



## OPEN ACCESS

EDITED AND REVIEWED BY  
Paola Grenni,  
National Research Council, Italy

\*CORRESPONDENCE  
Yong Li  
✉ liyong@zju.edu.cn

RECEIVED 31 December 2023  
ACCEPTED 08 January 2024  
PUBLISHED 18 January 2024

CITATION  
Zhu B, Chen Z, Hu H, Andrei A-S and Li Y  
(2024) Editorial: Greenhouse gas emissions  
and mitigation: microbes, mechanisms and  
modeling. *Front. Microbiol.* 15:1363814.  
doi: 10.3389/fmicb.2024.1363814

COPYRIGHT  
© 2024 Zhu, Chen, Hu, Andrei and Li. This is  
an open-access article distributed under the  
terms of the [Creative Commons Attribution  
License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or  
reproduction in other forums is permitted,  
provided the original author(s) and the  
copyright owner(s) are credited and that the  
original publication in this journal is cited, in  
accordance with accepted academic practice.  
No use, distribution or reproduction is  
permitted which does not comply with these  
terms.

# Editorial: Greenhouse gas emissions and mitigation: microbes, mechanisms and modeling

Baoli Zhu<sup>1</sup>, Zengming Chen<sup>2</sup>, Hangwei Hu<sup>3</sup>,  
Adrain-Stefan Andrei<sup>4</sup> and Yong Li<sup>5\*</sup>

<sup>1</sup>Key Laboratory of Agro-Ecological Processes in Subtropical Region, Institute of Subtropical Agriculture, Chinese Academy of Sciences (CAS), Changsha, China, <sup>2</sup>Institute of Soil Science, Chinese Academy of Sciences (CAS), Nanjing, China, <sup>3</sup>School of Agriculture, The University of Melbourne, Melbourne, VIC, Australia, <sup>4</sup>Department of Plant and Microbial Biology, University of Zurich, Zurich, Switzerland, <sup>5</sup>College of Environmental and Resource Sciences, Zhejiang University, Hangzhou, China

## KEYWORDS

greenhouse gas (CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>), climate change, nitrification, denitrification, ammonia oxidizing microorganisms

## Editorial on the Research Topic

[Greenhouse gas emissions and mitigation: microbes, mechanisms and modeling](#)

The soil, holding ~1500 Pg of total carbon (C) and 136 Pg of total nitrogen (N), represents the largest terrestrial reservoirs of these elements (Nieder and Benbi, 2008). Yet, it also stands as a significant source of greenhouse gas (GHG) emissions, contributing over 350 Pg CO<sub>2</sub>-equivalents annually and thereby significantly impacting global warming. Over the years, atmospheric N<sub>2</sub>O concentrations have risen by more than 20%, and CH<sub>4</sub> concentrations have nearly tripled to 1900 ppb, primarily attributed to microbial activities (Schaefer et al., 2016). Understanding the microbial mechanisms alongside the production and reduction of GHGs is crucial. Recent discoveries, such as atypical nitrous oxide reductase (NosZ II), comammox, and novel processes like oxygenic denitrification and anaerobic oxidation of CH<sub>4</sub> linked to the reduction of nitrate, nitrite, iron, and manganese oxides, underscore the pivotal role of soil microbes in regulating the biogeochemical cycles of C and N, and highlight avenues for targeted strategies to reduce GHG emissions and mitigate global warming. This Research Topic comprises nine articles that offer insights on the factors that influencing the emission of GHGs, especially N<sub>2</sub>O, and the potential roles of microorganisms.

Nitrification and denitrification are the main processes producing N<sub>2</sub>O. Fertilizer applications, especially N-fertilizers, fuel the emission of this potent greenhouse gas. Thus, nitrification inhibition can be a potential approach to reduce N<sub>2</sub>O emissions. In this Research Topic, Lei et al. analyzed over 200 datasets from 48 studies and found that application of nitrification inhibitors on average reduced about 60% of total N<sub>2</sub>O emission, increased over 70% of soil ammonium concentration, and decreased about 50% of AOB abundances. The findings emphasize AOB's significant role in N<sub>2</sub>O emissions, and can be a better indicator and target for N<sub>2</sub>O mitigation. Xie et al. compared N<sub>2</sub>O emissions from grasslands featuring a

tropical grass species *Brachiaria humidicola*, whose root exudates with the capacity of biological nitrification inhibition, and a native grass *Eremochloa ophiuroides*, in Hainan, China. Interestingly, the N<sub>2</sub>O emission rate of the *B. humidicola* grassland was significantly higher, especially under N-fertilization treatment. Nevertheless, its yield-scaled N<sub>2</sub>O emission was significantly lower than the native *E. ophiuroides* grassland.

