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Development of Multifunctional Colloidal Gas Aphron and Its Applicability on BTEX-Contaminated Subsurface Remediation

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ABSTRACT

The use of colloidal gas aphron (CGA) provides a promising alternative to promote aerobic biodegradation of BTEX contaminated in the subsurface environment. CGA is a micrometer-sized stable air bubble encapsulated by double surfactant films. Air core is surrounded by a surfactant layer filled with water (namely, soapy shell) which can act as a carrier medium of microorganisms and nutrients and outer shell composed of hydrophobic surfactant tails can act as a partitioning medium for hydrophobic contaminants. When CGA is generated with a solution containing BTEX-degrading microorganisms and inorganic nutrients and is provided into the anoxic environment in an appropriate manner it is plausible to achieve bioaugmentation and biostimulation effects as well as oxygenation. Furthermore, CGA can convey materials necessary to BTEX biodegradation uniformly to subsurface due to its plug-flow characteristic.

This study was conducted to evaluate the feasibility of multifunctional CGA for *in situ* remediation of BTEX-contaminated subsurface. For this purpose, we tested various surfactants including a plant-origin biosurfactant saponin, a cationic surfactactant dodecylethyldimethylammonium bromide (DEDAB), an anionic surfactant sodium dodecyl sulfate (SDS), a nonionic surfactant triethylene glycol monododecyl ether ($C_{12}E_3$), and collagen. CGA was generated by mixing surfactant solution at 7000 rpm for 5 min with a two-baffle generator. A preliminary study showed that CGA generated with two baffles produced more stable CGA compared to that generated from no- and four-baffle generators. The physical characteristics of generated CGA were determined

by measuring physical properties such as half drainage time, gas hold-up, generation efficiency and aphron size distribution.

Among the surfactants tested, saponin was chosen as the most appropriate CGA-generating surfactant due to the physical properties of generated CGA as well as its harmless, easily biodegradable characteristics. Saponin concentrations of 0.5, 1, and 2 CMC (CMC of saponin is 0.1%) increased CGA generation efficiency from 5.43 to 18.64 and further to 100% while gas holdup and half drainage time decreased from 0.8409, 0.6944, to 0.4194 and from 95.16, 16.78, to 4.78 min, respectively. Collagen and synthetic surfactants generated less stable CGA than saponin at all concentrations tested except for one case (i.e., 2 CMC of SDS). Triethylene glycol monododecyl ether ($C_{12}E_3$), a nonionic surfactant, did not create CGA at all. Most CGA right after generation from 1 CMC saponin solution fell into diameters ranging from 100 to 200 μm while diameters of 2 to 10 min-old CGA and 20 min-old CGA fell into 150 to 300 μm and 300 to 400 μm, respectively. This may indicates that CGA become larger and transform into foam as time passed by, and eventually will collapse.

The flowing property of CGA in porous media was determined. Dyed CGA was injected into a visualization cell packed with Ottawa sand at 10 mL/min in an upflow manner. Photographs were taken at time interval of 5 min and loading pressures were recorded each time. It was observed that CGA flow generated two separated fronts, liquid front advancing faster and gas front retarded by the medium. This bubble and gas retardation resulted in pressure increase. The plug-flow characteristic of CGA was evidenced by the observation of horizontal gas front in the homogeneous medium (i.e., visualization cell). Plug-flow characteristic of CGA will be further validated under heterogeneous porous media mixed with sand and clay, and the applicability of CGA as an *in situ* aerobic bioremediation technology of BTEX is under evaluated.

Key words: Saponin, Colloidal Gas Aphron (CGA), BTEX, Aerobic Bioremediation, Oxygenation, Bioaugmentation, Biostimulation.