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Power Plant Cooling Towers and Cooling Water Issues

McIlvaine Company Hot Topic Hour - 11 AM EST
February 16, 2012
Water Management Issues at Power Plants

- Waste Heat Removed (once through or Cooling Towers w/recycle)
- 316(b) Phase II rules will affect 670 plants
  - 343 Fossil Plants & 42 Nuclear plants will install Cooling Towers
- New Air Rules – Mercury Air Toxics (MATS) and Boiler MACT
  - Constituents to water phase?
- Steam Electric Power Generating Effluent Guidelines will impact
  - Nutrient Discharge rules
  - Affects cycles of concentration –
    - salts, metals, toxics, trace contaminants
  - Impacts discharge quality
- Water for CT becoming scarce and more expensive
- SO…
Worldwide Trends

- 2009 – 10 billion m³/yr
- 2014 – 29 billion m³/yr

Source: Global Water Intelligence
Cooling Water at Power Plants

- 95 liters (25 gal) per KW produced – average all types of generation
  - Steam for turbines, but most to cool steam
- Power is second largest US water user = 40% all freshwater withdrawals
- 43% US Power Plants use “once-through” cooling
- New plants use closed-cycle cooling – typ. 4 – 8 cycles
Cooling Tower Sources

- **Traditional (Allocation, Cost, Droughts)**
  - Surface Water
  - Groundwater

- **Untraditional (Quality, Location)**
  - Surface Runoff Capture
  - Acid Mine Drainage
  - Ash Transport Water
  - Municipal/Industrial Wastewater Effluents

- **University of Pittsburgh Study**
  - 50% of all existing US Power Plants can obtain all cooling water from POTW within 10 mile radius!
  - 78% of all existing US power plants, if radius extended to 25 miles
  - 80% of proposed power plants within 10 miles

“Reuse of Treated Internal or External Wastewaters in the Cooling Systems of Coal-Based Thermoelectric Power Plants”
Cooling Tower Sources

- **Reclaimed POTW Water Usage**
  - 5400 US Power Plants
  - 60 use reclaimed water – FL, CA, TX, AZ
  - Reclaimed water started 30+ years ago, but trend growing

- **POTW usage concerns**
  - Elevated nutrients
    - bacteria, fungi, algae
    - Forms slime coating on heat exchangers
  - Salts precipitate as scale
  - Phosphate and ammonia corrode metals
  - Emerging Concerns (typically ppb and ppt range) – Discharge, Return, Drift
    - Endocrine Disruptors (modifiers), PPCP, others

*Figure 8: Cooling Tower Makeup Water Reuse Sources*
Reuse Impediments

- Transmission line routing
  - ROW Issues – Private, Highway, Rail lines
  - Multiple Ownership
  - Efficiency Loss from Pumping Long Distances
  - Cost of Lines

- Storage
  - Closed v. Open Tanks
  - Impoundments
  - Polymer/Alum for TSS – “burps” – flocculation & settling
  - Disinfection/residual

- Where to discharge?
  - Return line to POTW
  - Surface Discharge
  - ZLD – evaporation/crystallization; Evaporation Ponds

- Higher recycle rates concentrate salts, constituents
  - TDS
  - Metals
  - Nitrogen/Nutrients to TMDL Limited waters
Reuse Impediments

- Regulatory
  - discharge quality, maintain low flow in streams
  - Cross basin transfer issues with discharge?
  - If recycle municipal wastewater, concentrate other constituents with discharge back to POTW – increased fees for concentrated wastewater?
  - Cost of reclaim water supply?
  - Cost of discharge v. ZLD?
  - Drift Constituents
  - Air Toxics, 316(b),
  - Effluent Guidelines, Nutrients rules
  - Worker Safety Programs
    - Purple Pipe
    - Training
    - Immunizations
Reclaimed Municipal Wastewater can be used for Cooling Tower Makeup at Power Plants, but…

- Almost all states have adopted some regulations
- 34 states have detailed regulations
- 16 states have guidelines or design standard
- Reuse may be permitted on a case-by-case basis
<table>
<thead>
<tr>
<th>State</th>
<th>Date</th>
<th>Regulation – (Other Parameters in Regulations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL</td>
<td>Nov 2009</td>
<td>5 mg/l TSS; 20 mg/l CBOD5; C.T. - 300 ft setback, minimize drift</td>
</tr>
<tr>
<td>CA</td>
<td>Jan 2009</td>
<td>2.2 MPN/100 ml (7 day)</td>
</tr>
<tr>
<td>TX</td>
<td>Nov 2009</td>
<td>5 mg/l BOD; 3 NTU; 20 CFU/2100 ml</td>
</tr>
<tr>
<td>AZ</td>
<td>Jan 2001</td>
<td>&lt;2 NTU; 23/100 ml</td>
</tr>
<tr>
<td>CO</td>
<td>Nov 2007</td>
<td>126/100 ml (class 2 /class 3)</td>
</tr>
<tr>
<td>VA</td>
<td>Jan 2010</td>
<td>14/100 ml FC</td>
</tr>
<tr>
<td>WA</td>
<td>Dec 2010</td>
<td>2.2/100 ml; BOD,30 mg/l</td>
</tr>
<tr>
<td>OR</td>
<td>Jun 2009</td>
<td>Oxidized. Filtered, NTU, bacteria</td>
</tr>
<tr>
<td>NC</td>
<td>2008</td>
<td>14/100 ml FC; TSS 5 mg/l; BOD 10 mg/l</td>
</tr>
<tr>
<td>MA</td>
<td>2000</td>
<td>0/100 (median); no test over 14/100 ml FC</td>
</tr>
</tbody>
</table>
Why US EPA Guidelines Updated in 2004?

