REDOX-BASED ELECTROCHEMICAL ADSORPTION TECHNOLOGIES FOR ENERGY-EFFICIENT WATER PURIFICATION AND WASTEWATER TREATMENT

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Water scarcity, both economic and physical, affects close to a third of the world population. Efficient, affordable and robust purification technologies are needed for a range of separation contexts, from point-of-source treatment or remote in-situ purification devices to large-scale, centralized wastewater treatment facilities. Micropollutants (e.g., organic endocrine disruptors, pesticides, household chemicals, dyes and heavy metal cations) pose a particularly vexing problem in wastewater treatment, since current technologies suffer from high energetic penalties and performance limitations when confronted with pollutants at these very low concentrations (nM to μM), often in the presence of excess competing species.

Redox-based electrochemical technologies offer a next-generation purification technology. Through specifically designed chemical selectivity at the electrode interface, redox-based systems can achieve high separation factors towards toxic pollutants, at low overpotentials and much higher current efficiencies than needed for capacitive-based methods. We present a novel redox-mediated electrochemical system, utilizing organometallic polymeric electrodes, to target pollutants ranging from pesticides to toxic heavy metals. Capture and release are controlled solely by electrochemical potential, thus there is no need for chemical regenerants or post-treatment, with little chemical waste produced and low water usage ratios (<0.05). In addition, an asymmetric configuration can be implemented to achieve higher electrochemical performance and energy storage; at the same time, we control the water chemistry (i.e., no current diversion to water reduction and pH changes) and thus enhance separation factors >300 towards target pesticides and organic pollutants in the μM range. Finally, through materials optimization, we show the strong stability of these electrodes for >500 cycles with over 95% current efficiency.

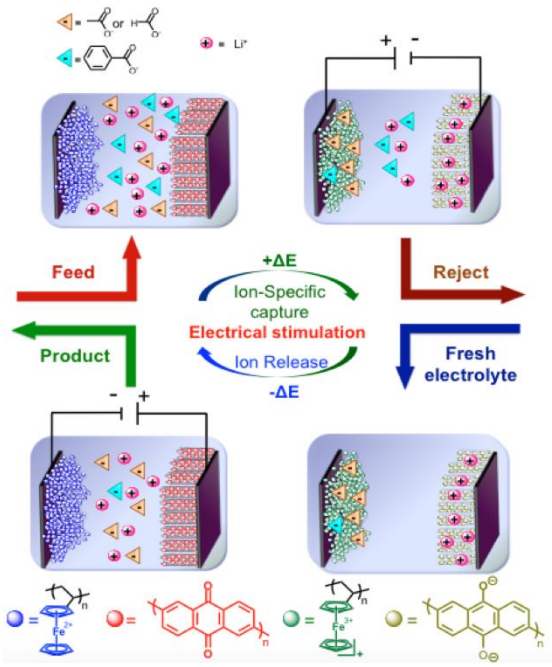

Figure 1. Redox-activated electro-swing adsorption technology concept

Significantly lower energy consumption is observed (estimated to be ~0.3 - 1 kWh/m^3 purified water) than with traditional methods, which results in a reduced carbon footprint. In addition, due to their electrochemical nature, redox-based systems can be easily integrated with renewable energy sources in remote locations (e.g. agricultural waterscape or villages in the developing world). In the long-term, energy-efficient selective electrochemical methods offer a powerful solution for water purification and treatment across a range of scales.

References:

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