

LA-UR-96- 1686

CONF-9607121--1

Title:

IN SITU RF/MICROWAVE REMEDIATION OF SOIL
BENCHTOP EXPERIMENT OVERVIEW AND RESULTS

Author(s):

A.H. Regan, M.E. Palomares, C. Polston,
D.E. Rees, W.T. Roybal

Submitted to:

31st Annual Microwave Symposium
International Microwave Power Institute
Boston, MA

RECEIVED

JUN 11 1996

OSTI

MASTER

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Form No. 836 R5
ST 2629 10/91

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

IN SITU RF/MICROWAVE REMEDIATION OF SOIL BENCHTOP EXPERIMENT OVERVIEW AND RESULTS

AMY H. REGAN*, M.E. PALOMARES**, C. POLSTON**, D.E. REES*, W.T. ROYBAL*

*Regan, Rees, Roybal, Los Alamos National Laboratory, AOT-5, MS H827, Los Alamos, NM 87545

**Palomares, Polston, Los Alamos National Laboratory, ESA-EPE, MS J576, Los Alamos, NM 87545

We have developed an in-situ process that combines RF/microwave energy application with soil vapor extraction to help mobilize and efficiently remove soil contaminants. We have conducted a number of benchtop experiments involving RF/microwave energy deposition and vapor extraction on controlled contaminated soil samples with successful removal of the DNAPL contaminants. This paper will describe the experiments performed and present results.

INTRODUCTION

Contaminant plumes are significant waste problems that require remediation in both the government and private sectors. We have developed an in situ process that uses RF/microwave stimulation to remove pollutants from contaminated soils. This process is more efficient than existing technologies, creates less secondary pollution, and is applicable to situations that are not amenable to treatment by existing technologies. Currently the most commonly used process is soil vapor extraction. However, even when it is successful, this technology is energy inefficient.^{1,2} Our objective is to combine RF/microwave energy application with soil vapor extraction to help mobilize and efficiently remove the soil contaminants, specifically demonstrating the viability of RF/microwave induced, in situ, soil remediation of "light and dense non-aqueous phase liquids" (LNAPL, DNAPL) contaminants. This concept is depicted in figure 1. We have conducted a number of benchtop experiments involving RF/microwave energy deposition and vapor extraction on controlled contaminated soil samples with successful removal of the contaminants.

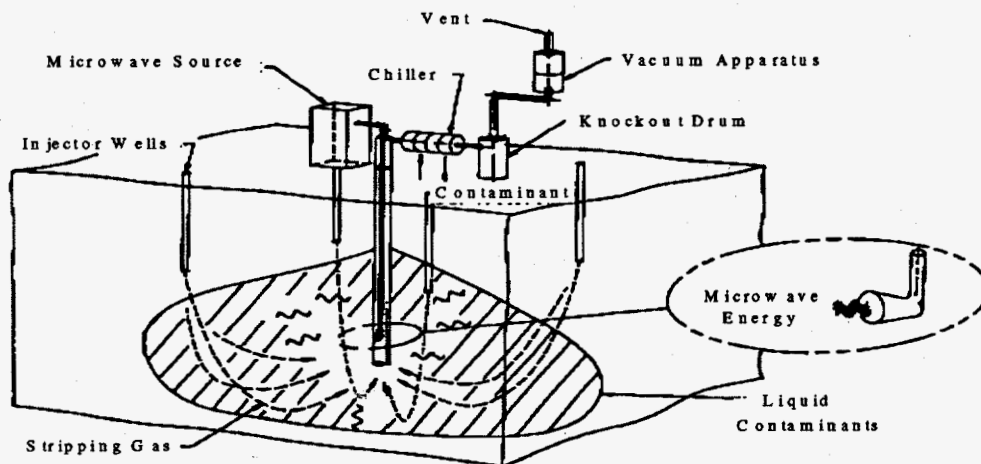


Figure 1. Artist's rendition of vapor extraction soil remediation enhanced with RF/microwave energy deposition.

Two different sets of experiments were performed. The main difference between the two is related to applicator design. For the first set of experiments, a portion of coaxial transmission line was isolated using gas barriers and filled with contaminated soil; the output end was short-circuited. This portion was the phase 1 microwave "chamber." RF energy was applied through the coax to the soil contaminated with a controlled amount of DNAPL (carbon tetrachloride, or 1,1,1-trichloroethane). The next phase entailed designing a larger experimental chamber (2.5 gallons) with an antenna applicator to introduce the RF/microwave energy to the chamber. This setup more closely represents the envisioned application of RF/microwaves in situ in conjunction with vapor extraction. Although figure 1 depicts a horn antenna, the second set of experiments utilized a monopole antenna. Several different soils were used in the experiments. The soils originally examined included volcanic tuff, peat moss, indigenous dirt from Los Alamos National Laboratory and soil from an air force base (a possible end-user of the technology). The air force soil was utilized as the primary testing sample throughout the laboratory experiments. For all of the soils, initial characteristics were calculated through permittivity measurements, as described in reference 3.

