A ^{13}C DOC tracer approach to estimate the contribution of semi-labile dissolved organic carbon to stream ecosystem metabolism

LOUIS A. KAPLAN, J. DENIS NEWBOLD and ANTHONY K. AUFDENKAMPE
Stroud Water Research Center, Avondale, PA, and DENIN, U. of D., Newark, DE

Introduction

In streams and rivers, dissolved organic carbon (DOC) supplies energy and carbon (C) to heterotrophic bacteria. The complexity of the DOC pool combined with simultaneous processes that continually produce, transform and consume DOC molecules in transport, makes in situ measurements of DOC uptake challenging. We used a tracer approach and prepared a ^{13}C tracer of semi-labile DOC from soil-aged ^{13}C-labeled *Liriodendron tulipifera* tissues for use in bioreactors and whole stream releases.

Fig. 1. Stream DOC is mixture of > 10,000 molecules with various biological labilities. A central question in stream ecology is **does DOC contribute to stream ecosystem metabolism?**

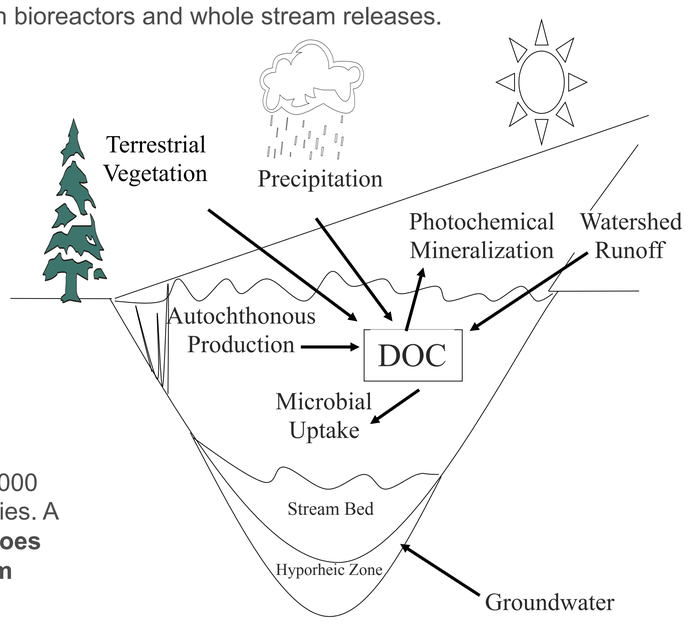

Fig. 2. Processes altering DOC concentrations and quality

Laboratory Methods

(A) Bioreactor with density, activity, and species gradients

(B) Lability Profiling Using Bioreactors with Different Hydraulic Residence Times

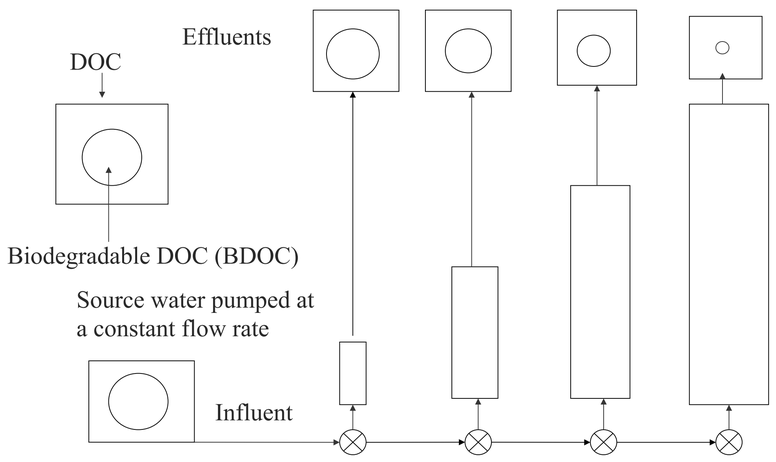

Fig. 3. (A) Bioreactors kept in the dark and fed stream water in the upflow mode develop gradients of bacterial densities, activity, and species composition. (B) Residence time influences the amount of DOC metabolized. Uptake of BDOC of lower lability increases in larger bioreactors with increasing empty bed contact time (EBCT) and leads to effluents that are increasingly refractory. A series of bioreactors with increasing residence times from 0.5 min to 74 min. were used to separate the stream water DOC and the ^{13}C -DOC tracer into different biological lability classes.

