Mineralogy of paloverde (Parkinsonia microphylla) tree ash from the Sonoran Desert: A combined field and laboratory study

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ABSTRACT

This study describes the wood chemistry and ash mineralogy of the desert tree Parkinsonia microphylla (Torr.) and follows the mineralogical effects of natural and laboratory aging and weathering. Ash was collected in the field (field ash) following a wildfire east of Phoenix, Arizona, May 8th, 2011, and its mineralogy compared with ash produced under laboratory conditions (laboratory ash): 25 minerals were identified by powder X-ray diffraction (XRD) in the fresh and weathered ash. To guide the interpretation of the XRD patterns, the major ash-forming elements (for elements of Na and heavier) in the wood were determined by particle-induced X-ray emission (PIXE) spectroscopy. Mg (816 to 3677 ppm), K (3965 to 17 581 ppm), and Ca (935 to 61 772 ppm) were the dominant metals, and P (to 1528 ppm), S (to 1024 ppm), and Cl (318 to 2648 ppm) were the dominant non-metals. In general, smaller branches and bark showed higher concentrations of ash-forming cations than mature wood. Powder XRD patterns from fresh field ash were dominated by various proportions of fairchildite \( [K\text{Ca}(CO_3)_2]\), calcite \((\text{CaCO}_3)\), lime \((\text{CaO})\), bütschliite (dimorph of fairchildite), and periclase \((\text{MgO})\), with traces of other K-bearing salts. Following gentle rains (total 0.7 cm) at the end of May, a brittle ash crust formed that was dominated by calcite, with variable amounts of fairchildite, sylvite \((\text{KCl})\), kalciinite \((\text{KHC}_2\text{O})\), magnesite \([\text{CaMg(CO}_3]\), magnesite \((\text{MgCO}_3)\), K\text{CO}_3\cdot\text{H}_2\text{O}\), and arcanite \((\text{K}_2\text{SO}_4)\). Further exposure to rain (total of 7 cm) in July and August left an ash dominated by calcite, magnesian calcite, and periclase. Ash collected two years after forming was dominated by calcite, magnesian calcite, and minor nesquihonite \((\text{MgCO}_3\cdot3\text{H}_2\text{O})\). The mineralogy of ash produced in the laboratory from wood collected in the fire zone was dependent on the diameter and hence age of the wood. Ash from thin branches was dominated by calcite and fairchildite, consistent with the high Ca revealed by PIXE. Ash from large logs was dominated by fairchildite, with reflections from nine ad

INTRODUCTION

Biomass combustion recycles the atmospherically derived carbon, which is bound primarily as organic plant material, back into the atmosphere as CO₂. This simple cyclic model can be thought of as a net zero sequestration process as the carbon release is coupled with vegetation regrowth. However, this model does not take into account production of inorganic C-rich ash with long terrestrial residence times. Ash is an often overlooked trap of atmospherically bound CO₂, which is typically on the order of a few weight percent (wt%) of the biomass and commonly dominated by Ca and Mg oxides and carbonates (Etiégni and Campbell 1991; Humphreys et al. 2004; Liodakis et al. 2005; Milton and Axelrod 1947; Ulery et al. 1993; Yusiharni and Gilkes 2012). In addition, the ash contributes to the soil chemistry, which is important in determining the quantity of organic carbon stored in soil, its turnover time, and long-term carbon fluxes (Torn et al. 1997), and affects soil properties and influences nutrient uptake by plants (e.g., Demeyer et al. 2001; Ulery et al. 1993). For example, Ulery et al. (1993) found high pH values in wood ash and surface soil “caused by K and Na oxides, hydroxides, and carbonates”; though these compounds are rapidly removed by rain, the soil pH remained high for several years as a result of the persistence of the wood-ash calcite. In general though, the nutrient and chemical effects on soil of...