TRITIUM TRACER MOVEMENT AS AN ANALOGY
FOR PUMP AND TREAT REMEDIATION

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1. Interest in pump and treat remediation

There has been debate over effectiveness of groundwater pump and treat remediation. The goal of the following discussion is to present evidence from a tracer test that illustrates the difficulty in removing contaminants from fractured shale that is typical of portions of the DOE-Oak Ridge Reservation (ORR). This report provides a brief prelude to more detailed analysis that is in progress.

Attempts to remediate groundwater contamination with pump and treat technology have been hampered by difficulties in removing contaminants in slow flow zones. There is interest in using this remediation method on the ORR because it is an existing technology. However, this setting provides a rather extreme contrast between fast flow zones (fractures) and slow flow zones (the matrix surrounding the fractures).

Over the past few years, we have begun to develop an understanding of how contaminants move in fractures and how contaminant exchange between the fracture and matrix occurs. In particular, we have evidence from a long term tritium tracer test that has direct bearing on potential success or failure of pump and treat remediation in fractured rocks.

2. Tritium tracer test in fractured rock, Oak Ridge Reservation

In July 1977 50 curies of tritium were released as a one-time slug in an open borehole at about 7.5 m depth, then monitored in downgradient monitoring wells 3.6 m distant. The experiment took place near Waste Area Grouping 4 in Melton Valley under the supervision of the U.S. Geological Survey (USGS). Tritium was monitored by the USGS in the injection well and in seven downgradient wells for 5 years. A follow up sampling occurred in 1993. Details of the experiment and monitoring will be reported elsewhere (David Webster, personal communication, December 1994); this summary is only an abstract of relevant data.

The tracer showed characteristics of both the fast (fracture) and slow (matrix) flow paths (Fig. 1). The first appearance of tritium was fast -- within 21 days with a transport rate of 0.1 m/day. However, this initial breakthrough represented just a small amount of the total tritium. The bulk of mass travelled at 0.002 m/day. After the first appearance of tritium, the tracer developed a persistent, low concentration plume that can still be detected 16 years after injection (GWPO, 1994).

These tritium levels have persisted in spite of 100's of borehole volumes that have flushed through the wells for many years -- a sort of natural gradient pumping system. The decline and persistence of tritium, which has also been observed for contaminants in the waste areas, is likely due to slow movement of the large reservoir of tritium in the matrix. The initial rapid appearance of tritium is believed to be due to fracture flow.

3. Failure of pumping to "remediate" tritium tracer

Approximately 200 days after the injection of the tritium, an attempt was made to remove the remaining tracer from the injection well to try to shorten the duration of the test. On several occasions over a period of weeks, tritiated water was removed from the injection well and simultaneously replaced with clean groundwater to reduce the tritium concentrations roughly an order of magnitude. Each time, tritium levels returned to pre-treatment concentrations. It was finally concluded that the attempts to remove tritium were not effective and had no impact on the experiment (Fig. 2). Based on current knowledge, it can be concluded that matrix diffusion was controlling the amount of tritium that could be removed, and the inventory of tritium in the rock matrix was not amenable to effective removal by pumping.

4. Implications for failure of pump and treat

Pumping failed to remove the tritium because only the tritium in the well and in the fast flow zones could be removed. Significant amounts of water and contaminants will not be removed from the slow flow zones by pumping or natural flow because only the fractures are flushed, not the matrix.

This experiment presented an optimal case for source removal on the ORR because the shallow zone is highly fractured and is more likely than deeper zones to behave as a porous rather than a fractured medium. However, conventional pump and treat will fail as a plume remediation technology in fractured rock because the matrix has become a long term secondary source of contaminants (e.g., long tail in Fig. 2). The long time and high costs of removal in this setting make it impractical. The use of pump and treat to contain contamination and prevent continued spreading (source control rather than source removal) may hold promise if done properly.

This experiment confirms recent evidence pointing to the importance of the matrix in contaminant movement and persistence on the Oak Ridge Reservation (Wilson et al., 1993, Sanford et al., 1994, Wickliff et al., 1991). At present, work is underway to quantify the effects of secondary sources through modeling and field experiments to provide technically sound estimates of time needed to reach remediation goals (GWPO, 1994). It is recommended that a combination of methods be used for source control, but that source removal from the matrix is not a viable option using pumping.

5. References

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Observation Well (3.6 m)

Fig. 1: Tritium concentration through time in observation well 3.6 m from injection well, showing initial rapid rise in concentration and persistent leveling off of concentration over the last 11 years.

Injection Well

Fig. 2: Tritium concentration over first 2 years in the injection well. The effects of removing the tritium from the pumping well (arrow) were only short term.

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