Nitrogen fertilizer application is also critical in influencing soil organic carbon (SOC) stability. Song et al. reported that nitrate addition enhanced the abundance and activity of SOC decomposers, thus, stimulating SOC decomposition in deep soils (>1 m), particularly when nitrate presented as the dominant electron acceptor over oxygen. This suggests the link between above-ground anthropogenic N input and deep soil carbon dynamics. Xu et al. demonstrated that delayed N fertilizer application in pea and maize intercropping reduced soil respiration rates and altered soil microbial community structures, thereby decreasing carbon emissions. This shed lights on agriculture management strategies in achieving carbon neutrality goals.

In addition, moisture plays important role in influencing greenhouse gas emissions and soil organic carbon (SOC) stability. Through laboratory incubations and literature synthesis, Wang et al. quantified N<sub>2</sub>O emission rates from nitrification and denitrification under different soil moisture levels (40% to 120% WFPS, water-filled pore space), and found that N<sub>2</sub>O emitting rate peaked at 80%–95% WFPS, while the dominating process switched from nitrification to denitrification when moisture increased over about 60% WFPS. Moisture as a major driver controls the relative contribution of nitrification and denitrification to N<sub>2</sub>O emissions was evident from synthesized 80 groups of data.

Han et al. investigated the responses of total microbial community and ammonium oxidizing microbes to short-term moisture level changes and nitrogen fertilizer application in paddy soils. Moisture influenced the abundance and composition of total soil microbes, and nitrogen fertilizer reduced the connectivity and complexity of the total bacteria network. The community structures of ammonium-oxidizing-bacteria (AOB) and -archaea (AOA) were largely influenced by ammonium and nitrate, respectively, which play crucial roles in nitrification, indicating a differential response of these microbes.

Qu et al. investigated the respiration rates of different layer soils of the Loess Plateau, and underscored soil temperature and moisture as critical factors influencing soil respiration rates, suggesting a positive feedback loop amplifying global warming. Yang et al. investigated the impact of maize and rice straw biochar on N<sub>2</sub>O emissions during paddy soil freeze-thaw cycles via simulating microcosm incubations. Results showed that biochar application decreased 10% of AOB abundance and reduced about two thirds of the total N<sub>2</sub>O emissions, revealing the application potential of biochar in decreasing soil N<sub>2</sub>O emissions.

By employing <sup>15</sup>N tracing and N<sub>2</sub>O isotopocule methods, Karlowsky et al. dissected the contribution of bacterial denitrification and nitrifier denitrification to N<sub>2</sub>O emissions in hydroponic tomato cultivation system. Results indicated that bacterial denitrification, nitrifier denitrification and coupled nitrification and denitrification all contributed to the N<sub>2</sub>O emissions in the system.

In essence, these studies collectively offer profound insights into microbial mechanisms governing GHG emissions, presenting avenues for targeted mitigation strategies. More comprehensive and large-scale investigations are necessary to understand the intricate microbial processes driving GHG emissions, including methane, and to devise effective approaches to combat climate change.

## Author contributions

BZ: Writing – original draft, Writing – review & editing. ZC: Writing – original draft, Writing – review & editing. HH: Writing – original draft, Writing – review & editing. A-SA: Writing – original draft, Writing – review & editing. YL: Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The research was supported by the National Natural Science Foundation of China (project no. 42177104).

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References

- Nieder, R., and Benbi, D. K. (2008). *Carbon and Nitrogen in the Terrestrial Environment*. Cham: Springer Science and Business Media.
- Schaefer, H., Fletcher, S. E. M., Veidt, C., Lassey, K. R., Brailsford, G. W., Bromley, T. M., et al. (2016). A 21st-century shift from fossil-fuel to biogenic methane emissions indicated by <sup>13</sup>CH<sub>4</sub>. *Science* 352, 80–84. doi: 10.1126/science.aad2705