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Observation of infiltration experiments with time lapse electrical resistivity tomography

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Recent progress in the development of resistivity equipment enables the real time observation of infiltration processes through the vadose zone. In order to study the advantages and limitations of the method infiltration experiments are carried out for different soil types at various locations. All sites are subsequently excavated and investigated in detail. For an improved verification of the resistivity data the most recent experiment is conducted using a colour tracer.

Two infiltration experiments are carried out in sandy soil. The location is Fuhrberg, close to Hannover, Germany. The area has been intensively studied for soil research purposes for more than 30 years. During both infiltration experiments water (110 l/80 l) is infiltrated for a period of 4.5 h and 8 h, respectively, and the infiltration process is observed by ERT. The resistivity measurements are conducted using a 3D-dipole-dipole configuration with electrode distances of 20 cm in the centre of the infiltration field. The whole resistivity array consists of 200 and 300 electrodes, respectively. The second experiment uses increased electrode spacing in the border area in order to enable the resolution of the deeper groundwater table (3.5 m during the second experiment compared to about 1.2 m for the first experiment).

Immediately after completion of the resistivity measurements TDR and tensiometer measurements are carried out in 5-8 slices of the excavated infiltration area over a period of several days. The colour tracer used during the second experiment clearly outlines the infiltration plume with sharp outer limits. The ERT inversion depicts the shape of the plume successfully. Time lapse ERT interpretation reveals the development of the plume in time. The combination of ERT interpretation and TDR measurements enables the construction of the relationship between water content and resistivity as reconstructed by ERT using an Archie approach. By using this function water content changes can be analysed quantitatively. For the first experiment this calculation shows one day after the infiltration about 40% of the infiltrated water being lost to the groundwater. For the second experiment the quantitative interpretation takes into account the increased conductivity of the infiltrating tracer solution compared to the pore water of the vadose zone before infiltration.

Another infiltration experiment is done on Loess. Due to the low infiltration rate only about 9l of water could be infiltrated within about 3 h (38mm/h). The time lapse ERT clearly reveals the water remaining close to surface and no sign of resistivity change due to the infiltration is observed to penetrate deeper than 30cm. At this depth the plough pan seems to inhibit the infiltration. The analysis shows the high sensitivity of the ERT method. Although the original water content is quite high and therefore the resistivity changes due to water content changes are small (the flat part of the Archie function) the time lapse ERT inversion depicts the changes of resistivity quite clearly.
The experiments show the advantages of ERT measurements to observe the infiltration process in real time. However, the interpretation of such measurements still poses difficulties mainly due to the limited resolution and the ill posedness of the inversion problem of electrical resistivity tomography (ERT). These problems are investigated further in order to advance the applicability of the method to infiltration problems showing signs of preferential flow.