Emerging Water Treatment Technologies to Treat Our Increasingly Complex Wastewaters

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Dramatic population growth across many parts of the world coupled to a growing global middle class, which requires more resources to support its lifestyle (e.g., larger per-capita meat and energy consumption), are increasing the strain on traditional potable water resources. In addition, changing climate patterns are driving many regions of the world into de-facto water scarcity conditions, with the recent situation in Cape Town, South Africa, representing a real-life experiment in what happens to a densely populated urban area that runs out of water. Due to the growing scarcity of traditional potable water resources (i.e., groundwater, rivers, and lakes/reservoirs), there is a growing interest in the utilization of marginal and contaminated water resources for domestic, agricultural, and industrial applications. In addition to water scarcity, stricter regulations are pushing producers, such as farmers and the oil and gas service sector, to minimize their environmental footprint by reducing the contaminant load released by their activities. These regulations are driven both by the desire to protect the surrounding ecosystem, and by the desire to protect water resources for future generations.

Traditional water treatment technologies and processes are capable of reducing contaminant concentrations in many waste streams, although their cost can be unacceptably high. In addition, many of the traditional wastewater treatment methods were developed in a time when little attention was paid to energy consumption and efficiency or the potential to recover valuable components found in aqueous waste streams. A good example of this is the traditional way we treat municipal wastewater, where the primary concern is to remove nutrients (C, N, P) from the effluent stream to prevent eutrophication in the receiving water body. In this traditional process, organic carbon is converted to CO_2 and NH_4^+ (the primary form of nitrogen) is oxidized to either NO_3^- or N_2. However, both organic carbon and NH_4^+ are valuable resources: reduced carbon as a source of energy and NH_4^+ as a valuable fertilizer. Under current practices, these resources are wasted. In addition to these process inefficiencies, modern lifestyle habits, such as pharmaceutical consumption and the use of complex personal care products, are introducing new and recalcitrant chemical compounds to wastewater streams. Traditional wastewater treatment processes were not designed to degrade these compounds, and as a result, these compounds find their way into the environment, where they have been demonstrated to cause adverse impacts, such as the feminization of fish and amphibious populations. Thus, there is a real need to develop treatment processes capable of removing emerging contaminants, and in addition, do so both efficiently and with an eye towards the recovery of valuable commodities from these waste streams. Another example of an underutilized waste stream is agricultural runoff (approximately 57% of consumptive water use is for agriculture). Agricultural runoff often contains elevated concentrations of ionic species, such as nitrate. While technology such as reverse osmosis is capable of removing such ionic contaminants, the cost of this treatment method is far too high for the technology to be deployed at the large scales and remote areas required by farming. New water treatment technologies capable of removing target constituents (while leaving non-toxic constituents in the water) that can be readily scaled to treat large volumes of water have the potential of transforming many sectors, which could dramatically reduce water scarcity in many regions of the world.

In this talk we will discuss new and emerging wastewater treatment processes that take advantage of the latest advances in polymer chemistry, biology, and electrochemistry. In addition, we will describe current gaps in the state-of-the art of wastewater treatment, and articulate where further research is needed, with the goal of exploiting knowledge and techniques used in other fields, such as machine learning and synthetic biology. Critically, our analysis will concern itself with not only technological and scientific hurdles, but also social and economic considerations.

Keywords:

Wastewater treatment; nutrient and energy recovery; recalcitrant organic contaminants