**Supporting information**

**Chemical emissions from offshore wind farms: From identification to challenges in impact assessment and regulation**

Elena Hengstmanna,\*, Pablo Zapata Corellab,\*, Katharina Alterc, Maria J. Belzunce-Segarrad, Andy M. Boothe, Javier Castro-Jiménezb, Niklas Czernerf, Karien De Cauwerg, Geneviève Devillerh, Alessio Gomieroi, Nils Gosebergf,p, Simone Hasenbeina, Torben Kirchgeorga, Claire Masonj, Wiebke Papea, Koen Parmentierg, Anna, Plaßa, Daniel Pröfrockk, Ali Sarhadil, David Vanavermaetem, Johan van der Molenc, Pedro Almeida Vinagren, Daniel Woodj, Ingo Weinberga, Christian Windtf, Alexa Zondermank, Jennifer Kenyono, Bavo De Witten,1

\*Shared first authorship

a Federal Maritime and Hydrographic Agency (BSH), Marine Sciences Department, Wüstland 2, 22589 Hamburg, Germany ([elena.hengstmann@bsh.de](mailto:elena.hengstmann@bsh.de); [Simone.Hasenbein@bsh.de](mailto:Simone.Hasenbein@bsh.de); [Torben.Kirchgeorg@bsh.de](mailto:Torben.Kirchgeorg@bsh.de); [Wiebke.Pape@bsh.de](mailto:Wiebke.Pape@bsh.de); [Anna.Plass@bsh.de](mailto:Anna.Plass@bsh.de); Ingo.Weinberg@bsh.de)

b IFREMER, CCEM Contamination Chimique des Écosystèmes Marins, 44000 Nantes, France ([pablo.zapata.corella@ifremer.fr](mailto:pablo.zapata.corella@ifremer.fr); javier.castro.jimenez@ifremer.fr)

c Department of Coastal Systems, Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, The Netherlands ([katharina.alter@nioz.nl](mailto:katharina.alter@nioz.nl); johan.van.der.molen@nioz.nl)

d AZTI, Marine Research Division (Basque Research and Technology Alliance - BRTA); Herrera Kaia, Portualdea z/g, 20110 Pasaia, Spain (jbelzunce@azti.es)

e SINTEF Ocean, Postboks 4762 Torgard, N-7465 Trondheim, Norway (andy.booth@sintef.no)

f Leichtweiß-Institute for Hydraulic Engineering and Water Resources, Technische Universität Braunschweig, Beethovenstr. 51a, 38106 Braunschweig, Germany ([n.czerner@tu-braunschweig.de](mailto:n.czerner@tu-braunschweig.de); [n.goseberg@tu-braunschweig.de](mailto:n.goseberg@tu-braunschweig.de); c.windt@tu-braunschweig.de)

g Royal Belgian Institute of Natural Sciences (RBINS), Operational Directorate Natural Environment, Vautierstraat 29, Brussels, Belgium (kdecauwer@naturalsciences.be; kparmentier@naturalsciences.be)

h DERAC, Environmental Risk Assessment of Chemicals consultancy, 104 Grande Rue 44240 Suce-sur-Erdre, France (genevieve.deviller@derac.eu)

i Norwegian Research Centre- NORCE, Dep of Climate and Environment, Mekjarvik, 12, 4072 Randaberg, Norway (alessio.gomiero@gmail.com)

j Centre for Environment, Fisheries and Aquaculture Science (Cefas), Pakefield Road, Lowestoft, NR33 0HT, UK ([claire.mason@cefas.co.uk](mailto:claire.mason@cefas.co.uk); daniel.wood@cefas.gov.uk)

k Helmholtz-Zentrum Hereon, Institute of Coastal Environmental Chemistry, Department Inorganic Environmental Chemistry, Max-Planck Str. 1, 21502 Geesthacht, Germany ([daniel.proefrock@hereon.de](mailto:daniel.proefrock@hereon.de); alexa.zonderman@hereon.de)

l Department of Wind and Energy Systems, Technical University of Denmark, Risø Campus, Frederiksborgvej 399, 4000 Roskilde, Denmark (asar@dtu.dk)