EXPERIMENTAL

In both cases the RF source was a 425 MHz, 200 W, continuous-wave amplifier, connected to the test chamber through a coaxial transmission line. A double stub tuner was used to minimize the reflected power throughout all experiments. Rate-monitored inlet air flowed through the contaminated soil and exited through an outlet port to various collection apparatus. In the first phase, a portion of the coaxial transmission line was isolated using gas barriers and filled with contaminated soil; the output end was short-circuited. This portion was the phase 1 microwave "chamber." In the second phase of the experiment, a 2.5 gallon can placed inside an 8 gallon drum was the contaminated soil chamber. Figure 2 shows the phase 2 microwave test chamber as well as the type of collection apparatus utilized to determine the amount of the contaminant removed.

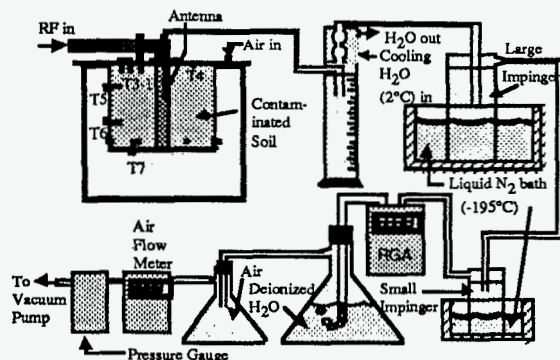


Figure 2. Phase 2 chamber and collection

For this second set of experiments the RF power was transmitted to the can chamber via a coaxial transmission line, then delivered through an antenna to the soil. The antenna was encased in a Teflon tube (1.5" inside diameter). The temperature of the soil was measured using thermocouples inserted 1/4" into the soil's outer surface, placed at different locations on the can chamber. Measurements performed on both sets of experiments consisted of recording the amount of soil used, the original amount of contaminant injected, the starting temperatures, and the amount of water introduced (for saturated soil measurements). After turning on the RF source, the power delivered, temperature at the thermocouples, amount of contaminant collected, and time elapsed were

monitored. A detailed description of all of the experiments can be found in reference 4.

RESULTS

The type of data recorded is shown in figure 3. The bottomline is that for the first set of the experiments, 99.6% of the carbon tetrachloride and 97% of the 1,1,1-trichloroethane was recovered from the dry soil. In the water saturated soil experiments, as the amount of water was increased, the amount of contaminant recovered decreased. In order to maintain the same level of contaminant removal, the amount of applied RF power had to be increased.

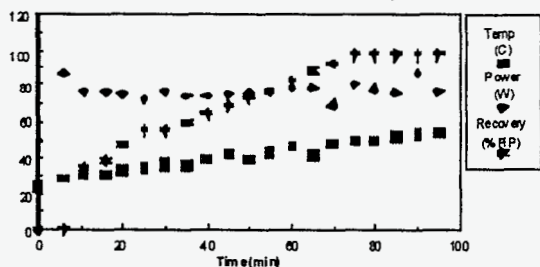


Figure 3. Phase 1 results: dried air force base soil contaminated with 1,1,1-trichloroethane.

A baseline experiment was also performed with air stripping alone, no RF heating. In this experiment, only 16.6% of the carbon tetrachloride was recovered from the soil. The temperature of the chamber did not exceed 24.6°C, the initial temperature of the chamber. This baseline experiment verified our premise that application of RF energy enhances vapor extraction.

In the second phase of the experiment, about 90% of the 1,1,1-trichloroethane was recovered from the dry soil. This decrease in contaminant amount removed was attributed to the larger volume of soil and differences in collection apparatus. Reference 4 goes into much more detail regarding this effort.

ACKNOWLEDGMENT

This research was sponsored by internal Los Alamos National Laboratory R&D funds. Special thanks go to Alan Graham, Ray Steele, Doris Tischler, Robert Ortega, and Raphael Cordova for their help and support during this project.

REFERENCES

1. Phelan, J. "RCRA Research, Development, and Demonstration Permit Application for a Thermal Enhanced Vapor Extraction System," Sandia National Laboratories, 29 October 1993.
2. Feenstra, S., & Kueper, B.H. "Elimination of Dense Non-Aqueous Phase Liquids (DNAPLs) from Fractured Bedrock Formations: Principles and Potential Remedial Technologies," ENSR Consulting & Engr., Acton, MA, 8/90.
3. Regan, et al, "In Situ RF/Microwave Remediation of Soil Experiment Overview," Proc. of Internat'l Conf. on Microwave and High Frequency Heating, St. John's College, Cambridge England, 17-21 Sept. 1995, pp. D3.1-3.4.
4. Regan, et al, "In Situ RF/Microwave Remediation of Soil Experiment Overview" Spectrum '96, Proceedings of the Nuclear and Hazardous Waste Management International Topical Mtg, American Nuclear Soc., Seattle, WA, Aug. 1996.