

Cryptic constituents: The paradox of high flux – low concentration components of aquatic ecosystems

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Running title: Revealing cryptic resources

Calculations on the dissolved organic carbon metabolism in the “Median” lake

Many limnologists have claimed that because terrestrially derived dissolved organic carbon (t-DOC) is often the largest pool of organic matter in the water columns of lakes - this means t-DOC plays a very large role in the “metabolism” of lakes [1-4]. However, from a mass balance perspective, a high concentration of a constituent in a reactor (or a lake) is strong evidence that that constituent has very low reactivity and thus should only play a minor role in the metabolism of the system.

Consider dissolved organic carbon processing in a “Median Lake”. This example considers bacterial processing of terrestrially derived DOC and autochthonous primary producer derived DOC (PPr-DOC). The hypothetical lake has the median hydraulic residence time (HRT) from 305 lakes reported by Brett and Benjamin [5], the median t-DOC loading for 20 lakes reported by Brett et al. [6], and the median pelagic plus benthic autochthonous gross primary production (PPr) for 58 oligo/mesotrophic lakes from Brett et al. [6]. Assume the algal derived dissolved organic carbon flux (PPr-DOC) is $\approx 25\%$ of gross primary production according to Wetzel [4] and Lewis [7], the median gross primary production in lakes with total phosphorus concentrations $\leq 20 \mu\text{g L}^{-1}$ is $253 \text{ mg C (m}^{-2}\cdot\text{d}^{-1})$ [6], t-DOC is degraded at $0.1\% \text{ d}^{-1}$ [6, 8], and PPr-DOC is degraded at $10\% \text{ d}^{-1}$ according to Wetzel [4; page 512).

The proportion of the t-DOC and PPr-DOC fluxes that are removed from the water in this lake can be calculated as the first-order DOC degradation constant (σ) divided by the sum of the first-order degradation constant and the advective flushing term for the lake (ρ) [5].

$$\text{t-DOC Removal} = \frac{\sigma_{T-DOC}}{\sigma_{T-DOC} + \rho_{lake}} = \frac{0.001 \text{ d}^{-1}}{0.001 \text{ d}^{-1} + 0.005 \text{ d}^{-1}} = 0.18$$

$$\text{PPr-DOC Removal} = \frac{\sigma_{PPr-DOC}}{\sigma_{PPr-DOC} + \rho_{lake}} = \frac{0.1 \text{ d}^{-1}}{(0.1 \text{ d}^{-1} + 0.005 \text{ d}^{-1})} = 0.96$$

The total flux of DOC from the two sources that is processed or degraded within the lake is calculated as the total flux of DOC from that source times the Removal for that source.

$$\text{t-DOC Removed} = \frac{62 \text{ mgC}}{\text{m}^2\text{d}} * 0.18 = \frac{11.2 \text{ mgC}}{\text{m}^2\text{d}}$$

$$\text{PPr-DOC Removed} = \frac{63 \text{ mgC}}{\text{m}^2\text{d}} * 0.96 = \frac{60.5 \text{ mgC}}{\text{m}^2\text{d}}$$

The flux of terrestrial and autochthonous DOC that is removed from the lake water, as a percent the total DOC [$\sum(\text{t-DOC}_{\text{removed}} + \text{PPr-DOC}_{\text{removed}})$] that is removed, is calculated as the source specific DOC removed divided by the total DOC removed.

$$\% \text{ t-DOC} = \frac{\text{t-DOC Removed}}{\sum \text{DOC Removed}} \times 100\% = \frac{\frac{11.2 \text{ mgC}}{\text{m}^2\text{d}}}{\frac{71.7 \text{ mgC}}{\text{m}^2\text{d}}} \times 100\% = 15.6\%$$

$$\% \text{ PPr-DOC} = \frac{\text{PPr-DOC Removed}}{\sum \text{DOC Removed}} \times 100\% = \frac{\frac{60.5 \text{ mgC}}{\text{m}^2\text{d}}}{\frac{71.7 \text{ mgC}}{\text{m}^2\text{d}}} \times 100\% = 84.4\%$$

The DOC from each source that remains in the lake water and is ultimately advected from the lake is calculated as the influx of DOC minus the flux that is removed.

