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Organic carbon dynamics in the hyporheic zone of a small lowland stream

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BACKGROUND AND AIMS

Hyporheic zone (HC) plays a crucial role in the biogeochemical carbon cycling in lotic ecosystems (Pusch 1996). Metabolism of the HC relies either on dissolved organic carbon (DOC) or on particulate organic carbon (POC) input (Findlay 1995). Proportion of these organic carbon inputs in streams are variable and often unknown, because they occur simultaneously. HC can act as a sink for organic carbon in the stream, when streamwater DOC is lost as it moves through the sediment. On the contrary, hyporheic zone can be a source of organic carbon, if the decomposition of particulate organic matter (POM) in sediments causes the release of DOC to both interstitial and stream waters.

Our study focuses on organic carbon dynamics in a gravel bar (downwelling-upwelling zone) of a small lowland stream. We tried to determine the major carbon sources, the efficiency at which organic carbon inputs are retained and processed, and the forms and amounts of organic carbon exported. **Various pathways suggested to be important in the organic carbon cycling within hyporheic zone are depicted in fig. 1**

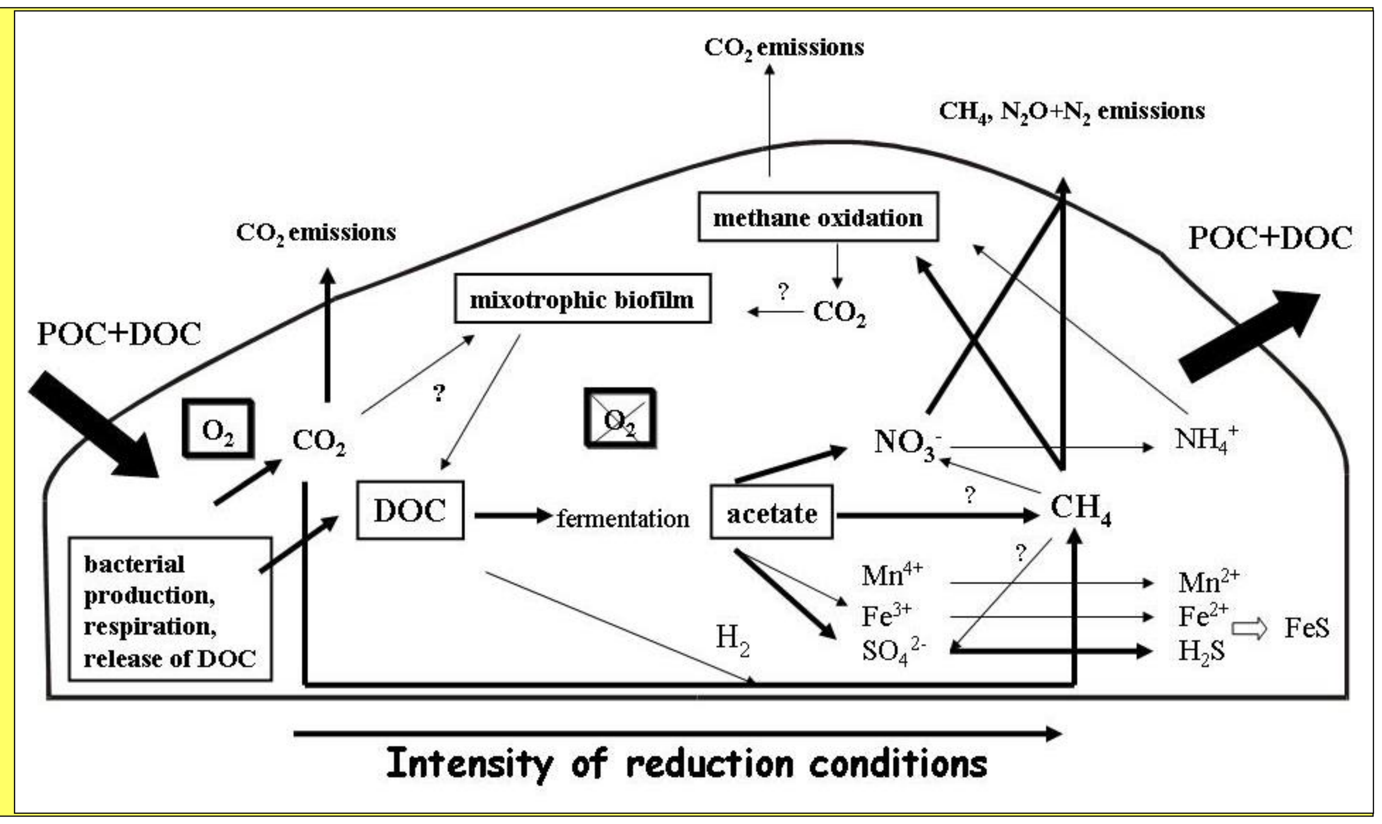


Fig. 1. Idealized view of organic carbon cycling within hyporheic sediments. Bold arrows indicate major processes (original M. Rulík).

MATERIAL AND METHODS

The study area is located in downstream part of the Sitka, an undisturbed, third-order, 35 km long lowland stream in Czech Republic (Fig.2). The study area was ≈ 20m long and 4.5 m wide. Measurements were carried out during the summer months 1997-2002. Various parameters and methods used for their measurements are mentioned in the table 1. A schematic view of the site with sampling point positions have been given previously (Rulík et al. 2000).

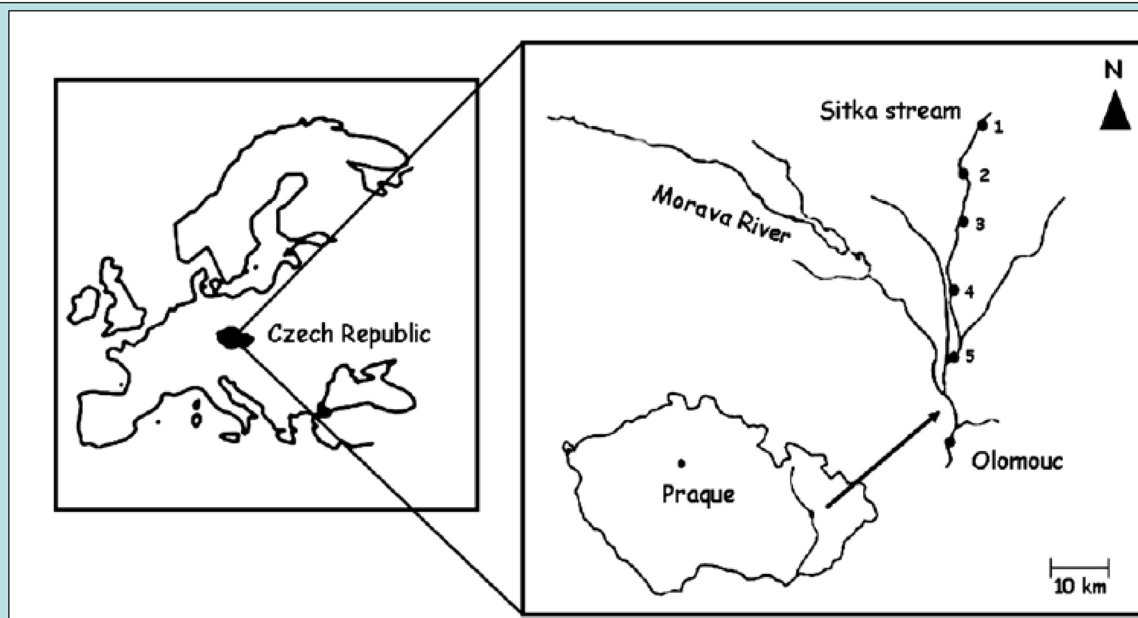
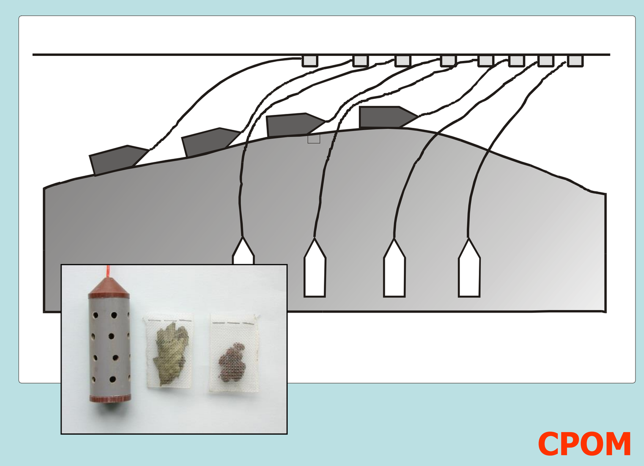
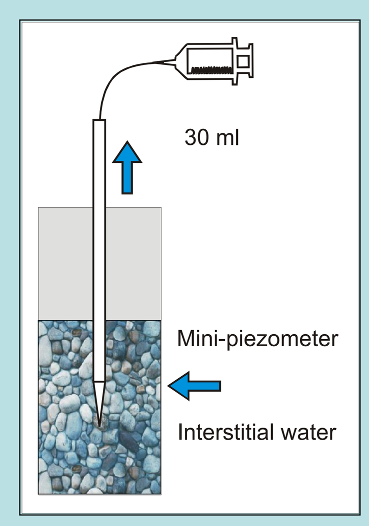


