Nitrate Transport in Unsaturated Soil Treated with Fly Ash

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A bench scale study to investigate nitrate transport in a variably saturated soil is presented. A clayey sand soil was amended with various levels of flyash ranging from 0-20% (wt./wt.). The direct effect of flyash level on the nitrate movement in unsaturated media was investigated by injecting a nitrate solution through a soil fixed at a specified saturation level. Flyash is a byproduct of coal combustion power plants generally described as a fine powdered ferroaluminosilicate with Al, Ca, Fe, Na, and Si as the predominant elements. Flyash has previously been used as an amendment to restore and balance soil ph of acidic soils from mine tailings [1] and has been shown to increase production of crops such as rice, wheat, maize, grass, mustard, as well as other cereals and grains [1, 2, 3] when flyash was added as a soil amendment. Nevertheless, concerns for heavy metals leaching still persist.

Recent studies have shown that saturation alone can have a significant effect on the nitrate transport in both steady-state [4] and transient [5] soil saturation level. It was shown, that low saturation nitrate transport is enhanced by an effect known as anion exclusion. Anion exclusion is caused by electrostatic repulsive forces of negatively charged clay surfaces and negative nitrate ions. The anion exclusion effect is enhanced in a low-saturation soil because the bulk solute travels closer to the clay surfaces, approaching a thin layer flow, thus increasing the repulsive forces. The enhanced anion effect at low saturation was reported by Medina et al. [4] and shows up as concentration peaks in the breakthrough curves. These peaks are up to 18 % higher than the input nitrate concentration. We hypothesize that the positively charged aluminum and iron found at the surface of flyash [1, 6, 7] can mitigate anion exclusion in a variably saturated clayey sand amended with flyash.

The hypothesis was tested by amending a clayey sand soil with Class F Flyash (FA) at four different levels: 0% (no flyash, NFA), 2% (low flyash, LFA), 10% (medium flyash, MFA), and 20% (high flyash, HFA). Each soil mixture is packed into a small soil column (3.3 cm radius and 5.0 cm height) and placed inside the steady state centrifugation - unsaturated flow apparatus (UFA). The rotation speed and fluid flux are controlled using the UFA such that the desired saturation level remains constant. Three saturation ranges were investigated: 0.75-0.9, 0.4-0.45, and 0.27-0.29 designated as high, medium, and low-saturation, respectively. Initially, Deionized (DI) water is passed through the column until the target saturation level reaches steady state; at which point the DI injection line is replaced with a 7.0 mM ammonium nitrate solution. Leachate from the soil column is collected at predetermined intervals, to a total volume of approximately twelve effective pore volumes. The leachate samples are analyzed for nitrate (NO_3^-) concentration using ion chromatography and the breakthrough curves are constructed. In addition to nitrate transport, the effect of flyash on soil hydraulic properties was also investigated.

The experimental results obtained (not shown here) demonstrate that the soil hydraulic properties are affected by the FA amendment level as follows: (a) soil bulk density increased with increasing FA content, (b) saturated volumetric water content decreased with increased FA, (c) hydraulic conductivity decreased with increased FA, and (d) water retention was increased as FA

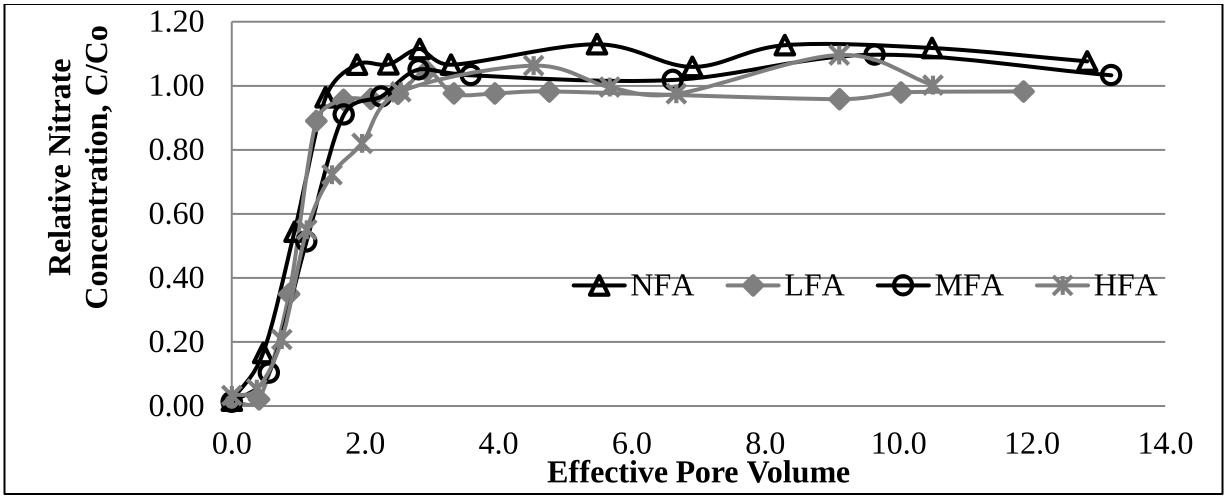

Figure 1. Nitrate breakthrough curves for a soil subjected to low saturation level.

content was increased. Additionally, it was shown that the effect of FA treatment is minimal on soils subjected to high and medium saturation levels. However, flyash has a significant effect on nitrate transport at low saturation levels. It is shown in Figure 1, that all three FA treatments decrease the nitrate transport as compared to the NFA sample. The reduced nitrate transport is most significant for the LFA sample, as the breakthrough curve persistently remains below, albeit still close to, the input nitrate concentration. The soil hydraulic properties enhanced as function of FA level further supports a widely recommended amendment level of approximately 20%. The reduced anion exclusion shown here suggests that even a low addition of FA can significantly reduce nitrate transport, making it a viable soil amendment.

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