

Changes in the size partitioning of metals in storm runoff following wildfires: Implications for the transport of bioactive trace metals



Paulina Pinedo-Gonzalez ^{a,*}, Bridget Hellige ^a, A. Joshua West ^a, Sergio A. Sañudo-Wilhelmy ^{a, b}

^a Department of Earth Sciences, University of Southern California, Los Angeles, CA, 90089-0740, United States

^b Department of Biological Sciences, University of Southern California, Los Angeles, CA, 90089-0740, United States

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ABSTRACT

Mountainous areas affected by natural wildfires and highly urbanized settings both have been identified as sources of pollutants to receiving waters. In this study, the partitioning of metals between the colloidal (0.02–0.2 μm) and soluble (<0.02 μm) phases in storm-runoff was evaluated in three different environments: (i) a catchment affected by the 2012 Williams Fire (2–13 September 2012) in the San Gabriel Mountains, (ii) a neighboring control catchment in the San Gabriels, and (iii) three rivers draining the Los Angeles County area. Results from each region were compared to each other in order to gain information about potential sources of soluble (i.e., bioavailable) elements that are delivered to receiving waters. Results show that in runoff from recently burned areas, 58% and 24% of the total dissolved (<0.2 μm) Pb and Fe, respectively, was present in the soluble pool. In contrast, runoff from urban and natural unburned areas carried less than 17% and 8% of the total dissolved Pb and Fe, respectively, in the soluble pool. These results suggest that storm runoff from burned landscapes has the previously unrecognized potential to supply a greater proportion of trace elements in bioactive soluble form, compared to runoff from urban or unburned areas, potentially increasing the impact of wildfire-delivered metals on receiving waters.

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1. Introduction

Contaminant loading associated with urban runoff contributes to the pollution and impairment of watersheds around the world (e.g., Vaze and Chiew, 2004; Ahn et al., 2005; Joshi and Balasubramanian, 2010). Similar delivery of pollutants, including suspended solids, nutrients, trace elements, and organic compounds, can occur following wildfires (e.g., in southern California: Stein et al., 2012; Burke et al., 2013; in Iran: Norouzi and Ramezanpour, 2013; in New Mexico: Bitner et al., 2001; in Australia: Smith et al., 2011; in Portugal: Campos et al., 2015).

Trace metals are one of the most extensively studied categories of pollutants due to their direct impact on the ecosystems of receiving waters, both through toxicity and, in some cases, as required micronutrients that affect aquatic productivity (Tuccillo, 2006). Most prior studies on trace metal pollution of surface waters have focused on identifying metal sources, concentrations, and loadings, whereas only a few have paid attention to metal

speciation and size fractionation (e.g., Grout et al., 1999; Guéguen and Dominik, 2003; Tuccillo, 2006; Brown et al., 2011, 2013). In natural waters, the partitioning of metals between different sizes – particulate, colloidal, and soluble – affects the dynamics of metal transport, reactivity, and bioavailability (Gächter et al., 1973; Kaplan et al., 1995; Laegdsmand et al., 1999; Paquin et al., 2002). These size fractions are generally operationally defined, with particulate metals defined as those associated with material larger than a 0.45 or 0.2 μm membrane filter, colloidal metals in the size fraction between 0.2 μm and 0.02 μm (or sometimes smaller), and the soluble pool comprising metals in the <0.02 μm fraction (cf. Pinedo-Gonzalez et al., 2014). The soluble and colloidal metals together make up the “total dissolved” pool (i.e. all metals associated with the size fraction <0.2 μm).

The distinction of colloidal- versus soluble-associated metals is important from a water quality perspective since toxicity of trace elements depends not only on their abundance but also on their bioavailability, and it is well documented that trace metals in the colloidal phase do not pose immediate risk to many organisms (Guéguen and Dominik, 2003; Guéguen et al., 2004; Tuccillo, 2006). It has even been suggested that in many cases the

* Corresponding author.

E-mail address: pinedogo@usc.edu (P. Pinedo-Gonzalez).

physico-chemical forms in which metals exist are more important for the ecosystems of receiving waters than the total metal concentrations (Tessier and Turner, 1995).

The extent to which dissolved metals are associated with colloidal vs. soluble fractions in natural waters depends on (i) the metal geochemistry and (ii) the nature of the colloids, which varies in different settings. Some prior work has explored colloidal partitioning of metals in natural and urban runoff, reporting that Cd, Co, Mo and Ni reside primarily in soluble phases due to metal association with soluble ligands, while Fe and Pb are typically found associated with colloidal particles, e.g., in size fractions $>0.01 \mu\text{m}$ (Sañudo-Wilhelmy et al., 1996; Grout et al., 1999; Wen et al., 1999; Guéguen and Dominik, 2003; Tuccillo, 2006; Brown et al., 2011, 2013). However, there is little data on colloidal partitioning of metals from burned landscapes, leaving a gap in understanding how these environments act as metal pollution sources.

The primary goal of the current study was to evaluate whether dissolved metals from urban vs. wildfire sources are associated with different partitioning between colloidal and soluble forms. The focus is on storm runoff in Southern California, where such partitioning data have not been reported previously. Storm runoff is a major source of pollution to many waterways in this region, delivering contaminants from both urban (e.g., Davis et al., 2001; Ackerman et al., 2003; Ahn et al., 2005; Rule et al., 2006; Aryal et al., 2010; Tang et al., 2013) and burned lands (e.g., Stein et al., 2012; Burke et al., 2013). In this study, the partitioning of metals between the colloidal and soluble phases in storm runoff was evaluated in three different environments: (i) a catchment affected by the 2012 Williams Fire in the San Gabriel Mountains, (ii) a neighboring control catchment in the San Gabriels, and (iii) three rivers draining an urban-to-rural gradient in the Los Angeles County area. Results from each region were compared to each other,

focusing on how the partitioning of metals between different size fractions differs for urban vs. wildfire settings.

