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Identifying hot-spot methane emission sites in an impounded river

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Greenhouse gas (GHG) emissions on a landscape level are difficult to assess due to large spatial and temporal variations in fluxes. Freshwater ecosystems in particular, despite their limited spatial extent, can often have a disproportionately high impact on the GHG balance within the terrestrial landscape. Compounding the difficulties in assessing GHG emissions within these aquatic systems is that local production and emission rates show large variations due to small-scale physical and biogeochemical heterogeneity within the waterbody and sediment. Therefore, to ultimately characterize the total methane emissions from a limnic system using a bottom-up approach, the primary emission pathways and locations must be identified and quantified.

To achieve this goal, we recorded continuous data with ship-mounted instruments over a 93 km longitudinal transect of the heavily impounded River Saar which consists of 7 dams and locks located every 15 km on average (Germany, France). A Contros HydroC Methane sensor measured the dissolved methane concentration to locate hot-spots and to estimate the diffusive flux across the water-air interface. Gas bubbles were detected and mapped using a Simrad Scientific echosounder and were processed to quantify ebullition-flux rates. Concentration differences directly up- and downstream of the dams were used to quantify the atmospheric transport component due to outgassing at the dams. Additional water and sediment samples along the 93 km transect completed the data set and allowed for sensor calibration.

Methane concentrations ranged from 60 nM up to 1800 nM during the survey. Sharp and significant increases in dissolved methane concentrations were observed towards the forebay of three dams, with lower concentrations observed in the immediate tailwater of these dams. The areas of increasing concentrations coincided well with acoustically detected bubbles and with the distribution of cohesive muddy sediments. Ebullition flux rates varied between 20 to as much as 1300 mg CH_4 m^{-2} d^{-1}. While the areas where ebullition was detected covered only 15% of the total water surface area, they contributed 43% of the total emissions, while outgassing at the dams was quantified to yield about 53% of the total emissions (the remaining 4% by surface diffusion).

Both pathways combined account for over 90% of the total methane emissions to the atmosphere and were identified using our high-resolution longitudinal methane concentration and acoustic bubble-detection survey. Our approach and results illustrate the importance of performing spatially-fine surveys on accurately resolving the spatial extent of outgassing “hot-spots” and pathways within freshwater systems. Temporal extrapolation of the quantified emissions would lead to the emission of 117 t CH_4 yr^{-1} or 87 t CH_4-C yr^{-1} from the Saar river system, but this estimate is limited because it represents only a snap-shot of the emission pattern and seasonal variations are not included. Despite this limitation, we show the importance of rivers, which are under-represented in the literature, as significant GHG contributors.