FEASIBILITY OF

IN-SITU ELECTRICAL CORONA

FOR SOIL DETOXIFICATION

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ABSTRACT:

The In-Situ Corona Project, which is part of the U.S. Department of Energy's Office of Technology Development In Situ Remediation Integrated Program, is developing a new technology that uses electric fields to oxidize organic compounds in situ by means of a two-step process: (1) Relatively low voltage heats the soil in the vadose zone; steam formed from intrinsic soil moisture and any volatile and semivolatile soil contaminants are removed through a central soil-vapor extraction vent. (2) Higher voltages delivered through the same electrode array create corona directly on soil particles in narrow bands along spreading interfaces between moist and dry soil, ions, electrons, and secondary oxidants formed in the corona oxidize any residual organic contaminants.

Results from this study indicate that in-situ corona is feasible on a bench scale, providing remarkably uniform soil treatment at levels that exceed regulatory objectives. Projected voltage and power requirements for treating large soil volumes appear achievable with readily available, relatively inexpensive equipment. Compared to other in-situ technologies, in-situ corona may prove uniquely applicable to:

Sites with complex stratigraphies that include low-permeability soils contaminated with nonvolatile or bound contaminants;

Difficult organic contaminants, such as polyaromatic hydrocarbons and polychlorinated biphenyls, that are not removable by other means;

Situations where the need for added chemicals or long treatment times precludes use of other in-situ techniques.

Above all, at a total cost of $60 to $80 per ton of soil treated, in-situ corona appears promising as a cost-effective alternative to above-surface treatment.

INTRODUCTION:

Growing public and governmental interest has made environmental restoration a topic of wide concern. In-situ corona may offer an efficient, cost-effective approach to removal of a wide variety of organic contaminants, including polyaronatic hydrocarbons (PAH) and polychlorinated biphenyls (PCB) that are difficult to remediate by other techniques.

Corona is a low-temperature or nonequilibrium plasma produced when strong electric fields cause the partial breakdown (ionization) of air molecules. In moist air, these partial electrical discharges produce ozone, superoxide anion-radicals, hydrogen peroxide, hydroperoxy radicals, hydroxyl ions and radicals, hydronium ions, various excited states of oxygen, and probably other species in a complex set of parallel and series-reversible reactions. The net result is a mixture of gas-phase oxidants capable of destroying a wide variety of organic compounds, including hydrocarbons (Heath et. al., 1990), chlorinated organics (Virden et. al., 1992), and chlorofluorocarbons (Yamamoto et. al., 1992). Direct destruction of contaminants also occurs in the plasma region itself, where energetic electrons produced in the electrical discharge cause bond disassociation. For soil treatment, the basic premise is that the plasma can be made to spread through the contaminated soil as a reactive front, with diffusion of gas-phase oxidants providing secondary treatment. The expected result would be clean soil, without need for excavation, high temperatures, or injected chemicals.

To be effective, the electrically driven chemical reactions need to break nonvolatile contaminants into fragments that are volatile enough for removal through a soil-vapor extraction vent and subsequent above-surface treatment. Complete in-situ mineralization (conversion to inorganic compounds, such as carbon dioxide, water, and chloride ions) is not an absolute requirement.

The soil being treated must be dried before it can support the relatively strong electric fields required to produce corona. The soil-drying step was recently field-demonstrated (at the U.S. Department of Energy's (DOE) Savannah River Site) as a treatment technology in its own right (Gauglitz et. al., 1994). Called Six-Phase Soil Heating (SPSH), the drying technology uses six-phase alternating current delivered to a hexagonal array of six electrodes to heat soil to the boiling point of soil moisture (Heath et. al., 1992). The steam carries with it volatile and semivolatile compounds as it is drawn through a soil-vapor extraction vent. Once a soil has been dried (and any volatile contaminants removed) by SPSH, the in-situ corona process can be initiated with the same hardware, operated at higher voltages.

A planned 3-yr research and development effort was to provide preliminary answers to the following questions:

- Is in-situ corona feasible?
- What level of cleanup can be achieved?
- What byproducts are formed?
- At what rate does treatment occur?
- What voltages and power are required to treat soil on a large scale?
- What will it cost?

The 3-yr effort is expected to culminate in field demonstration of the in-situ corona process.