Modeling of plasma and reactive transport phenomena in Dielectric Barrier Discharge reactors during soil remediation

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ABSTRACT

A numerical investigation of plasma generation, mass and thermal transport, and reaction phenomena in the interior of a Dielectric Barrier Discharge (DBD) reactor has been developed. The DBD plasma reactor is used for soil remediation applications, as it has been shown that it can restore a wide range of soils efficiently and cost-effectively. The reactor accelerates free electrons and ions inside the pores of the soil, that collide with the air species to generate, among others, NO_x, O_3, and O_1d species, thus enforcing the degradation of soil pollutants. The reactions between the oxidants and the pollutants are the key determinant factor of the remediation process, while the mass and thermal transport phenomena are regulating factors. Simulations are integrated from the nanosecond to the millisecond timescale, where plasma discharges occur, and up to the minute timescale, to account for pollutant degradation. Specifically, the externally applied electrical conditions create a particular thermodynamic state inside the reactor which, in turn, affects the reaction pathways and, finally, the oxidant concentration. Convective mass transport is also an important mechanism, as it controls the accessibility of the pollutant reaction sites.

In addition, simulations are performed towards an *in situ* investigation of plasma application in an actual field, aiming at direct soil remediation. An effective mobility factor for the simulation of plasma discharges can be used to simplify the analysis and treat the porous soil as a homogeneous medium. In addition, unlike previous attempts, the porous soil medium is now numerically reconstructed to its actual geometry, within which the plasma equations are solved. Moreover, an analytical kinetic scheme is defined under specific thermodynamic conditions inside the DBD reactor. 97 key plasma collision and oxidation reactions are selected based on experimental measurements and other studies in the same area [1,2].

Optimized reactor structures and processes are proposed through a parametric analysis of electron density production, tested for various soil thicknesses. In addition, stimulating results emerged for a range of frequencies and electric voltages that were applied. Finally, the convection mechanism indicates quantitatively the importance of the flow rate on degradation. Moreover, the kinetic rates of pollutant reactions with O_3 and OH^- in the presence of moisture prove quite important for the determination of the overall remediation rate.

REFERENCES

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