

Ground Water Contamination By Crude Oil

By Geoffrey N. Delin and William N. Herkelrath

INTRODUCTION

Ground water contamination by crude oil, and other petroleum-based liquids, is a widespread problem. An average of 83 crude-oil spills occurred per year during 1994-96 in the United States, each spilling an average of about 50,000 barrels of crude oil (U.S. Office of Pipeline Safety, electronic commun., 1997). An understanding of the fate of organic contaminants (such as oil and gasoline) in the subsurface is needed to design innovative and cost-effective remedial solutions at contaminated sites.

A long-term, interdisciplinary research project by the U.S. Geological Survey (USGS) Toxic Substances Hydrology Program began in 1983 at a crude-oil spill site near Bemidji, Minnesota. The project involves research by scientists from the USGS and several academic institutions. Research at the site is directed toward understanding physical, chemical, and biological processes controlling the migration and fate of hydrocarbon contaminants in the subsurface. The goal is to provide information and methods to help evaluate the potential for, and long-term performance of, natural and enhanced bioremediation of hydrocarbon contamination across the Nation.

The crude-oil spill site near Bemidji is one of the better characterized sites of its kind in the world. Results of research conducted on processes affecting the migration and fate of crude oil at the site have provided fundamental knowledge that has been used to remediate similar sites

worldwide. The Bemidji research project was first to document that the extent of crude-oil contamination can be limited by natural attenuation. Scientists studying natural attenuation at other contaminated sites have used many of the methods and approaches developed at the site.

DESCRIPTION AND HISTORY OF THE BEMIDJI SITE

On August 20, 1979, approximately 16 kilometers northwest of Bemidji, Minnesota, the land surface and shallow subsurface were contaminated when a crude-oil pipeline burst. About 1,700,000 L (liters) (about 10,700 barrels) of crude oil spilled onto a glacial outwash deposit. Crude oil also sprayed to the southwest covering an approximately 7,500 m² (square meters) area of land (spray zone, figure 1). After cleanup

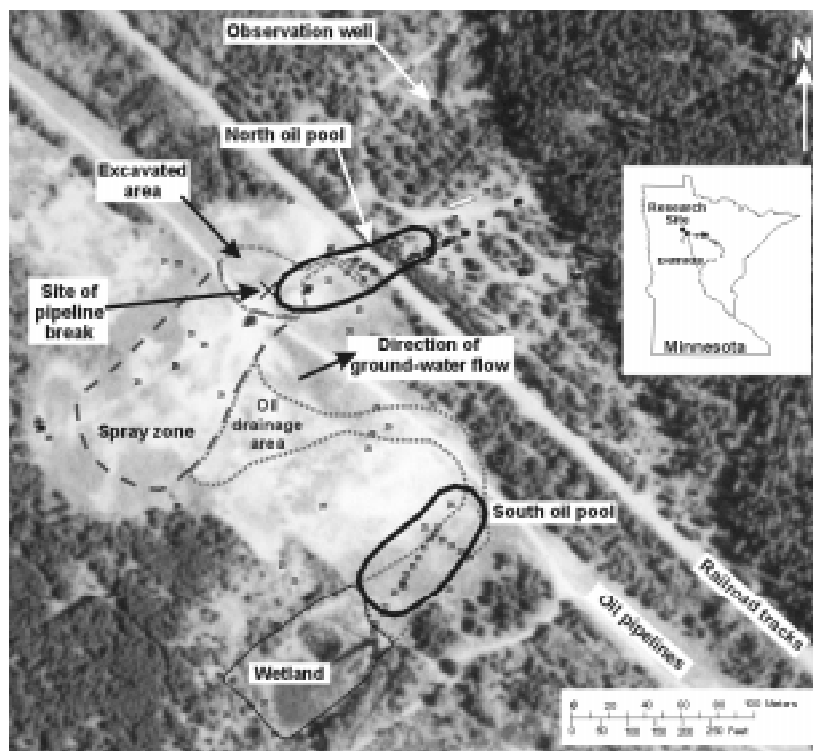


Figure 1. Features of the Bemidji, Minnesota crude-oil spill research site superimposed on a 1991 aerial photograph.

efforts were completed about 400,000 L (about 2,500 barrels) of crude oil remained in the ground. Some crude oil percolated through the unsaturated zone to the water table near the rupture site (North oil pool). Some of the sprayed oil flowed over the surface toward a small wetland forming a second area of significant oil infiltration (South oil pool).