m Flanders Research Institute for Agriculture, Fisheries and Food, Animal Sciences Unit - Aquatic Environment and Quality, Jacobsenstraat 1, 8400 Ostend, Belgium ([david.vanavermaete@ilvo.vlaanderen.be](mailto:david.vanavermaete@ilvo.vlaanderen.be); bavo.dewitte@ilvo.vlaanderen.be)

n WavEC Offshore Renewables – Marine Environment & Licensing, Edifício Diogo Cão, Doca de Alcântara Norte, 1350-352 Lisbon, Portugal ([pedro.vinagre@wavec.org](mailto:pedro.vinagre@wavec.org))

o Bureau of Ocean Energy Management, U.S. Department of the Interior, Washington, D.C., United States of America ([Jennifer.Kenyon@boem.gov](mailto:Jennifer.Kenyon@boem.gov))

p Coastal Research Center, Joint Research Facility of Leibniz Univ. Hannover and Technische Universität Braunschweig, Merkurstr. 11, 30419 Hannover, Germany ([n.goseberg@tu-braunschweig.de](mailto:n.goseberg@tu-braunschweig.de))

1Corresponding author: [Bavo.Dewitte@ilvo.vlaanderen.be](mailto:Bavo.Dewitte@ilvo.vlaanderen.be)

**Dataset:**

Zapata Corella, P., Hengstmann, E., Castro-Jiménez, J., Deviller, G., Vanavermaete, D., Plaß, A., De Witte, B., 2025. Literature study on chemical emissions from offshore wind farms\_Project Anemoi. Dataset, 10.5281/zenodo.14865443