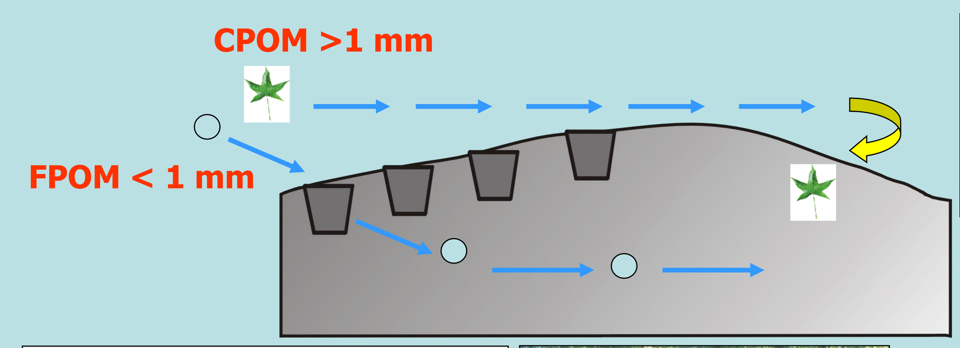
Fig. 2. A map showing the location of the Sitka stream

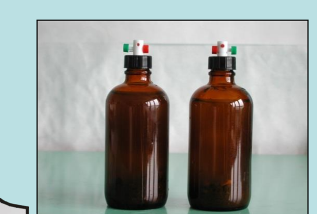
Table 1. Oveview of the measured paremters and methods employed

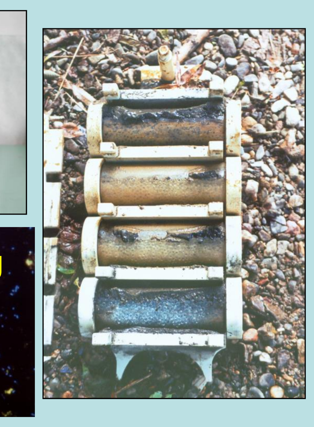
Measured parameter	Methods employed
Litterfall of riparian vegetation	6 dm² silk bags (30x30 cm) placed on the stream bottom
Input of particulate organic matter (POM) into the sediments	10 sediment traps with a volume of 0.6 l and filled by natural sediment were inserted into the sediments
Detrital and biofilm standing stock in sediments	freeze-core method and ash-free dry weight measurement after combustion (550 °C, 4 hrs).
Microbial abundance, biomass and production (BCP)	DAPI staining, biomass was enumerated from cell volume of bacteria that was converting to bacterial biomass (fgC/cell), BCP was estimated from rates of radiolabeled ^{14}C-leucine incorporation
Hyporheic bacterial respiration (HCR) and POC turnover (POC_T)	measurement of oxygen consumption rate by sediment size fraction 0.1-5.6 mm (Pusch 1996), POC_T = POC/HCR
DOC, DOC immobilization and release	flow reactor (Fischer et al. 2002), leaching from sediment biofilm and detrital particles
Concentrations of terminal electron acceptors	O2, NO3-, SO42-, CO2, CH4 measured by portable oximeter, one-capillary type isotachophoresis and gas chromatography
Relative importance of each type of electron acceptors in organic carbon respiration	estimated by assuming molar respiratory quotient of 1:1 for O_2, 5:4 for NO_3^- and 2:1 for SO_4^{2-} according to Kelly et al. (1988).

