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Associate Professor, Director of the Center for Groundwater Research; (b. 1951); B.S. Chemistry, University of Washington, 1973; M.S. 1981, Ph.D., 1984 Environmental Science, Oregon Graduate Center (James F. Pankow).

Research Interests

DR. RICHARD L. JOHNSON is the Director of the Center for Groundwater Research, a multi-disciplinary group of scientists from OGI's Departments of Environmental Science and Engineering, Chemical and Biological Sciences, and Applied Physics and Electrical Engineering. There is also strong participation from the Centre for Groundwater Research at the University of Waterloo. Current Center research programs include the Large Experimental Aquifer Program (LEAP), the Bioremediation Program, the Subsurface Sensors Program, the University Consortium Solvents-in-Groundwater Program, and the Analytical Methods Development Program. Dr. Johnson's overall research is focused on the processes which control the movement of pollutants in the environment. Five major research areas are currently being pursued:

1. Transport and fate of chlorophenols in the subsurface.
2. Diffusive contaminant transportation fine-grained media.
3. Gas-phase contaminant transportation unsaturated porous media.
4. Behavior of immiscible fluids (e.g. solvents, gasoline) in porous media.
5. Simulation of subsurface processes using very-large physical models.

Selected Research Activities

Diffusive Contaminant Transport in Fine Grained Media.

Subsurface burial of hazardous wastes is an important component of most current waste disposal strategies. At many facilities, clay liners are used to contain the wastes by eliminating advective transport. If successful, transport in the liner will be molecular diffusion limited. Diffusion can, however, transport large quantities of hazardous materials out of the disposal site. The rate at which contaminants move into and through the liner can be predicted using Fickian diffusion models, if the effective diffusion coefficient of the contaminant of interest is known. These may be estimated in the laboratory using intact pieces of liner material, or they may be observed directly at existing waste disposal sites. The latter approach is being used in a joint research project with the University of Waterloo at a site in southwestern Ontario. Core samples of clay liner were collected from immediately below the waste. The cores were sectioned and contaminant concentrations determined in each section. Concentration profiles which show compound-specific variations were constructed for a variety of contaminants. The variations are primarily the result of differences in the extent to which the compounds sorb onto the medium. This work represents the first *in situ* observation of compound-specific effective diffusion coefficients and confirms the role of diffusion in mass transport in fine-grained media.

Gas-phase Contaminant Transport in Unsaturated Porous Media

Transport through the unsaturated zone to the water table is an important pathway for groundwater contamination. The processes that control contaminant transport in this region include aqueous-phase advection and gas-phase diffusion. For volatile contaminants, gas-phase diffusion can be the dominant processes and can carry mass over distances of meters in a matter of days. The process of movement across the water table and into groundwater is much slower and can be controlled by aqueous-phase diffusion. Similarly, the transport of volatile contaminants from the groundwater to the atmosphere is controlled by aqueous-phase below the water table and gas-phase diffusion above. As seen in Figure 1, this results in sharp concentration gradients across the water table. These processes have an important effect on contaminant surface and the experiments at OGI are at the forefront of this research area.

Groundwater Contamination by Immiscible Phase Fluids.

Millions of gallons of gasoline and solvents are leaked or spilled into the subsurface annually. There are many factors which control the fate of these materials. In general, however, they will either be 1) degraded, 2) volatilized to the atmosphere or, 3) dissolved in the groundwater. The balance between these pathways will determine the extent to which groundwater is contaminated. Several projects are currenfly underway to evaluate the role of vapor-phase diffusion in the unsaturated zone, as well as transport to the groundwater. Laboratory studies of diffusion in unsaturated media are being used to evaluate the effects of water content, sorption, vapor-density and boundary conditions on diffusion. Large physical model studies are being used to evaluate the role of vapor-phase diffusion under realistic conditions. In addition, theoretical studies of the times required to dissolve pools of solvent are being made. Finally. actual sites of groundwater contamination by gasoline are being studied (in conjunction with the U.S. EPA) to better understand the processes which have controlled the fate of the gasoline.

Simulation of Subsurface Processes Using Very Large-Scale Physical Models.

The OGI Large Experimental Aquifer Program (OGI/LEAP), under the direction of Dr. Johnson, is focusing on the chemical, physical and biological processes which control chemical transport and fate in the saturated and unsaturated zones. Current research activities include gravity-driven movement of organic vapor in the unsaturated zone, biodegradation and diffusion of organics in the unsaturated zone, and movement and fate of gasoline compounds in the unsaturated and groundwater zones.

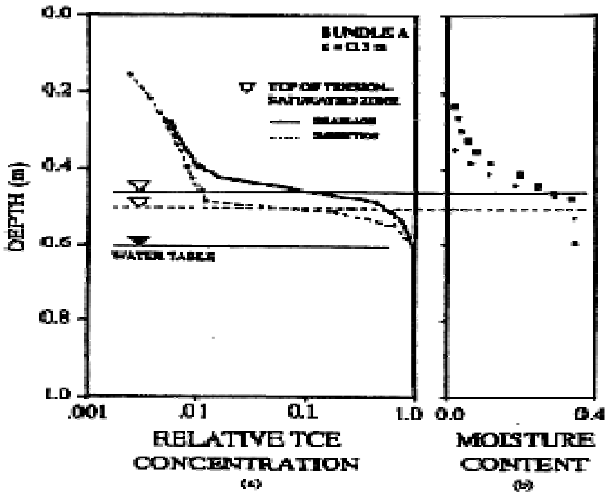

Figure 1

(a) Steady state profiles of depth vs. TCE concentration under drainage (solid squares connected with solid curve), and inbi- bition (pluses connected with dashed curve) conditions. (b) Moisture content vs. depth under drainage (solid squares), and imbibition (pluses) conditions. (Concentrations are reported relative to the maximum concentration at bundle A [x = 0.3 m].)

Selected Publications

Measurement of trichloroethylene diffusion as a function of moisture content in sections of gravity-drained soil columns. K.A. McCarthy & R.L. Johnson; *J. Environ. Quality*, **24**:49 (1995).

Transport of volatile organic compounds across the capillary fringe. K.A. McCarthy & R.L. Johnson; *Water Resources Research,* **29**:1675 (1993).

Dissolution of dense chlorinated solvents into groundwater. 2. Source functions for pools of solvent. R.L. Johnson and J.F. Pankow; *Environ. Sci. and Technol.,* **26:**896-901, 1992.

Gasoline vapor transport through a high-water-content soil. R.L. Johnson and M. Perrott, *J. Contamin. Hydrol.,* **8:**317-334, 1991.

Diffusive contaminant transport in natural clay: A field example and implications for clay-lined waste disposal sites. R.L. Johnson, J.A. Cherry, and J.F. Pankow; *Environ. Sci. and Technol.,* **23:**340, 1989.

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