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HYDROGEOLOGIC EVIDENCE

Time of Travel to the Water Table

From Runoff

The incident site is located on an alluvial fan which drains toward a normally dry lake bed. The area receives an average annual precipitation of less than 17 centimeters (French, 1986). Potential evapotranspiration greatly exceeds this precipitation. The depth to the water table under the site, as indicated by the static water level in wells in the area, is in excess of 30 meters. Drill logs of these wells and test borings show that the profile above the water table is composed of silty sands and gravels, some of which are cemented (Farrimond, 1988).

An estimate of the travel time from surface to the water table can be obtained by following an EPA example (Batelle, 1986) for calculating travel time through the vadose zone. This technique utilizes the equations:

$$t = \frac{L\,h}{q}$$

where: t is travel time in years,

L is distance through the vadose zone in centimeters,

q is the flow into the surface in centimeters per year, and

h is the average vadose zone moisture content calculated with:

$$h = \left(\frac{q}{K_s}\right)^m h_0$$

where: K_s is the saturated conductivity in centimeters per year,

h_0 is the saturated moisture content usually taken as being equal to the porosity, and

^{m} is calculated with:

$$m = \frac{1}{2b+3}$$

where: b is the absolute value of the logarithmic slope of the soil moisture-capillary pressure curve. The closest location for which this curve has been determined is Frenchman Flat (Kearl, 1982), for which the value of b is 4. K_s can be estimated at 10^5 centimeters per year for the site from percolation tests made in the design of a leach field at the nearby Sandia Compound (Madsen, 1988). Since standard percolation tests include some radial as well as vertical percolation, this estimate is in excess of the actual vertical hydraulic conductivity. The similar soil at Frenchman Flat has a measured hydraulic conductivity of 10^4 centimeters per year (Kearl, 1982). The porosity of a sandy soil can be taken as greater than 0.3 (Luthin, 1973). The flow into the surface, q, can be no more than the average precipitation, 17 centimeters (French, 1986), plus the water used in flushing the spreader. The pump at the fill stand was designed to lift water 6 meters at about 200 liters per second (Klein Products). Estimates of the time required to fill a 40 cubic meter tank confirm this flow rate. The pump was run for an estimated 1 1/2 hours, which resulted in a total volume of water of less than 1100 cubic meters. The water spread out about 30 degrees across and approximately 1000 meters down the alluvial fan over a total area of greater than 20 hectares. This results in an application depth of less than a centimeter, which is insignificant compared to the annual precipitation and its deviation of 5 centimeters (French, 1986). These parameter values result in a m of 0.09, a h of 0.14, and a very conservative estimate of the travel time through the vadose zone of greater than 20 years. A more realistic estimate of q as less than 3 per cent of the precipitation (Rush, 1970) results in a time of travel of over 500 years.

From Sump

The travel time to the water table beneath the construction sump could be different from that for the surrounding soil. The sump was originally constructed to the dimensions of about 30 by 40 by 3 meters deep in late 1985, but was soon doubled in area to 60 by 40 meters. Some of the original berm is still between the original sump and its addition. A layer about 1/2 meter thick of clay from the nearby dry lake bed was used for a liner. The side slopes of the sump are about 2:1. The capacity of the sump calculated from these dimensions is less than 5000 cubic meters. The sump has not been filled or used since the incident. The 1100 cubic meters used to flush and dilute the urea would have lowered the sump level by about 1 meter. The water level was about 1 1/2 meters below the overflow 45 days after the incident. If the sump was full after the incident and lateral flow and evaporation losses not considered, the worst case average leakage rate would be about 1 centimeters per day or less than 400 centimeters per year. Through calculations similar to those above this leads to a travel time to the water table of over 8 months. A test of the clay liner material at the nearby Fire Training Burn Pit, about 1000 meters to the northwest of the sump, (Madsen, 1988) showed no measurable infiltration over 7 days. This indicates that the above depression in sump level was due mainly to pumping and evaporation and not leakage. The actual time of travel could be greater than that for the surrounding area because of this impeding layer.

Urea Degradation

In Soil

The amount of urea that was flushed out of the spreader was estimated to be 500 to 2000 kilograms. If this was mixed with the 1100 cubic meters of water pumped from the sump the original concentration was between 500 and 2000 parts per million. This was equivalent to a fertilizer application of 25 to 100 kilograms per hectare. Agricultural applications of urea-water solutions can be well over 1000 kilograms per hectare (Hargrove and Kissel, 1979), being usually limited only by the economic value of the crop response. Urea readily under goes hydrolysis in the soil producing ammonium carbonate by the reaction (Buckman and Brady, 1969):

$$CO(NH_2)_2 + 2H_2O \dashrightarrow (NH_4)_2CO_3.$$

The ammonium carbonate which results is unstable and promptly produces ammonia by the reaction:

$$(NH_4)_2CO_3 \dashrightarrow 2NH_3\uparrow + CO_2\uparrow + H_2O.$$

greater that 8, indicating the above soils are alkaline. Therefore, urea is quickly lost to the atmosphere as ammonia and carbon dioxide gases with the resulting water mixing with existing soil moisture.

In Sump

Urea degrades in waste water treatment at 2°C by psychrophilic bacteria at the average rate of 3.2 milligrams per liter per hour (Verschueren, 1983). At this rate, even if the urea in the sump was equal to that calculated by dilution of the estimated hopper contents of 2000 parts per million, the urea would be degraded in less than 30 days. Ground water samples in the area (Sullivan, 1988) have temperatures greater than 20°C indicating that the degradation rate for part of the vadose zone would be greater than 10.9 milligrams per liter per hour (Verschueren, 1977) and degradation might occur in less than 50 hours.

Conclusions

The conservative estimates of the travel times from the ground surface to the groundwater table of 20 years and from the sump bottom of 8 months greatly exceed the time required for the urea to degrade. The soil degradation of urea is essentially immediate and the sump degradation of urea is less than a month. **Therefore, no contamination of the usable groundwater can result from this incident.**