Profile sections of hypothetical systems illustrate the nature, form, and extent of hydrologic system response to the stress of subsurface waste storage. Representative values of travel time for advances of the waste cylinder versus the cone of pressure increase are given for selected values of injection rate and aquifer diffusivity.

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CONTROL OF UNCONSOLIDATED SANDS IN WASTE-DISPOSAL WELLS

Sand control methods were first used in water wells, and later, modified methods were applied to oil and gas wells. The most recent application for sand control is in waste-disposal wells. The increasing use of unconsolidated sands as disposal zones has created a need for better sand-control systems.

We suggest that the primary causes of sand control problems in disposal wells are: (1) greater completion intervals, (2) intermittent operation of the well, and (3) chemical characteristics of the injected effluent. Therefore, successfully to prevent sand production in disposal wells, consideration must be given to: (1) formation characteristics, (2) completion fluid, (3) type of completion, and (4) completion method.

Two universally used methods of sand exclusion, with suggested modifications when applied to disposal wells, are the method of in-place sand consolidation with plastics, and the use of gravel packs in conjunction with sand screens. Sand consolidation has limited application owing to the large completion intervals normally used in disposal wells, and to possible chemical reactions with injected effluent. However, a gravel-packed–sand-screen completion generally eliminates the three primary causes of sand production in disposal wells. Factors of prime importance are (1) the drilling and completion fluids, (2) formation grain size and composition, (3) size and amount of gravel, (4) pumping rate, (5) pressure, and (6) gravel concentration.

Field and laboratory data show that the method of gravel-packed–sand-screen completions can be used successfully over intervals as large as 500 ft in unconsolidated Frio sands.

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GEOLOGIC FRAMEWORK FOR SUCCESSFUL UNDERGROUND WASTE MANAGEMENT

Geologic requisites for successful underground waste management include: (1) porous and permeable reservoir rocks, in which the storage space may be caverns, intergranular pores, or fracture crevices; (2) impermeable seals to prevent escape of fluid wastes; (3) adequate understanding of hydrologic parameters, and planning to prevent undesirable migration of fluids; and (4) compatibility between waste materials and the reservoir rocks and their natural fluids.

Layered sedimentary rocks, rather than igneous or metamorphic rocks, provide the most suitable reservoir space, for both geologic and hydrologic reasons, but they must lie below, and be well shielded from, fresh groundwater aquifers. If wastes are hazardous to the biosphere, objective reservoir zones must be located deep enough to provide permanent protection to groundwater aquifers.

The site must be reasonably stable and not actively moving along or broken by faults.

Choice of a suitable underground disposal site can be made only after a thorough investigation of available subsurface data, or by drilling and various other processes of subsurface exploration if sufficient data are not available. Preliminary investigations and later subsurface operations will be expensive but they cannot be avoided in locating new sites. Public insistence on an end to pollution must be accompanied by public understanding that a clean environment can be purchased only by higher taxes (if government managed) or by higher prices for consumer goods (if industry managed), plus individual cleanliness.

As waste-management costs rise, it will become more economical to convert wastes into usable products, in effect eliminating rather than managing wastes.

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GEOCHEMICAL EFFECTS AND MOVEMENT OF INJECTED INDUSTRIAL WASTE IN A LIMESTONE AQUIFER

Since 1963 more than 4 billion gal of acidic industrial waste has been injected into a limestone aquifer near Pensacola, Florida. This aquifer is overlain by an extensive clay confining layer, which at the injection site, is approximately 200 ft thick. The waste—an aqueous solution containing organic acids, nitric acid, inorganic salts, and numerous organic compounds—is injected into the aquifer through two wells 1,300 ft apart between depths of approximately 1,400 and 1,700 ft. The present pH of the injected solution is about 2.5; however, before April 1968 the pH was about 5.5.

Approximately 10 months after waste injection began, an increase in calcium-ion concentration and alkalinity was detected in a monitor well open only to the receiving aquifer and located 0.25 mi south of the injection wells. About 5 months after lowering the waste pH, an abrupt increase in calcium-ion concentration followed by an increase in nitrate-ion concentration was observed at this monitor well. Large quantities of nitrogen and methane gas were present in water from the monitor well. This information plus other available data indicate that a major part of the waste is entering the upper 30–50 ft of the aquifer and that waste has moved more than 1 mi from the injection site. Geochemical effects have not been detected in two monitor wells open only to the receiving aquifer and located 1.5 mi south and 1.9 mi north of the injection site nor in a shallow monitor well at the injection site which is open only to the aquifer just above the clay confining layer.

Before the pH of the waste decreased, backflushing tests indicated that denitrification and neutralization of the waste occurred within a very short distance from the injection wells. Denitrification may have accounted for more than half the neutralization, the remainder being caused by solution of calcium carbonate. Denitrification has not been observed since the waste pH was lowered.

Wellhead injection pressures were about 200 psi before the decrease in waste pH but subsequently have decreased slightly to about 175 psi, even though injection rates have increased from about 1,600 to about 2,000 gpm. Wellhead pressures in the monitor wells south and north of the injection site are about 108 psi, which is approximately 90 psi above the preinjection pressure. Calculations indicate that pressure effects in the receiving aquifer may extend more than 30 mi from the injection site. No apparent change in pressure has been detected in the aquifer directly above the clay confining layer.