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**DEVELOPMENT OF A SAFETY REGULATORY FRAMEWORK TO SUPPORT
THE REDUCTION OF GHG EMISSIONS FROM SHIPS USING NEW TECHNOLOGIES
AND ALTERNATIVE FUELS**

The potential environmental impact of ammonia spills on the marine environment

**Submitted by Pacific Environment, Clean Shipping Coalition (CSC)
and Environmental Defense Fund (EDF)**

SUMMARY

<i>Executive summary:</i>	This document provides information on the potential impacts of ammonia (NH ₃) spills on the marine environment and climate.
<i>Strategic direction, if applicable:</i>	3
<i>Output:</i>	3.8
<i>Action to be taken:</i>	Paragraph 19
<i>Related documents:</i>	PPR 12/3; CCC 9/INF.27; CCC 10/INF.24, CCC10/16 and MSC.1/Circ.1687

Introduction

1 Following the report of the thirtieth session of the technical group on the evaluation of safety and pollution hazards of chemicals (ESPH 30) and the approval of interim guidelines for the safety of ships using ammonia as fuel which were approved at MSC 109 in December 2024, the co-sponsors of this submission wish to bring to the Committee's attention concerns around the use of ammonia (NH₃) as an energy carrier, which will increase its transport by ship both as fuel and as cargo. The subsequently increased risk of spills will negatively impact aquatic environments, biodiversity, climate and perturb the nitrogen cycle, unless appropriate mitigations are introduced.

Risks to ocean health from NH₃ spills (main focus)

2 If NH₃ is spilled into water, it floats on the surface, rapidly dissolving within the water body into ammonium hydroxide, while at the same time boiling into the atmosphere as gaseous NH₃. The ratio of ammonia dissolved in the water versus that released to the atmosphere as vapour depends on the dynamics and location (i.e. above or below the waterline) of release.

3 Dissolved NH₃ is a serious threat to aquatic organisms. The environmental hazard category for ammonia indicates that ammonia is very toxic to aquatic life (hazard category H400 – hazardous to the aquatic environment, acute hazard category 1¹). Lethal concentrations² can easily be exceeded, resulting in the death of most aquatic organisms in close proximity (Ayvalı et al. 2021³).

4 Indeed, various studies show that the acute ecotoxicity of ammonia to fish and aquatic invertebrates is very high (Zhang et al. 2023⁴). In addition to short-term effects, ammonia also has longer-term toxic effects on fish and aquatic invertebrates (Wissner, 2024⁵). For example, ammonia safety data sheet shows that toxicity values for fish range from 0.083 mg/L – 4.6 mg/L over 96 h, while for rats the concentrations are 2000 ppm – 4h and 5.1 mg/L – 1 h (Ammonia Safety Data sheet from OCI Global 2022⁶).

5 The toxic effects of an NH₃ spill may extend far from the location of the spill. For instance, in a paper which modelled alternative fuel spills in the Port of Vancouver, Reich et al. (2023)⁷ showed that NH₃ can create large areas of water column contamination (2.42 km³) if discharged under the water surface. In this model, the area within the toxic threshold of concern for NH₃ is extremely high, extending 43.8 km from the discharge location. Similarly, a recently published report simulating marine fuel spills showed that an ammonia spill following a collision in the English Channel would lead to highly toxic concentrations (up to 7.6 mg/L) in a 125 km²-sea area during the first day after the spill (Rasmussen et al. 2025⁸).

6 In addition to environmental impacts, the toxicity of NH₃ also poses challenges for those working with, or in proximity to, NH₃. For instance, if compressed NH₃ is released, condensation and droplet formation can result in "NH₃ clouds" at the ground level. These clustered concentrations of NH₃ in the air are a critical problem due to its toxicity, especially for distributors and end users, including seafarers (Karlsson et al. 2024⁹).