Ground water affected by the oil spill discharges to a small lake 400-m east of the pipeline. The land surface is a glacial outwash plain underlain by stratified glacial outwash deposits. At a depth of about 25 m, a regionally persistent and uniform layer of low permeability sediment restricts vertical ground-water movement. The water table ranges from near land surface to about 11 m below the land surface. About 370 wells and test holes had been installed at the Bemidji research site as of 1998.

ONGOING AND FUTURE RESEARCH

The fate of hydrocarbons depends on the processes of transport, multiphase flow, volatilization, dissolution, geochemical reactions, biodegradation, and sorption (figure 2). An interdisciplinary investigation of these processes is critical to successfully evaluate the potential for migration of hydrocarbons in the subsurface. The investigation at the Bemidji site has involved the collection and analysis of crude oil, water, soil, vapor, and sediment samples. The oil phase that occurs as floating product on the water table and as residuum on sediment grains provides a

continuing source of hydrocarbons to the ground water and vapor plumes. Studies have also been conducted to document the concentrations of gases in the unsaturated zone.

Numerical models are useful for integrating information collected in the field and have been used at the site for studying the importance of the simultaneously occurring processes. Multiphase-flow modeling was used to study the oil movement after the spill. Transport and biodegradation modeling was used to simulate the evolution of the plume, to evaluate factors limiting biodegradation, and to develop a mass balance for contaminants at the site and thus evaluate the amount and rate of removal of hydrocarbons by biodegradation.

Although initial remediation of the research site was completed more than 15 years ago, a State regulatory agency has required the pipeline company to remove more of the remaining oil. While this renewed remediation may result in termination of ongoing research documenting natural attenuation, it has also provided an opportunity to work with industry in documenting the effects of the renewed remediation. One goal of ongoing research is to add to the published literature a thorough documentation of the remediation of this site; very few remediation efforts at crude-oil contamination sites are documented in the literature.

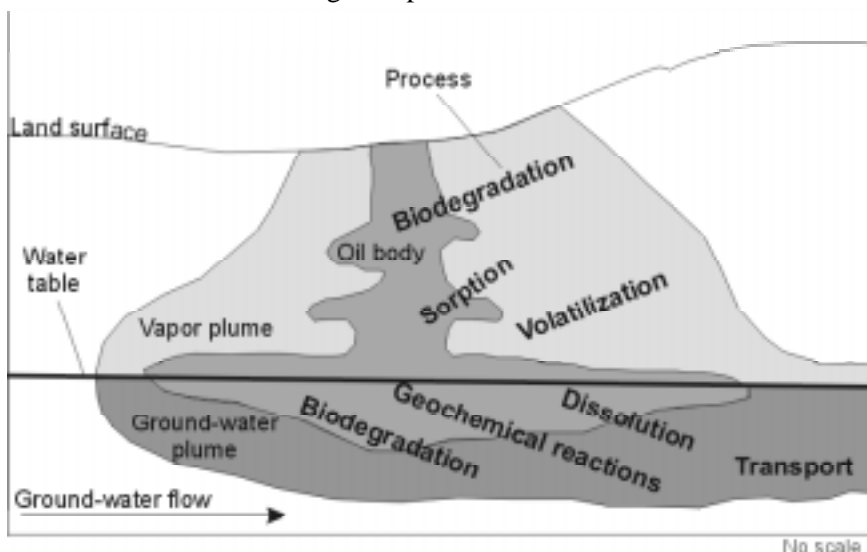


Figure 2. Processes critical to understanding the fate and transport of hydrocarbons in the subsurface at the Bemidji site.

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