Road salt retention and transport in soils and subsequent releases of toxic trace elements to porewaters

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Road deicing salts are widely used to improve winter travel safety. However, their application causes the release of Na, Cl, and other contaminants into the environment. While Na may temporarily be stored in soil porewaters or adsorped on soil particles, it can gradually be released over longer timescales. We evaluated road salt retention and transport by collecting soil porewater samples from a roadside soil immediately after deicing applications using suction lysimeters weekly over one year. Lysimeters were arranged by depth (10, 20, 50 cm) into four nests that increased in distance from the road (1.0, 1.5, 4.0, 18.0 m), allowing us to assess salt transport in three dimensions. Water samples from a nearby karst spring-fed stream were concomitantly collected with soil waters. Waters were analyzed for Na, Cl, other major ions (Ca, Mg, K, Si), toxic trace elements (e.g., As, Pb, Co), and stable isotopes ($\delta^{18}O$, δD). Stable isotope results showed that soil water retention time increased with depth and distance from the road. Soil water Na levels decreased significantly ($p < 0.01$) with distance from the road at all studied depths, though they were low on average (0.28 mM) compared to the spring-fed stream (1.84 mM). This indicates differences in Na retention times between the soil and karst aquifer. Na levels at 1.5 and 4.0 m from the road increased with depth ($p < 0.01$). In contrast, Na levels 1.0 m from the road were much higher near the surface ($p < 0.01$), evidencing higher Na inputs at the soil surface from road salting. Following road deicing, the nests located 1.5 and 4.0 m from the road featured an overall decrease in Na over time. At 1.0 m from the road, Na did not change at 10 cm ($p = 0.41$) and increased at 20 cm ($p < 0.01$), suggesting delayed release of the higher Na levels at the roadside via cation exchange. Our field results support previous lab findings that Na is retained for up to 5 months in the soil after salt applications. Indeed, we observed that concentrations of Cl were ~1.5× higher than Na in the spring-fed stream water, evidencing Na retention in the soil or aquifer. Toxic trace element levels were also significantly ($p < 0.02$) higher near the road after salt applications, suggesting they were mobilized due to ion exchange in soils. Understanding road salt and associated contaminant transport through multiple reservoirs will allow us to better assess their harmful impacts.