1 <https://unece.org/transport/standards/transport/dangerous-goods/ghs-rev9-2021>

2 For example, the Maersk-coordinated report says lethal concentrations above 0.025 - 0.076 mg/L (source: <https://ballastwater.dhigroup.com/environmental-and-human-health-impact-assessment/>)

3 Ayvalı, T, Tsang, S. Van Vrijaldenhoven, 2021. The Position Of Ammonia In Decarbonising Maritime Industry: An Overview And Perspectives. <https://technology.matthey.com/content/journals/10.1595/205651321X16043240667033>

4 Zhang, T. Li, M. Liu, C. Wang, S. Yan, Z., 2023. A review of the toxic effects of ammonia on invertebrates in aquatic environments. <https://doi.org/10.1016/j.envpol.2023.122374>

5 Wissner, 2024. Ammonia as a Marine Fuel: A Closer Look from an Environmental Perspective. The Magazine for Environmental Managers, November 2024. <https://www.awma.org/>

6 OCI Global 2022, <https://documentation.oci-global.com/wp-content/uploads/2022/06/OCI-Beaumont-Safety-Data-Sheet-Anhydrous-Ammonia-1.pdf>

7 Reich, 2023. Modeling Alternative Fuel Spills in the Port of Vancouver. <https://policycommons.net/artifacts/11020065/modeling-alternative-fuel-spills-in-the-port-of-vancouver/11898730/>

8 <https://ballastwater.dhigroup.com/environmental-and-human-health-impact-assessment/>

9 Karlsson et al. 2024. Safety of ammonia on board. LIGHTHOUSE REPORTS. https://lighthouse.nu/images/Rapporter/FS31_2023_Safety_of_ammonia_on_board.pdf

Disturbance to nitrogen cycle from reactive nitrogen (Nr) emissions

7 The global nitrogen cycle has already been dangerously disrupted by human activities (Wolfram et al. 2022¹⁰). Currently, these activities convert about 254 Tg of nitrogen gas (N₂) to ammonia (NH₃) and other forms of reactive nitrogen (Nr) every year (Wolfram et al. 2022⁷): Disruption to the global nitrogen cycle has previously been driven predominantly by the use of NH₃ in the agriculture sector. Demand for NH₃ as an energy carrier has the potential to cause significant, additional nitrogen cycle disruption. Recent studies suggest that nitrous oxide (N₂O) emissions from the use of ammonia as a shipping fuel could, if not managed properly, exceed the already high agricultural N₂O emissions.¹¹

8 In the case of NH₃ as an energy carrier, Nr (including N₂O, NH₃, NO_x and other forms of Nr) may be released to the environment by losses throughout the NH₃ value chain—from production to combustion. The amount of Nr lost could range from 0.5% to as much as 5% of the supply chain input (Bertagni et al. 2023¹²).

9 Disruption to the nitrogen cycle of this magnitude is potentially significant. For instance, losses from a relatively robust NH₃ economy (30 EJ/y) could perturb the global nitrogen cycle by up to 65 Mt/y with a 5% nitrogen loss rate, equivalent to 50% of the current global perturbation caused by fertilizers (Bertagni et al. 2023¹²).

10 Nitrogen (Nr) released throughout the NH₃ value chain can harm air quality, human health, ecosystems, and climate, as well as leading to stratospheric ozone depletion. The Nitrogen Cycle is one of the key focus areas of the Stockholm Resilience Centre's work on Planetary Boundaries. Anthropogenic emissions of Nr have far exceeded "safe" levels on this planet, even more so than the carbon emissions that drive climate change (Richardson et al. 2023¹³).

Nr emissions impact on ocean health

11 In aquatic and marine environments, Nr emissions contribute to eutrophication. Eutrophication refers to an oversupply of nutrients, which can stimulate excessive algal growth. In turn, this can lead to harmful (and sometimes toxic) algal blooms that, upon decomposition, are broken down by oxygen-consuming microorganisms. The increased oxygen demand depletes oxygen levels in the water, creating hypoxic areas commonly referred to as "dead zones". Hypoxic conditions can be deadly for fish, crustaceans and other marine life forms (e.g. Gray et al. 2002¹⁴). Hypoxic zones typically occur when there is a lot of nutrient run-off from agriculture and little mixing of the water column. These low-oxygen zones often

¹⁰ Wolfram, P., Kyle, P., Zhang, X. et al. 2023. Using ammonia as a shipping fuel could disturb the nitrogen cycle. *Nat Energy* 8, 548. <https://www.nature.com/articles/s41560-022-01124-4>

¹¹ United Nations Environment Programme, & Food and Agriculture Organization of the United Nations (2024). Global Nitrous Oxide Assessment. <https://wedocs.unep.org/20.500.11822/46562>.

