CIBO Focus Group Meeting

Biological Treatment for Power Generation Wastewater

June 11, 2013

Outline

- New ELGs for Fossil Fuel Power Generation
- Biological Treatment Fundamentals
- Aerobic Treatment – Ammonia, Organics
  - Biochemistry
  - Process Configurations
- Anoxic Treatment – Nitrate, Selenium
  - Biochemistry
  - Process Technology Providers
  - Case studies
  - Fringe Benefits

Draft Effluent Limitations Guidelines for FGD and Leachate Streams

- Applies to FGD discharges, new sources of landfill leachate only.
- Other wastewater streams limited for conventional pollutants (TSS, O&G, pH)
- Cleaning wastewaters limited for copper and iron.

	30-day Rolling Average	Daily Maximum
Arsenic, ppb	6	8
Mercury, ppt	119	242
Selenium, ppb	10	16
Nitrite-Nitrate, ppm as N	0.13	0.17

Basics of Biological Wastewater Treatment

- At the most fundamental level, biological treatment provides removal of aqueous contaminants as part of the life cycle of microorganisms.
- Microorganisms like other living things need to respire, eat and reproduce.
- The organic contaminant removed may supply energy as food, provide carbon for new cell growth, and may serve as an electron receptor in place of oxygen.
- Biological wastewater treatment involves providing a home for microorganisms that they are comfortable in, with consideration of temperature, pH, food supply, respiration supply, mixing conditions.
- While biological treatment is often considered a black art, it is firmly grounded in science, and the performance of biological systems can be as consistent and predictable as physical and chemical treatment processes. It generally requires a little more operator attention and a little more process monitoring than physical/chemical processes. No magic is involved.

Basics of Biological Wastewater Treatment (cont'd)

- The roots of current biological treatment technology go back to the mid 1800s, when collection systems for sewage were installed, but little treatment technology existed.
- By 1870, septic tanks had been introduced for the anaerobic treatment of domestic wastewater.
- In the early 1900s, aerobic filters were used to treat domestic wastewater
- In 1914, Arden and Lockett conducted experiments and published papers on what is today known as activated sludge.
- The Clean Water Act of 1972 mandated removal of carbonaceous components of domestic wastewater and industrial wastewater, which was most effectively accomplished by biological treatment.
- The first designs of biological systems for nitrification and denitrification were also put forth in the early 1970s.

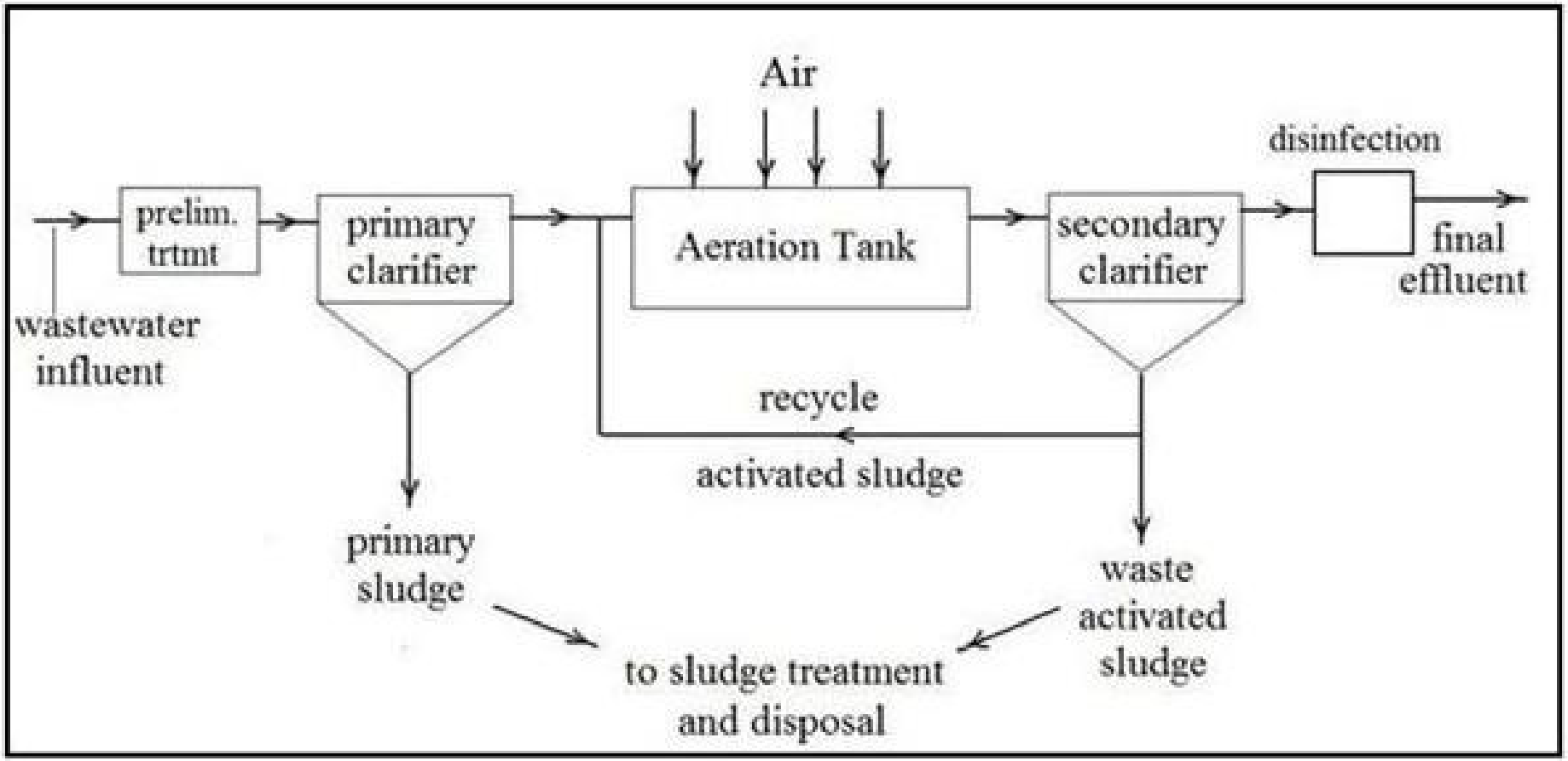
Basics of Biological Wastewater Treatment (cont'd)
Biochemistry of Aerobic Biological Treatment

