Geophysical Research Abstracts
Vol. 20, EGU2018-7456, 2018
EGU General Assembly 2018
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Groundwater protection and agricultural development: Conflict and challenges

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Developing efficient productive agriculture, while preserving groundwater quality, is one of the most important challenges in water resources management. Although groundwater pollution is caused by a vast array of chemicals, on the global scale, most drinking-water well shut-downs are related to elevated nitrate concentrations, which are primarily the result of excessive fertilizer applications in agriculture. Moreover, scientific efforts in developing agricultural practices too frequently focus on improving agricultural productivity using marginal quality water regardless of the potential for the down-leaching of low quality water below the root zone and into the unsaturated zone and the groundwater.

Today, most monitoring programs for protecting groundwater from pollution hazards are based on observation wells that monitor the saturated section of the subsurface. Unfortunately, the identification of pollutants in well water is clear evidence that the contaminants have already crossed the entire vadose zone and accumulated in the aquifer water in detectable concentrations. Therefore, effective monitoring programs that aim at protecting groundwater from pollution hazards must include vadose zone monitoring technologies that are capable of providing real-time information on the chemical composition of the percolating water. Obviously, identification of pollution processes in the vadose zone may provide an early warning of potential risks to groundwater quality, long before contaminants reach the water table and accumulate in the aquifers. Since productive agriculture must inherently include the down-leaching of excess low quality water, understanding the mechanisms controlling the transport and degradation of pollutants in the unsaturated zone with respect to the agricultural regime is crucial for water resources management.

Examples of the scientific and technological challenges in assessing agricultural impacts on groundwater quality may be found in studies based on the newly developed vadose zone monitoring system (VMS). The VMS was specially developed to enable continuous measurements of the hydrological and chemical properties of percolating water. Currently, the system has been successfully implemented in several studies on water flow and contaminant transport in various hydrological and geological settings, including floodwater infiltration and groundwater recharge, agricultural impact on groundwater quality, evolution of landfill leaches, and control of remediation processes in contaminated sites. In these applications, frequent sampling of vadose zone porewater was used for chemical and isotopic analysis along with continuous measurement of variations in the sediment water content, in order to assess the link between land use and groundwater pollution potential. In agricultural applications, transient data from the unsaturated zone were used to calibrate flow and transport models, which were then used to assess the long term impact of various agricultural setups on the quantity and quality of groundwater recharge.