SAGEEP - 20

Laboratory Assessment of Nano-Silver Transport in Sand Columns Using Complex Conductivity Measurements

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Abstract

A flow through experiment was conducted to investigate the capabilities of complex conductivity (CR) measurements in detecting and monitoring the transport of three different concentrations (100, 500, 1000 mg/l) of stabilized nano-silver (90-210 nm) dispersions in laboratory sand columns. A dye tracer test was conducted and the break through curves obtained were of identical trend and shape, indicating similarity in the transport properties of the three sand packed columns. A peristaltic pump was used to introduce the stabilized suspensions of nano-silver into the sand columns at a flow rate of 12 mL/min for 15 minutes. The pump was stopped every minute for effluent samples and CR (1-1000Hz) measurements. Breakthrough curves obtained from normalized imaginary conductivity (σ''/σ''_0) showed a similar form to those obtained from normalized concentrations of nano-silver dispersions (C/C_0). However, the lower concentration of the nano-silver dispersion showed a higher mobility and normalized imaginary conductivity values compared to higher nano-silver concentrations. We suggest this is due to possible aggregation of silver nano-particles at higher concentrations, resulting in a reduction in their mobility and surface area, which exerts a major control on complex conductivity measurements. In general, the results of this study demonstrated the sensitivity of complex conductivity measurements, specifically the imaginary conductivity (σ'') component, to detect the fate and transport of different concentrations of nano-silver in porous media.

Introduction

- Nano-materials are becoming prevalent in today's global marketplace, therefore inevitability of nano-materials being introduced to the environment increases.
- Potential aquifer contamination by nano-materials poses risk to human health and may result in aquatic toxicity.
- There are currently many questions on the transport, hazards and fate of nanomaterials in the environment.
- Few studies have been conducted that investigate the fate and transport of nano-materials in the environment.
- Such knowledge is important for the proper evaluation of nanomaterial exposure risks and for the development of effective waste management strategies (Pennel et al., 2008).

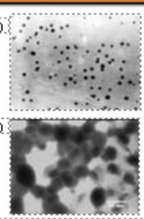

Figure 1: **A)** TEM image of dispersed nano-silver after thorough sonication **B)** TEM image of nano-silver with average diameter of 40nm (Nanosilver.autofibrecraft.com)

Objective

This study was conducted to:

- Investigate the effectiveness of complex conductivity measurements in measuring different concentrations of nano-silver.
- Assess the potential to use complex conductivity measurements to monitor the transport of silver nano-particles in the subsurface.

Methods

Preparation:

- Three identical columns (made of PVC pipe) were dry packed with clean quartz sand and flushed with several pore volumes of background solution having the same conductivity as the nano-silver solutions.
- Three separate concentrations of suspended nano-silver (100, 500, 1000 mg/L) were prepared according to Bihari et al. (2008).
- A tracer test using phenol red was performed and break through curves (A/A_0) were obtained to ensure similarity between columns.

Procedures:

- Each concentration was pumped through a separate column. The nano-silver solutions were kept in suspension to prevent coagulation by using an agitator (sonicator) and a magnetic stirrer.
- A peristaltic pump with a flow rate of 12 mL/min was used to transport the nano-silver solutions through the columns.
- A spectrophotometer with a wavelength of 600nm was used to measure the optical density of the effluent samples.
- Current electrodes (Ag), non-polarizable potential electrodes (Ag-AgCl), and a dynamic signal analyzer were used for the CR measurements (1-1000 Hz).
- The pump was stopped every minute for CR measurements and effluent sampling.
- Break through curves (BTC) of the normalized imaginary conductivity at 10 Hz (σ''/σ''_0 vs. pore volume) and normalized concentrations of nano-silver dispersions (C/C_0 vs. pore volume) were constructed for comparison.

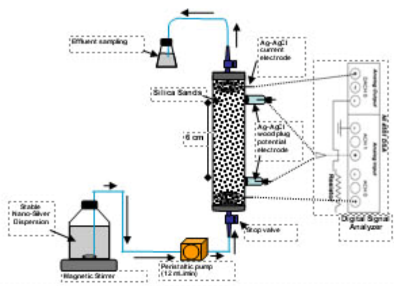

Figure 2: Schematic representation of the experimental set up. Columns were filled with medium grained silica sands(20-30 mesh) with an initial porosity of 40%. Separate setups were used for each concentration (100, 500, 1000 mg/L) of nano-silver dispersion.

Results

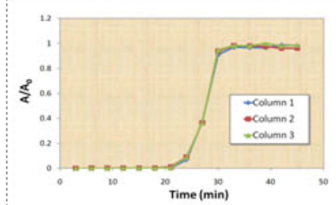

Figure 3: Break through curves (BTC's) from tracer tests using phenol red conducted prior to the start of the experiment for the three sand packed columns used in the experiment.

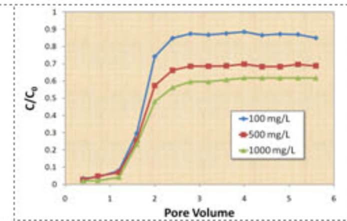

Figure 4: Breakthrough curves of nano-silver dispersions, showing the change in normalized effluent nano-particle concentration (C/C_0) as a function of pore volume. C_0 is the applied concentration and C is the measured effluent concentration.

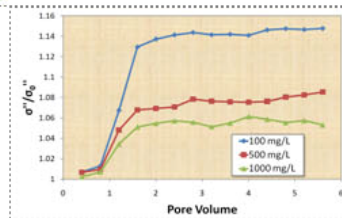

Figure 5: Breakthrough curves of nano-silver dispersions, showing the change in normalized imaginary conductivity values at 10 Hz (σ''/σ_0'') as a function of pore volume. σ_0'' is the background measurement and σ'' is the measurement after introducing nano-silver in the column.

Discussion

- The BTCs from the dye tracer test (Fig. 3) show similar trend and shape suggesting similar transport properties of the three columns sand columns.
- Nano-silver appeared in the column effluent after injection of <2 pore volumes of nano-silver suspension.
- Observed steady-state effluent concentration decreased with increasing particle concentration suggesting substantial retention of nano-silver with concentrations greater than 100 mg/L.
- The normalized imaginary conductivity (σ'') data (Figure 4) reflected the transport data (Fig. 3) with the lower nano-silver concentration (100 mg/L) showing the highest response.
- Previous studies (Baalousha 2009) have shown that at higher concentrations and pH values, nano-particles tend to aggregate (Figure 1), particularly when the aqueous suspentsion contains a background electrolyte as was the case in this study.
- Aggregation at higher nano-silver concentration would result in larger size particles (micron size) increasing their retention in the columns and limiting their transport. At the same time the increased particle size would reduce their surface area and hence the imaginary conductivity component of the complex conductivity (Wu et al. 2008).
- SEM images would have been useful to provide evidence for aggregation.

Conclusions

- The similarity in shape and trend of the concentration and imaginary conductivity break through curves suggests that geophysical methods cans be used to monitor the presence, fate, and transport of nano-silver in porous media.
- More studies are needed to investigate the effects of pH, ionic strength, and surface chemistry on the transport of nano-particles and their geophysical signatures.

Acknowledgements

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