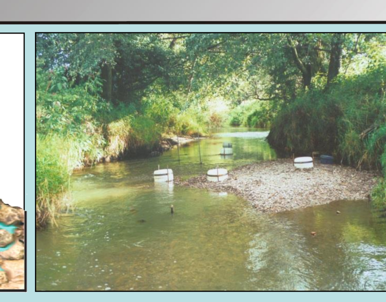












Sketches of some methods

RESULTS

➢We estimated that about 58 % of the dissolved organic carbon (DOC), which discharges through sediments, is immobilized. Decomposition of sediment particulate organic matter (POM) accounts for about 84 % of carbon need for bacterial production in sediments, revealing that POM content is important factor for bacterial metabolism. Mean bacterial carbon production was estimated at about 2.55 g C.dm³.y⁻¹. Hyporheic community respiration (HCR) was found to be negatively correlated with grain size and positively with sediment organic carbon content. Turnover time of POC was 332 days (**Tab.2**).

➢Anaerobic metabolism is an important pathway in organic carbon cycling in hyporheic sediments. Nitrate respiration seems to be a dominant respiration process, responsible for 46% of the organic carbon respiration, while both sulfate respiration and methanogenesis contributed to organic carbon respiration 30 % and 6 %, respectively. The aerobic respiration rate was 5 fold lower than anaerobic, probably due to relatively low oxygen concetration within hyporheic zone (**Tab.3**). The imbalance between changes in DOC concentrations and organic carbon reduced via declining electron acceptors observed in our study strongly suggests that carbon sources other than infiltrating DOC contributed substantially to microbial demand. Thus, we propose that POM is likely the predominant carbon source for microbial metabolism in the Sitka stream hyporheic zone. Moreover, production of the methane within the Sitka stream hyporheic zone implies intense anaerobic microbial activity.

Table 2: Organic matter parameters from the Sitka stream

Litterfall	41.75 g C m² year⁻¹
Fluvial input of POC	20.44 g C dm⁻³ year⁻¹
Standing stock of detritus < 1 mm	1.33 g C dm⁻³
Standing stock of biofilm	18.67 g C dm⁻³
- bacteria	0.44 g C dm⁻³
- extracellular polysacharides	6.03 g C dm⁻³
DOC release from biofilm	16.18 g C dm⁻³ year⁻¹
DOC release from detritus	3.66 g C dm⁻³ year⁻¹
Bacterial production	2.55 g C dm⁻³ year⁻¹
Hyporheic community respiration (HCR)	8.03 g C dm⁻³ year⁻¹
Turnover time of bacterial carbon	60 days
Turnover time of POC	332 days

Table 3: Changes in concentrations of electron acceptors and methane between downwelling and upwelling, revealing their relative importance in organic carbon decomposition, expressed as a carbon equivalent, and DOC changes during discharge through the bar. Concentration changes, and values of CO_2 produced correspond to retention time of surface water within sediment (6 hour).

Reactions (final C products)	Mean changes in concentration (µM) [number of samples]	CO_2 produced (µM)	% of measured C metabolism	organic C respired (mg per day)
O_2 reduction (CO_2)	- 87,5 [22]	67.4	18	3.2
NO_3^- reduction (CO_2)	- 139 [32]	173.4	46	8.3
SO_4^{2-} reduction (CO_2)	- 56 [32]	112.4	30	5.4
CH_4 production (CO_2+CH_4)	+ 22,3 (15) [34]	22.3	6	1.4
DOC production	+ 8.3 [34]			

References

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CONCLUSION

Our calculations show that (1) the hyporheic zone is an important consumer of DOC and (2) POC supports a substantial portion of hyporheic respiration and contributes to DOC production. We conclude that DOC can enter the sediment food web as POC by first being sorbed abiotically to stream sediments. Thus, hyporheic sediments of the Sitka stream are a POC-dominated system; sediment POM is the significant source of metabolizable energy for stream ecosystem. If our estimatation that aerobic respiration accounts for only a smaller portion of organic carbon consumption is correct, whole-stream respiration based on measures of changes in dissolved oxygen concentration could substantially underestimate total respiration.

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