RALF CONRAD

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2006-2013	Adjunct Professor, Chinese Agricultural University, Beijing
1991-2017	Director and Head of the Department of Biogeochemistry, Max Planck Institute for Terrestrial Microbiology, Marburg
since 1993	Adjunct Professor (Microbiology), Philipps-University Marburg
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1985	Habilitation (Microbiology), University of Mainz
1983	Postdoc (Microbiology), University of Wisconsin, Madison
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1976	Dr. rer.nat. (Microbiology), University of Göttingen, 1973 Diplom (Biology), University of Göttingen
1949	Year of Birth

METHANOGENIC DEGRADATION AND MICROBIAL METABOLISM OF TRACE GASES

The objectives of the Conrad lab in the past years have been to learn which groups of soil microorganisms are responsible for particular biogeochemical processes and to understand the reason why. For this purpose we investigated biogeochemical processes involved in the exchange of climatically relevant trace gases (CH_4, H_2) between soil and atmosphere. A particular focus was on processes in flooded rice fields, which we have used during the last thirty years as a model system for studying biogeochemistry and ecology of soil microbes.

After my retirement in 2017, I continued publishing together with former co-workers and outside colleagues. These publications concerned experimental work that had been done in the previous years but had not been completely evaluated and written up. This process is still on-going. The complete list of publications for 2018 to 2020 is found below. Most of the work was on the structure and function of methanogenic microbial communities in soil and sediments. The most important findings concerned the effects of abiotic variables (e.g., organic matter, inorganic oxidants,

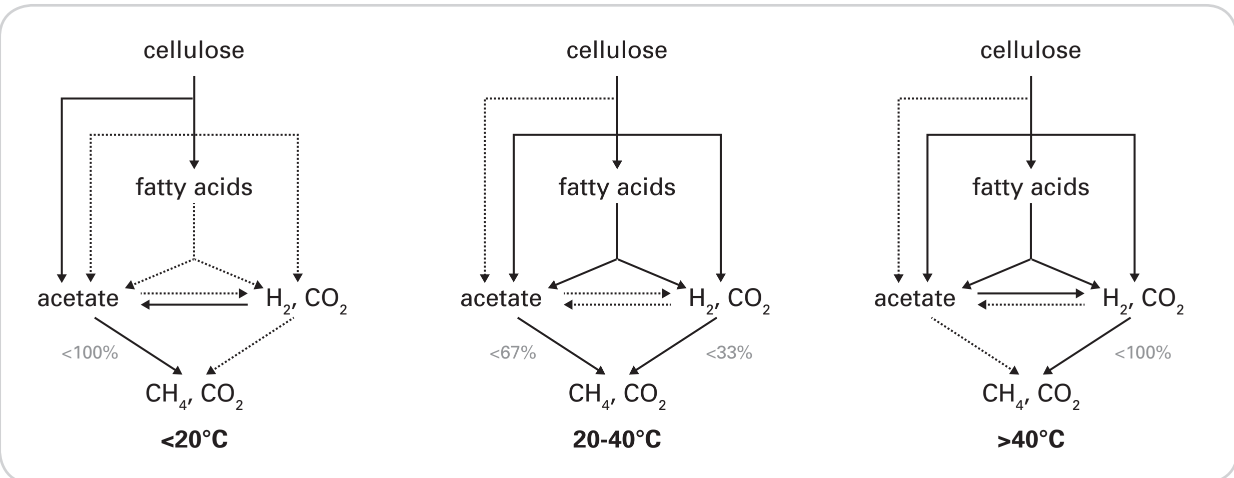

Figure 1 | Carbon flow during methanogenic degradation of organic matter at three different temperature ranges.

temperature, desiccation) on the pathways of CH_4 production, i.e. the importance of hydrogenotrophic, aceticlastic, and methylotrophic methanogenesis (Conrad, 2020a, b). In the following I will give three examples:

(1) In flooded rice fields, methanogenesis is the most important terminal process of organic matter degradation. However, sulfate reduction may also play an important role, especially at the beginning of flooding, after the application of S-containing fertilizers (e.g., ammonium sulfate) and after addition of gypsum for mitigation of CH_4 production. We found that the family *Syntrophobacteraceae* is the most important group of sulfate reducers utilizing the two major fermentation products of organic matter, i.e. propionate (see last report) and acetate (Liu *et al.*, 2018).

