Influence of Temperature on Carbon Decay Rates

David M. Crohn and J. Al Hunt III
Department of Environmental Sciences
UC Riverside

Abstract

The goal of this investigation is to develop and test a convenient procedure for estimating carbon decomposition under different temperature conditions. To model carbon decomposition, investigators often assume that organic materials are composed of a rapidly decomposing *labile* fraction, and a more environmentally stabile *recalcitrant* fraction. The labile and recalcitrant fractions are then assumed to decompose as first-order processes. Laboratory experiments are often used to calibrate such models but laboratory conditions generally fail to consider environmentally dynamic factors such as temperature and moisture which are likely to significantly impact actual decay rates. We are currently studying the influence of temperature on the decomposition of seven organic amendments commonly used in California agriculture including old and fresh dairy manure, dried poultry manure, anaerobically digested biosolids, a greenwaste compost, a greenwaste compost amended with biosolids, and a greenwaste compost amended with dairy manure. Each material was mixed into a 50/50 blend of sandy loam soil and quartz sand. The amendments were introduced to compose two percent of the total amendment/soil/sand dry mass. A total of sixteen 750 g (dry weight) replicates were prepared for each amendment and placed into 2 L canning jars fitted with airtight septa. Water was added to each amended mixture to bring it to field capacity as determined with pressure plates.

To study the influence of temperature on decomposition, four replicates of each mixture are currently decomposing under four different conditions including cool (~6.4 °C) treatment, moderate (~20 °C), and warm (~41 °C) conditions as well as a treatment that varies diurnally under greenhouse conditions. The headspaces above the soils are being sampled through the septa with a 20 mL syringe and the evolved CO2 is then measured with a PP Systems-EGM4 infrared gas chromatograph. The experiment began on August 1 and will continue until October 31, 2003.

Data from the experiment will be used to test a method for modeling first-order decay under temperature varying conditions. The traditional approach is to use the Arrhenius equation to increase decay rates under warm conditions and to reduce them under cool conditions. Decay rates must be estimated repeatedly each time temperatures change. Our approach is similar except, instead of altering the decay rates, we use a constant decay rate for all conditions that modifies time such that time expands under warm conditions and contracts under cool conditions. This approach makes parameterization and use of first-order models much more convenient.

Introduction

- Temperature strongly affects decay rates
- California's climate varies considerably
- A convenient method is needed to incorporate temperature into decay functions
- Our approach tests the use of the "temperature-adjusted-time" concept for modeling decay (Crohn and Valenzuela (2003)

Temperature Adjusted Time

Standard first-order decay is expressed as

$$M_t = M_0 e^{-kt}$$

- M_0 and M_t are the initial and time t masses of the decaying material (g)
- t is time

A two-compartment form of the first-order decay model may be written as

$$M_t = AM_0 e^{-k_L t} + (1-A)M_0 e^{-k_R t}$$

- A is the labile fraction of the material
- k_L and k_R are decay constants for the labile and recalcitrant organic matter fractions (1/time)

Decay parameters are temperature dependent, however. To apply this equation under varying temperature conditions the following integrals must be solved

$$M_t = AM_0 e^{-\int_0^t k_L(T(\hat t))d\hat t} + (1-A)M_0 e^{-\int_0^t k_R(T(\hat t))d\hat t}$$

- decay constants k_L and k_R are functions of temperature, T (K), which is in turn a function of time, $\hat t$.

The Arrhenius equation is often used to correct decay rates for temperature (Haug 1993, Leirós et al. 1999, Levenspiel 1999, Nielsen and Berthelsen, 2002).

$$k_T = k_r Q_{10}^{(1+T_r/10)(1-T_r/T)}$$

- where k_T (1/day) is the decay rate at temperature T (K)
- k_r (1/day) is the decay rate at reference temperature T_r (K)
- Q_{10} is the relative proportion by which k_r increases after a 10 K temperature increase from the reference temperature ($Q_{10} \approx 2$).
- Note that the decay rates are constants and can be taken outside of the integrals.

$$M_t = AM_0 e^{-k_L \int_0^t T(\hat t)d\hat t} + (1-A)M_0 e^{-k_R \int_0^t T(\hat t)d\hat t}$$

- Numerical solutions to the integrals are easily computed. The linear model can therefore be expressed in term of temperature-adjusted-time, t^o (days), permitting the use of a decay rate suitable for all temperatures t^o (days).

Temperature adjusted time:

$$t^\circ = \sum_{\forall i \ni \hat t_i < t} Q_{10}^{\left(1+\frac{T_r}{10}\right)\left(1-\frac{T_r}{T(\hat t_i)}\right)} \left(\hat t_{i+1} - \hat t_i\right)$$

- where $\hat t_i$ are ordered points in time and
- T_r is a reference temperature (K)

The linear model becomes:

$$M_t = AM_0 e^{-k_L t^\circ} + (1-A)M_0 e^{-k_R t^\circ}$$

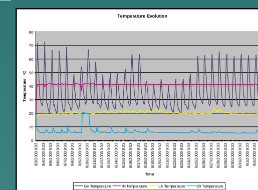
Experimental Procedure

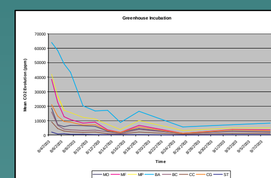
Considering seven organic amendments common in California

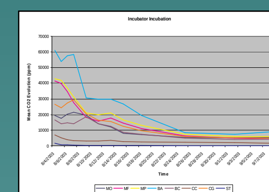
- MO - old dairy manure
- MF - fresh dairy manure
- MP - dried poultry manure
- BA - anaerobically digested biosolids
- CG - a greenwaste compost
- BC - a greenwaste compost amended with biosolids
- CC - a greenwaste compost amended with dairy manure.

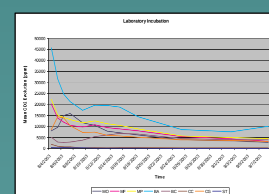
- Each material mixed into a 50/50 sandy loam soil and quartz sand at a 2 percent dry weight rate
- Moisture adjusted to field capacity
- 750 g (dry weight) replicates placed into 2 L canning jars fitted with airtight septa.
- four different conditions including
  - cool (~6.4 °C) treatment
  - moderate (~20 °C)
  - warm (~41 °C) conditions
  - diurnally varying greenhouse conditions
- evolved CO2 measured with a PP Systems-EGM4 infrared gas chromatograph
- experiment began on August 1 and will continue until October 31, 2003.

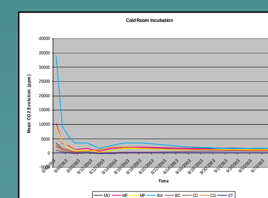
Current Results











Anticipated Results

- Data will be used to develop *Q10* and decay parameters and to test the temperature-adjusted time concept.
- Results will be used to begin developing and extending a procedure for predicting decomposition rates under various California climates

References

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