Slide 1

ARPA-E Energy from Wastewater

Breakout Group #1 - Clean Water from Wastewater: Science and Technology Needed, with Associated Metrics

Group 1: Science and technological challenges to obtaining clean water from wastewater, with more than an order of magnitude better performance than current technologies

Chair: Jim Smith, US EPA NRML

Slide 2

How could we achieve the following goals: zero-pathogens (including viruses), sub-parts per trillion in disinfection by-products, and clean water <250 ppm potable TDS in water derived from wastewater? If it is not possible, why? What are the biggest challenges? How close can we get to these goals?

- Capturing of wastewater contaminants at the earliest step possible at the WWT Facility – 98.2% solid removal w/ 95% BOD removal, organics
- Separation mechanisms – physical/chemical/biological approaches – membranes, algal mass, hydrodynamics
- Disinfection – wave energy – How close can you get to zero pathogens vs. the energy applied?
  - Logarithmic removal improvements with lower energy use
- Concentration techs – reduce volume for transport vs. on-site treatment with fractionation technologies for oil and gas production
- Scalability, portability and sustainability metrics for all processes with order of magnitude improvements
- What are detectable limits – moving target – can't say no pathogens
- Public perception – people are leery of reuse – how to overcome this obstacle?

This group had a very engaged discussion. The material presented to the general audience is found on Slide 2. The additional notes contained in this document capture the general discussion that took place during breakout session 1 by group 1.

Slide 3

What technology/combination of technologies demonstrates the greatest potential to minimize the many energy intensive steps of the current water treatment process (contaminant removal, nutrient extraction, hydrogen peroxide treatment, and UV radiation, etc) across the entire spectrum of wastewater sources (agricultural, municipal, industrial)? How could the energy (all forms including chemical) to clean water from wastewater be less than 1 kW.hr/m3 (3.6 MJ/ m3) for clean water of less than 250 ppm of potable TDS?

- Jim Smith lead off with a discussion of the definition of clean water – really grey water used for irrigation etc.
  - Community wastewater – what is in it – organics, personal care products, pharmaceuticals
  - With decentralized systems; septic systems – what is the importance of removing residuals?
  - Would you reuse the liquid and solids part with home treatment?
  - Study at Water and Environmental Research Associates found that a considerable amount of the energy in the material released can be lost prior to getting to the WWTF
- What is meant by clean water and what can we do with it
  - BODs, suspended solids, nutrients, organics – how much treatment is required and where?
  - What do we know about removal of contaminants?
  - Is it based on regulatory structure? Clean vs. potable water is the discussion
  - Water reuse handbook and reuse requirements – pathogens are issues and what is an adequate reduction requirement?
  - Organic contaminants are currently the focus
  - Drinking water is not screened for the myraid of contaminants that can be in the wastewater
  - Organics can be removed with underlying refractive organics that have an energy value for combustion
- From a technology perspective
  - Advances or changes to have a broader reach of technology
  - Tier technologies by contaminant to make the water clean by category depending on beneficial use
  - Energy production capability
  - These two cases don't match 1 to 1

