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CLAY LANDFILL LINERS LEAK IN WAYS THAT SURPRISE LANDFILL DESIGNERS.

Organic chemicals are moving through clay landfill liners much more rapidly than was previously thought possible, according to a report published by a team of American and Canadian scientists in the March, 1989, issue of ENVIRONMENTAL SCIENCE AND TECHNOLOGY, a journal of the American Chemical Society. This is bad news for people who have been relying on clay landfill liners to protect them from dangerous chemicals such as benzene, toluene, trichloroethylene, and ethylbenzene.

The team investigated a five-year-old landfill in southwestern Ontario and found a rapid movement of organic chemicals through tight clay; they then developed mathematical models to help explain what they had observed. After they developed computer models that fit well with what they had observed, they used the computer models to predict the time it would take for benzene and other organic chemicals to pass through a typical clay landfill liner. They conclude that a mechanism called diffusion will move organic chemicals like benzene through a three-foot thick clay landfill liner in approximately 5 years. Furthermore, they conclude that diffusion will move large quantities of benzene (or other dangerous organics) through the liner year after year in a steady flow.

Obviously, this specific information is important, but what's equally important is their general conclusion that engineers have, up until now, misunderstood the basic principles that explain how chemicals move through clay. It is a shocking and embarrassing revelation: up until now, the civil engineering profession has failed to understand the most fundamental mechanisms controlling landfill behavior.

There are two basic ways that chemicals move through clay; they are called advection and diffusion. To understand these, we need to know a little about clay. Clay is like sand, except that each individual clay-grain is much smaller than each individual sand-grain. As a conequence, the spaces between grains of clay are much smaller than the spaces between sand grains. These small spaces make it difficult for fluids to pass through clay, which is why clay has gained a reputation as a "tight" material.

Advection is what you might call "normal" movement of fluids through soil. The fluids travel through the spaces between grains of soil as if those spaces were pipes. The more pressure you apply to the fluids, the faster the fluids will pass through the pipes. Modern clay-lined landfills are designed and built to specifications that require that the "pipes" or spaces between clay grains be very small. This is expressed as an allowable "permeability" of one ten-millionth of a centimeter per second (10-7 cm/sec), also expressed as one billionth of a meter per second (10-9 m/s). A meter is about a yard and a centimeter is a little less than half an inch.

In addition to being built with clay that passes fluids through it very slowly, a modern landfill is also designed to prevent the buildup of fluids inside the landfill. Fluids building up inside a landfill provide weight that pushes down on the landfill liner, creating pressure that forces fluids through the "pipes" between the grains of clay. The theory of advective flow [expressed in Darcy's law] says that, if you reduce the pressure, you will reduce the flow of fluid through the bottom clay liner. To reduce the pressure, a modern landfill is equipped with a leachate collection system to prevent fluid buildup. (See RHWN #119 for more details.)

However, the Canadian-American team emphasizes that advective flow is not the only means by which fluids flow through the spaces between grains of clay. The second means by which fluids move is called "diffusion" or Fickean diffusion after the man who first explained the phenomenon. All molecules are in constant motion; this motion is what we call "heat." Hotter molecules are moving more rapidly than cooler molecules. Due to the motion of heat, molecules tend to move from a more concentrated chemical solution to a less concentrated chemical solution. As a consequence of this, the concentrated chemicals inside a landfill tend to move through the bottom clay liner even if there is no pressure pushing them downward. The random motion of the molecules causes the chemicals inside the landfill to move steadily through the clay liner.

The engineers who design landfills have, up until now, simply ignored diffusion. They have concentrated their efforts entirely on minimizing advective flow of fluids through clay. Now the Canadian-American research team has shown that diffusion is an important mechanism by which substantial quantities of dangerous chemicals are moving through clay landfill liners. This is not just a theory; it is based on observations of real landfills built of nearly-ideal clay. Thus, they stress that their conclusions are, if anything, optimistic; real landfills made out of less-ideal clay will leak more rapidly. Furthermore, the Canadian-American team has pointed out that diffusion will transport chemicals through a double clay liner EVEN IF THE LEACHATE COLLECTION SYSTEM BETWEEN THE TWO CLAY LAYERS IS WORKING PERFECTLY.

They conclude that even a small landfill (2.5 acres) will pollute groundwater with 42 pounds of benzene per year, year after year; they note that 42 pounds of benzene is sufficient to contaminate 3.8 billion liters of water (1.004 billion gallons) up to the allowable drinking water criterion of 0.005 milligrams per liter (5 parts per billion).

In their report the researchers cite eight prior studies that have reached similar conclusions about diffusive transport of organic chemicals through clay.

There are four important lessons to be drawn from this most recent report, and from the earlier studies that had reached similar conclusions:

1) Clay-lined landfills will leak, and are leaking, much more rapidly than their designers assumed they would. Even very thick deposits of clay will be penetrated much more rapidly that had previously been assumed. For example, the Ontario site studied by the Canadian-American team has 130 feet of clay beneath it, yet they conclude that it will leak in 1000 years or less. Such leak-rates will only be judged satisfactory by persons who believe it is morally acceptable to poison future generations to preserve modern life-styles based on convenience and waste.

2) The designers of clay-lined landfills prior to 1989 have not understood the physical principles by which chemicals pass through clay, and they have therefore built landfills that are not adequate to protect public health and safety. This information should shake our confidence in the civil engineering profession that has been giving its stamp of approval to flawed landfill designs for decades.

3) The nation's best-informed and best-funded engineers have once again given the public false assurances and have promoted a technology that has now proven to be unreliable and dangerous. We should develop a healthy skepticism about high-tech solutions to social problems like waste disposal. Today's "state of the art" is very likely tomorrow's disaster.

4) All clay-lined landfills should be stopped from accepting dangerous chemicals immediately.

Get: Richard L. Johnson, John A. Cherry, and James F. Pankanow. "Diffusive Contaminant Transport in Natural Clay: A Field Example and Implications for Clay Lined Waste Disposal Sites." ENVIRONMENTAL SCIENCE AND TECHNOLOGY, Vol. 23 (March, 1989), pgs. 340-349.
--Peter Montague, Ph.D.

Descriptor terms: studies; landfilling; clay; liners; leaks; organic chemicals; cn; ontario; groundwater; benzene;