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Bacterial trajectories tracked with time-lapse video-microscopy reveal the impact of manganese biomineralization on bacterial sedimentation.

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In aquatic and subsurface environments, sedimentation may influence bacterial transport. Microorganisms that carry out biomineralization reactions may exhibit distinct transport properties from non-biomineralizing organisms due an apparent increase in density caused by biomineral production. For several decades, the biomineralization of manganese (Mn) has been recognized to be a major environmental process, whereby Mn oxide (MnO_2(s)) minerals participate in a plethora of biogeochemical processes including contaminant adsorption, organic matter oxidation. Typically, manganese biomineralization proceeds through the enzymatic oxidation of aqueous Mn2+ to Mn4+ and precipitation of MnO_2(s) in a biofilm matrix outside the bacterial cell. Here, we present a study of the impact of biomineralization on the sedimentation properties of bacteria at small scales (over mm distances) under hydrostatic conditions. We hypothesize that bacteria will sediment faster when biomineralization is active due to encrustation of the organisms by mineral particles. To test this hypothesis, we tracked the vertical notion of individual bacteria (Pseudomonas putida GB-1) using time-lapse video-microscopy. We compared the sedimentation velocity of bacteria in the case where significant biomineralization had occurred, as inferred from bulk measurements of solid phase Mn, with the sinking velocity of bacteria grown without Mn. We calibrated the proposed method by comparing velocity measurements of sinking polystyrene micro-sphere of known density and size with Stokes law, obtaining results that were accurate within 1% of the theoretical value (29.4 nm/s). We also measured a diffusion coefficient of 7x10-13 m2/s for the particles. Following this approach, we measured the sedimentation velocity of P. putida with and without MnO_2(s). Our results show that biomineralization leads to faster sedimentation of the bacteria. In natural environments, biomineralization reactions may increase the sinking velocity of bacteria and therefore contribute to the physical separation of organisms according to phenotype and give rise to localized spots of high mineralization rates.