$$\text{Remaining t-DOC} = \text{flux t-DOC}_{\text{in}} - \text{flux t-DOC}_{\text{removed}}$$

$$= \frac{62 \text{ mgC}}{\text{m}^2\text{d}} - \frac{11.2 \text{ mgC}}{\text{m}^2\text{d}} = \frac{50.8 \text{ mgC}}{\text{m}^2\text{d}}$$

$$\text{Remaining PPr-DOC} = \text{flux PPr-DOC}_{\text{in}} - \text{flux PPr-DOC}_{\text{removed}}$$

$$= \frac{63 \text{ mgC}}{\text{m}^2\text{d}} - \frac{60.5 \text{ mgC}}{\text{m}^2\text{d}} = \frac{2.5 \text{ mgC}}{\text{m}^2\text{d}}$$

The DOC remaining in the water can also be expressed as a concentration by dividing the areal DOC mass flux by the areal hydrologic loading to the lake, which has a median value of 13.8 m/yr or 5.0 L/m²*d for the data reported in Brett and Benjamin [5].

$$\text{t-DOC concentration} = \frac{\text{remaining t-DOC flux}}{\text{areal hydrologic loading}} = \frac{\frac{50.8 \text{ mgC}}{\text{m}^2\text{d}}}{\frac{5.0 \text{ L}}{\text{m}^2\text{d}}} = 10.1 \text{ mg/L}$$

$$\text{PPr-DOC concentration} = \frac{\text{remaining PPr-DOC flux}}{\text{areal hydrologic loading}} = \frac{\frac{2.5 \text{ mgC}}{\text{m}^2\text{d}}}{\frac{5.0 \text{ L}}{\text{m}^2\text{d}}} = 0.5 \text{ mg/L}$$

The concentration of terrestrial and autochthonous DOC that remains in the water, as a percent the total DOC concentration, is calculated as the source specific DOC concentration divided by the total DOC concentration.

$$\% \text{ t-DOC} = \frac{\text{t-DOC concentration}}{\text{Total DOC concentration}} \times 100\% = \frac{10.1 \text{ mg/L}}{10.6 \text{ mg/L}} \times 100\% = 95.3\%$$

$$\% \text{ PPr-DOC} = \frac{\text{PPr-DOC concentration}}{\text{Total DOC concentration}} \times 100\% = \frac{0.5 \frac{\text{mg}}{\text{L}}}{10.6 \frac{\text{mg}}{\text{L}}} \times 100\% = 4.7\%$$

The bacterial production supported by each DOC flux is calculated as the total influx of the DOC fraction, multiplied by its Removal, multiplied by the Bacterial Growth Efficiency for that fraction [9].

$$\text{t-DOC supported Bact. Prod.} = \text{t-DOC flux} * R * BGE$$

$$= \frac{62 \text{ mgC}}{\text{m}^2\text{d}} * 0.18 * 0.1 = \frac{1.1 \text{ mgC}}{\text{m}^2\text{d}}$$

$$\text{PPr-DOC supported Bact. Prod.} = \text{PPr-DOC flux} * R * BGE$$

$$= \frac{63 \text{ mgC}}{\text{m}^2\text{d}} * 0.96 * 0.5 = \frac{30.2 \text{ mgC}}{\text{m}^2\text{d}}$$

The bacterial production supported of terrestrial and autochthonous DOC, as a percent the total bacterial production supported by DOC, is calculated as the source specific bacterial production divided by the total bacterial production.

$$\% \text{ Bact. Prod. supported by t-DOC} = \frac{\text{t-DOC supported Bact. Prod.}}{\text{Total Bact. Prod.}}$$

$$= \frac{\left(\frac{1.1 \text{ mgC}}{\text{m}^2\text{d}}\right)}{\left(\frac{31.2 \text{ mgC}}{\text{m}^2\text{d}}\right)} * 100\% = 3.6\%$$

$$\% \text{ Bact. Prod. supported by PPr-DOC} = \frac{\text{PPr-DOC supported Bact. Prod.}}{\text{Total Bact. Prod.}}$$

$$= \frac{\left(\frac{30.1 \text{ mgC}}{\text{m}^2\text{d}}\right)}{\left(\frac{31.2 \text{ mgC}}{\text{m}^2\text{d}}\right)} * 100\% = 96.4\%$$

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