2. Method

2.1. Study area

To study post-fire runoff chemistry, storm-water runoff was sampled from two immediately adjacent, similar sized catchments in the San Gabriel Mountains, one burned by the Williams Fire and the other not burned (Fig. 1). We refer to the former as the San Gabriels Burned catchment and the latter as the San Gabriels Control catchment. The Williams fire occurred on 2 September 2012, originating at 34.239°N , 117.822°W between the Shooting Range and Camp Williams along East Fork Road in San Gabriel Canyon (InciWeb, 2012). The fire took 10 days to contain and burned roughly 4192 acres, fueled by mainly chaparral vegetation and 15–20 year old conifers (InciWeb, 2012). The fire stopped at the divide between the burned and control catchments, and these two catchments share similar pre-fire land cover, geology, soils, and climate. The bedrock in both catchments is Precambrian igneous and metamorphic rock (Table 1). The primary native soil types in this area are sandy loam, silt loam, and clay loam (Los Angeles County Department of Public Works (2015)).

For comparison to the burned-unburned catchment pair in the San Gabriels, we also collected samples from two unburned, urban sites in the greater Los Angeles region and a reference, non-urban site on the Santa Clara River (Fig. 1). The two urban storm runoff collection sites were located at the downstream end of the Los Angeles and San Gabriel Rivers in Long Beach, California (Fig. 1; Table 1). At the sampling locations, which were chosen to avoid tidal influences, the total upstream drainage area is 2136 and 1761

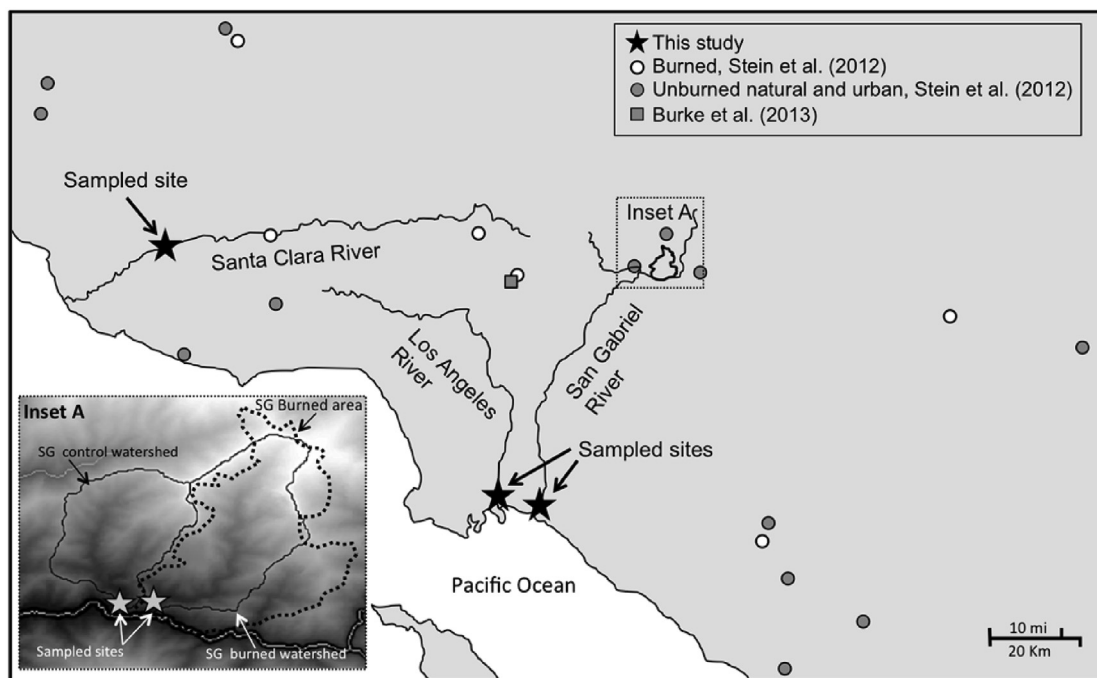


Fig. 1. Map showing approximate sample collection sites in the Los Angeles, San Gabriel, and Santa Clara Rivers (black stars). Inset A shows a shaded elevation map (whites - high elevation; blacks-low; from an SRTM-derived 90 m digital elevation model; Reuter et al., 2007) with the approximate sample collection sites in the San Gabriels burned catchment and the neighboring control catchment (white stars). Dashed line in Inset A shows extent of the Williams Fire burn area (from U.S. Forest Service, unit identifier: CA-ANF, fire number: G7L0). The sampling sites are located at: San Gabriel River – East Wardlow Rd ($33^\circ 49' 08''\text{N}$, $118^\circ 05' 28''\text{W}$); Los Angeles River – West Willow St ($33^\circ 48' 15''\text{N}$, $118^\circ 12' 19''\text{W}$); Santa Clara River – South Mountain Rd ($34^\circ 20' 53''\text{N}$, $119^\circ 03' 05''\text{W}$); San Gabriels burned catchment ($34^\circ 14' 24''\text{N}$, $117^\circ 48' 27''\text{W}$); and San Gabriels unburned control catchment ($34^\circ 14' 40''\text{N}$, $117^\circ 49' 16''\text{W}$). White circles (burned sites) and gray circles (unburned natural and urban sites) are from the study by Stein et al. (2012). Gray square is from the study by Burke et al. (2013).

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