Biofilms as Biobarriers

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Tank Car Derails & Spills Toxic Chemical

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The Pennsylvania Department of Environmental Resources reported today that a team of engineers and scientists is working furiously to contain a 1000 gallon (4000 l) spill of highly toxic vinyl chloride. Vinyl chloride, a carcinogenic compound used in plastics manufacture, was released from a Con Rail tank car that derailed and split open four miles north of the city last week. The dramatic containment effort was spurred by the close proximity of the Little Juniata River that serves as a water supply for Tyrone, Huntingdon, Harrisburg and other towns down stream from the accident site.

Hazardous materials (hazmat) teams from as far away as Philadelphia descended on the site and quickly contained the surface spill. Cleanup of vinyl chloride-contaminated soil continues. Of more immediate concern to health professionals is the fact that the soil in the vicinity is sandy and quite porous. Test drilling has confirmed that a significant amount of the spilled material has seeped into the soil and contaminated the water table. A plume of toxic material has been detected, carried by the groundwater in the direction of the Little Juniata. Environmental Protection Agency spokesperson Allison Jeffries stated, “Contamination of the river would be a disaster for communities all the way down the Susquehanna River and into the Chesapeake Bay.”

EPA specialists are employing a new “biobarrier” technology to stem the flow of vinyl chloride that has entered the groundwater and is flowing inexorably toward the river. Using heavy drilling equipment, the scientists are directing the boring of a series of holes into which they will inject volumes of “starved” harmless bacteria. The wellfield, drilled in the shape of a funnel, is being placed in front of and at right angles to the developing subsurface plume.

The bacteria are being prepared in the laboratories of the American Type Culture Collection in Manassas, Virginia. Cells of a bacterium (Klebsiella oxytoca) have been cultured in large fermentation tanks and are now being “starved,” a process that reduces their size and increases their ability to penetrate pores in the soil. After injection underground, the bacteria will be resuscitated by a cocktail of nitrate and molasses. The molasses is a nutrient and the nitrate will serve in place of oxygen to enable the bacteria to metabolize the molasses in the oxygen-deficient environment. The scientists expect that, in the soil the bacteria will produce large amounts of slime that will clog pores in the soil and greatly reduce the movement of vinyl chloride-contaminated water. It is now a race against the clock. The plume is moving at an estimated rate of 200 feet (67 m) per day in the sandy soil. The river is only a quarter mile from the wreck site. That gives workers about a week to stem the flow and the tank car derailed three days ago. If successful, the biobarrier is expected to reduce the flow of vinyl chloride by more than 99% to just 2 inches (~5 cm) a day, buying time for the protracted cleanup to follow.

The scenario described here is fictitious. Numerous laboratory scale and field studies have been carried out, but few full-scale tests of this technology have been attempted. One exception, at a gasoline spill in Port Hueneme, California, has demonstrated the potential benefit of this technology (Johnson et al., 2003).

In a climate of increased concern for the environment and its protection, teachers in disciplines as diverse as biology, microbiology, environmental studies, and environmental engineering may be seeking teaching materials and laboratory exercises that will enable them to introduce these new concepts into their classrooms and laboratories. The materials and exercise presented here are intended to enable teachers to illustrate the seamlessness of the intersection between the theory of microbiology and the practice of environmental protection.

The Concept

Microbiologists have known for over a decade that the number of bacteria attached to surfaces in substrates

Figure 1. Formation of a biobarrier to slow the spread of a contaminant. Courtesy of the Center for Biofilm Engineering.