(2) The organic matter in rice fields mainly consists of polysaccharides, which are almost completely (>90%) degraded during the first year of flooding. Complete methanogenic degradation of polysaccharides theoretically results in CH_4 production by >2/3 aceticlastic and <1/3 hydrogenotrophic methanogenesis. However, as the degradation of organic matter (e.g., rice straw and soil organic matter) is progressing, hydrogenotrophic methanogenesis was found to become increasingly more important (Ji *et al.*, 2018a, b). This observation is consistent with earlier reports that aged organic matter (e.g. in lake sediments or deep peat layers) is predominantly degraded via hydrogenotrophic rather than aceticlastic methanogenesis (compare last report).

(3) The pathway of methanogenesis was found to be affected by temperature. Whereas low temperatures (<20°C) stimulate acetate production from chemolithotrophic homoacetogenesis and thus favour aceticlastic methanogenesis as terminal process (Fu *et al.*, 2018, 2019), elevated temperatures (>40°C) often inhibit aceticlastic methanogenesis, which is then replaced by syntrophic acetate oxidation coupled to hydrogenotrophic methanogenesis (Liu *et al.*, 2018, 2019; Deng *et al.*, 2019). The C flow from organic matter to CH_4 and CO_2 at three different temperature ranges is shown in Fig. 1.

PUBLICATIONS

Dong, X., Greening, C., Brüls, T., Conrad, R., Guo, K., Blaskowski, S., Kaschani, F., Kaiser, M., AbuLaban, N., Meckenstock, R. U. (2018). Fermentative Spirochaetes mediate necromass recycling in anoxic hydrocarbon-contaminated habitats. ISME J. 12, 2039-2050.

Fu, B., Conrad, R., Blaser, M., (2018). Potential contribution of acetogenesis to anaerobic degradation in methanogenic rice field soils. Soil Biol. Biochem. 119, 1-10.

Ji, Y., Liu, P., Conrad, R., (2018). Change of the pathway of methane production with progressing anoxic incubation of paddy soil. Soil Biol. Biochem. 121, 177-184.

Ji, Y., Liu, P., Conrad, R., (2018). Response of fermenting bacterial and methanogenic archaeal communities in paddy soil to progressing rice straw degradation. Soil Biol. Biochem. 124, 70-80.

Liu, P., Klose, M., Conrad, R., (2018). Temperature effects on structure and function of the methanogenic microbial communities in two paddy soils and one desert soil. Soil Biol. Biochem. 124, 236-244.

Liu, P., Pommerenke, B., Conrad, R., (2018). Identification of Syntrophobacteraceae as major acetate-degrading sulfate reducing bacteria in Italian paddy soil. Environ. Microbiol. 20, 337-354.

Martinson, G. O., Pommerenke, B., Brandt, F. B., Hohmeier, J., Bruneo, J. I., Conrad, R., (2018). Hydrogenotrophic methanogenesis is the dominant methanogenic pathway in neotropical tank bromeliad wetlands. Environ. Microbiol. Reports 10, 33-39.

Valle, J., Gonsior, M., Harir, M., Enrich-Prast, A., Schmitt-Kopplin, P., Conrad, R., Hertkorn, N., (2018). Extensive processing of sediment pore water dissolved organic matter during anoxic incubation as observed by high-field mass spectrometry (FTICR-MS). Water Res. 129, 252-263.

Yuan, Q., Hernandez, M., Dumont, M. G., Rui, J., Fernandez Scavino, A., Conrad, R., (2018). Soil bacterial community mediates the effect of plant material on methanogenic decomposition of soil organic matter. Soil Biol. Biochem. 116, 99-109.

