NATURAL BIOVENTING REMEDIATION FROM TIDAL WAVE ACTION AT A FIELD SITE

D.H. Kampbell[1], J.E. Hansen[2], and J.A. Kittel[3], [1]USEPA National Risk Management Research Laboratory, Ada, OK, 74820, [2]U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, TX, 78235, and [3]Battelle, 505 King Avenue, Columbus, OH, 43201

ABSTRACT A remediation research study has been implemented at a jet fuel spill site on an island airport. A buried pipeline fracture several years ago resulted in a fuel spill exceeding 160,000 gallons. The site hydrogeology is a fragmented coral matrix with fresh water overlying more dense salt water. Water table fluctuations of about two feet occur once every twelve hours from tidal action. The research approach being pursued is to recover free-phase floating petroleum liquid using vacuum-mediated subsurface skimming wells. The vacuum will create an active vadose zone aeration to enhance aerobic biodegradation processes and vaporization of fuel. Once the floating fuel is removed, a natural bioventing action caused by tidal oscillations will complete remediation of the spill site.

KEYWORDS: bioventing, slurper, wave action, jet fuel

INTRODUCTION

Natural attenuation is a combination of forces that cleanse fuel contaminants from the subsurface. Select water quality parameters can be used to measure the extent and rate of natural attenuation [1]. The site spill occurred in 1991 at a U.S. Air Force Base on Diego Garcia Atoll in the Indian Ocean. An 18-inch diameter underground pipeline had fractured. Over 160,000 gallons of jet fuel was lost before the leak was discovered. The plume of contamination is mostly under a concrete airport tarmac and covers about a 400 x 1,000 feet area. The water table is typically five feet below land surface and is subjected to diurnal oscillations of one to four feet in response to ocean tides. A fresh water lens from rainfall floats on top of more dense saltwater. The aquifer material is unconsolidated calcareous coral sediments.

The objective of the site study will be to remove free-product by slurper wells and monitor soil gas and plume water for effectiveness of the bioremedial actions. The research approach has not been subjected to the U.S. Environmental Protection Agency's peer and administrative review, so an official endorsement should not be inferred.

SOLUTION APPROACH

Mechanisms of natural attenuation include dispersion, sorption, and biodegradation. Bioremediation occurs when indigenous microbes work to decompose the subsurface contamination through oxidation-reduction reactions. During oxidation of fuel hydrocarbons, ground water constituents such as dissolved oxygen, nitrate, ferric iron, sulfate, and carbon dioxide are reduced. The process may continue beyond oxidation to the generation of methane. These reactions cause measurable changes in ground water and can be used as evidence of biodegradation mechanisms.

Bioslurping is a vacuum-assisted remediation technology that simultaneously recovers free fuel product from the water table and aerates the vadose zone [2]. The system

withdraws a small amount of ground water at the water table, free product, and soil gas in the same process stream within the radius of influence of a single pump. Several well points can be connected by transfer lines to the single pump. Pumped material is collected into a single oil/water separator for disposal.

RESULTS

Some major components of ground water as related to natural attenuation are shown in Table 1. Ground water not contaminated by fuel had appreciable amounts of dissolved oxygen. Fuel carbon as listed is a summation of benzene, toluene, ethylbenzene, xylenes, and trimethylbenzenes which are jet fuel components. Low oxidation-reduction potential coincided with high fuel carbon, high methane, and high sulfide. All well samples were devoid of nitrates and ferrous iron. The ground water quality parameters measured indicated that bioremediation processes were occurring. Additional evidence obtained was the presence of intermediate microbial breakdown products such as benzoic acid, pronanoic acid, phenol, dimethylbenzoic acids, and trimethylbenzoic acids.

Water table fluctuations of about two feet every twelve hours along with changes in soil gas components as shown in Table 2 suggested that a natural bioventing process was occurring. The vadose zone soil gas measurements determined that oxygen increased as the tide dropped and methane, along with carbon dioxide, increased as the tide rose.

Four interception bioslurper wells across the plume of contamination removed 2,000 gallons of free-floating fuel during the first month of operation. The radius of influence for subsurface aeration at each well point

TABLE 1. WATER QUALITY ANALYSES.

Back-ground Wells	Dissolved Oxygen mg/l	Fuel Carbon µg/l	Methane mg/l	Sulfate mg/l	Nitrate mg/l	Sulfide mg/l	Redox Potential mV
C3-4	5.2	<1	<0.01	20.5	0.1	<0.1	+23
C3-1	4.5	<1	0.8	5.1	<0.05	0.1	+3
Plume of Contamination Wells							
S1-20	0.0	781	11.6	9.7	<0.05	2.0	-108
S1-30	0.0	528	11.0	18.6	<0.05	5.0	-137
S2-20	0.1	725	10.7	11.5	<0.05	2.0	-135

TABLE 2. SOIL GAS COMPONENTS AS RELATED TO WATER TABLE FLUCTIONS.

Water Level (bgs, ft)	Time (hour +/-15 min)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
2.0	0800	3.1	10.1	10.0
0.9	1000	6.2	1.9	2.0
0.7	1200	8.6	1.0	1.0
1.1	1400	1.7	8.8	8.9
2.1	1600	1.6	11.5	12.2
2.4	1800	1.8	11.0	11.4
1.9	2000	3.9	9.0	8.9

was measured to be at least 30 feet. A nine hour respiration test of the bioslurper treated subsurface is shown in Table 3. The vadose zone measurements indicated that active microbial processes were utilizing oxygen and producing carbon dioxide and methane. A biodegradation rate at a five feet depth into the vadose zone based on oxygen consumption was calculated to be 13.4 mg hydrocarbon per kilogram soil per day.

CONCLUSIONS

The bioslurper system is operating satisfactorily to remove free-floating fuel and aerating the vadose zone at least 30 feet within each well point. Soil gas constituents indicated that microbial biodegradation is actively destroying the fuel hydrocarbons. Microbial oxidation of fuel is proceeding naturally in ground water by oxygen consumption, methanogenesis, and sulfate reduction.

ACKNOWLEDGMENT

This project was supported by United States HQ Pacific Air Forces-Environmental Quality Division at Hickam Air Force Base, Hawaii. Mr. Mano K. Husain was the project manager.

REFERENCES

1. T.H. Wiedemeier, J.T. Wilson, D.H. Kampbell, R.N. Miller, and J.E. Hansen, Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Ground Water, vol. 1, Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas, 1995a.

2. Battelle, Test Plan and Technical Protocol for Bioslurping, Columbus, Ohio, January 30, 1995.

TABLE 3. RESPIRATION TEST FOR BIOSLURPER.

Time (Hours)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
Initial	20.1	0.0	1.2
3.8	15.8	0.6	6.7
8.8	13.2	2.1	10.5