Microbial fuel cell as mitigation strategy for methane emissions from paddy fields

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Introduction

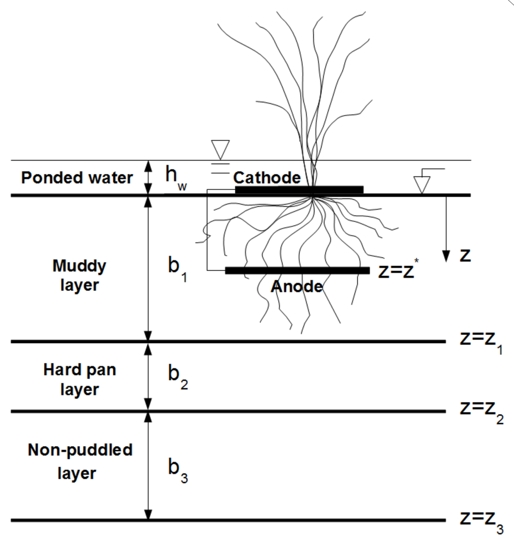
- Eco-compatibility of rice production is compromised by emissions of methane (CH_4 – green house gas with GWP_{100}~25)
- microbial fuel cells (MFCs) can generate electricity from paddy soils [1]
- MFCs could also reduce CH_4 emissons from paddy [2]
  - MFC → dissolved organic carbon (DOC) sink
  - DOC → microbial energy source for CH_4 production
  - MFC → ↓↓ DOC → ↓↓ CH4 production → ↓↓ CH_4 emissions
- Objective

  Investigate MFC effectiveness in reducing CH_4 emissions

  → process-based model approach

Process-based model

- Hydro_chemical model [3]
  - **Soil stratigraphy** → three layers
  - **Hydraulic** → Subsurface flow
  - **Roots** → gas mass balance PDE
  - **Biogeochemistry** → chemical compound mass balance PDE
  - **Temperature** → heat transfer equation



- MFC model → additional DOC sink
  - I — current intensity [1,4]
  - A_{MFC} — anode projected area [1]
  - e_{DOC} — mol_{e-} per mol_{DOC}
  - F — Faraday constant
  - DOC — dissolved organic carbon concentration
  - Δt — time step

$$R^{MFC}_{DOC} = min\left[\frac{I\,A_{MFC}}{e_{DOC}\,F}, \frac{DOC}{\Delta t}\right]$$

Results

S^{y}_{x} → y: Current intensity, *I*, in mA/m²; x: anode depth, z_{MFC}, in cm

- up to -26.5% total CH_4 emissions
- CH_4 emissions =f (*I*)
  - ↑↑ Current intensity ↓↓ CH_4 emissions
  - asymptotic plateau
  - transport processes limit CH_4 mitigation
- CH_4 emissions =f (z_{MFC})
  - near the top → ↓↓ CH_4 emission reductions
  - Middle of muddy layer→ ↑↑ CH_4 emission reductions
  - near the bottom → no maximum reductions → ↓↓ roots

Conclusions

- MFC can be an effective mitigation technique for CH_4 emissions
- process-based model can be a powerful tool for preliminary investigation of novel mitigation strategy of CH_4 emissions from paddy field

References

[1] Kaku, N.et al., 2008. Plant/microbe cooperation for electricity generation in a rice paddy field. Appl. Microbiol. Biotechnol.

[2] Deng, H. et al., 2012. Energy from plants and microorganisms. Progress in plant-microbial fuel cells. ChemSusChem 5,

[3] Rizzo, A. et al., 2013. Role of water flow in modeling methane emissions from flooded paddy soils. Adv. Water Resour. 52

[4] Takanezawa, et al., 2010. Factors affecting electric output from rice-paddy microbial fuel cells. Biosci. Biotechnol. Biochem. 74