Black Carbon Concentrations in Urban and Rural Arid-Land Soils

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Introduction

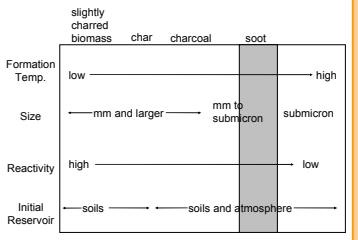
This project investigates the composition and distribution of black carbon (BC) in soil samples from Phoenix, AZ collected during the Central Arizona Phoenix Long-Term Ecosystem Research Program (CAP LTER) 200-point Survey.

Black carbon (BC) is the product of incomplete combustion of biomass and fossil fuel. It is operationally defined, and has a wide range of physical structures from slightly charred biomass to soot carbon, which vary in size from mm and larger to submicron, respectively. Uncertainties exist in the BC global and regional budget that is directly related to the wide variety of experimental techniques used to measure BC. However, BC has been shown to make up a large portion (up to 50 %) of soil organic carbon and has been shown to be a climate-warming agent.

This study focuses on BC in soils located in central Arizona. Soil samples were collected as a part of the CAP-LTER monitoring program. Forty-eight representative survey points ranging from rural desert soils to urban soils were chosen randomly for investigation of BC concentration. Concentrations of BC are measured by elemental analysis and detected using an isotope ratio mass spectrometer.

Current results show that BC makes up 0.01 to 0.78 % of the total weight of soil and 1.65 to 62.86 % of the weight of organic carbon. This indicates that a significant portion of the organic carbon in central Arizona soil can be defined as black carbon. A map of the Phoenix metropolitan area containing these results plotted as a concentration gradient specifies that urban locations have a higher concentration of BC than urban fringe and rural soils. This indicates that a major source of BC in this area is from the burning of fossil fuels.

Combustion Continuum



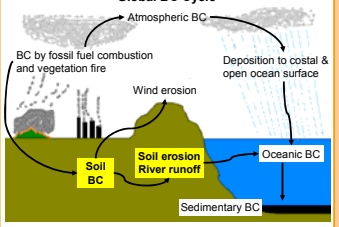
Shaded region denotes the component of the black carbon pool under investigation

Masiello C.A. *New directions in black carbon organic geochemistry.*Marine Chemistry. 2004.

Essential questions for this investigation:

- How much black carbon is stored in Phoenix-area soils?
- How is that carbon distributed across the city?
- What is the structure and reactivity of soil black carbon?

Global BC Cycle



Sources (Biomass burning and Fossil Fuel)	62 to 284 Tg yr^{-1}
Sinks (Sedimentary BC)	10 Tg yr^{-1}
Imbalance **:**	52 to 274 Tg yr^{-1}

Inputs do not equal outputs!

This work addresses the ***soil BC*** pool as the project moves forward we will examine ***riverine BC***

A range of methods have been applied for BC investigation; each is specific for a different portion of the combustion continuum. We use a method commonly referred to as CTO 375 (Gustafsson,1997) that detects soot carbon. The currently accepted standard reference material is an Australian Vertisol.

Accuracy

Standard Reference Material (SRM) Australian Vertisol

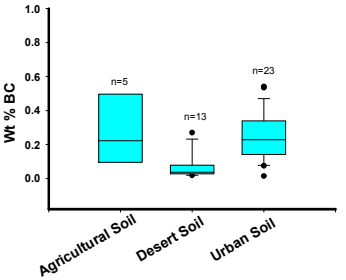
	Wt % OC	Wt % BC
Measured	3.21	0.18
Reported SRM	3.27	0.1 (Hammes, 2007)

Precision

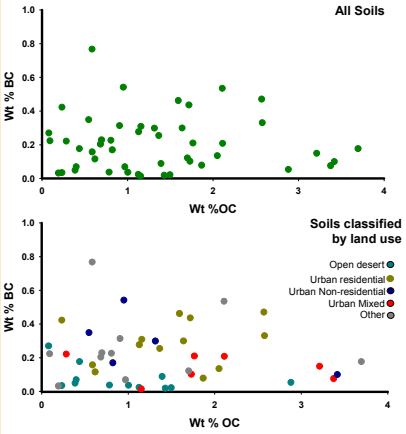
	Wt % BC
Replicate analyses (n = 5)	
Urban soil (V515)	0.16 ±0.03