¹² M.B. Bertagni, R.H. Socolow, J.M.P. Martirez, E.A. Carter, C. Greig, Y. Ju, T. Lieuwen, M.E. Mueller, S. Sundaresan, R. Wang, M.A. Zondlo, A. Porporato, 2023. Minimizing the impacts of the ammonia economy on the nitrogen cycle and climate. *Proc. Natl. Acad. Sci. U.S.A.* 120 (46) e2311728120. <https://doi.org/10.1073/pnas.2311728120> (2023)

¹³ Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S.E., Donges, J.F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Weber, L. & Rockström, J., 2023. Earth beyond six of nine planetary boundaries. *Science Advances* 9, 37. <https://www.science.org/doi/10.1126/>

¹⁴ Gray, J., Wu, R., Or, Y., 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. *Mar. Ecol. Prog. Ser.* 238, 249–279. <https://doi.org/10.3354/meps238249>

overlap with maritime activity hot spots like ports and shipping lanes. Some well-documented hypoxic zones include the northern Gulf of Mexico, the upwelling regions of California and the Pacific Northwest, Chesapeake Bay, and the Baltic, Black, Bohai, Yellow, and Mediterranean Seas (Bhuiyan et al. 2024¹⁵).

12 Additional reactive nitrogen inputs from the use of NH₃ as an energy carrier, such as NH₃ spills or leaks, would further exacerbate both eutrophication and hypoxia. Therefore, the detrimental ecological effects of NH₃ spills and leaks can extend beyond the acute and long-term toxic effects on aquatic and marine organisms.

13 Additionally, Nr inputs to aquatic and marine environments (for example if an ammonia spill or leak from a ship occurred) can cause acidification (Hassellöv et al. 2013¹⁶). Ocean acidification is a serious ecological problem: according to the inaugural Planetary Health Check, the planetary boundary for acidification is close to being exceeded (Caesar et al. 2024¹⁷). Increasing acidification poses a growing threat to marine ecosystems, especially those which build calcium carbonate shells and skeletons, such as corals (e.g. Doney et al, 2009;¹⁸ Chen & Mai. 2024¹⁹).

Ocean health impacts on climate

14 The previous section outlines the negative impacts that Nr emissions can have on ocean health. In turn, these impacts on ocean health can exacerbate climate change.

15 Firstly, hypoxic zones are major sources of marine nitrous oxide (N₂O) emissions (Limburg et al. 2020²⁰). N₂O is a potent greenhouse gas with 273 times the warming potential of CO₂ on a 100-year timescale. As noted above, Nr inputs to aquatic and marine environments can cause eutrophication and hypoxia, meaning additional input of Nr from maritime activities could further exacerbate this problem.

16 Studies have also shown that marine N₂O emissions can be increased by ocean acidification. For example, the acidification of the Pacific Ocean in northern Japan is increasing the natural production rate of N₂O (Breider et al. 2019).²¹ As noted above, increased Nr inputs to marine environments have the potential to increase acidification and therefore may increase marine N₂O emissions.

¹⁵ Bhuiyan., Rahman., Naher., Hasan Shahed., Mohammad Ali., Islam., 2024. Oxygen declination in the coastal ocean over the twenty-first century: Driving forces, trends, and impacts. <https://doi.org/10.1016/j.cscee.2024.100621>

¹⁶ Hassellöv, I. Turner, D. Lauer, A. Corbett, J., 2013. Shipping contributes to ocean acidification. *Geophysical Research Letters*. <https://agupubs.onlinelibrary.wiley.com/doi/10.1002/grl.50521>

¹⁷ L. Caesar, B. Sakschewski, L. S. Andersen, T. Beringer, J. Braun, D. Dennis, D. Gerten, A. Heilemann, J. Kaiser, N.H. Kitzmann, S. Loriani, W. Lucht, J. Ludescher, M. Martin, S. Mathesius, A. Paolucci, S. te Wierik, J. Rockström, 2024. Planetary Health Check Report 2024. Potsdam Institute for Climate Impact Research, Potsdam, Germany. https://www.planetaryhealthcheck.org/storyblok-cdn/f/301438/x/a4efc3f6d5/planetaryhealthcheck2024_report.pdf