- $O_2 + C_{10}H_{19}O_3N$ + aerobic bacteria + nutrients ⇨ $CO_2 + NH_3 + H_2O + C_5H_7NO_2$ (bact. cells)

- $C_5H_7NO_2 + 5\ O_2$ ⇨ $5CO_2 + 2H_2O + NH_3$ + energy + products

- $2\ NH_4 + 3\ O_2$ + bacteria ⇨ $2\ NO_2 + 4H^+ + 2H_2O$
- $2\ NO_2 + O_2$ + bacteria ⇨ $2NO_3$
- Net reaction requires CO3/HCO3 consumed in reaction, provides carbon source.

Generic Aerobic Biological Treatment System

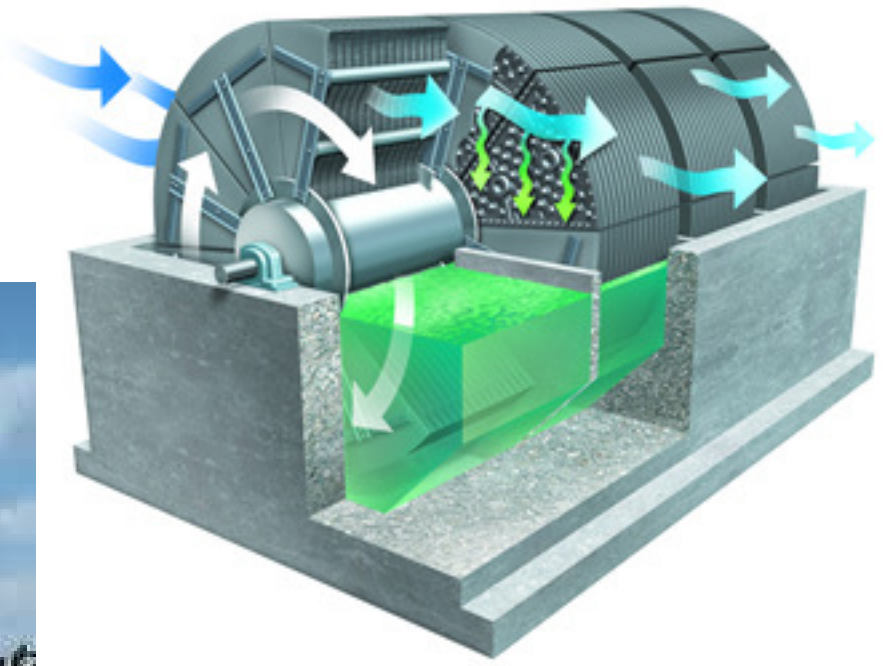


Activated Sludge Wastewater Treatment Flow Diagram