**List of documents considered to compile the compound list.**

1. Ali, A., Ul Amin, B., Yu, W., Gui, T., Cong, W., Zhang, K., Tong, Z., Hu, J., Zhan, X., Zhang, Q., 2023. Eco-friendly biodegradable polyurethane based coating for antibacterial and antifouling performance. Chin. J. Chem. Eng. 54, 80–88. <https://doi.org/10.1016/j.cjche.2022.09.004>
2. Amara, I., Miled, W., Slama, R.B., Ladhari, N., 2018. Antifouling processes and toxicity effects of antifouling paints on marine environment. A review. Environ. Toxicol. Pharmacol. 57, 115–130. <https://doi.org/10.1016/j.etap.2017.12.001>
3. Bell, A.M., Baier, R., Kocher, B., Reifferscheid, G., Buchinger, S., Ternes, T., 2020. Ecotoxicological characterization of emissions from steel coatings in contact with water. Water Res. 173, 115525. <https://doi.org/10.1016/j.watres.2020.115525>
4. Bell, A.M., Keltsch, N., Schweyen, P., Reifferscheid, G., Ternes, T., Buchinger, S., 2021. UV aged epoxy coatings ̶ Ecotoxicological effects and released compounds. Water Res. X 12, 100105. <https://doi.org/10.1016/j.wroa.2021.100105>
5. Brand, S., Veith, L., Baier, R., Dietrich, C., Schmid, M.J., Ternes, T.A., 2020. New methodical approaches for the investigation of weathered epoxy resins used for corrosion protection of steel constructions. J. Hazard. Mater. 395, 122289. <https://doi.org/10.1016/j.jhazmat.2020.122289>
6. Castro-Jiménez, J., Tornero, V., 2023. Organic additives in marine plastics: occurrence, leaching, impacts, and regulatory aspects, in: Contaminants of Emerging Concern in the Marine Environment. Elsevier, pp. 349–373. <https://doi.org/10.1016/B978-0-323-90297-7.00002-0>
7. Deborde, J., Refait, P., Bustamante, P., Caplat, C., Basuyaux, O., Grolleau, A.-M., Mahaut, M.-L., Brach-Papa, C., Gonzalez, J.-L., Pineau, S., 2015. Impact of Galvanic Anode Dissolution on Metal Trace Element Concentrations in Marine Waters. Water. Air. Soil Pollut. 226, 423. <https://doi.org/10.1007/s11270-015-2694-x>
8. ECHA, 2022. Annex XV Restriction report. Proposal for a restriction-Terphenyl, hydrogenated. <https://echa.europa.eu/documents/10162/c0cb9178-9bc7-b4f3-1c25-0fda75b81fb1>. Accesed November 2024.
9. Fauser, P., Vorkamp, K., Strand, J., 2022. Residual additives in marine microplastics and their risk assessment – A critical review. Mar. Pollut. Bull. 177, 113467. <https://doi.org/10.1016/j.marpolbul.2022.113467>
10. Finnie, A.A., Williams, D.N., 2009. Paint and Coatings Technology for the Control of Marine Fouling, in: Dürr, S., Thomason, J.C. (Eds.), Biofouling. Wiley, pp. 185–206. <https://doi.org/10.1002/9781444315462.ch13>
11. Gomiero, A., Da Ros, L., Nasci, C., Meneghetti, F., Spagnolo, A., Fabi, G., 2011. Integrated use of biomarkers in the mussel Mytilus galloprovincialis for assessing off-shore gas platforms in the Adriatic Sea: Results of a two-year biomonitoring program. Mar. Pollut. Bull. 62, 2483–2495. <https://doi.org/10.1016/j.marpolbul.2011.08.015>
12. Gomiero, A., Volpato, E., Nasci, C., Perra, G., Viarengo, A., Dagnino, A., Spagnolo, A., Fabi, G., 2015. Use of multiple cell and tissue-level biomarkers in mussels collected along two gas fields in the northern Adriatic Sea as a tool for long term environmental monitoring. Mar. Pollut. Bull. 93, 228–244. <https://doi.org/10.1016/j.marpolbul.2014.12.034>
13. He, J., Xu, W., Liu, H., Luo, Q., Dai, J., Xu, Y., Zeng, B., Chen, G., Yuan, C., Dai, L., 2023. Preparation of a novel 2-amino benzothiazole loaded ZIF-8/layer double hydroxide composite and its application in anti-corrosion epoxy coatings. Prog. Org. Coat. 185, 107927. <https://doi.org/10.1016/j.porgcoat.2023.107927>
14. Heisterkamp, I., Gartiser, S., Schoknecht, U., Happel, O., Kalbe, U., Kretzschmar, M., Ilvonen, O., 2023. Investigating the ecotoxicity of construction product eluates as multicomponent mixtures. Environ. Sci. Eur. 35, 7. <https://doi.org/10.1186/s12302-023-00711-w>
15. Hsissou, R., 2021. Review on epoxy polymers and its composites as a potential anticorrosive coatings for carbon steel in 3.5% NaCl solution: Computational approaches. J. Mol. Liq. 336, 116307. <https://doi.org/10.1016/j.molliq.2021.116307>
