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Enhanced Remediation of Crude Oil-Contaminated Soil by Bioelectrochemical Systems

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Background/Objectives. Remediation of crude oil contaminated soil is a major challenge, as the crude contaminants are difficult to degrade and affect soil physical and chemical properties, which causes irreversible damage to the ecosystem. Our previous works demonstrated that bioelectrochemical system (BES) can serve as a self-sustaining process for highly efficient remediation of diesel-contaminated soil. BECs use electrodes as the electron acceptor which channels O_2 reduction, and they extract electrons from organic substrates and produce current as an proxy for in situ remediation monitoring. Since no study has reported crude oil degradation by BES under anaerobic environment, we investigated such feasibility using bench scale systems.

Approach/Activities. A rectangle tank with (40 × 5.5 × 20 cm) was filled with saturated raw crude-oil contaminated soil. The soil had a total petroleum hydrocarbon (TPH) concentration of 30 g/kg-dry soil. Tubular BES (4.5 cm diameter and 25 cm length) was inserted into the soil on the one end side of tank. Air cathode made of carbon cloth (90 cm^2) uses oxygen in air as electron acceptor to consume electrons from degradation of hydrocarbons on the anode (90 cm^2 carbon felt). Control reactors were operated under the same condition but without BES. Soil samples were collected at distance of 2 cm, 16 cm and 30 cm from the BES.

Results/Lessons Learned. After 180 days operation, the TPH removals in the active reactor were 28% (2 cm distance), 15% (16 cm) and 8% (30 cm), which were high than 7% obtained by natural attenuation in control, corresponding to 13?250% enhancement of TPH removal by BES without any energy or chemicals input. On the other hand, a stable current of 0.1?0.15 mA and maximum power density of 6.5 mW/m^2 were produced by the BES. Higher oxidation-reduction potential (ORP) of around -450 mV was consistently found near the BES (2 cm distance), while lower ORP was (-550 mV) was found further away at 30cm distance from the BES. This ORP gradient is believed facilitate the electron flux towards BES, which is hypothesized to form a long-distance electron transfer and accelerated TPH degradation at larger radius of influence. The soil conductivities gradually increased from 175 (30 cm) to 210 (2 cm) µS/cm with distance closer to BES. All these soil conductivities were higher than the readings from the control reactor (150 µS/cm) and in raw soil (125 µS/cm). This result agreed with our previous conclusion that non-conductive TPH degradation will lead to increase of soil conductivity. The pH of all soil samples decreased from initial 7.7 to minimum of 7.45, which was also another proof of TPH degradation. Several studies have demonstrated a soil pH decrease during hydrocarbon degradation due to production of intermediates such as fatty acids. Our experiment showed that BES can be a feasible and sustainable technology for remediation of crude oil-contaminated soil with low cost.