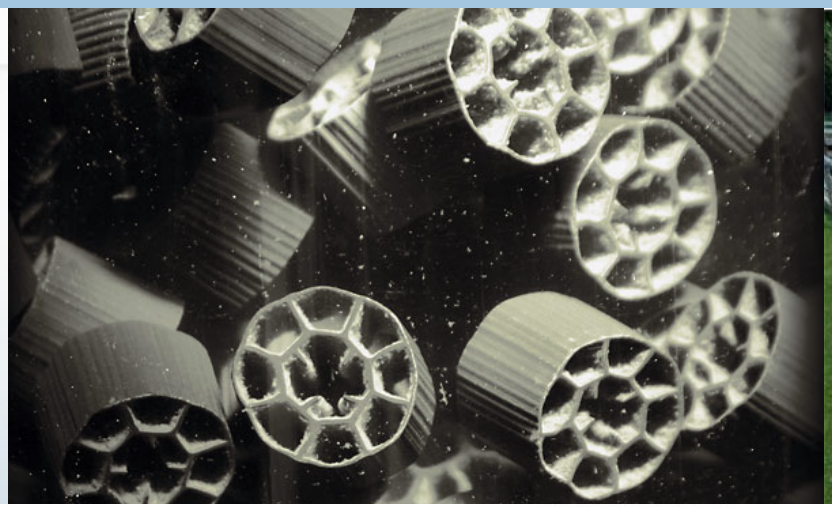
Typical Biological Treatment Systems for Organics and Ammonia Removal

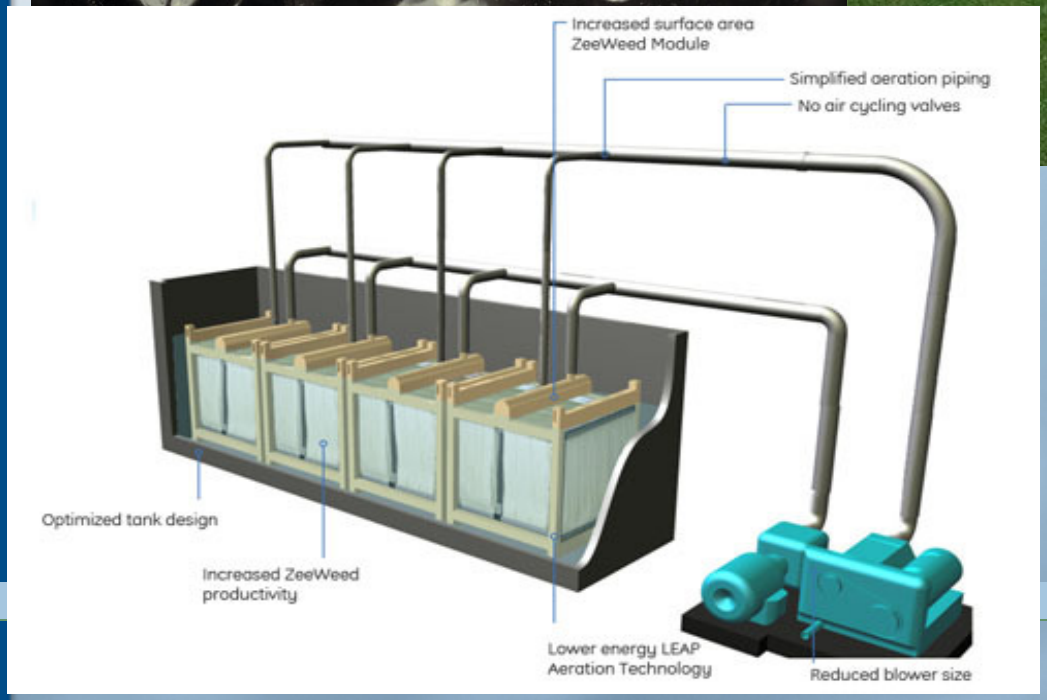
- Processes generally fall into two types, fixed film and suspended growth.
- Generally aerobic processes for low strength wastewaters, anaerobic treatment for sludges and high strength wastewater.
- Aeration is required for oxygen transfer.
- In some situations, nutrients and micronutrients must be added.
- For nitrification, a source of alkalinity must be added.