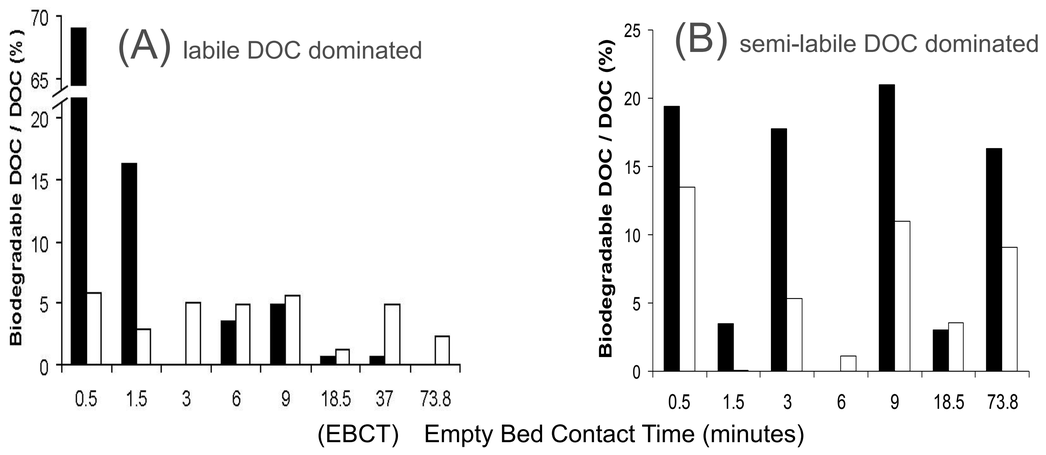

Fig. 4. Lability profiles of DOC from White Clay Creek stream water (open bars) and the ^{13}C-DOC tracer (solid bars) from fresh (A) and soil-aged (B) tree tissues generated in stream water-fed bioreactors as a function of residence time or EBCT. Labile DOC (≤ 1.5 min. EBCT) accounted for 85% of the fresh tracer and 22% of the soil-aged tracer while the semi-labile class (≥3 min. EBCT) accounted for 15% of the fresh tracer and 78% of the soil-aged tracer. Bioreactor lability profiling was calibrated with glucose and arabinose. Glucose was completely removed in the bioreactors after EBCT of 0.5 min. while arabinose was completely removed after EBCT of 6 min. In whole stream releases of glucose and arabinose, the uptake length of arabinose was ~ 3 times longer than that of glucose (2.9 ± 0.7, n = 59; mean, s.d.).

The stream water BDOC data from the bioreactors provide concentrations of the labile and semi-labile BDOC classes. These concentrations are used along with mass transfer coefficients derived from the whole stream additions to estimate fluxes of DOC uptake in the stream ecosystem.

Field Methods: ^{13}C Release and Metabolism

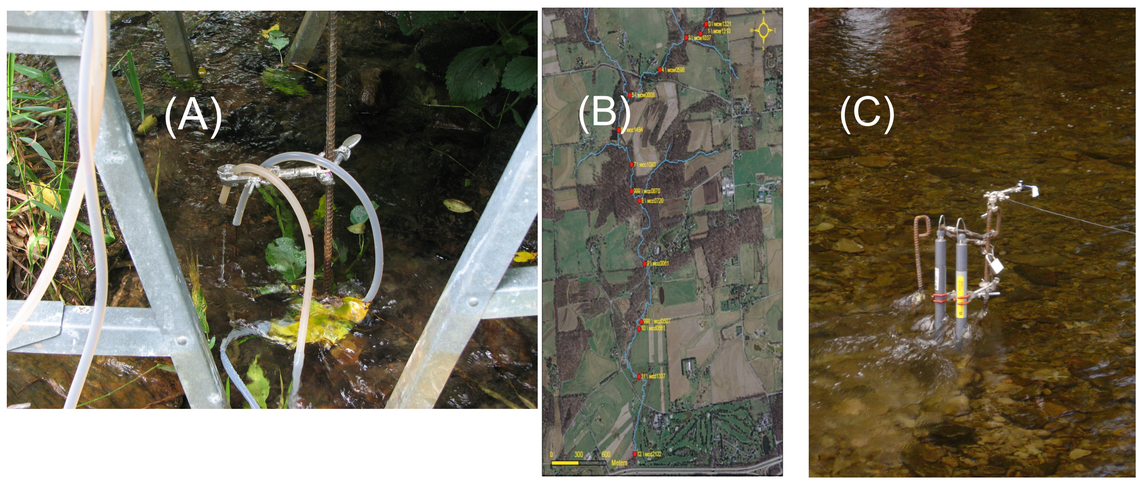

Fig. 6. (A) The ^{13}C tracer and Br^- conservative tracer were injected into a 2nd –order reach of White Clay Creek. (B) The 2-h injection was followed at 12 stations extending downstream for 5.4 km over the next 20 hr. (C) Dissolved oxygen was measured with sondes and corrected for reaeration by propane evasion measurements for the estimates of stream ecosystem metabolism.

