Scientists reveal a hidden, sunlight-driven source of a potent greenhouse gas

March 19 2025, by Sanjukta Mondal

Cubillas reservoir with Sierra Nevada mountains in the background. Credit: Elizabeth Leon-Palmero

The term greenhouse gas often brings carbon dioxide (CO_2) to mind, and rightly so, as it is a key contributor to rising global temperatures.

However, a more potent pollutant and greenhouse gas that often gets overlooked is nitrous oxide (N_2O). Molecule for molecule, N_2O is 300 times stronger than CO_2 and is accumulating in the atmosphere faster than expected.

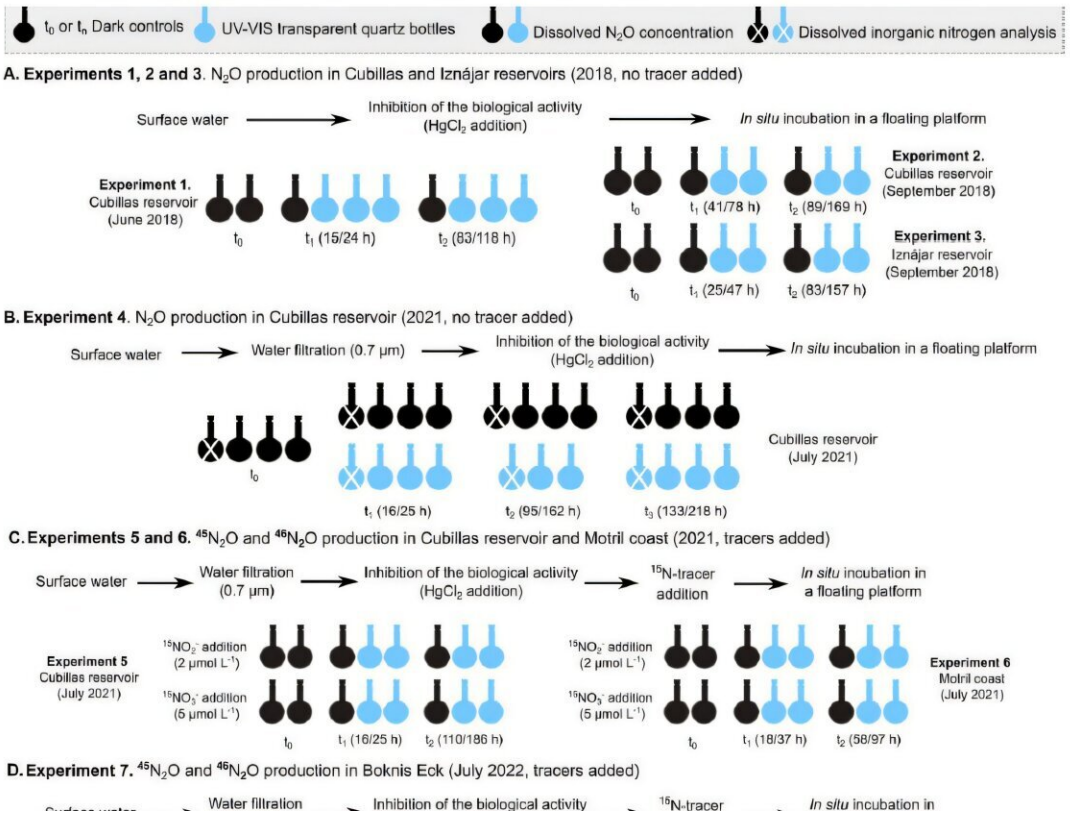
A recent study by researchers from Denmark and Spain identified a new abiotic (not biological) pathway for N_2O production in surface waters, called photochemodenitrification, driven by sunlight. They found this process produced N_2O at higher rates than biological methods like ammonia oxidation, which was previously considered the primary source of N_2O emission in surface waters.

The work is published in the journal *Science*.

N_2O enters the atmosphere through various pathways, including anthropogenic sources like nitrogen-rich synthetic fertilizers, chemical reduction of nitrate and nitrites in metal-rich soils and marine sediments, and microbial breakdown of nitrogenous compounds.

Among these, microbes such as ammonia-oxidizing bacteria and archaea play the most significant role in the nitrogen cycle and are major global producers of N_2O.

Although current models account for various factors to predict N_2O emissions, atmospheric levels have increased faster than the prediction of the Intergovernmental Panel on Climate Change (IPCC) over the past decade. Thus exposing a critical gap in our understanding of possible sources of N_2O.



Water samples collected from freshwater and marine coastal marine systems were exposed to UV radiation. Credit: *Science* (2025). DOI: 10.1126/science.adq0302

The discovery of this previously unrecognized photochemodenitrification pathway in this study could explain why the observed increase in atmospheric N_2O concentrations has been faster than predicted.

In this study, researchers collected water samples from two freshwater and coastal marine systems and placed them in quartz vials where, upon exposure to sunlight, the samples produced N_2O.

To rule out the involvement of microbial processes (biotic pathways) ,

they added the biocide $HgCl_2$ to the water samples. However, the biocide had no effect on N_2O production, confirming the abiotic nature of the photochemodenitrification process.

To identify the substrates involved in the abiotic production of N_2O, the researchers added isotopic tracers, nitrogen-15 labeled nitrite and nitrate to the water samples.

They found that nitrite was the main substrate directly involved with the process whereas nitrate likely contributes to the process indirectly. The experiment also found that the higher the intensity ultraviolet radiation from sunlight, the higher the N_2O production. However, the exact chemical mechanisms behind photochemodenitrification remain unclear.

The researchers suggest that the reactions involved in the abiotic process might be especially significant in the major global N_2O emission hotspots, such as eutrophic freshwater bodies, coastal regions, and upwelling marine areas.

Integrating this newly discovered N_2O production pathway into climate models could help improve emission predictions and inform more effective mitigation strategies. To ensure inclusion on a global scale, similar experiments must be conducted across geographic locations and conditions.

More information: Elizabeth Leon-Palmero et al, Sunlight drives the abiotic formation of nitrous oxide in fresh and marine waters, *Science* (2025). DOI: 10.1126/science.adq0302

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