Fixed Film Bioreactors



Suspended Growth Systems





Basics of Biological Wastewater Treatment (cont'd)
Selenium Chemistry

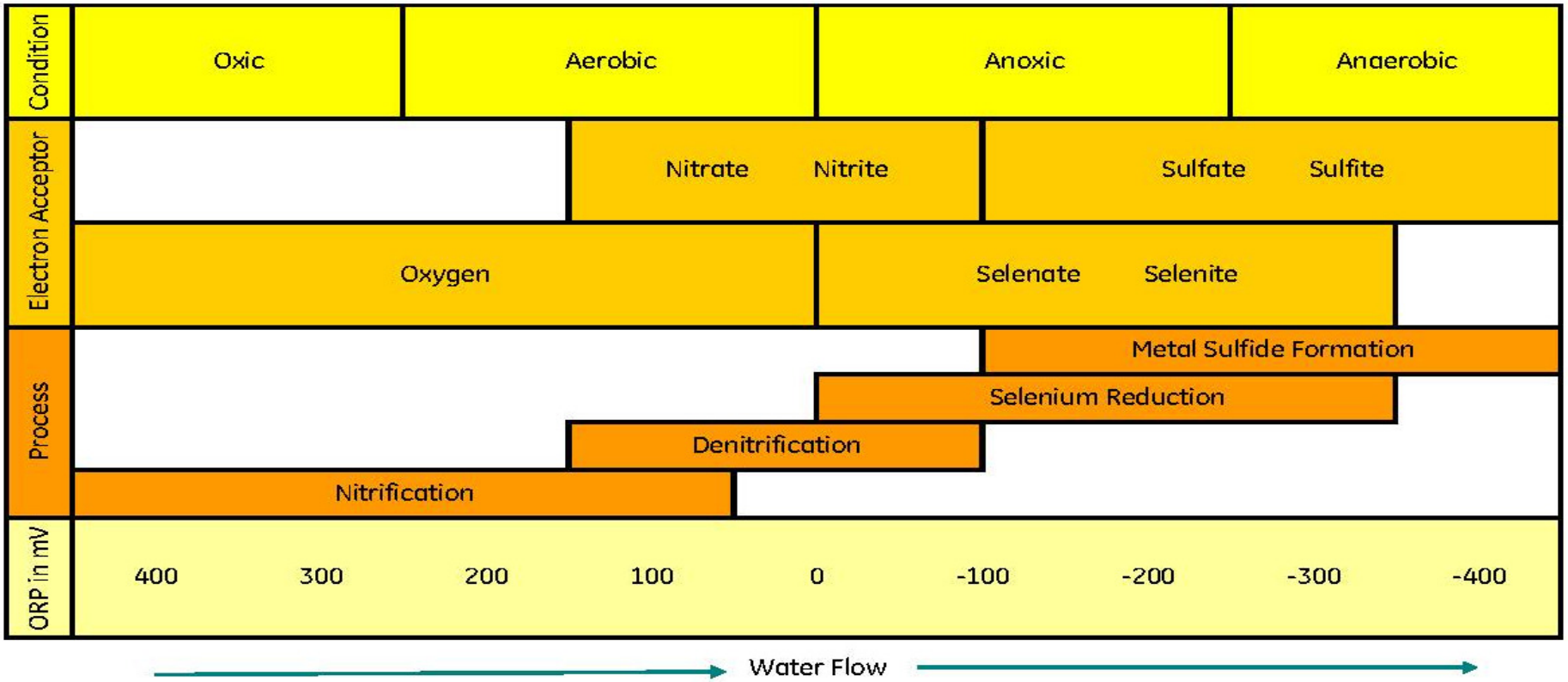
- Exists as elemental selenium, selenide, selenite, selenate. Analogous to sulfur, positioned below it on periodic chart.
- Elemental selenium can occur from biological reduction of selenate/selenite, and is an inert solid material.
- Selenide (Se^{2-} most reduced sol. form) is analogous to sulfides. Metals will precipitate in the presence of selenides like sulfides. Also smells bad. Se^{2-}
- Selenite(Se^{4-}) partially oxygenated – SeO_3^{2-}
- Selenate(Se^{6-}) most oxidized form, analogous to sulfate in chemistry – SeO_4^{2-}
- Can also exist as organoselenium compounds.

