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Anaerobic oxidation of methane (AOM) in paddy soil: the alternative electron acceptors

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The anaerobic oxidation of methane (AOM) in marine ecosystems is ubiquitous and coupled largely to sulfate reduction. In comparison, little is known about the role of AOM in terrestrial environments, and the dominant mechanisms for terrestrial AOM remain elusive. Submerged agricultural fields, such as rice paddies, with intensive CH_4 turnover, may provide a high potential for AOM; however, the AOM rate, electron acceptors and mechanisms in these environments are largely unexplored. Here, we used $^{13}CH_4$ isotope tracers to quantify the AOM rate in paddy soils under organic (i.e. pig manure, biochar) and mineral fertilizers (i.e. NPK), and examine the potential of alternative electron acceptors (AEAs) including Fe^{3+}, NO_3^-, SO_4^{2-} and humic acids.
During 84 days of incubation, the cumulative AOM ($^{13}CH^4$-derived CO_2) reached 0.15-1.3 μg C g^{-1} soil depending on fertilization. There was a linear correlation (R2 = 0.55 $\sim$ 0.93, $p < 0.05$) between the amount of gross produced and net oxidized CH^4. NO_3^- was the most potent AEA with an AOM rate reaching 0.80 ng C g^{-1} soil h^{-1} under pig manure fertilization. The role of Fe^{3+} on AOM remained unclear, whereas SO_4^{2-} inhibited AOM but strongly stimulated CO_2 production indicating intensive sulfate-induced anaerobic organic matter oxidation. Humic acids were the second most potent AEA, especially when without mineral fertilizers and after biochar addition. Humic acids addition increased methanogenesis for 5-6-times in all paddy soils as compared with control and other AEAs. We demonstrated for the first time that organic AEAs (e.g. humic acids) are important drivers of AOM – this along with the proven nitrate (nitrite)-dependent AOM mechanisms in paddy soils, whereas Fe^{3+} and SO_4^{2-} are preferential electron donors for mineralization of native soil organic matter. Consequently, in a broader ecological view, the organic and mineral fertilization controls an important methane sink under anaerobic conditions in submerged agricultural paddy ecosystems.