

Behaviour of humic-bentonite aggregates in diluted suspensions

Dragoljub D Bilanovic*, Timothy J Kroeger and Steven A Spigarelli

Center for Environmental Earth and Space Studies, Sattgast Hall 107, Bemidji State University, 1500 Birchmont Drive, Bemidji, Minnesota 56601, USA

Abstract

Processes of aggregate formation and disaggregation are common in both waters and soils and are widely used in different industries. Aggregates composed of clays and humic substances (HSs) are, either directly or indirectly, associated with almost all biological, chemical, and physical phenomena in waters and soils. Formation and disaggregation of micron-size aggregates in a diluted suspension made up of HSs and bentonite (B) were studied by tracing distribution of aggregate sizes and their counts in freshly prepared and aged suspensions, and at high (10 000) and low (1.0) [HS]/[B] ratios. Diluted HSB suspensions are unstable over time with respect to number of aggregates, and distribution of aggregate sizes at particular [HS]/[B] ratios. The observed disaggregation to aggregation and aggregation to disaggregation events are probably a consequence of exposure of fresh clay surface upon disaggregation of HSB aggregates, partitioning of adsorbed humic substances between old and freshly exposed clay surfaces, adsorption of dissolved HSs on fresh bentonite surface, and decomposition of large units of HSs into smaller ones, a process probably catalysed by clays. Successive aggregation to disaggregation or disaggregation to aggregation events yield both qualitative and quantitative transformations in HSB aggregates, which thus may affect availability, transport and fate of adsorbed chemicals in both aquatic and terrestrial systems.

Keywords: aggregates, clays, humic substances

Nomenclature

bentonite (B)
fulvic acids (FAs)
humic acids (HAs)
humic substances (HSs)

Introduction

Processes of aggregate formation and disaggregation are common in both waters and soils and are widely used in different industries. Natural aggregates usually contain inorganic, gaseous, microbial, and organic fractions that determine behaviour of a particular aggregate in waters or soils.

Clays are a common inorganic fraction in natural aggregates. A huge amount of bentonite clay (B), primarily made of montmorillonite, is used each year in various industries (Lagaly and Ziesmer, 2003); part of it finds its way to waters and soils. Catalytic and adsorption properties of clays make them important in soil/water-chemistry but also in retention/transport of organic and inorganic chemicals through the environment (Kersting et al., 1999; Plaschke et al., 2001; Schwartz and Matijevic, 1974). Montmorillonite clay, $[(1/2\text{Ca}, \text{Na})_{0.7}(\text{Al}, \text{Mg}, \text{Fe})_4(\text{Si}, \text{Al})_8\text{O}_{20}(\text{OH})_4 \cdot 7\text{nH}_2\text{O}]$, is an inorganic fraction of aggregates found in both poorly drained soils and those of arid regions (Donahue et al., 1983). Montmorillonite has a substantial internal surface area, elevated ion-exchange capacity, and expands up to 10 times its dry volume upon contact with water by crystalline and osmotic swelling (Luckham and Rossi, 1999; Norrish, 1954).

Humic substances (HSs) exist in dissolved and particulate forms in sediments, soils and waters (Tipping, 2002). They are reported to facilitate transport of contaminants to lower soil horizons and within aquifers, participate in removal and release of organic and inorganic compounds to/from bulk media, and influence availability of inorganic phosphate (Alvarez et al., 2004; Fitch and Du, 1996; Tipping, 2002).

HSs are formed by decomposition of biological material but organics in secondary effluents are quite similar to HSs in soil (Rebhun and Manka, 1971). HSs contain alcohol, amino, carboxyl, and other functional groups (Stevenson, 1994; Tipping, 2002) and their molecular weights are in the range of 600 to more than 200 000 (Stevenson, 1994; Tipping, 2002) with highest values, probably, a consequence of aggregation of smaller units into larger ones (Stevenson, 1994). HSs are polyelectrolytes containing both hydrophilic and hydrophobic moieties (Schulten and Schnitzer, 1995; Schulten and Gleixner, 1999) so they behave like surfactants (Rebhun et al., 1996). Different research schools are currently arguing whether HSs are macromolecules randomly coiled in a solution, associations of relatively small molecules held together by weak interactions, or micellar or pseudomicellar structures (Clapp and Hayes, 1999; Sutton and Sposito, 2005). Knowledge of sizes and shapes of HSs in a solution could improve understanding of their behaviour in both soils and waters.

Particles, made of clays and HSs, are frequently carriers of atrazine (Lesan and Bhandari, 2000), mercury (Amirbehman et al., 2002; Bilanovic et al., 2001), lead and copper (Hizal and Apak, 2006), plutonium (Kersting et al., 1999) and other pollutants (Rebhun et al., 1992).

Clays and HSs are, either directly or indirectly, associated with almost all biological, chemical and physical phenomena in waters and soils. Quantitative and qualitative advances in understanding of mobilisation and deposition of colloidal aggregates

* To whom all correspondence should be addressed.

☎ (218) 755 2801; fax: (218) 755 4107;

e-mail: dbilanovic@bemidjistate.edu

Received 31 January 2006; accepted in revised form 20 October 2006.