Basics of Biological Wastewater Treatment (cont'd)
Biochemistry of Anoxic Biological Treatment

- Anoxic Degradation of Nitrate/Nitrite:
  - $6\ NO_3^- + 2CH_3OH \Rightarrow 6\ NO_2^- + 2\ CO_2 + 4\ H_20$
  - $6\ NO_2^- + 3CH_3OH \Rightarrow 3\ N_2 + 3\ CO_2 + 3\ H_2O + 6\ OH^-$

- Anoxic Degradation of Selenate/Selenite
  - $3\ SeO_4^{2-} + CH_3OH \Rightarrow 3\ SeO_3^{2-} + CO_2 + 2\ H_20$
  - $3\ SeO_3^{2-} + CH_3OH \Rightarrow 3\ Se^0 + CO_2 + 2\ H_20$

Basics of Biological Wastewater Treatment (cont'd)
Biochemistry of Anoxic Biological Treatment



imagination at work

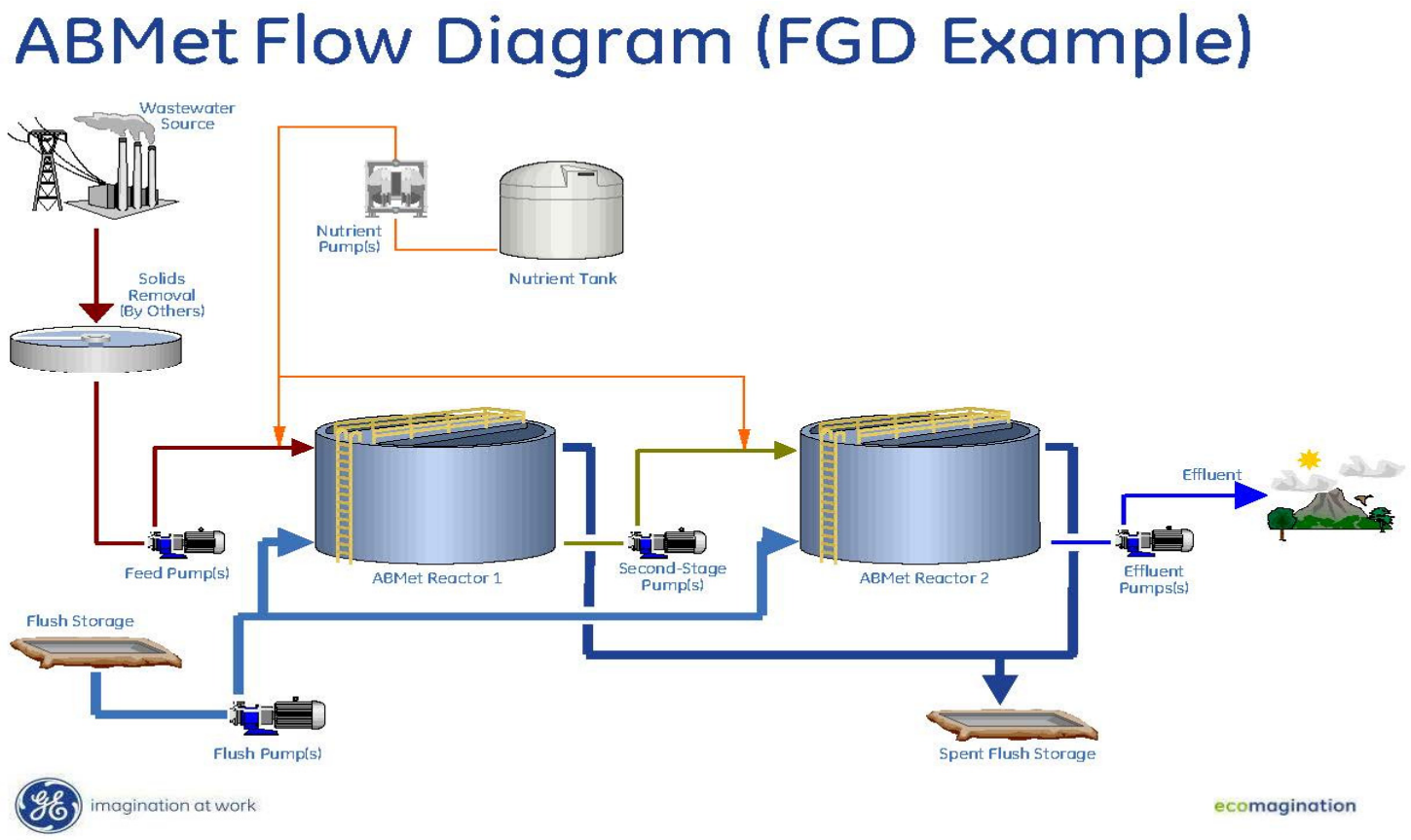
ecomagination

Basics of Biological Wastewater Treatment (cont'd)
Biochemistry of Anoxic Biological Treatment

- Process Overview: Instead of using oxygen to supply electron acceptor, as none is available, use oxygen associated with other ions:
- In order of energy available to microorganisms:

