A shallow aquifer CO2 contamination experiment was performed to investigate evolution of water chemistry and sediment alteration following leakage from geological storage by physically simulating a leak from a hypothetical storage site. In a carbonate-free aquifer, in western Denmark, a total of 1600 kg of gas phase CO2 was injected at 5 and 10 m depth over 72 days through four inclined injection wells into aeolian and glacial sands. Water chemistry was monitored for pH, EC, and dissolved element evolution through an extensive network of multilevel sampling points over 305 days. Sediment cores were taken pre and postinjection and analyzed to search for effects on mineralogy and sediment properties. Results showed the simulated leak to evolve in two distinct phases; an advective elevated ion pulse followed by increasing persistent acidification. Spatial and temporal differences in evolution of phases suggest separate chemical mechanisms and geochemical signatures. Dissolved element concentrations developed exhibiting four behaviors: (1) advective pulse (Ca, Mg, Na, Si, Ba, and Sr), (2) pH sensitive abundance dependent (Al and Zn), (3) decreasing (Mn and Fe), and (4) unaffected (K). Concentration behaviors were characterized by: (1) a maximal front moving with advective flow, (2) continual increase in close proximity to the injection plane, (3) removal from solution, and (4) no significant change. Only Al was observed to exceed WHO guidelines, however significantly so (10-fold excess). The data indicate that pH is controlled by equilibrium with gibbsite which is again coupled to cation exchange processes. Pre and postinjection sediment analysis indicated alteration of sediment composition and properties including depletion of reactive mineral species. Key Points Effects of sustained injection of CO2 into shallow potable aquifer studied Water chemistry monitored over 305 days and effects on sediment investigated Results show distinct chemical development, high Al concentrations, and sediment alteration © 2014. American Geophysical Union. All Rights Reserved.