Results

Summary of survey 200 soils	**AVG (n = 48)**
Wt % OC (g OC/g soil)	1.88 ± 0.88
Wt % BC (g BC/g soil)	0.21 ± 0.17
BC/OC (g BC/g OC * 100)	34.69 ± 62.52
Avg. Black Carbon $\delta^{13}C$ (‰)	-16.27 ± -2.63



- Desert soils have lower BC contents than urban soils
- Urban soils have a fairly even distribution of BC concentrations



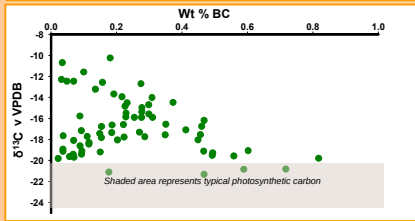
- *No correlation between BC content and organic content*
- *Suggests different source or processing*
- *BC in soils can be grouped by land use*
- *Generally, desert soils have lower BC than urban soils*

Does isotopic fractionation occur during BC formation?

- BC is enriched relative to typical photosynthetic carbon →
- The $\delta^{13}C$ of hexane soot synthesized in the laboratory is -22.12 ± 0.18 ‰ (n=3). The $\delta^{13}C$ of liquid hexane has been reported to be -30.5 ‰ (Bouchard et al. 2004)

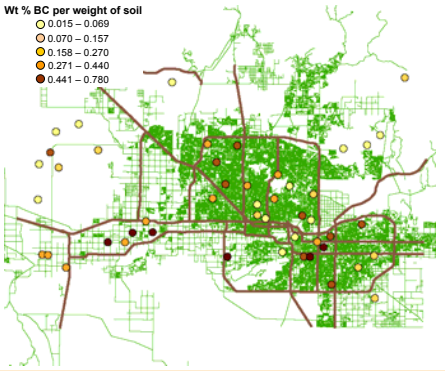
this data suggests there may a fractionation during combustion

- Quay et al. (1991) suggests that no fractionation occurs during combustion; this topic will need further investigation.

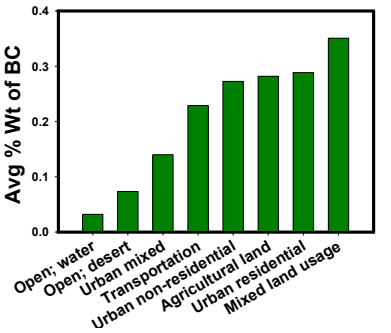


- *$\delta^{13}C$ of BC is enriched relative to typical C3 photosynthate*
- *Fractionation during combustion or during soil processing?*

CAP-LTER Survey Area - Survey 200 soil sites

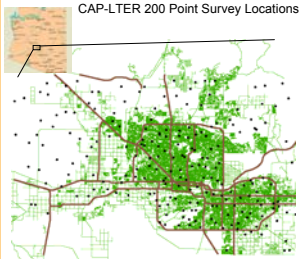


BC distribution by land use



Materials and Methods

CAP-LTER 200 Point Survey Locations



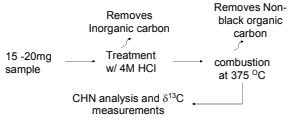
Central Arizona Project Long-term Ecological Research (CAP-LTER) program explores biological and anthropogenic influences on urban ecology in a desert biome.

This region is potentially ideal for BC research because it has both biomass and fossil fuel sources of BC!

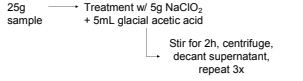
Ancillary Soils Data

- Land-use classification
- Wt % organic and inorganic carbon
- GIS locations
- Soil bulk density

Chemo-Thermo Oxidation at 375 ºC



Removal of Lignin (for NMR experiments)



Instrumentation:

Costech Elemental Analyzer coupled to a Thermo Delta Plus Advantage Isotope ratio mass-spectrometer

Conclusions

- BC is a significant portion of soil organic matter in central Arizona soils
- BC is generally isotopically heavier than bulk soil carbon
- There is no apparent correlation between Wt % OC and Wt % BC.
  - suggests different sources or different reactivity
- BC concentrations generally group by land use type, BC is higher in more urban settings

Future Directions

- Investigate BC functional groups using solid state ^{13}C NMR
- Correlate results with variables such as:
  - Distance from roads
  - Traffic flow
  - Fire history
- Investigate the possibility of isotopic fractionation in BC formation

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