Oxygen	$O_2 \Rightarrow H_2O$
Nitrate/nitrite	$NO_3 \Rightarrow N$
Chlorate	$ClO_3 \Rightarrow Cl^-$
Selenate/Selenite	$SeO_4^{2-} \Rightarrow Se^0$
Perchlorate	$ClO_4 \Rightarrow Cl^-$
Sulfate	$SO_4 \Rightarrow S^-$
Methanogenesis	$CO_2 \Rightarrow CH_4$

GE ABMet Process



AEP Mountaineer Selenium Reduction System

American Electric Power | WV

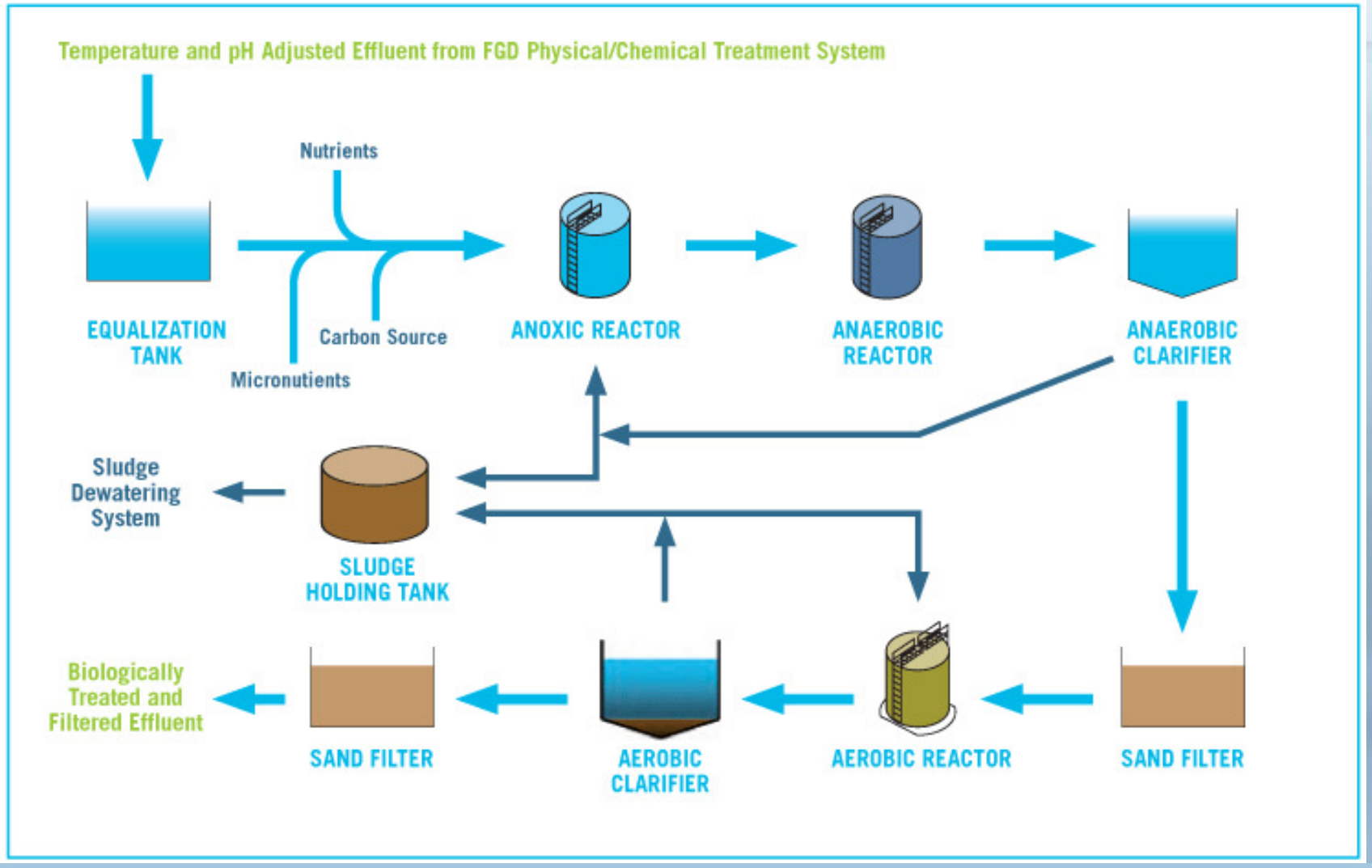
- Design/build, operational 2012
- Selenium removal
- Influent combination of FGD effluent and landfill leachate
- Included pump station and pipeline from landfill ponds
- Reduce Se from 2,500 µg/l to NPDES limit (<25 µg/l)
- GE ABmet process

Patriot Coal Selenium Reduction System

Surface Water Treatment System
Patriot Coal | WV

- Design/build project to remove selenium from surface runoff at large surface mine
- Modular system design for ease of expansion from 800 gpm to 1,500 gpm
- Effluent limits at <5 µg/l Se
- Design complete, construction to be complete 2013
- GE ABMet process.