16. Khodabux, W., Causon, P., Brennan, F., 2020. Profiling Corrosion Rates for Offshore Wind Turbines with Depth in the North Sea. Energies 13, 2518. <https://doi.org/10.3390/en13102518>
17. Kirchgeorg, T., Weinberg, I., Hörnig, M., Baier, R., Schmid, M.J., Brockmeyer, B., 2018. Emissions from corrosion protection systems of offshore wind farms: Evaluation of the potential impact on the marine environment. Mar. Pollut. Bull. 136, 257–268. <https://doi.org/10.1016/j.marpolbul.2018.08.058>
18. Li, G., Wu, Y., Chen, Z., Chen, M., Xiao, P., Li, X., Zhang, H., Zhang, P., Cui, C., Liu, W., Zhao, X., Zhang, Y., 2022. Biomimetic epoxy adhesive capable of large-scale preparation: From structural underwater bonding to hydrothermal durability. Chem. Eng. J. 431, 134011. <https://doi.org/10.1016/j.cej.2021.134011>
19. Lithner, D., Larsson, Å., Dave, G., 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of The Total Environment 409, 3309–3324. <https://doi.org/10.1016/j.scitotenv.2011.04.038>
20. Luft, A., Bröder, K., Kunkel, U., Schulz, M., Dietrich, C., Baier, R., Heininger, P., Ternes, T.A., 2017. Nontarget Analysis via LC-QTOF-MS to Assess the Release of Organic Substances from Polyurethane Coating. Environ. Sci. Technol. 51, 9979–9988. <https://doi.org/10.1021/acs.est.7b01573>
21. Luo, H.-W., Lin, M., Bai, X.-X., Xu, B., Li, M., Ding, J.-J., Hong, W.-J., Guo, L.-H., 2023. Water quality criteria derivation and tiered ecological risk evaluation of antifouling biocides in marine environment. Mar. Pollut. Bull. 187, 114500. <https://doi.org/10.1016/j.marpolbul.2022.114500>
22. Ma, Y., Zhang, Y., Liu, J., Ge, Y., Yan, X., Sun, Y., Wu, J., Zhang, P., 2020. GO-modified double-walled polyurea microcapsules/epoxy composites for marine anticorrosive self-healing coating. Mater. Des. 189, 108547. <https://doi.org/10.1016/j.matdes.2020.108547>
23. Marand, A., Dahlin, J., Karlsson, D., Skarping, G., Dalene, M., 2004. Determination of technical grade isocyanates used in the production of polyurethane plastics. J. Environ. Monit. 6, 606. <https://doi.org/10.1039/b402775b>
24. Michelet N., Julian N., Duarte R., Burgeot T., Amouroux I., Dallet M., Caplat C., Gonzalez J.-L., Garreau P., Aragon E., Perrin F.-X., Safi G., 2020. Recommendations for the quantitative assessment of metal inputs in the marine environment from the galvanic anodes of offshore renewable energy structures. France Energies Marines Editions. <https://www.france-energies-marines.org/wp-content/uploads/2020/12/rapport_reco_anode_EN_BD.pdf> Accessed November 2024.
25. Miquerol, L., Bultel, E., Michel, S., Coz, R., La Rivière, M., Sauboua, P., 2023. Référentiel pour la préservation de l’environnement marin dans les projets d’éoliennes en mer. TOME 2. Interactions entre les projets d’éoliennes en mer et le milieu marin – avec focus sur les habitats benthiques de métropole et les espèces Natura 2000. (Office français de la biodiversité).
26. Mirmohseni, A., Azizi, M., Dorraji, M.S.S., 2020. Cationic graphene oxide nanosheets intercalated with polyaniline nanofibers: A promising candidate for simultaneous anticorrosion, antistatic, and antibacterial applications. Prog. Org. Coat. 139, 105419. <https://doi.org/10.1016/j.porgcoat.2019.105419>
27. Momber, A.W., Fröck, L., Marquardt, T., 2021. Effects of adhesive type on the mechanical properties of adhesive joints between polyurethane top coats and polyurethane-based adhesives after accelerated atmospheric ageing. Mar. Struct. 79, 103022. <https://doi.org/10.1016/j.marstruc.2021.103022>
28. Momber, A.W., Marquardt, T., 2018. Protective coatings for offshore wind energy devices (OWEAs): a review. J. Coat. Technol. Res. 15, 13–40. <https://doi.org/10.1007/s11998-017-9979-5>
29. Powers, D., 2009. Interaction of water with epoxy. (No. SAND2009-4405, 985494). <https://doi.org/10.2172/985494>
