparative assessment





Modelling ammonia spills to water

Modelling conclusions

- Weather conditions have significant impact on the spread of gaseous and liquid ammonia
- ‘Worst case’ spill scenario is from a hole in the storage tank due to a collision or grounding event, however this is a low probability event
- Most likely ‘worst case’ scenario is a spill of ammonia from the full bore rupture of the bunkering line, under low wind and stable conditions

Limitations and further work

- Modelling utilises weather conditions as typical of the port of Rotterdam, reducing applicability of results in regions with different conditions
- Modelling does not consider variation in pH and salinity of water
- Further experimental data on spills is required to validate results of previous studies

AEA Webinar: Ammonia at Sea

Ricardo Energy and Environment

Steve Coates, Dr Lauren Dawson, Dr Jess Ware & Lindsey Vest

Habitats and Ecological Receptors Evaluated

Habitat	Ecological Receptors
Rivers	Plankton, Invertebrates, Macrophytes, Fish, Reptiles, Birds and Mammals
Estuaries	Plankton, Invertebrates, Macrophytes, Reptiles, Fish, Birds and Mammals
Wetlands	Plankton, Invertebrates, Macrophytes, Fish, Birds and Mammals
Coastal Waters	Plankton, Invertebrates, Macrophytes, Reptiles Fish, Birds and Mammals
Coral Reefs	Plankton, Invertebrates, Macrophytes, Reptiles, Fish, Birds and Mammals
Polar regions	Plankton, Invertebrates, Macrophytes, Fish, Birds and Mammals
Mangroves	Plankton, Invertebrates, Macrophytes, Reptiles, Fish, Birds and Mammals
Deep Sea	Plankton, Invertebrates, Fish and Mammals

Evaluating Environmental Impact

High level summary of the potential impacts of an ammonia spill on ecological receptors and aquatic habitats

Habitat	Key impacts of ammonia
Rivers	Increase in algal growth and biochemical oxygen demand could lead to eutrophication. Toxicity to fauna could have implications on food chain dynamics.
Estuaries	Increase in algal growth and biochemical oxygen demand could lead to eutrophication. Toxicity to fauna could have implications on food chain dynamics.
Wetlands	Increase in algal growth and biochemical oxygen demand could lead to eutrophication. Toxicity to fauna could have implications on food chain dynamics.
Coastal Waters	Increase in algal growth and biochemical oxygen demand could lead to eutrophication and smothering of intertidal habitats. Toxicity to fauna could have implications on food chain dynamics.
Coral Reefs	Increase in algal growth and biochemical oxygen demand could lead to eutrophication and smothering of intertidal habitats. Toxicity to fauna could have implications on food chain dynamics.
Polar regions	Changes in phytoplankton and ammonia oxidising organism population abundance. Toxicity to fauna could have implications on food chain dynamics.
Mangroves	Potential beneficial effects on mangrove growth and ecosystem health as nutrient limited systems. However, could result in stunted growth, increased sensitivity to drought and hypersalinity. Toxicity to fauna could have implications on food chain dynamics.
Deep Sea	Unknown impacts.

Ecological receptors	Key impacts of ammonia
Bacteria	Elevated growth until tolerance threshold exceeded, causing a reduction in reproductive success via slower cell growth and mortality at toxic levels.
Plankton	Elevated growth until tolerance threshold exceeded which alters the ionic equilibrium, causing inhibited growth and photosynthesis and mortality at toxic levels.
Macrophytes	Elevated growth until tolerance threshold exceeded which alters the ionic equilibrium, causing inhibited growth and photosynthesis and mortality at toxic levels.
Invertebrates	Reduction in growth and reproductive rate and mortality at toxic levels.
Reptiles	Physiological damage and mortality at toxic levels, impacts on habitat quality and prey availability.
Fish	Physiological damage and mortality at toxic levels, impacts on habitat quality and prey availability.
Birds	Physiological damage and mortality at toxic levels, impacts on habitat quality and prey availability.
Marine mammals	Physiological damage and mortality at toxic levels, impacts on habitat quality and prey availability.

