WATER REUSE AN INTEGRAL ASPECT OF SUSTAINABILITY: THE ROLE OF ADVANCED OXIDATION PROCESSES – CHEMISTRY AND ECONOMICS

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Outline of Talk

- Water
  - Constraints
  - Options
- Advanced Oxidation Processes
  - What are they
  - Why will they find more applications
  - How do we make them cost effective
- Economic Considerations
  - Are the present models correct
  - What must we consider in the future
- Paradigm Shift in Policy

- This is an overview talk with little detail – however, some “water” for thought

Water

- Constraints
  - Population will increase
  - Water is essential for life and a healthy Planet
  - The most important issue is the safety of water!
  - Global climate change is likely the single largest unknown in the equation – at least now that we admit that WE are the problem - we can start to tackle it with increased funding to improve our understanding, our predictive capability and to develop realistic solutions
- Present day – California – 20 % of energy goes to service the water and wastewater industry
  - My guess - that will be hard to reduce significantly
  - We must try to seek solutions to this vexing problem
    - There is no silver bullet and NO easy solution!
    - Particularly in a totally developed environment like S. CA

Water

- In our portfolio of water we must expand several options
  - Water reuse is in fact one of the most underutilized and likely is the cheapest in terms of “water cost” and “energy” of these alternatives
    - Close to 1/5th the cost of desal – but desal is an alternative
  - Once water is treated to drinking quality – and we add a little “matter” to it, it is too valuable a resource to continue to dispose of into the ocean (in coastal regions) and rivers (in inland regions)
  - Technology may not be as big a hurdle as policy and a realistic view of the holistic problem (economics)

Why Advanced Oxidation Processes

- AOPs are destruction processes
  - don't merely transfer the problem from one media to another (not necessarily the short term "cheapest" solution – but I would argue maybe a longer term optimal strategy)
- They are defined by those that form the hydroxyl radical - •OH
- The provide a barrier to both microbial and chemical contamination
  - one process – multiple benefits and barriers
  - Effective against the low concentrations of emerging contaminants
- Can also be thought of as AO/RP
  - Some have both oxidizing and reducing reactive species that expand the potential of treating an as yet unidentified problem

Advanced Oxidation Technologies

- Ozone
- Ozone/UV
- Ozone/Hydrogen Peroxide
- TiO_2/light
- Fenton's Chemistry ($Fe(II)/H_2O_2$)
- Sonolysis
- UV/ H_2O_2
- Electron Beam
- etc.

Electron Beam - Example

- This is the most efficient way to generate •OH – we measured 72 % from socket to water, i.e. for 100 kW at the socket you get 72 kW chemistry
- It is or was capital intensive (costs have plummeted with new technology) e.g. in today's dollars for the cost of the plant built in 1980, you can get more than 4x the power – flow through
- O&M is likely the cheapest of all of the AOPs
  - The beam in our trailer was built in 1963
- As engineers particularly at Universities we MUST think out of the box

Overall Research Goal

- To develop kinetic models which describe the destruction of chemicals of interest in water treatment (in it's broadest sense) based on free radical chemistry
- Series of coupled differential equations that describe the details of the destruction of chemicals – broken down into three parts:
  - Equations describing the formation of radicals
  - Equations which describe the destruction of the chemicals
  - Equations that describe the fluid dynamics of the process of interest

Study Areas of Interest in Reuse

- Emerging Contaminants of Concern (> 400 chemicals that are on the radar screen)
  - Characterized by high or potentially high biological activity at low concentrations
    - Personal care products
    - Hormones/steroids
    - Antibiotics
    - Etc.
- Disinfection By-Products (> 600 that have been identified or are suspected to be present)
    - Carbonaceous
    - Nitrogenous
    - Iodinated

Why this approach?

- Modeling of systems provides the easiest approach to assessing system costs and optimization and, therefore, applicability to problem solving

- As an aside, I believe that through these types of studies we can also bridge the gap between science, engineering and potentially provide insight into health effects of chemicals

  – Biological self-defense mechanisms and treatment systems employ free radicals – i.e. liver cytochrome P-450 enzyme system

Economic Models

- I believe that the models used today are inadequate to predict how we will solve problems of tomorrow
- Our ideas of life-cycle costs at too narrow
- Our evaluation of the ecosystem and it's health are inadequate, at best, and more realistically dead wrong
- And, we have to think on a broader scale NOT the next fiscal quarter, next year or next decade – but Centuries

Paradigm Shift in Policy

- If we as scientists and engineers are to develop real solutions there has to be a large shift in policy approaches to the problems
- We have to get around command and control and prescriptive solutions, to those solutions that make sense – where common sense prevails
- To do this we have to educate the public, develop adequate risk assessment procedures and re-write some of the less than operable procedures that have been set in place
- This ties back into economic models where companies should be rewarded for doing the right thing – after all one of the biggest polluters was the US Government.

Thank you

- If there is time, I’d be happy to stimulate some discussion