Development of a Self-Contained, PV-Powered Domestic Toilet and Wastewater Treatment System

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With support provided by the Gates Foundation (BMGF), we have developed an infrastructure-free, self-contained wastewater treatment system that incorporates a series of PV-powered electrolysis cells that generate molecular hydrogen for subsequent conversion to electricity in a hydrogen fuel cell. First, we will report on the efficacy of a laboratory-scale using real human waste containing feces and urine using bismuth oxide doped titanium dioxide (BiO_x/TiO_2) electrode arrays. A comprehensive environmental analysis has been coupled together with a robust kinetic model based under the chemical reaction limited regime to investigate the role of various redox reactions mediated by chloride present in human waste. Under current densities (J) higher than 200 A m^{-2}, the oxidative elimination of the *chemical oxygen demand* (COD) and ammonium ion can be modeled using experimentally-determined pseudo first-order rate constants and current efficiencies In combination with an anaerobic pretreatment step, the real human wastes including COD, protein and color are eliminated within 6 hours of continuous treatment in the WEC. The reactor effluent has residual inorganic nitrogen concentrations close to 40 mM of total nitrogen (TN). The current efficiency (CE) and specific energy consumption were 8.5% and 200 kWh kg-COD^{-1} for COD removal, while 11% and 260 for kWh kg-$TN^{-1}$for the TN conversion. The CE and energy efficiency (EE) for hydrogen production were estimated to be 90% and 25%, respectively.

On a pilot-plant scale with have developed a transportable prototype design for the treatment of raw domestic wastewater, human urine, human feces, and synthetic human waste analogues. After several hours of PV-powered electrochemical treatment, the turbid, black-water influent can be clarified with the elimination of the suspended particles along with the reduction or total elimination of the chemical oxygen demand (COD), total enteric coliform disinfection via *in situ* reactive chlorine species generation, and the elimination of measurable protein after 3 to 4 hours of PV-powered treatment. Our Phase II prototype incorporates additional features such as a residual sludge handling unit, a hydrogen purification and filter system, a closed water reuse We have packaged our second-generation prototypes into modified shipping containers that are ready for field testing in remote locations that lack traditional urban infrastructure. Alternative applications include electrochemically-enhanced septic tanks.