Deng, Y., Liu, P., Conrad, R., (2019). Effect of temperature on the microbial community responsible for methane production in alkaline NamCo wetland soil. Soil Biol. Biochem. 132, 69-79.

Deng, Y., Che, R., Wang, F., Conrad, R., Dumont, M., Yun, J., Wu, Y., Hu, A., Fang, J., Xu, Z., Cui, X., Wang, Y., (2019). Upland Soil Cluster Gamma dominates methanotrophic communities in upland grassland soils. Sci.Total Environ. 670, 826-836.

Fu, B., Jin, X., Conrad, R., Liu, H., Liu, H., (2019). Competition between chemolithotrophic acetogenesis and hydrogenotrophic methanogenesis for exogenous H_2/CO_2 in anaerobically digested sludge: impact of temperature. Frontiers Microbiol. 10, 2418, doi: 10.3389/fmicb.2019.02418.

Hernandez, M., Klose, M., Claus, P., Bastviken, D., Marotta, H., Figueiredo, V., Enrich-Prast, A., Conrad, R., (2019). Structure, function and resilience to desiccation of methanogenic microbial communities in temporarily inundated soils of the Amazon rainforest (Cunia Reserve, Rondonia). Environ. Microbiol. 21, 1702-1717.

Liu, P., Klose, M., Conrad, R., (2019). Temperature-dependent network modules of soil methanogenic bacterial and archaeal communities. Frontiers Microbiol. 10, 496, doi:10.3389/fmicb.2019.00496.

Yuan, H., Zhang, Z., Qin, S., Zhou, S., Hu, C., Clough, T., Wrage-Mönnig, N., Luo, J., Conrad, R., (2019). Effects of nitrate and water content on acetylene inhibition technique bias when analysing soil denitrification rates under an aerobic atmosphere. Geoderma 334, 33-36.

Conrad, R. (2020a) Importance of hydrogenotrophic, aceticlastic, and methylotrophic methanogenesis for methane production in terrestrial, aquatic and other anoxic environments: a mini review. Pedosphere 30, 25-39.

Conrad, R. (2020b) Methane production in soil environments - anaerobic biogeochemistry and microbial life between flooding and desiccation [review]. Microorganisms 8, 881, doi:10.3390/microorganisms8060881.

Conrad, R., Klose, M., Enrich-Prast, A. (2020) Acetate turnover and methanogenic pathways in Amazonian lake sediments. Biogeosciences 17, 1063-1069.

Hernandez, M., Calabi, M., Conrad, R., Dumont, M. G. (2020) Analysis of the microbial communities in soils of different ages following volcanic eruptions. Pedosphere 30, 126-134.

Ji, Y., Conrad, R., Xu, H. (2020 Responses of archaeal, bacterial and functional microbial communities to growth season and nitrogen fertilization in rice fields. Biol. Fertil. Soils 56, 81-95.

Yuan, Q., Huang, X., Rui, J., Qiu, S., Conrad, R. (2020) Methane production from rice straw carbon in five different methanogenic rice soils: rates, quantities and microbial communities. Acta Geochim. 39, 181-191.

THESES

None

TRANSFER OF KNOWLEDGE/CONTACTS TO THE BUSINESS WORLD

None

EXTERNAL FUNDING

None

COMMITTEE WORK OUTSIDE MPITerMic

Hanse Wissenschaftskolleg, Study Group 'Methane and Earth'

EDITORIAL BOARDS

None

INTERNATIONAL & NATIONAL COOPERATIONS WITH JOINT PUBLICATIONS, FUNDING ETC.

None

INVITED LECTURES

American Soc. Limnol. Oceanogr., Meeting, Victoria, Canada, June 2018

Seminar, Helmholtz Centre, Neuherberg, Jul 2018

World Congress on Soil Science, Rio de Janeiro, Aug 2018

Int. Conference on Sustainable Energy and Environment, Bangkok, Nov 2018

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