

Selective Sorption of Dissolved Organic Carbon Compounds by Temperate Soils

Sindhu Jagadamma*, Melanie A. Mayes, Jana R. Phillips

Climate Change Science Institute and Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States of America

Abstract

Background: Physico-chemical sorption onto soil minerals is one of the major processes of dissolved organic carbon (DOC) stabilization in deeper soils. The interaction of DOC on soil solids is related to the reactivity of soil minerals, the chemistry of sorbate functional groups, and the stability of sorbate to microbial degradation. This study was conducted to examine the sorption of diverse OC compounds (D-glucose, L-alanine, oxalic acid, salicylic acid, and sinapyl alcohol) on temperate climate soil orders (Mollisols, Ultisols and Alfisols).

Methodology: Equilibrium batch experiments were conducted using 0–100 mg C L⁻¹ at a solid-solution ratio of 1:60 for 48 hrs on natural soils and on soils sterilized by γ -irradiation. The maximum sorption capacity, Q_{max} , and binding coefficient, k were calculated by fitting to the Langmuir model.

Results: Ultisols appeared to sorb more glucose, alanine, and salicylic acid than did Alfisols or Mollisols and the isotherms followed a non-linear pattern (higher k). Sterile experiments revealed that glucose and alanine were both readily degraded and/or incorporated into microbial biomass because the observed Q_{max} under sterile conditions decreased by 22–46% for glucose and 17–77% for alanine as compared to non-sterile conditions. Mollisols, in contrast, more readily reacted with oxalic acid (Q_{max} of 886 mg kg⁻¹) and sinapyl alcohol (Q_{max} of 2031 mg kg⁻¹), and no degradation was observed. The reactivity of Alfisols to DOC was intermediate to that of Ultisols and Mollisols, and degradation followed similar patterns as for Ultisols.

Conclusion: This study demonstrated that three common temperate soil orders experienced differential sorption and degradation of simple OC compounds, indicating that sorbate chemistry plays a significant role in the sorptive stabilization of DOC.

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* E-mail: jagadamma@ornl.gov

Introduction

Organic carbon (OC) in soil is the largest C sink in the biosphere and storing this pool is important to combat climate change. One third of the 2544 Pg C stored in soils is located in profiles below 1 m [1]. The C stored in deeper soil horizons is characterized by decreased C:N ratio and increased ¹⁴C age, indicating that subsoil C is more stabilized than the surface soil C [2–3]. The longer stability of OC in subsoil than surface soil is attributed to several reasons including more favorable physico-chemical properties of subsoil minerals for sorption [4,5], non-availability of fresh OC in subsoil to provide sufficient energy to microbial sustenance [6] and reduced microbial activities due to sub-optimal environmental conditions [7]. As a consequence of one or more of above reasons, deeper horizons of mature soils such as Alfisols, Ultisols and Oxisols possess a potential of storing 165 Pg C for each meter of soil [8,9]. Thus, subsoil C storage has a significant role in determining the extent to which soils provide a sink for atmospheric CO₂.

Sorption of dissolved organic carbon (DOC) on soil minerals is considered to be the major process of OC preservation in deeper soils, accounting for 25–50% of the measured soil OC (SOC) stock [10]. Currie et al. [11] reported that 217–366 kg C ha⁻¹ yr⁻¹ is retained in the mineral forest subsoil by sorption. The retention of DOC is influenced by the chemical properties of mineral sorption sites [12] and in general, the primary sorbents for DOC are minerals dominated by variable charges [13]. Close correlations between Fe and Al oxyhydroxides and OC concentrations in soils were reported in many studies [14–16], and strong binding of OC functional groups on Fe and Al oxide surfaces limits desorption [17,18]. Kothawala et al. [19] found that poorly crystalline Fe and Al minerals contributed more than the total clay content to the sorption capacity of a wide range of soils. They did not find any influence of soil OC content to sorption capacity of soils. A recent study using 213 subsoils from US provided evidence that bulk DOC sorption was correlated with different properties for Mollisols, Ultisols and Alfisols [20]. When the soils were grouped, sorption capacity correlated with clay and Fe content. However, when data was analyzed separately for soil orders, clay was most

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