Degremont IBIO Process

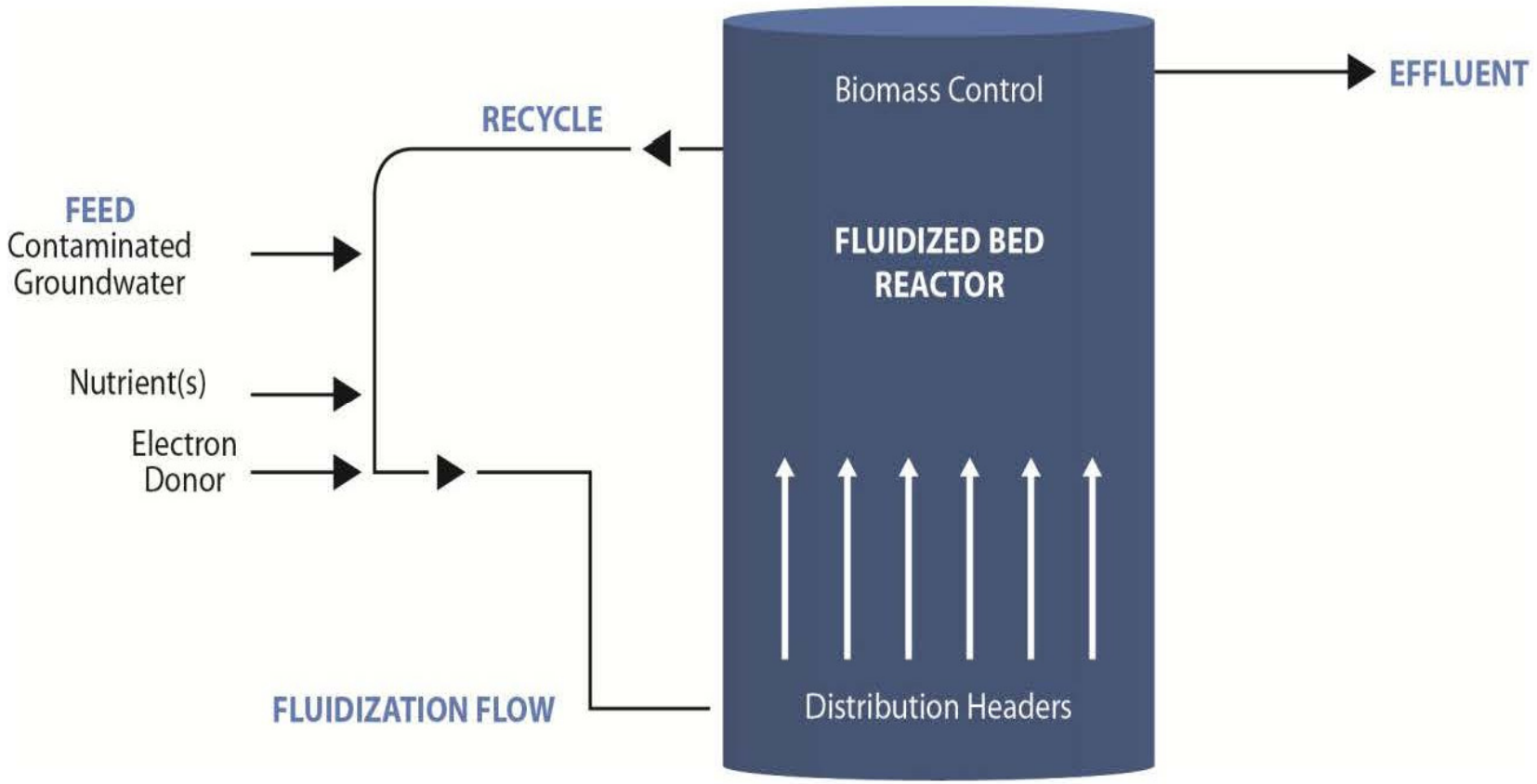


Conemaugh FGD WWTP Upgrades

Conemaugh Wastewater Treatment Facility Upgrades
GenON (NRG) | PA

- Selenium removal via iBio suspended growth process
- Boron removal using ion exchange
- Manganese removal through standard oxidation /precipitation approach.
- Retrofit to existing FGD WWTP
- Supported NPDES permit modifications