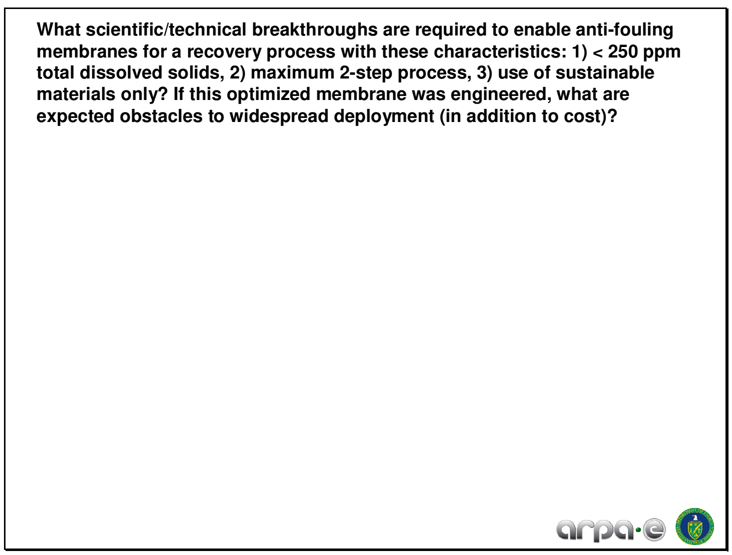
- Viruses, personal care products removal defines clean vs. other screening technology to remove personal products, i.e., pharmaceuticals (energy vs. clean water use are not directly aligned)
  - Focus on science – there is a need to advance basic science
  - Filtration, RO, etc. to remove selected compounds at the lowest energy – how to achieve?
  - Materials perspective UF and MF removals – multifunctional UF and MF to do particle rejection and decontamination
- Objective of session is the concern – identification of path
  - What has been done so far? Components in grey water and energy content
  - Rework existing process to reduce energy requirements vs. development of new technologies
  - Water use – what is clean water – municipal wastewater here vs. industrial wastewater
  - Community has a combination
  - Pharmaceutical contaminants are not a consideration for community wastewater
  - Industrial reuse vs. community reuse (potable) – different metrics are required
  - Ag wastewater vs. industrial pretreatment
- Wastewater sources and end products should be defined
  - Grey water? At the location of buildings with reuse options
  - Centralized vs. decentralized
  - Modular perspective is consideration
  - Vs RO selective low pressure selective membranes depending on the source characteristics
  - Consider a system by what goes in vs. what goes out and scale by application
  - Some techs are appropriate for minerals (dissolved constituents) – community wastewater vs. oil and gas field wastewater
- What techs can be brought into the community wastewater system to reduce energy requirements?
- Procesing at homes with reuse at the location
  - Japan has closed building systems
  - Breaking the linked system in the US is difficult as the wastewater collection and distribution systems is a decade + process
  - Product intent - potable vs. non-potable use
- LEED certification – University of California Merced – largest LEED wastewater project – 2MGD plant – most homeowners don't do a LEED system
  - Dual flush
  - Zero discharge kills the source of BOD and COD sources
  - Municipality looses a BOC/COD surcharge with a LEED system
- Aeration is where to start – 60% of cost is wastewater
  - Combust BOD with turbocharger and cut system energy cost by 60%
- One order of magnitude reduction is 10X reduction which can be met through multiple efficiency improvements or new technologies
  - Expansion of new technologies to use the existing infrastructure with new materials
  - Basic materials used today are limited – water industry can be modified to expand the new materials
  - Where do materials go when removed from the system?
  - Fertilizer and grey water irrigation
- Inorganic removal vs. ammonia removal – based on the source
- Carbon sequestration and land application of solids – how to remove contaminants and then transport solids to the final user

- What is the Utopia of separate systems
  - Average person is not concerned in water removal but will be very concerned with wastewater reuse
  - Sustainability test requires a societal reaction test – how will the reuse be considered
  - Biosolids – public perception of clean water vs. reuse water – public perception issue – how do we define clean with pharmaceuticals and others as they are not considered contaminants now – not screened for in fresh water but perceived as issues with wastewater reuse
  - Public perceptions will affect water reuse
- This is a nexus of water and energy – there are efficiencies to be gained on both sides but they are usually considered separately
  - One would make different choices if efficiencies on both systems are considered in parallel vs. the process being maximized for only one side of the equation
  - Must consider both to maximize the benefits from the system
- Water treatment is versed with filtration but it is energy intensive
  - Water quality prior to screening can help to lower energy requirement for backflushing etc.
- How can we remove 95% of solids prior to biological treatment?
  - What are the processes that can do this
  - Hydrodynamic separation and concentration/diversion
  - Chemicals with scalant separation or flocculation can achieve 90-95% solids removal
  - Timeframe
  - Membranes are also necessary
  - Upfront process without a barrier to reduce suspended solids to reduce sedimentation requirements will be useful
  - Membrane bioreactors
  - Attached growth vs. suspended growth
  - Nutrient separation
  - Activated sludge treatment to bioreactors
  - Headworks degritting to remove primary solids primary to desolidifiers
  - How to remove needles (diabetics flush needles)?
  - Baseball bats; dead possums; night dumping in sewer grates
  - Cleanscreen with rotating screen and pressing
  - Gravity settling
  - Sand
  - Upfront removal and use for energy
- Dissolved carbon passes on to be treated with biological means
  - How can this carbon be captured and used/reduced
  - After secondary treatment to remove carbon concentration in the wastewater stream
  - 1st step to remove solids and BOD (dissolved with membrane) then very little to pass into biological treatment with a lower air requirement
  - The following biological system with filters to reduce turbidity to drinking water level makes it almost clean
- What are the big problems? Organics vs. pharmaceutical residues?
  - Cracked organics so that the bugs can convert them
  - Refractory organics – biological systems don't readily address and can't easily precipitate
  - Resistant to activated carbon
- Can you replace RO in systems to reduce energy requirements – low hanging fruit