^{13}C DOC Uptake

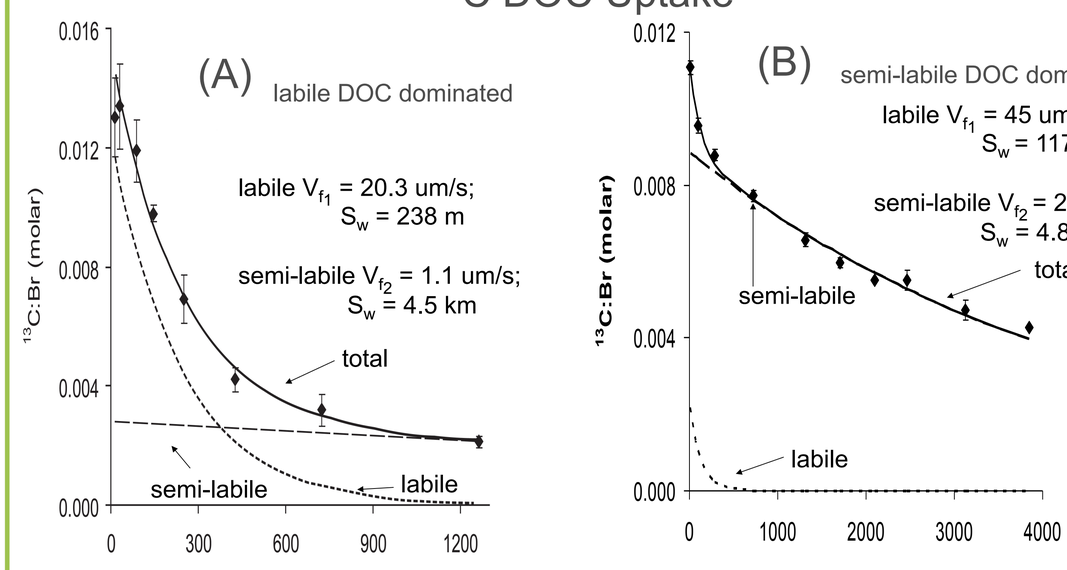

Fig. 7. Longitudinal uptake of fresh (A) and soil-aged (B) ^{13}C-DOC tracer during whole-stream additions dominated by labile and semi-labile lability classes, respectively. Mass transfer coefficients (V_f) or uptake velocities are calculated from the inverse of the longitudinal uptake rate coefficients of each lability class.

O_2 Dynamics

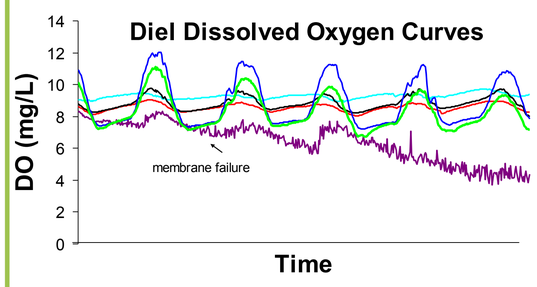

Fig. 8. Diel oxygen curves for the 5 stations used to calculate metabolism. Ecosystem metabolism generated from O_2 uptake in the dark, corrected for algal respiration to approximate heterotrophic respiration (H_r), and converted to units of C. H_r rates ranged from 0.05 to 4.8 $gO_2/m^2/d$ and averaged 3.2 ± 1.6 $gO_2/m^2/d$ (mean, s.d.)

Calculations with Field and Laboratory Data

Average heterotrophic metabolism: 1.22 g C/m²/d

Uptake of stream DOC:
(mass transfer coefficient) x (lability class concentration) = flux

Labile = (45 µm/s) (250 µg C/L) = 0.97 g C/m²/d

Semi-labile = (2.4 µm/s) (804 µgC/L) = 0.19 g C/m²/d

DOC uptake (1.16 g C/m²/d) can support 85% of the stream metabolism with the semi-labile constituents supporting 15% of the metabolism.

Conclusions

Soil-aging of the ^{13}C tree tissue tracer increased our ability to measure the uptake of semi-labile DOC classes in whole-stream releases. The bioreactors are laboratory tools that facilitate measurements of DOC uptake without the confounding issues of algal excretion, photolysis, inputs from groundwater, and leaching of benthic organic matter, permitting measurements that can not be made *in situ*. Increasing bioreactor residence time, EBCT, becomes a surrogate for DOC biological lability. The ^{13}C-DOC tracer, derived from tulip poplar trees, is a natural product present in White Clay Creek. However, our goal was not to assess the importance of tulip poplar molecules to stream respiration, but rather the role of the natural, complex mixture of DOC molecules in the stream. The validity of our DOC lability profiling scheme rests on a primary assumption regarding the fidelity of the bioreactors as models of stream processes, i.e., that organic molecules of similar lability at the bioreactor scale will have similar lability in the stream. We assert that the ordering of DOC lability is preserved across systems with different spatial and temporal scales. This method can be used with molecular-level analyses to begin to provide lability information for individual molecules within the >10,000 molecule DOC pool in freshwaters.

DELAWARE ENVIRONMENTAL INSTITUTE, UNIVERSITY OF DELAWARE
NSF EAR-0724971
Christina River Basin CZO
STROUD WATER RESEARCH CENTER
www.stroudcenter.org