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KINETICS OF METAL SORPTION REACTIONS

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1. INTRODUCTION

Macroscopic measurements of metal sorption reactions on soils are ubiquitous in the soil and environmental sciences literature. Metal sorption has been described using an array of empirical, semi-empirical and surface complexation models including Freundlich, Langmuir, Temkin, constant capacitance and triple layer. In some cases, these models equally well describe sorption data and are often useful for describing metal sorption over a range of pH and ionic strength values. However, many of these models have numerous adjustable parameters, and, thus, it is not surprising that sorption data can be well described using them. In effect, most sorption models that employ macroscopic data are often curve-fitting exercises. Despite this, many investigators have used them to make mechanistic interpretations about metal sorption on surfaces. However, some of these models can describe several different sorption mechanisms. Thus, conformity of material balance data to a particular model does not prove that a particular mechanism is operational.

I do not wish to imply that equilibrium-based modeling of metal sorption on clay minerals, oxides, sediments, and soils is useless. To the contrary, much useful information has been obtained from macroscopic studies. However, one cannot glean mechanistic information from such approaches. Moreover, equilibrium studies are often not appropriate to simulate field conditions since soils are seldom,

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if ever, at equilibrium with respect to ion and molecular transformations and interactions.

To properly understand the fate of metals in soils and particularly to comprehend their mobility with time, kinetic investigations are necessary. Such time-dependent data can also be used to derive mechanisms for metal sorption. Of course, to definitively ascertain sorption mechanisms, one should employ surface spectroscopic or microscopic techniques.

Only within the last 30 years, and particularly in the past decade, have kinetic investigations of metal sorption on soils appeared in the literature. Soils are indeed complex, heterogeneous systems, and the application of kinetics to such solid surfaces is arduous and fraught with pitfalls. While many advances have been made in describing the kinetics of metal reactions on soils [1], I believe we are only in the infancy of this important area of soil and environmental chemistry. In this paper, I wish to describe some of the recent advances in the area of kinetics of metal sorption on soils and soil components. Unfortunately, space does not allow for a comprehensive review of the topic, but the reader can consult a number of other publications if he or she is interested in more comprehensive treatments [1-4]. The objectives of this review are to discuss several aspects of metal sorption kinetics. These include soil components that are important in metal retention; time scales for reactions on soils; a critique of kinetic models and data interpretations; methods that can be used to study metal sorption kinetics; and applications of pressure-jump relaxation to glean mechanistic information about metal sorption kinetics on soil constituents.