Deposition and mobilization of pathogenic virus in unsaturated porous media: role of soil−water interfaces and air−water interfaces

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This study explored the mechanisms that govern the transport and retention of pathogenic viruses in laboratory−scale columns under unsaturated conditions. Classical DLVO interaction energies were calculated to analyze pathogenic virus retention at the solid−water interface (SWI) and air−water interface (AWI). The results indicated that the role of SWI and AWI in pathogenic virus retention is strongly controlled by moisture content in conjunction with various hydrochemical conditions. Analysis of the breakthrough curves (BTCs) and DLVO calculations revealed pathogenic viruses had lower affinity for both SWI and AWI (pH=7.4, IS<0.002M) and thus the larger deposition with decreasing moisture content could be attributed to straining. A combination of moisture content and suspension ionic strength (IS) caused higher pathogenic virus retention, especially in suspensions of higher IS. According to DLVO energy profiles, pathogenic virus retention mainly occurred at the SWI, whereas retention at the AWI was minimal when the suspension IS was 0.01 and 0.03M for both NaCl and $CaCl_2$, suggesting that retention at the SWI is the primary mechanism controlling pathogenic virus particle retention. When the suspension IS ($CaCl_2$) was 0.06M, pathogenic viruses were strongly retained by attachment to both SWI and AWI. This was probably because the interactions between negatively charged interfaces and pathogenic viruses decreased, resulting in favorable attachment conditions. Repulsion forces were dominant between pathogenic virus−interface systems under various pH conditions, but exhibited high affinity to the SWI at pH 5.0.Thus, large amounts of E. coli phage particle retention were observed under acidic condition conditions. The results of this study show that SWI as the main retention interfaces for pathogenic virus in unsaturated porous media with various suspension pHs and ISs.