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Developing the scientific framework for urban geochemistry

Lisa G. Chambers [a], Yu-Ping Chin [b], Gabriel M. Filippelli [c], Christopher B. Gardner [b, *], Elizabeth M. Herndon [d], David T. Long [e], W. Berry Lyons [b], G.L. Macpherson [f], Shawn P. McElmurry [g], Colleen E. McLean [h], Joel Moore [i], Ryan P. Moyer [j], Klaus Neumann [k], Carmen A. Nezat [l], Keir Soderberg [m], Nadya Teutsch [n], Elisabeth Widom [o]

[a] Department of Biology, University of Central Florida, Orlando, FL, 32816, United States
[b] School of Earth Sciences, The Ohio State University, Columbus, OH, 43210, United States
[c] Department of Earth Sciences and Center for Urban Health, Indiana University-Purdue University Indianapolis, Indianapolis, IN, 46202, United States
[d] Department of Geology, Kent State University, Kent, OH, 44242, United States
[e] Department of Geological Sciences, Michigan State University, East Lansing, MI, 48824, United States
[f] Department of Geology, University of Kansas, Lawrence, KS, 66045, United States
[g] Department of Civil and Environmental Engineering, Wayne State University, Detroit, MI, 48073, United States
[h] Department of Geological and Environmental Sciences, Youngstown State University, Youngstown, OH, 44555, United States
[i] Department of Physics, Astronomy, and Geosciences, Towson University, Towson, MD, 21252, United States
[j] Florida Fish & Wildlife Conservation Commission, Fish & Wildlife Research Institute, St. Petersburg, FL, 33701, United States
[k] Department of Geological Sciences, Ball State University, Muncie, IN, 47306, United States
[l] Department of Geology, Eastern Washington University, Cheney, WA, 99004, United States
[m] S.S. Papadopulos & Associates, Inc., Bethesda, MD, 20814, United States
[n] Geological Survey of Israel, Jerusalem, 95501, Israel
[o] Department of Geology & Environmental Earth Science, Miami University, Oxford, OH, 45056, United States

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ABSTRACT

Urban geochemistry is a unique discipline that is distinguished from general geochemistry by the complex infrastructure and intense human activities associated with concentrated population centers. As stated by Thornton (1991) “This subject is concerned with the complex interactions and relationships between chemical elements and their compounds in the urban environment, the influence of past and present human and industrial activities on these, and the impacts or effects of geochemical parameters in urban areas on plant, animal and human health.” Urban areas present special challenges to geochemists attempting to understand geochemical states and fluxes. On the 5–6 of August, 2014, the first meeting of the reorganized Urban Geochemistry Working Group of the International Association of GeoChemistry (IAGC) was held in Columbus, Ohio, United States. Two goals of the meeting were to develop the overall scope, and a general definition of urban geochemistry. Five grand themes were developed: 1) recognizing the urban geochemical signature; 2) recognizing the legacy of altered hydrologic and geochemical cycles in urban environments; 3) measuring the urban geochemical signature; 4) understanding the urban influence on geochemical cycles from the continuous development and erosion of physical infrastructure and episodic perturbations; and 5) relating urban geochemistry to human and environmental health and policy. After synthesizing the discussion of these themes we offer the following perspective on the science of urban geochemistry building on the work of Thornton (1991): Urban geochemistry as a scientific discipline provides valuable information on the chemical composition of environments that support large populations and are critical to human health and well-being. Research into urban geochemistry seeks to 1) elucidate and quantify the sources, transport, transformations, and fate of chemicals in the urban environment, 2) recognize the spatial and temporal (including legacies) variability in these processes, and 3) integrate urban studies into global perspectives on climate change, biogeochemical cycles, and human and ecosystem health. We hope that this discussion will encourage

* Corresponding author.
E-mail address: Gardner.177@osu.edu (C.B. Gardner).

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other geochemists to engage in challenges unique to urban systems, as well as provide a framework for the future of urban geochemistry research.

Contents

1. Introduction

Over the past century there has been a great increase in the percentage of the total global population living in urban areas. By 2050, the United Nations predicts as many as 6.3 billion humans will inhabit urban regions, up 75% from 2010 (United Nations, 2015). The impact of this rapid growth on natural resources and environmental quality has received much attention (e.g. Grimm et al., 2008; Roche et al., 2014). This growth has directly impacted land use and land cover, and also changed the biogeochemical cycles of most elements (Wayland et al., 2003). Such impacts, albeit not fully understood, will almost certainly increase as a result of future predicted growth, affecting human and ecosystem health.

Thornton (1991) coined the term urban geochemistry and stated that "This subject is concerned with the complex interactions and relationships between chemical elements and their compounds in the urban environment, the influence of past and present human and industrial activities on these, and the impacts or effects of geochemical parameters in urban areas on plant, animal and human health." Thus, urban geochemistry is unique from general geochemistry due to both the presence of complex infrastructure and the intense human activities associated with concentrated population centers. As such, urban areas present special challenges to geochemists attempting to understand geochemical states and fluxes (Lyons and Harmon, 2012). The rate and scale of human-influenced biogeochemical processes make urban environments very different from "natural" environments, and has historically caused most geochemists trained to solve problems involving earth systems to shy away from urban studies. This has been changing over the past twenty years, and more geochemists have become interested in the biogeochemical issues brought about by urbanization. The application of biogeochemical approaches to human-built environments are needed in order to understand the sources, transport, transformations, and the fate (including human and ecosystem health) of chemical constituents in urban settings. For example, this approach has been taken by the two National Science Foundation (NSF)-sponsored urban Long Term Ecological Research (LTER) sites in Baltimore and Phoenix, USA. In addition, increasing numbers of researchers around the world have embraced the idea that studying geochemistry in urban environments is a worthwhile endeavor (e.g., Thornton, 2012), demonstrated by the fact that 14% of the papers from non-special issues of *Applied Geochemistry* in 2014 had an "urban" aspect to them.

Given that natural resources comprise the bulk of raw materials used for human purposes, the overall geochemical signature of urban areas is similar to that of the lithosphere, which is dominated by silicates and carbonates. However, urban areas differ from the lithosphere in key ways: 1) natural materials are altered chemically and physically to achieve desired characteristics for use in urban infrastructure and processes; 2) heterogeneous mixtures of earth materials and synthetic materials coexist within confined geographic areas; 3) materials are instantaneously placed in new environments (e.g., above the ground surface) where they are exposed to both natural (e.g., weathering by wind, water and ultraviolet light) and anthropogenic (e.g., combustion) degradation processes; 4) many elements and chemical compounds are introduced into the urban environment at concentrations that are orders of magnitude above their natural abundance (e.g., lead [Pb], and others have no "natural" concentration (e.g., polychlorinated biphenyls [PCBs]). As a result, urban geochemical cycles are impacted by both the introduction of non-native materials (e.g., concrete, refined metals, and alloys) and the release of elements and compounds such as platinum group metals, pharmaceuticals, and pesticides (de Vos et al., 2002; Kolpin et al., 2004) from