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Pulsed submerged arc nanoparticle synthesis, disinfection and decontamination

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Generating a pulsed submerged arc (SA) within a liquid produces a plasma bubble comprised of ionized material evaporated from the electrodes and the liquid. This plasma bubble serves as a microplasma reactor in which radiation, active chemical species, and nano-particles are produced. The arc discharge may be initiated by high voltage breakdown, or by mechanically breaking contact between current carrying electrodes and drawing an arc; the initiation method influences the type of particles produced and the energy expended. Micro- and nano-particle production was studied using pulsed arcs submerged in ethanol and water. Drawn arc initiation tended to produce a larger proportion of micro-particles than with breakdown initiation. The micro-particles tended to be comprised mostly of the electrode material, while nano-particles tended more to incorporate material from both the electrodes and the liquid. Particularly interesting were: (a) Ni nano-particles produced with Ni electrodes in ethanol, in which the Ni was supersaturated with dissolved C, and enveloped with a protective C outer layer, and (b) pure C nano-particles produced with graphite electrodes in ethanol, including nano-onions and magnetic C nano-particles. UV radiation and OH radicals produced by the SA disinfected water was inoculated with E. coli bacteria. Treatment of 50 ml of water containing 2×104 c.f.u./ml of bacteria for 5s with 48 mJ pulses applied at a 100 Hz repetition rate produced a survival rate of <5×10-4 with an energy expenditure of 0.14 kW-hr/m^3. Water contaminated with various organics, including Methylene Blue (MB), Sulfadimathoxine (SDM) antibiotic, phenol, and effluents from various industrial plants, was treated with a drawn arc initiated SA using C, Fe, Ti, and Cu electrodes, and their combinations, both without and with the addition of (0.01-0.5%) H_2O_2. The treated solutions were examined by Raman and absorption spectroscopy. Particles produced during the arc treatment were studied by SEM, XPS and XRD. It was found that MB was decomposed both during and after arc treatment. The produced nano-particles defined the character of the pollutant removal and the level of the removal ratio after SA treatment. With C electrodes, the MB concentration exponentially decreased for the duration of the treatment, while with the other electrodes the MB concentration saturated. The saturation is explained by a decrease of the oxidative species concentration with SA treatment time for these electrodes. Aging of the solutions after the SA treatment with all combinations of electrodes in the presence of H_2O_2 removed ~99% of the MB contaminant. The decomposition during aging may be associated with the accumulation of oxidative species, particularly peroxides, on the surface of eroded particles that gradually oxidized the MB. The association of particles with the decomposition of impurities is supported by faster decomposition in cases where the particle diameters were smaller. An MB decomposition yield of G99.6=90 g/kWhr was obtained using SA with Ti and Fe electrodes and 0.5% H_2O_2 addition. SA was successfully applied to treating industrial waste water from a pharmaceutical plant and decomposing phenol dissolved in water.

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