広範な pH 範囲におけるアルミナビーズ充填カラム中におけるセルロースナノクリスタル粒子の沈着挙動

Deposition Behavior of Cellulose Nanocrystal Particles through a Packed Alumina Beads across a Various pH Range

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要旨(Abstract)：

This study investigates the effect of pH on the deposition behavior of rod-like cellulose nanocrystal (CNC) particles on alumina beads. CNC particles with pH-independent surface charges and non-spherical shape. Column experiments show significant deposition at low pH due to electrostatic attraction between CNC particles and alumina beads, while higher pH results in reduced deposition due to repulsion.

キーワード：セルロースナノクリスタル（CNC）粒子；充填アルミナビーズ；帯電挙動；沈着

Keywords: Cellulose nanocrystal (CNC) particles; Packed alumina beads; Charging behavior; Deposition

1. はじめに

In the environment, various colloidal particles exist with sizes ranging from tens of nanometers to a few micrometers, such as clay minerals and soil organic matters. These particles undergo changes during transport, such as adsorbing pollutants and migrating. Currently, theories related to colloidal deposition behavior are primarily based on spherical particles. However, many colloidal particles involved in environmental transport are non-spherical, such as rod-shaped particles. Therefore, we chose to study how the deposition behavior of rod-shaped particles changes when the pH is altered in a simulated environment.

2. 方法

In this experiment, alumina beads were used as collectors to investigate the deposition behavior of CNC particles. The CNC particles used in this research are rod-shaped [1] and possess pH-independent charges. We first examined the charging behavior of CNC particles through electrophoretic measurements and then conducted column transport experiments at different NaCl concentrations.

In the column experiments, an acrylic column with a diameter of 1.8 cm and a height of 5.3 cm was packed with alumina beads, achieving a porosity of 0.383 under water saturation, with a flow rate set at 5.0 × 10^{-2} mL/s. A background salt solution was injected from the bottom of the column until the electrical conductivity and pH stabilized. Then we injected CNC suspensions for 20 seconds as a pulse input and quantified the effluent concentration of CNC particles. This injection was repeated three times to observe the deposition and blocking effect, obtaining breakthrough curves (BTC) for different pH and salt conditions.

Using this data, we analyzed the deposition and blocking effects in conjunction with the advection-dispersion equation to study how the deposition behavior of non-spherical CNC particles. Here, for simplicity, we use a blocking function which assumes spherical model.

3. 結果

We verified the surface charge of the CNC particles, and observed the deposition behavior of CNC under different environmental conditions through column experiments.

(1) The surface charge of the CNC particles we used is not affected by pH and remains negative, and that the alumina beads exhibit isoelectric points around pH 7.

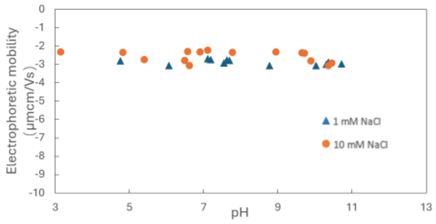

Fig.1 EPM of CNC particles

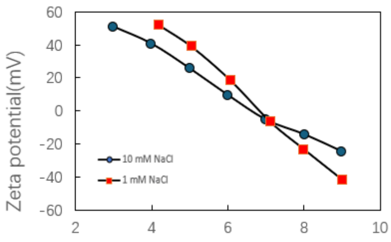

Fig.2 Zeta potential of alumina beads [2]

(2) We observed that at pH below the isoelectric point around pH 7, the deposition and blocking of CNC particles significantly increased. In contrast, at pH above the isoelectric point, the deposition of CNC particles decreased.

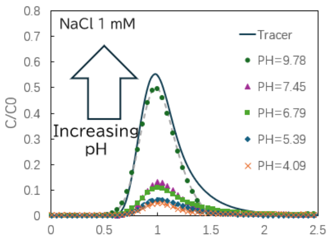

Fig.3 pH dependence of effluent conc.

(3) In a low pH environment, the deposition rate constant remains constant. When the pH exceeds the isoelectric point, the deposition rate constant rapidly decreases with increasing pH, indicating that the deposition of CNC becomes more difficult.

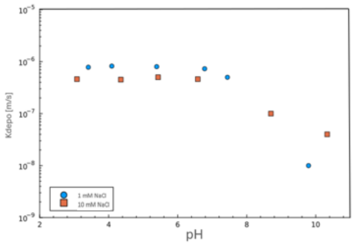

Fig.4 pH dependence of deposition rate constant (K_{depo}) of CNC particles

4. 考察

From the results, at pH below the isoelectric point, the CNC particles and alumina beads experience electrostatic attraction due to their opposite surface charges, resulting in a significant increase in the deposition and blocking of CNC particles. In contrast, in a high pH environment, the surface of the alumina beads carries a negative charge, causing electrostatic repulsion with the CNC particles, which makes deposition of CNC particles more difficult.

5. おわりに

Different pH conditions and salt concentrations alter the electrostatic effects between the alumina beads and negatively charged CNC particles, leading to an enhanced deposition effect at low pH and a reduced effect at high pH.

[1] National Research Council Canada, CNC CNCD-1 Characterization Method Report, (n.d.) 1–19

[2] T. D. Pham et al., Colloids and Surfaces A, Vol.436, 148-157, 2013