- Removal of solids early and concentration to reduce volumes of water to treat and increase concentration for more efficient conversion
- Community water vs. unconventional oil and gas production using water fractionation with subsequent water treatment – today they cook and evaporate this water
  - Concentrate management – recovered value of metals, organics (energy value), salts, arsenic and chloride removal (today use evaporation)
  - Oil and gas wells don't use on-site treatment - $18B trucking cost annually in US to transport this water to WWTF
  - Ship bilge water with UF to remove oil and RO to remove dissolved
  - Fractionation water issue – reuse of water with salts – salt causes issues with polymers
- How to make these systems portable vs. trucking – point of use treatment appropriate to industry
- Mobile conversion for fracturing water – 100 mile trucking is max cost effective distance (to injection well and injection is 2$/bbl – salts and polymers not good for reinjection – can you go right back down the well for EOR and EGR?)
- City of Shreveport to reverse city effluent and pipeline - fracturing water at 3-4K pressure – presulfate bacteria plugs well – don't want to use chlorine or other chemicals
- Zero pathogens is not possible
  - Cross connect and pathogen growth in pipes – reason for hydrant flushing by fire departments etc.
- Key challenges to crack to make order of magnitude improvements in systems
  - Capture at the beginning of the pipe
  - Removal of 98.2% of total suspended solids up front
  - Membranes and polymers with transformational change
- Metrics here
- Consideration of questions
- What are membrane requirements
- Advance separation technology to reduce energy requirements
- UF membrane 1 to 5 bar – RO 10 bar – can you reduce these requirements?
- Grey water – will membranes bio-foul quickly
  - How to reduce fouling and energy requirements?
- Is the technology saleable and portable?
  - To the mine mouth for hydrofractionation
- Capture solids at home – energy at lift pumps and stations is a huge amount – impellers are key and engineers don't want to specify stainless – LOTS of maintenance
- 17K POTWs vs treatment at home?
- How to enhance existing infrastructure?
  - Low energy non-fouling membranes
  - Separation science – separation mechanisms need to be enhanced to lower energy – i.e., absorbent (separation techs) vs. membranes
  - Tertiary systems – emerging areas – algae for nutrient removal and energy production – depends on location and likely requires a large footprint
- Scale and stage – circumstances and reduced energy
- Low concentration high volume streams (fracturing water) – evaporation and crystallization with tons of salts – what to do with this?
- Separation techs
  - Concentration techs (6M gal per fractionation – concentrate contaminants – capture methane – concentrate discharge – mine waste with metals – naturally occurring radioactive materials (NORM))
  - Separation and destruction

  - Contaminants vs. carbon – carbon is usually converted to CO_2 – other uses? Biogas?
  - Use of final residuals
- Disinfection – chemicals like chlorine are going away – UV lights will be the future – cleaning is key
- Photocatalysis and visible light will be key – IR, photocatalysts like EMR – optical approaches vs. ozone vs. onsite hydrogen peroxide production and introduction – wave energy like ultrasound – REDOX-based reaction like plasma – wind or solar DC – Logarithmic removal with lower energy use
- How close can you get to zero pathogens vs. the energy applied?
- Concentrate with hydrodynamic with neutrally buoyant – viruses are too small
- 40% of carbon is in the biomass
- How to disinfect – must use energy

Slide 4



Slide 5

Are there any other non-energy intensive (heat, mechanical) options for anti-fouling (reversible fouling, forward osmosis, etc), or for the separation of wastewater into water/biomass in general?

Slide 6

To what extent could advanced photocatalysis alone deal with degrading complex hydrocarbons, eliminating pathogens, and degrading toxic compounds? What technological breakthroughs would be required to achieve this? What are expected obstacles to widespread deployment (in addition to cost)?