¹⁸ Doney, S.C., Fabry, V.J., Feely, R.A., Kleypas, J.A., 2009. Ocean Acidification: The Other CO₂ Problem. *Annu. Rev. Mar. Sci.* 1, 169–192. <https://doi.org/10.1146/annurev.marine.010908.163834>

¹⁹ Chen L., and Mai R.D., 2024. Impacts of ocean acidification on marine ecosystems and mitigation strategies. *International Journal of Marine Science*, 14(3): 231-244, 10.5376/ijms.2024.14.0027

²⁰ K.E. Limburg, D. Breitburg, D.P. Swaney, G. Jacinto, 2020. Ocean deoxygenation: a primer. *One Earth*, pp. 24-29, 10.1016/j.oneear.2020.01.001

²¹ Breider, F., Yoshikawa, C., Makabe, A., Toyoda, S., Wakita, M., Matsui, Y., Kawagucci, S., Fujiki, T., Harada, N., Yoshida, N., 2019. Response of N₂O production rate to ocean acidification in the western North Pacific. *Nat. Clim. Chang.* 9, 954–958. <https://doi.org/10.1038/s41558-019-0605-7>

17 Estuaries, mangroves and wetlands are also particularly sensitive to potential NH₃ spills (Dawson et al. 2021²²). Increased Nr inputs to coastal wetlands can have complex impacts on overall greenhouse gas emissions from these environments, however a number of studies suggest that increased Nr inputs can boost coastal wetland methane and N₂O emissions (e.g. Irvine et al. 2012;²³ Vivanco et al. 2015;²⁴ Chmura et al. 2016²⁵). Further, coastal ecosystems are recognized as critical stores of blue carbon (e.g. Lovelock and Duarte, 2019²⁶) as well as being important for biodiversity and productivity including spawning and nursery areas for commercial seafood species. Degradation of these habitats by Nr inputs risks impacting the ability of these ecosystems to sequester and store carbon (e.g. Deegan et al. 2012;²⁷ Climate Change Committee, 2022²⁸).

Conclusion

18 In conclusion, the only way to avoid the above-mentioned risks and challenges is by mitigating all reactive Nitrogen (Nr) emissions across the ammonia value chain: from production to transportation to end use (combustion).

Action requested of the Committee

19 The Committee is invited to note the information contained in paragraphs 1 to 18 and to note the co-sponsor's intent to bring forward more information, and to take action as appropriate.

²² Dawson et al. 2021, Ammonia at sea. EDF. <https://www.edfeurope.org/alternative-fuels-shipping>

²³ Irvine, I.C., Vivanco, L., Bentley, P.N., Martiny, J.B.H., 2012. The Effect of Nitrogen Enrichment on C1-Cycling Microorganisms and Methane Flux in Salt Marsh Sediments. *Front. Microbio.* 3. <https://doi.org/10.3389/fmicb.2012.00090>

²⁴ Vivanco, L., Irvine, I.C., Martiny, J.B.H., 2015. Nonlinear responses in salt marsh functioning to increased nitrogen addition. *Ecology* 96, 936–947. <https://doi.org/10.1890/13-1983.1>

²⁵ Chmura, G.L., Kellman, L., Van Ardenne, L., Guntenspergen, G.R., 2016. Greenhouse Gas Fluxes from Salt Marshes Exposed to Chronic Nutrient Enrichment. *PLoS ONE* 11, e0149937. <https://doi.org/10.1371/journal.pone.0149937>

²⁶ Lovelock, C.E., Duarte, C.M., 2019. Dimensions of Blue Carbon and emerging perspectives. *Biol. Lett.* 15, 20180781. <https://doi.org/10.1098/rsbl.2018.078>

²⁷ Deegan, L.A., Johnson, D.S., Warren, R.S., Peterson, B.J., Fleeger, J.W., Fagherazzi, S., Wollheim, W.M., 2012. Coastal eutrophication as a driver of salt marsh loss. *Nature* 490, 388–392. <https://doi.org/10.1038/nature11533>

²⁸ Climate Change Committee, 2022. Briefing: Blue Carbon. <https://www.theccc.org.uk/publication/briefing-blue-carbon/>