Envirogen Bio Se Removal



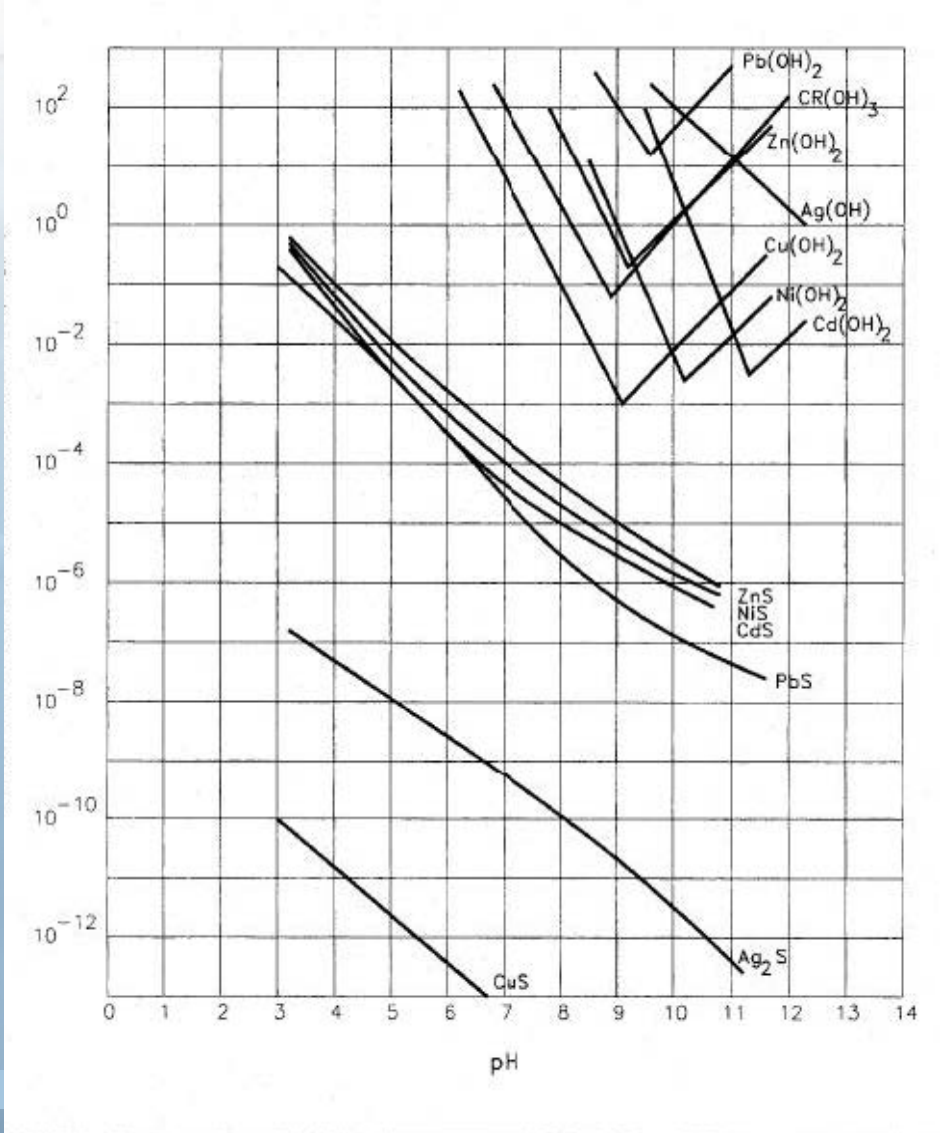
Envirogen – Nevada Perchlorate Installation

Passive Systems

- Offerings from a variety of sources including consultants, academics.
- Use recycle materials, wood chips to reduce carbon requirements/costs.
- Requires significant surface footprint.

Fringe Benefits of Bio Se Removal

- Some conversion of sulfate to sulfide occurs.
- Sulfide is very effective as a precipitant of many metals, including mercury.
- Sulfide precipitates have very low solubilities.
- Amount of sulfide generated can be influenced by ORP, which is driven in turn by food supply.



Questions ?

Contact information:
John Schubert, P.E.
HDR Engineering
2601 Cattleman Road, Suite 400
Sarasota, Fla 34232
941-342-2727
412-999-0124