

Reviewer#1's comment, 06 May 2025

1 L25 and L292: the phrase “by up to 0–42%” could be replaced with “by 0–42%” or “by up to 42%”.

We changed it to “by 0–42%.”

2. L27-32: The sentence is too long, and the authors might consider breaking the sentence into two shorter ones.

We changed it to “This review enhances our understanding of the role of SO_4^{2-} in promoting aerobic CH_4 oxidation. It lays the foundation for future research with two primary goals: (1) validating these findings by quantifying CH_4 flux and aerobic oxidation rates, and (2) elucidating the underlying microbial processes through experimental research. Concurrently, the review provides directions for further investigation into the impact of SO_4^{2-} on aerobic CH_4 oxidation.”

3. L29: “investigation of SO_4^{2-} ’s impact” could be replaced with “investigation into the impact of SO_4^{2-} ”.

We changed it to “investigation into the impact of SO_4^{2-} .”

4. L94: The title should be bolded.

I have bolded the font.

5. L122: “location” should be “locations”

We changed it to “locations”.

6. L144: the two clauses should be connected using proper conjunctions (“thus” is not

a conjunction).

I changed it to the conjunction “so”.

Reviewer#2's comment, 04 Jun 2025

1. In the abstract you write 25 times..which one is it?

We have unified the content in the abstract and introduction, changing it to 28 times.

2. methane related greenhouse effect

We changed it to “CH₄-related greenhouse effect”.

3. Please specify in which regions of the world this is a particular problem.

We changed it to “Acid rain, involving deposition of SO₄²⁻ and other acidic compounds, remains a globally significant environmental issue (Chen et al., 2020; Qi et al., 2022). The three largest affected regions are Europe, North America, and China (Li et al., 2021).”

4. “in anaerobic methane biogeochemical processes” would be more precise

We changed it to “playing a crucial role in anaerobic CH₄ biogeochemical processes.”

5. Can this really be described as a cycle? The term methane cycle in general is under debate as it implies similarity to the C/N/P-cycles which is somehow misleading.

We changed it to “Despite these well-documented effects on anaerobic CH₄ biogeochemical processes.”

6. Please display here the amount of studies indicating the positive effect of SO₄²⁻ on aerobic methane oxidation. Something like: “Based on the available literature, 3 out of 5 studies that investigated the influence of SO₄²⁻ on aerobic methane oxidation were able to demonstrate a positive effect on aerobic methane oxidation.”

We changed it to “Based on the available literature, 3 out of 5 studies that investigated the influence of SO₄²⁻ on aerobic CH₄ oxidation were able to demonstrate a positive effect on aerobic CH₄ oxidation.”

7. I don’t see why this is important for the SO₄²⁻ topic as you do not comment on the influence SO₄²⁻ has on either of those pathways. Either include the pathways into the discussion or conclusion or omit it including the respective part in Figure 1.

We changed it to “Aerobic CH₄ oxidation converts CH₄ to CO₂ in four steps: ① MMO oxidizes CH₄ to methanol (CH₃OH), ② methanol dehydrogenase (MDH) oxidizes CH₃OH to formaldehyde (HCHO), ③ FADH oxidizes HCHO to formate (HCOOH), ④ formate dehydrogenase (FDH) oxidizes HCOOH to CO₂ (Fig. 1, paths ①–④) (Mancinelli, 1995).” And the content of Figure 1 has been modified accordingly.

8. Not every methanotroph is able to utilize both forms, this should be addressed.

We changed it to “Except for *Methylocella silvestris* and *Methyloferula stellata*, all methanotrophs possess pMMO. sMMO has only been detected in a few specific genera, namely *Methylomonas* sp., *Methylomicrobium* sp., *Methylosinus* sp., and *Methylococcus capsulatus* (DiSpirito et al., 2016). Copper (Cu) concentration differentially regulates MMO expression (Fig. 1⑤): high Cu concentrations induces

pMMO (Fig. 1 ⑥), whereas low Cu concentrations triggers sMMO (Fig. 1 ⑦) (Hakemian & Rosenzweig, 2007).”

9. This sentence is confusing as above it is stated that SO_4^{2-} is promoting methane oxidation.

We have deleted this sentence.

10. This part reads as an introductory paragraph. It should be drastically shortened or omitted.

We changed it to “ SO_4^{2-} ’s impact on aerobic CH_4 oxidation—particularly its mechanisms for enhancement—remains unclear. Our literature review reveals two promotion pathways: Shifts in methanotroph activity and community structure (Fig. 2 path d) (Bradford et al., 2001b; Sitaula et al., 1995). Alterations to soil physicochemical properties (Fan et al., 2017), substrate availability (Bjorneras et al., 2019; Palmer et al., 2013; Xu et al., 2017), and nutrient dynamics (Islam, 2012) (Fig. 2).”

11. physical “does not seem to be the right choice here, as you are talking about the soil pH.” Physicochemical" might be the better choice.

We changed it to “physicochemical properties”.

12. I find these statements confusing as most of the H_2SO_4 -experiments were conducted in forests and some found an enhanced methane oxidation rates (s. Table 1).

We have provided corresponding explanations in the annotations on the side of the article.

13. How can Cu be synthesized from metabolized methane?

We changed it to “Cu is a crucial component in aerobic CH₄ oxidation processes, with its critical role stemming from its high abundance in catalytically active pMMO complexes—where it directly participates in methane oxidation and facilitates electron transfer from endogenous reductants to molecular oxygen (Balasubramanian & Rosenzweig, 2007; Semrau et al., 2010). This process drives the conversion of CH₄ to methanol (Dassama et al., 2016).”

14. This part reads as a summary not a conclusion (In my opinion, the ‘Conclusion’ section in particular needs a reorientation, as it currently summarises the manuscript rather than forming a conclusion. This would be the right place to formulate precise starting points for future studies, too.).

We have revised the conclusion to “This review synthesizes the double-scale mechanisms by which SO₄²⁻ influences aerobic CH₄ oxidation. Macroscopically, SO₄²⁻ enhances aerobic CH₄ oxidation rates by 0–42%. Mechanistic studies demonstrate that this regulation occurs through SO₄²⁻-driven alteration of environmental factors (e.g., pH, Cu/P availability, Al³⁺ toxicity, NH₄⁺ absorption), which subsequently modulate methanotroph physiology and MMO activity. Based on synthesized evidence, we hypothesize a net stimulatory effect of SO₄²⁻ on aerobic CH₄ oxidation. Validating this hypothesis requires deeper mechanistic insights; therefore, future research should prioritize quantifying aerobic CH₄ oxidation responses to SO₄²⁻ exposure while elucidating underlying microbial mechanisms. This integrated approach is projected to advance CH₄ mitigation strategies amid rising global SO₄²⁻ deposition.”

15. The order of the classification is confusing. “Id” is below “IIb” and also both find in column 1 and 2. Please order the groups in a clear pattern.

We have made corresponding modifications to Figure 1.