30. Plenker, D., van den Meiracker, R., Pans, S., Roex, E., 2024. Overview of hazardous substances potentially emitted from offshore industries to the marine environment - Part 1: Emissions from offshore wind industry (German Environment Agency No. 63/2024).
31. Reese, A., Voigt, N., Zimmermann, T., Irrgeher, J., Pröfrock, D., 2020. Characterization of alloying components in galvanic anodes as potential environmental tracers for heavy metal emissions from offshore wind structures. Chemosphere 257, 127182. <https://doi.org/10.1016/j.chemosphere.2020.127182>
32. Schoknecht, U., Kalbe, U., Heisterkamp, I., Kretzschmar, M., Gartiser, S., Happel, O., Ilvonen, O., 2022. Release of substances from joint grouts based on various binder types and their ecotoxic effects. Environ Sci Eur 34, 111. <https://doi.org/10.1186/s12302-022-00686-0>
33. Shi, C., Wang, M., Wang, Z., Qu, G., Jiang, W., Pan, X., Fang, M., 2023. Oligomers from the Synthetic Polymers: Another Potential Iceberg of New Pollutants. Environ. Health envhealth.3c00086. <https://doi.org/10.1021/envhealth.3c00086>
34. Silva, E.R., Ferreira, O., Ramalho, P.A., Azevedo, N.F., Bayón, R., Igartua, A., Bordado, J.C., Calhorda, M.J., 2019. Eco-friendly non-biocide-release coatings for marine biofouling prevention. Sci. Total Environ. 650, 2499–2511. <https://doi.org/10.1016/j.scitotenv.2018.10.010>
35. Tornero, V., Hanke, G., 2016. Chemical contaminants entering the marine environment from sea-based sources: A review with a focus on European seas. Mar. Pollut. Bull. 112, 17–38. <https://doi.org/10.1016/j.marpolbul.2016.06.091>
36. Van Der Veen, I., De Boer, J., 2012. Phosphorus flame retardants: Properties, production, environmental occurrence, toxicity and analysis. Chemosphere 88, 1119–1153. <https://doi.org/10.1016/j.chemosphere.2012.03.067>
37. Vermeirssen, E.L.M., Dietschweiler, C., Werner, I., Burkhardt, M., 2017. Corrosion protection products as a source of bisphenol A and toxicity to the aquatic environment. Water Res. 123, 586–593. <https://doi.org/10.1016/j.watres.2017.07.006>
38. Wang, Y., Hao, D., Yang, M., Su, X., Li, P., Liu, Q., Guo, X., 2022. Polyurethane antifouling coatings with various antifouling strategies in the side chain. Prog. Org. Coat. 173, 107225. <https://doi.org/10.1016/j.porgcoat.2022.107225>
39. Watermann, B., Eklund, B., 2019. Can the input of biocides and polymeric substances from antifouling paints into the sea be reduced by the use of non-toxic hard coatings? Mar. Pollut. Bull. 144, 146–151. <https://doi.org/10.1016/j.marpolbul.2019.04.059>
40. Watermann, B.T., Daehne, B., Sievers, S., Dannenberg, R., Overbeke, J.C., Klijnstra, J.W., Heemken, O., 2005. Bioassays and selected chemical analysis of biocide-free antifouling coatings. Chemosphere 60, 1530–1541. <https://doi.org/10.1016/j.chemosphere.2005.02.066>
41. Weller, S.D., Johanning, L., Davies, P., Banfield, S.J., 2015. Synthetic mooring ropes for marine renewable energy applications. Renew. Energy 83, 1268–1278. <https://doi.org/10.1016/j.renene.2015.03.058>
42. Zhao, Y., Zhang, P., Gu, X., Zhang, X., Huo, M., 2023. Preparation of PVDF-PDMS-SiO2 multi-stage rough superhydrophobic coating with excellent anti-corrosion and drag reduction performance via one-step cold spraying. Surf. Coat. Technol. 471, 129882. <https://doi.org/10.1016/j.surfcoat.2023.129882>
43. Zhou, H., Hu, X., Liu, M., Yin, D., 2023. Benzotriazole ultraviolet stabilizers in the environment: A review of analytical methods, occurrence, and human health impacts. TrAC Trends Anal. Chem. 166, 117170. <https://doi.org/10.1016/j.trac.2023.117170>
44. Hempel (2023a): Safety Data Sheet. Hempadur Multi-Strength 45755 Base.
45. Hempel (2023b): Safety Data Sheet. Hempathane HS 55619 Base.
46. Hempel (2023c): Safety Data Sheet. Hempel's Curing Agent 97050.
47. Hempel (2023d): Safety Data Sheet. Hempel's Curing Agent 98750.
48. International (2017): Safety Data Sheet. Interzone 954 White Part A.
49. International (2018a): Safety Data Sheet. Interthane 990 RAL1003 SignalYellow PtA.
50. International (2018b): Safety Data Sheet. Interzone 954 Part B.
51. International (2021): Safety Data Sheet. Interthane 990 Part B.