Water Vapor Transport in an Underground Mined Opening

Rohit Salve and Timothy J. Kneafsey
Contact: Rohit Salve, 510/486-6416, r_salve@lbl.gov

RESEARCH OBJECTIVES

During periods of suppressed ventilation, liquid water was observed as droplets on nonporous surfaces (such as metal surfaces and cables) and small pools of water (<1 liter) on impermeable surfaces in one of two large tunnels (i.e., the Cross Drift) at Yucca Mountain (Figure 1). Rust on steel surfaces and dense mold populations on some nonmetallic nonporous surfaces also suggest the presence of water. However, despite the presence of liquid water, there has been no evidence to suggest that this water is from seepage through localized flow paths. We hypothesize that the observed water entered the nonventilated drift through natural fractures as water vapor, and then condensed along sections of the drift.

The goal of this research effort is to develop an understanding of water vapor dynamics in the near-drift environment at Yucca Mountain, specifically to:

- Identify conditions resulting in the transformation between liquid- and vapor-phase moisture (evaporation and condensation processes) in the near-drift environment.
- Evaluate microclimates created by the configuration of drifts.
- Quantify the potential movement of water vapor through ventilated and nonventilated drifts.
- Quantify rates at which surrounding rock will yield water vapor during continuous ventilation of drifts.
- Develop numerical models for vapor-phase movement of water in the near-drift environment.

APPROACH

Over the last four years, we have monitored temperature and relative humidity to understand the microclimate in the terminal section of the Cross Drift. We have compared these observations to results from analytical and numerical models, to investigate processes associated with the movement of water vapor between the tunnel bore and the surrounding fractured rock formation.

Future work will include the creation of thermal gradients in nonventilated sections of the drift, to study the development of microclimates as well as the processes of condensation and evaporation. Gas tracer tests will be performed to evaluate internal drift flow, drift-scale air dynamics, and interaction with the mountain air flow.

ACCOMPLISHMENTS

We have analyzed observations of moisture and temperature dynamics made along the terminal ~1.2 km of the Cross Drift, using three numerical models. These models included the advection of air through the mountain (a mixed tank model), molecular diffusion into the drift from a 100% relative humidity (RH) boundary at the drift wall, and diffusion of water vapor from a 100% RH boundary within the rock through the fracture network (with fluid flow assumed to be inactive) into the drift. Our analyses suggest that fractures can be primary paths for vapor flow driven by a potential gradient within the unsaturated zone in the immediate vicinity of emplacement drifts.

SIGNIFICANCE OF FINDINGS

A model that incorporates fracture-dominated vapor-flow conditions would be a strong departure from existing conceptual models, which postulate the overwhelming importance of liquid traveling through fractures as the primary water-transport mechanism. However, such a model is required to explain recent observations and may be required to predict moisture dynamics under conditions encountered in an operating repository.

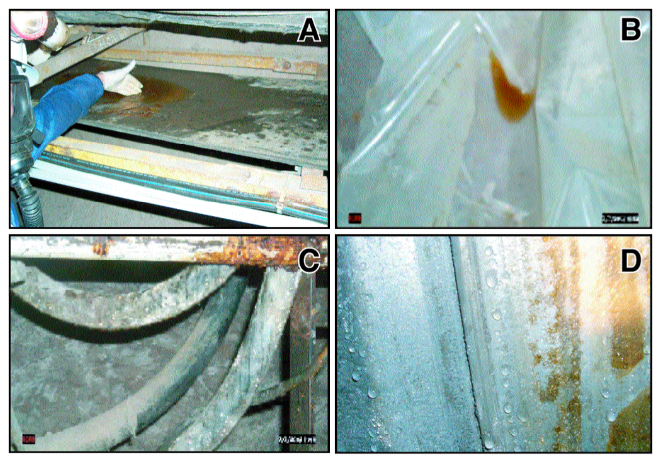

Figure 1. Observations of moisture in nonventilated sections of the Cross Drift: (A) pool of water on lower conveyor belt; (B) pool of water on plastic sheet; (C) mold on electrical cables and rust on metal surfaces; and (D) droplets on ventilation tube.

RELATED PUBLICATION

Salve, R., and T. Kneafsey, Vapor-phase transport in the near-drift environment at Yucca Mountain. Water Resour. Res., 41, doi:10.1029/2004WR003373, 2005. Berkeley Lab Report LBNL-55212.

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