Summary of Chapter 03: PAA Disinfection Kinetics

* + Mechanism of Disinfection
    - At pH < 8, the acid form is prominent (as opposed to peracetate anion which is prominent at pH > 8.2)
      * And has higher redox potential at pH < 8
    - Form reactive oxygen species (ROS) (e.g., hydroxyl radical)
    - Reactions occur with the bacterial wall, cytoplasmic membrane, or metabolism
      * Sporocide
    - Disinfection efficiency is similar to chlorine dioxide
      * Mechanism is similar to other peroxides and oxidizing agents
        + Oxidation of sulfur compounds in enzymes that affect biochemical pathways and membrane transport
        + Rupture of cell walls
  + Combination of UV and PAA
    - Results (i.e., target disinfection levels) vary widely, but generally UV/AOP process is effective
    - Configuration is cost effective if a utility has a capital budget constraint
    - Photochemistry
      * PAA and H2O2 generate radicals in solution, but insufficient for disinfection purposes at the relatively low UV doses used in wastewater
      * Most radicals are scavenged by background organic and inorganic material in wastewater
  + Decomposition
    - Spontaneous decomposition is negligible when:
      * < 55F, no contact with metals or organics
    - 15% PeroxyChem solution maintains equilibrium for 1 year < 29C (84F)
      * Above 100F, 1 month
    - 2 phases:
      * 0-5 minutes, instantaneous reduction of concentration due to oxidation of organic mater
        + Demand varies more than decay
      * First order decay associated with hydrolysis and transition metal-catalyzed decomposition
        + Decay is associated with reduced iron and orthophosphate (combined), salinity, and hardness
        + Dependent on quality of water (e.g., primary vs secondary effluent has 10x greater decay)
    - Water quality
      * TSS and organic matter affect initial demand
      * Transition metals increase decay rate
        + Redox reactions with reduced metals (Fe2+, Mn2+, Cu2+, Co2+)

When Fe2+ > 0.1 mg/L, catalyze PAA decay, decrease effective concentration

*Dissolved Iron from past two years are all < 0.1 mg/L*

Counteracted by presence of phosphates (act as chelating agents with the transition metals)

Phosphate can quench free radicals at > 30 mg/L

* + - * Salinity abates radicals
      * Temperature increase, decreases effective concentration but increases reaction rates with microorganisms
      * High pH, lower disinfection efficacy
      * Higher Mg/Ca ratios lead to slower kinetics
      * Higher Na/K ratios lead to faster reactions
      * Hardness only had slight impact
      * High COD, high initial PAA oxidative demand
      * High TSS (>40 mg/L), higher PAA decomposition
    - Modeling inactivation
      * Mathematical models fit microbial inactivation data for a specific set of conditions
      * No mechanistic basis for the inactivation observed
      * "S" model describes E.coli inactivation:
        + Rossi et al., 2007, “Peracetic Acid Disinfection: a feasible alternative to wastewater chlorination”
      * Double exponential model also describes inactivation kinetics well
        + Santaro etal., 2015
      * Microbes damaged by PAA are unable to repair and regrow after residual is quenched