Water Treatment: Technology Needs and Challenges

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Deshusses’ Lab Research Areas

- Bioremediation of contaminated water or sediments
  - Waste to energy
    - (bio and thermo-chemical)
- Biological techniques for air pollution control
  - (VOC, H₂S, odor, NOx, SOx, PM, Hg, treatment)
- Sanitation for developing countries
- Process intensification
- Mathematical modeling of processes
- Process fundamentals
  - Microbial population dynamics in engineered systems, mass transfer, biofilms and biofouling, extremophiles
Using hog waste to produce biogas (high strength wastewater)
System benefits and characteristics

**System Benefits**
- Simple system
- Renewable energy production
- GHG emission reductions
- Secondary benefits (e.g. odor)

**System Performance**
- Microturbine run time >85%
- 5800 m³ biogas prod./week (60-68% methane)
- Treatment of:
  - 1400 m³ manure/week
  - 16.5 tons COD/week
  - 2.2 tons N/week
  - 0.9 tons P/week

**R&D focus**
- Optimize renewable energy & offsets
- Minimize environmental impacts
Sanitation for Less-Developed Countries

Reinventing the pit latrine: the ADPL
Human waste to biogas to heat sterilization
Current demonstration in Kenya, Philippines and India

Omni Processor for Human Waste
Sanitation for the urban poor using supercritical oxidation. 1200 people equivalent, energy neutral

Funded by the Bill & Melinda Gates Foundation
In supercritical water, organics are rapidly oxidized (in seconds) resulting in heat, and CO$_2$.

Most salts precipitate under supercritical water conditions…

Could we use SCWO for reject or produced water?
3D model of our Supercritical Water Oxidation Unit
Pilot unit construction

- Heat and energy recovery
- Metallurgy and corrosion
- Process control
Basic kinetic determinations

Feed (5% solids)

18% excess $O_2$

29% excess $O_2$

48% excess $O_2$
Biofilter and biotrickling filters for air/gas or water tmt... Small, large, air, biogas, water, VOCs, H$_2$S, CO$_2$, perchlorate, MTBE, etc.
High Performance Biotrickling Filters for H$_2$S Control

Motivations: Chemical vs. Biological Scrubbers

**Chemical scrubbers**

\[
\text{H}_2\text{S} \rightarrow 2\text{NaOH} + 4\text{NaOCl} \rightarrow 4\text{NaCl} + \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}
\]

**Biological scrubbers**

\[
\text{H}_2\text{S} \rightarrow \text{VOCs and organic odors} \rightarrow \text{CO}_2 + \text{SO}_4^{--}
\]

\[
\text{H}_2\text{S} \rightarrow \text{O}_2 + \text{CO}_2 \rightarrow 2\text{H}^+ + \text{SO}_4^{--}
\]
The flowsheet of chemical or biological scrubbers is the same... so conversion is easy

Foul air

Treated air

biotrickling filters need a different packing

no chemical feed

New packing installed

...and a smaller pump
High performance biotrickling filters can be as effective as chemical scrubbers

At OCSD we converted 5 scrubbers

- #10 Plant 1 17,000 m³/h trunkline (roughing)
- #I Plant 2 17,000 m³/h trunkline (roughing)
- #Q Plant 2 40,000 m³/h primary (end-of-pipe)
- #J Plant 2 40,000 m³/h dewatering (end-of-pipe)
- #G Plant 2 47,000 m³/h DAFT (end-of-pipe)

- Gas contact time 1.1 - 3 seconds!

See papers with D. Gabriel
Long-term $\text{H}_2\text{S}$ elimination capacity

No automatic control for water make-up supply

Outlet below 1 ppm (SC-AQMD limit) most of the time
Biogas Sweetening

Inlet $\text{H}_2\text{S} \sim 1000$-10,000 ppm
Typical removal rates $\sim 100$-300 g $\text{H}_2\text{S} / (\text{m}_{\text{reactor}} \text{ hour})$

$$\text{H}_2\text{S} + \text{O}_2 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}$$

Bacteria w/ $\text{O}_2$
Bacteria $\text{O}_2$ limited
$\text{S}^0$ (can be recovered)
Pilot demonstrations

SITE 1
- Digester gas: “only” 2000 ppm H$_2$S
- 3 min gas contact time
- 100% removal

SITE 2
- Geothermal gas: 50,000 ppm H$_2$S!
- Partial removal, issues with sulfur and process control
CO₂ Biocatalytic Capture

Using *E. coli* with surfaced-expressed carbonic anhydrase (CA) for efficient CO₂ capture

\[
\text{H}_2\text{O} + \text{CO}_2 \xrightarrow{\text{CA}} \text{H}_2\text{CO}_3
\]

**Foam bioreactor**

*Inlet gas* → **Gas out**

*E. Coli* engineered with carbonic anhydrase on the cell surface

Work with E. Kan, U. of Hawaii
Methane Biological Treatment

Methane can also be treated in biotrickling filters:

Challenges:
- Methane is very hydrophobic
- Often air flows are really high
- Methane concentrations are often high

- Use second liquid phase
- Use fungi or very dry systems
- Use very high gas-liquid interfacial areas
- Other innovations, like producing bioplastics or making bacterial paints

\[ \text{CH}_4 + \text{O}_2 \xrightarrow{\text{bacteria}} \text{CO}_2 \]

Rates are ~10-100 g/(m\(_3\) h)
Difficult to get high removal %

Thin coatings are more efficient than thick biofilms
Challenges in the oil and gas industry

Very high-strength waste:
- High salt content / high TDS
- Some recalcitrant or volatile organics
- Radionuclides

Very high flows or volumes to be treated
Failure is a costly option
Industry may have a bad reputation / legacy pollution

Opportunities

Energy on site may be cheap, or freely available (heat)
Processes integration could lead to synergisms
How can we work together?

- What can we accomplish RIGHT NOW with the current knowledge / current tools?
- What requires a FEW TWEAKS but will make a difference?
- What is the next BIG IDEA, where are the knowledge GAPS?