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NATURAL MEMBRANE PHENOMENA AND SUBSURFACE WASTE EMPLACEMENT

Commonly, shales are considered to be effective aquitards in the subsurface environment owing to their generally low hydraulic conductivity compared to materials that comprise aquifer systems such as limestones and sandstones. However, recent laboratory and field studies indicate that clay minerals may behave as natural semipermeable membranes. A semipermeable membrane is capable of retarding the passage of charged species through its micropores when a driving force such as a hydraulic gradient is imposed across the membrane. Likewise, if a chemical, electrical, or thermal gradient is imposed across a semipermeable membrane, the result is a movement of H_2O in response to the gradient in order to equalize the chemical potential of H_2O on the two sides of the membrane.

If liquid wastes are emplaced in a subsurface aquifer system which was previously at steady-state equilibrium, the emplacement will likely upset the steady-state equilibrium; it may cause: (1) chemical reactions with the existing fluid and rocks, (2) thermal changes, and (3) increased pressure on the aqueous phase. In addition to these well-recognized effects, if a shale capable of behaving as a membrane is expected to serve as an aquitard, its membrane characteristics must be taken into account. For example, if the chemical concentration in the aquifer is greatly increased as a result of waste emplacement, an osmotic cell may be set up between a nearby aquifer and the emplacement aquifer with the intervening shale acting as a membrane. This could result in pressure increase beyond that anticipated. Likewise, thermal and electrical osmosis could occur across the shale membrane with attendant pressure changes.

Additionally, if pressure is increased owing simply to emplacement of waste, ultrafiltration can result. The effect would be to cause flow across the shale and increase the chemical concentration of the filtrate in the emplacement aquifer beyond the planned amount.

In any plan to emplace liquid waste in an aquifer system, the possible membrane behavior of shale in this system must be taken into account. Wherever feasible, laboratory membrane tests should be conducted on cores of the shale prior to full-scale operation; the entire system, not just the emplacement aquifer, should be tested with a computer simulation model prior to initiation of waste injection.

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FEDERAL REGULATIONS AS THEY RELATE TO UNDERGROUND WASTE MANAGEMENT

The basic authority for federal enforcement in water pollution is the Federal Water Pollution Control Act (Public Law 84-660, as amended, 33 USC 1151). The Environmental Protection Agency has been charged with the administration and enforcement of this act. The act declares the policy of Congress "to recognize, preserve and protect the primary responsibilities and rights of the states in preventing and controlling water pollution."

The 3 basic enforcement tools of the Environmental Protection Agency are the "Enforcement Conference" as set out in P.L. 84-660, as amended; the "180-day Notice" under the Water Quality Standards provisions of P.L. 84-660, as amended; and the "Permit Program" as authorized by Executive Order No. 11574, December 23, 1970, to enforce the 1899 Refuse Act (33 USC 407).

One significant policy of EPA was announced October 15, 1970, stating opposition to the disposal or storage of wastes by subsurface injection except where it is used as a last resort and meets certain criteria set out in the policy statement.

On June 25, 1971, EPA released its "Guidelines on Water Pollution Enforcement." The general guidelines for selection of cases are: (1) volume and nature of discharges, (2) effects on receiving waters, (3) failure of dischargers to make satisfactory progress in abatement efforts, and (4) relationship to an area-wide program.

The general guideline for use of the Refuse Act is that it may be used at the present time only against industries. It is applicable only to navigable waters and their tributaries. It is applicable regardless of interstate effects.

The Water Quality Act of 1965 (P.L. 89-234) requires the establishment of water quality standards for interstate waters by the states, together with an implementation and enforcement plan. Should the state not establish such standards, there is provision for the Administrator of EPA to promulgate the water quality standards.

The private nuisance suit is an old and long-used remedy available to the private citizen. Some new state legislation now provides for class actions in pollution cases.

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WASTE DISPOSAL IN SALINE AQUIFERS AFFECTED BY GEOTHERMAL HEATING

In recent years considerable interest has been focused on deep saline aquifers as reservoirs for the disposal of liquid waste. In general, the water in such aquifers is already in motion controlled by 3 sets of gradients: the hydraulic-pressure gradient, the geothermal gradient, and the salt concentration gradient. In thick aquifers, interaction of these gradients induces gravity convection currents which are not present in constant-density fluid systems. The fate of the waste liquids entrained in this fluid system will depend (among other things) upon the state of motion in the aquifer before injection and the modification of this state by the injection process.

A hydraulic laboratory sandstone model was built to simulate a saline aquifer, a geothermal source, freshwater recharge, and waste-injection wells. The studies show stream lines, velocities, and temperature/salinity distributions before and during waste injection. The governing equations, namely, the hydraulic flow equation, the diffusion equation for salt and injected contaminants, and the heat diffusion equation are solved simultaneously on a high-speed digital computer. Obtaining theoretical solutions comparable to the model data requires choosing correct empirical values of coefficients of salt and heat diffusion.

After the validity of solutions of the governing equations is established by comparison with the model studies, a basis for prediction is investigated by comparing theoretical solutions for field conditions with temperature and salinity data from selected oil exploratory wells in the Floridan aquifer of southern Florida.