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Experiments Investigating Adsorption of Sodium on Peat in the Presence of Calcium and Magnesium: Insights on Effects of Road Salt Pollution on Acidic Organic Soils

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Road salt (NaCl) pollution can increase the sodicity of soils due to adsorption of Na, yet these reactions on organic materials are poorly understood. The addition of $CaCl_2$ and $MgCl_2$ as deicing agents could create competition between Na, Ca, and Mg onto cation exchange sites and reduce Na adsorption. We conducted experiments to investigate the competitive selectivity of Na to peat soils in the presence of Ca and Mg. We reacted peat with NaCl-$CaCl_2$ and NaCl-$MgCl_2$ reagents characterized by their sodium adsorption ratio (SAR = 1, 2.5, 5, 7, 10, 20, 40, 60 $(mmol_c\ L^{-1})^{0.5}$) and ionic strength (I = 1, 5, 10, 20, 50 mmol L^{-1}). The initial cation exchange capacity of the peat (soil pH = 3.9) was 39±4.6 $cmol_c\ kg^{-1}$, and total acidity (65%) exceeded exchangeable Ca (27%) and Mg (8%). This peat was equilibrated with each reagent. Exchangeable base cation concentrations were determined by NH_4Cl extraction and ICP-MS, and acid cations (H^+ and Al^{3+}) were determined by KCl extraction and colorimetric titration. Entrained liquid from the reacted peat-reagent solutions was collected and measured for base cation concentrations and pH. Selectivity coefficients for cation exchange reactions (Vaneslow and Langmuir) were determined from the exchangeable cation and entrained solution chemistry.

For all NaCl-$CaCl_2$ reactions, the percentage of Na adsorbed increased with greater proportion of Na—and less Ca—in the entrained solution. At lower ionic strength (I = 1 and 5 $mmolL^{-1}$), selectivity of the cation exchange reactions favors Na over Ca and Mg. Exchangeable Ca and Mg are less than initial values, and the proportion of exchangeable acidity increased to 70% due to loss of divalent cations. However at higher I, exchangeable Ca exceeds initial values with a corresponding decline in exchangeable acidity; exchangeable Mg becomes negligible. Ca is the most abundant exchangeable cation at lower SAR values, and selectivity of the cation exchange reactions favors Ca over Na and Mg. The NaCl-$MgCl_2$ reactions showed similar patterns, although 10-26% of Ca remained adsorbed even without $CaCl_2$ in the reagent. These results suggest that addition of $CaCl_2$ and $MgCl_2$ to deicing agents will reduce Na adsorption on organic materials.

Equation 1: Sodium adsorption ratio (SAR) of a solution is calculated from the molar concentrations of Na, Ca, and Mg.

$$SAR\ (mmol_c\ L^{-1})^{0.5} = \frac{[Na]}{\sqrt{[Ca] + [Mg]}}$$

Equation 2: Cation Exchange Reaction, Vaneslow Convention, between Na in solution and Ca on peat.

$$Na^+ + CaX_{2(s)} = Ca^{2+} + 2NaX_{(s)}$$

Equation 3: The Vaneslow selectivity coefficient (Kv) is calculated by measuring the mole fraction of exchangeable cations (X) on peat and the activities of ions in solution.

$$K_v = \frac{[Ca^{2+}][NaX]^2}{[Na^+]^2[CaX]}$$