European Commission

Science for Environment Policy

Mussel study determines risk posed by rare earth metals to marine environments

Rare earth elements (REEs) are used increasingly often in innovative technologies, causing these elements to enter the natural environment. They can be sourced via deep-sea mining, raising concerns about marine exposure to mining processes and waste products. This study examined how two REEs, lanthanum and yttrium, affected and stressed marine ecosystems, using young marine mussels (*Mytilus galloprovincialis*) as indicators of water quality. The researchers determine a parameter known as the 'predicted no effect concentration' (PNEC) for La and Y — the maximum environmental level of each of the two elements at which no effect is seen on the most sensitive organisms and which is, therefore, deemed safe for the environment.

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Source: Mestre, N., Sousa, V., Rocha, T. and Bebianno, M. (2019). Ecotoxicity of rare earths in the marine mussel Mytilus galloprovincialis and a preliminary approach to assess environmental risk. *Ecotoxicology*, 28(3), pp.294-301.

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Past decades have seen the increasing use of REEs in innovative technologies: lanthanum (La), for example, is used in laptop batteries and lasers, and yttrium (Y) in colour televisions and temperature sensors. REEs are so named because complex mining processes limit their large-scale production, making them a rare commodity on the market. They feature on the EU's 2017 Critical Raw Materials list, which highlights materials that are considered important to the European economy but face issues relating to security of supply. The EU Raw Materials Initiative (RMI)[1] was also established in 2008 to help ensure the secure, sustainable and affordable supply of REEs.

Marine mineral mining is now a valid and cost-effective source of REEs and minerals, and crust deposits below the ocean are being considered as sources of elements such as La and Y. However, the toxic effects of these elements on marine life — during extraction, via sediment plumes, mine slurry and tailings — has yet to be established. Determining the PNEC for marine mining of such materials is thus relevant in meeting the aims of the RMI, and forms an important step in assessing the ecological risk faced by an ecosystem.

This study, developed under the European Commission MIDAS project,[2] used marine mussels as a biological indicator of seawater quality, as metals accumulate within their tissue. Mussels in the early stages of life are most sensitive to metal pollutants; the researchers, therefore, assessed juveniles and embryos, and noted the ecotoxicological effects — the biological, chemical or physical stressors placed on an ecosystem by a substance — of La and Y at different concentrations in seawater. They then combined their results with data from scientific literature to establish PNECs for La and Y.

Adult and juvenile marine mussels were collected from the Ria Formosa Lagoon in southern Portugal, transported to the laboratory, cleaned, and kept in aerated natural seawater on a 12-hour light/12-hour dark cycle for seven days prior to exposure to La and Y. The researchers created three solutions: a control solution, and solutions of lanthanum chloride and yttrium chloride at five concentrations (0.01, 0.1, 1, 10, 100 mg L^{-1} for La; and 0.001, 0.01, 0.1, 1, 10 mg L^{-1} for Y).

The mussels were induced to spawn via temperature and salinity shock, plus shaking, and the researchers counted the number of resulting embryos in 50 microlitres two hours after fertilisation via optical microscopy. The adequate volume of each culture was added to a 150-ml solution of filtered seawater and chemical stock to create a final density of 30 embryos per ml. The researchers then assessed the percentage of unfertilised eggs, abnormally and normally developed larvae by randomly counting 50 embryos/larvae from each of the La, Y, and control settings using a counting chamber and microscope, to determine the embryotoxicity for both chemicals. To do this, the researchers used a dose-modelling approach with statistical software to determine the REE concentration required to reduce embryo success by 50% (the EC_{50}) compared to the control results; and the acute toxicity to juveniles (the concentration required to kill 50% of the juveniles: LC_{50}).

Continued on next page.

1. See alos: The raw materials initiative — meeting our critical needs for growth and jobs in Europe https://echa.europa.eu/documents/10162/16960216/tgdpart2_2ed_en.pdf

2. This project was developed under the MIDAS project (Managing impacts of deep-sea resource exploitation), funded by the European Commission 7th Framework Programme.

https://www.eu-midas.net/

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As the embryos were exposed to increasing concentrations of La and Y, the percentage of normally developed embryos decreased and abnormal features increased. At 1 mgL^{-1}, for example, 89.3% of embryos for La and 79.3% for Y developed abnormally. Lower concentrations of La (0.01 and 0.1 mgL^{-1}) caused abnormalities such as shell deformations in later-stage development, whereas higher concentrations caused abnormalities to develop earlier. A similar pattern was noted for Y, but at higher concentrations (1 and 10 mgL^{-1}). The EC_{50} for La is 0.05 mgL^{-1}, and for Y 0.8 mgL^{-1}.

La and Y were found to be more toxic to developing embryos than to juveniles, with La being the most toxic — but Y being more toxic to juveniles than La. This highlights the importance of conducting toxicity tests over different stages of life, say the researchers, as these findings show that a hundred-fold difference in toxicity can occur between, for example, embryo and juvenile phases. The calculated PNEC, based on marine embryotoxicity data, is 0.015 μgL^{-1} for La and 0.09 μgL^{-1} for Y. These PNEC values fall at the lower end of the environmental data available for European stream (non-marine) waters (0.02 to 16 μgL^{-1} for La and 0.003 to 26.6 μgL^{-1} for Y); however, no environmental data are available for marine waters — more data are needed to improve PNEC derivation and robustness.

These PNECs, although based on a small-scale study, are useful starting points for defining water-quality criteria and regulatory standards, say the researchers. With suggestions that La accumulates in mussels' tissues as they grow, alongside the increasing use of REEs in agriculture and technology and the potential for an increase in deep-sea mining, eco-toxicity data for REEs is of great importance. Further toxicological study data for REEs would enable robust ecological risk assessments of marine environments with regard to future deep-sea mineral mining.

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