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Monitoring Microbe-Induced Physical Property Changes Using High-Frequency Acoustic Waveform Data

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A laboratory investigation was undertaken to determine the effect of microbially generated gas in controlled, saturated sediment columns utilizing a novel technique involving acoustic wave propagation. Specifically, the effect of N_2 gas production and the resulting hypothesized plugging of pore throats by gas bubbles was evaluated during denitrification by *Pseudomonas stutzeri* in pre-sterilized sediment columns. The propagation of high frequency acoustic waves through the sediment columns was used to locate those regions in the column where gas accumulation occurred. Over a period of six weeks, regions of gas accumulation resulted in the attenuation of acoustic wave energies with the decreases in amplitude typically greater than one order of magnitude. The temporal production of N_2 gas was evaluated quantitatively using the stable isotope ^{15}N in the form of added $Na^{15}NO_3$. This was done to ascertain the origin (biotic or abiotic) of any produced gas with the results showing a dramatic increase in microbe-respired $^{15}N_2$. Hydraulic conductivity (K_s) measurements made over the experimental period establish the rate and degree of pore throat blocking with the result being a reduction in K_s by more than 70 percent. The results were compared to a nutrient-amended but non-inoculated control column which showed neither a decrease in acoustic wave amplitudes nor hydraulic conductivity over the same time-period. Final destructive analysis of one column was performed in order to assess the cell density of denitrifying microbes throughout the column. Cell densities were found to be in close agreement with the stoichiometric predictions made prior to initiation of the experiment. Evaluation of the multiple data sets suggests that microbial gas production is both directly detectable using the high frequency acoustic wave approach and capable of significantly altering saturated flow conditions. The acoustic approach may be useful for time-course monitoring of locations of high microbial activity during engineered bioremediation and in uncontaminated subsurface environments with high nutrient flux.