Investigation of Zwitterion Sorption onto Montmorillonite
Tina Zhang, 2011

The release of pharmaceuticals into the environment is potentially harmful to some species and may also lead to the development of resistance. The primary source of release is through veterinary waste. Some common pharmaceuticals are zwitterions, chemicals containing both positively and negatively charged functional groups, under environmentally relevant conditions. Examples include ciprofloxacin and amoxicillin. The charged functional groups affect the sorption of these chemicals by soils and thus, human and ecosystem exposure. Sorption is the process through which compounds are retained by a solid surface.

The primary goal of this project was to investigate the effect of the distance between positively and negatively charged functional groups on the extent of sorption onto calcium enriched montmorillonite. It has been hypothesized that zwitterionic antibiotics with the positively and negatively charged functional groups further apart from one another sorb to a higher extent onto montmorillonite (Carrasquillo, 2008). However, there has been no systematic study on the sorption of zwitterions. Montmorillonite is an alumino-silicate clay abundant in soils and possesses a permanent negative charge due to isomorphous substitution. The aluminum atoms in montmorillonite clays are sometimes substituted for atoms of similar size but with a lesser nuclear charge. This results in clay with a net negative charge. Positively charged ions around the soil surface neutralize the permanent negative charge. These ions are calcium cations in calcium-enriched montmorillonite. These surface cations can be exchanged for other cations in solution, resulting in the sorption of chemicals onto the clay surface.

The sorption of two zwitterions was studied: 2 and 5-aminopentanoic acid. The positively charged amine group is located just beside the negatively charged carboxyl group in 2-aminopentanoic acid while the positively charged amine group is located on the other end of the molecule from the negatively charged carboxyl group in 5-aminopentanoic acid. A known, aqueous concentration of the test compound was mixed with solid montmorillonite. The reactor tubes were rotated for 24 hours in order to equilibrate. They were then centrifuged and filtered so that the montmorillonite solid and the aqueous solution could be separated. For reference, blank tubes were also rotated and analyzed in which there was only the test compound and no soil. The concentration sorbed by the montmorillonite was estimated by the difference between the aqueous concentration in the blanks and the concentration in solution after equilibration with montmorillonite. The concentration of the test compound in solution was quantified using capillary electrophoresis. Capillary electrophoresis is an instrument that separates and quantifies compounds by charge and size. Compounds of different charges and sizes move through the capillary at different velocities. The diode-array detector measures the compound’s absorbance of UV light. A compound’s absorbance of UV light can then be translated into a concentration.

Sorption was found to be low for both 2 and 5-aminopentanoic acid and not significantly different from one another. Sorption for 2-aminopentanoic acid was expected to be low because of the repulsive forces between negatively charged carboxyl groups and the soil surface. The repulsive forces can interfere with the attraction between positively charged amine groups and the soil. It is hypothesized that repulsion from the space between layers of montmorillonite accounts for the low extent of sorption of 5-aminopentanoic acid. The negatively charged carboxyl group was expected to be far enough away from the positively charge amine to group so that it would not interfere with sorption. Future work may include using x-ray diffraction to measure the spacing between layers during sorption to gain an understanding of the orientations of the compounds. The sorption of different antibiotics in zwitterionic and cationic species may be measured to determine the extent of the effect of zwitterions on sorption.

References

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