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Subsurface Chloride Transport in Shallow Groundwater

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High soil spatial heterogeneity was identified at the USDA-ARS Beltsville OPE3 field site using geophysical surveys (ground-penetrating radar) and soil textural analysis. It was confirmed with data on crop yields and pesticide concentrations in wells.
To assess effects of soil heterogeneity on soil hydrological regime, four locations with different soil texture were selected at a 13 x 14 m field plot. The locations were instrumented with Multisensor Capacitance Probes (MCPs, SENTEK) and tensiometers to measure soil water content and matric potential at depths from 10 to 100 cm with the 10-cm increment, and wells to monitor groundwater depth. Standard meteorological data were measured in the vicinity of the plot. The soil water and weather monitoring was conducted with 15-min frequency at the locations for two years.

Results of the monitoring revealed differences in the hydrological regime in four locations. Soil water contents at depths of 10 and 30 cm were consistently higher at the location 3 compared to other locations; consistently low water contents were observed at depths of 60 and 70 cm at the location 2. Groundwater at the location 2 was consistently deeper during wet periods and shallower during dry periods than at other locations. Decrease in the groundwater depth was generally faster at the locations 3 and 4, than at locations 1 and 2.

The tracer experiment followed the monitoring study to evaluate the effect of differences in hydrological regimes on the solute transport in the vadose zone and groundwater. A pulse of the KCl solution was applied with irrigation water from a rainfall simulator on the monitoring plot. After that, the plot was irrigated every 8 hours for 4 months at the rate of 2 cm/d. Five additional locations at the distance of 7 m and three locations at the distance of 14 m downslope from the irrigated plot were equipped with MCPs and observation wells to monitor soil water content and to sample groundwater at three depths (1.1 m, 1.4 m, and 1.7 m). The wells were designed to prevent the tracer mixing within them. Similar wells were installed at four locations at the irrigated plot. Chloride concentrations were measured in the groundwater samples twice a day during the first month and once a day during three subsequent months. Runoff from the irrigation events was captured, measured, and sampled for Cl. The area around the irrigated plot was kept at natural conditions.

Results of the tracer experiment indicated that both matrix and preferential flow processes affected Cl transport. The fast increase followed by the fast decrease in groundwater Cl content was observed at locations 1 and 4, while changes in Cl content were relatively slow at locations 2 and 3. Chloride concentrations in groundwater at the not irrigated area was different at different depths and locations, and was affected by the rainfall water and by the subsurface lateral groundwater flow. The degree of mixing and dilution after rainfalls varied among wells according to a definite spatial trend. The arrival time of the Cl differed between wells and depths, and was from seventy to one hundred days at the 7-m distance from the irrigated plot. The dispersion of Cl inferred from the breakthrough concentrations was different for each spatial location. Vertical concentration profiles were not monotonous, and inversions of Cl concentrations were observed in some wells. Some of the observed differences in the Cl breakthrough between the observation wells could be interpreted using the ground penetration radar data and the borehole data that revealed substantial variability of the subsurface texture and structure.