Evaluating Environmental Impact

Summary of the comparison of ammonia with marine gas oil by ecological receptor and environment type

Key	
Low Impact	(green)
Medium Impact	(yellow)
High Impact	(red)

Habitat	Ammonia	MGO
Rivers	Medium Impact	High Impact
Wetlands	High Impact	High Impact
Estuaries	High Impact	High Impact
Coastal Waters	High Impact	High Impact
Coral reefs	High Impact	High Impact
Mangroves	High Impact	High Impact
Deep sea	Low Impact	Medium Impact
Polar regions	Low Impact	High Impact

Ecological Receptors	Ammonia	MGO
Bacteria	Low Impact	Low Impact
Plankton	Medium Impact	Medium Impact
Macrophytes	Medium Impact	Medium Impact
Invertebrates	Medium Impact	High Impact
Reptiles	Medium Impact	Medium Impact
Fish	High Impact	Medium Impact
Birds	Medium Impact	High Impact
Marine Mammals	Medium Impact	Medium Impact

Limitations and Reccomendations of the Study

Limitations of Study

- Ammonia discussed in literature cited described ammonia from run-off or natural sources
- Knowledge gaps when completing literature review regarding potential impact of ammonia spills on multiple habitats and ecological receptors.
- The modelling is not able to complete a multi parameter assessment to evaluate cumulative effects
- Environmental factors such as salinity and pH variability have not been considered
- The impact of nitrogen loading have not been assessed as the environmental fate and products of an ammonia release were not assessed
- Ecotoxicology studies relating to ammonia tend to be very species or environ specific (e.g. fish in rivers)
- Modern ecotoxicology studies tend to be limited in relation to vertebrate species

Future Recommendations

- Feasibility and effective regulatory measures should be investigated further
- Effective health and safety measures should be investigated to ensure the safe implementation of ammonia
- Evaluation of chronic ammonia spills need to be assessed for the impact of nitrogen loading and the potential exacerbation of issues such as algal blooms

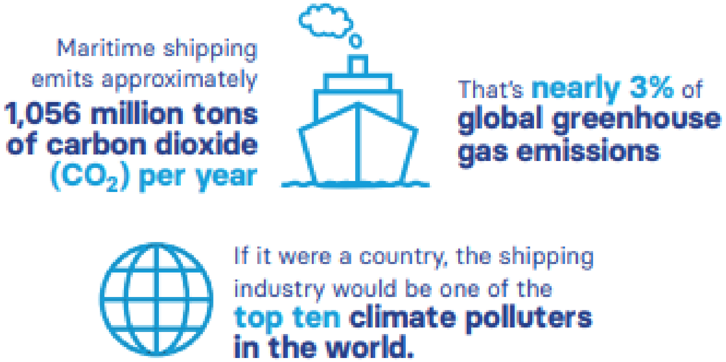
Ammonia at sea

Studying the potential of ammonia as a shipping fuel on marine ecosystems

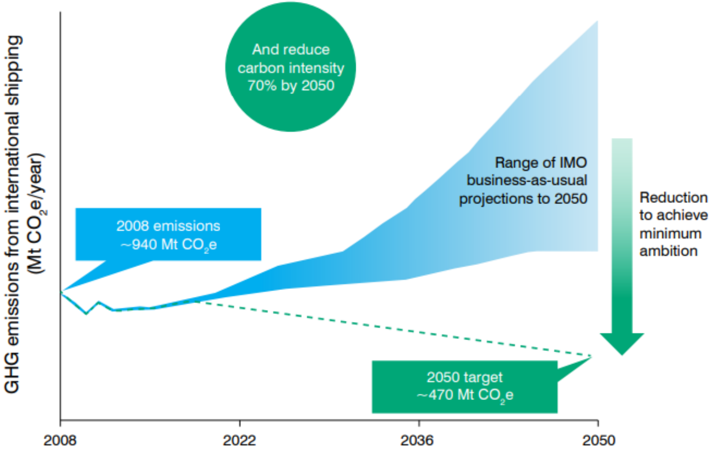
Marie Cabbia Hubatova
24 February 2023

Environmental Defense Fund

Shipping and climate



Reduction required to meet the IMO's absolute emissions reduction target



Ammonia as a solution?

- Ammonia is a popular alternative fuel:
  - In many aspects better properties than hydrogen,
  - Can be produced with renewable energy,
  - Straightforward production process without carbon,
  - Already carried by ships as cargo.
- Plays a pivotal role in many decarbonisation models and is expected to make up a big part of the future fuel market.

The ammonia challenge

- Many questions must be answered:
  - Toxicity – impacts on ecosystems, crew, communities.
  - Nitrogen deposition from chronic leakage.
  - Combustion by-products and climate impact.
- Better understanding is necessary to inform the policy process and create safe management practices.

Thank you!

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