- Emerging pathogens
- Increasing pressure on water resources
- Emerging pollutants of concern
  - PCPs - Personal Care Products
  - PhAC - Pharmaceutical Active Compounds
  - PPCPs - Pharmaceuticals and Personal Care Products
  - alkylphenol ethoxylates (APEOs) surfactants
  - polycyclic aromatic hydrocarbons (PAHs)
  - EDCs- Endocrine Disrupting Compounds/Chemicals
Management of Reclaimed Water CT

- Chemical control
  - Biofouling Control (slime control – bacteria, fungi, algae)
    - Sodium hypochlorite
    - Monochlormine
  - Scale Control
    - Chemical
      - pH control and dispersants
      - Polymaleic acid
      - Tetra-potassium pyrophosphate
  - Corrosion Control (phosphate, ammonia)
    - Tolytriazole
    - Sodium bromide
- Physical
  - SS, Titanium, or plastic piping
  - high flow rates for scaling issues
### Treatment - Reclaimed CT Water

<table>
<thead>
<tr>
<th>Recirculated Cooling</th>
<th>Blowdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment for cooling tower cycles of concentration</td>
<td>Chemical</td>
</tr>
<tr>
<td>Filtration/backwash</td>
<td>MF/UF</td>
</tr>
<tr>
<td>Lime softening</td>
<td>RO</td>
</tr>
<tr>
<td>Alum precipitation</td>
<td>AOP</td>
</tr>
<tr>
<td>Ion Exchange</td>
<td>UV</td>
</tr>
<tr>
<td>Membranes</td>
<td>H$_2$O$_2$</td>
</tr>
<tr>
<td>pH control</td>
<td>O$_3$</td>
</tr>
<tr>
<td>Solids/sludge management</td>
<td></td>
</tr>
</tbody>
</table>
## Case Study Examples

<table>
<thead>
<tr>
<th>Usage of Reclaimed Water</th>
<th>Number of Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Tower makeup</td>
<td>46</td>
</tr>
<tr>
<td>Cooling Ponds</td>
<td>2</td>
</tr>
<tr>
<td>Air Scrubbers</td>
<td>2</td>
</tr>
<tr>
<td>Injected to Increase Pressure at Geothermal Fields</td>
<td>2</td>
</tr>
<tr>
<td>Boiler Feed Water</td>
<td>1</td>
</tr>
<tr>
<td>Cooling Tower Makeup and Scrubber Water</td>
<td>1</td>
</tr>
</tbody>
</table>
Case Study Examples – Panda Plant, MD

- 248 MW Combined Cycle - 1997
- 1.5 mgd in 17 mile pipeline
- 8-10 cycles of concentration
- Mattawoman POTW
  - UV Disinfection
  - Panda adds sodium hypochlorite
  - POTW discharge limit 3 mg/l N

Panda Plant Aerial View
Reclaim Water
Cooling Tower
Recirculation pumps
South Florida

Miami Dade SW WWTP Effluent to Cool the Proposed FPL Turkey Point Nuclear Reactor Unit 7 – 75 MGD

- Citizens Groups challenged on many issues
- Florida Crocodiles
- Endocrine Disrupters, PPCP in Drift
West Basin Recycling Facility Produces 5 types of Reclaimed Water (30 mgd)

- Tertiary Water (Title 22) for a variety of industrial and irrigation uses;
- Nitrified Water for industrial cooling towers;
- Softened Reverse Osmosis Water: Secondary treated wastewater purified by micro-filtration (MF), reverse osmosis (RO), and disinfection for groundwater recharge;
- Pure Reverse Osmosis Water for refinery low-pressure boiler feed water; and
- Ultra-Pure Reverse Osmosis Water for refinery high-pressure boiler feed water.
Contaminants of Emerging Concern (CEC)

- Pharmaceuticals and Endocrine Disruptors
- Natural hormones – human or animal
  - Natural chemicals – produced by plants – phyto-estrogens
  - Synthetic pharmaceuticals hormonally active – such as the contraceptive pill
- Other man-made chemicals. Including:
  - cosmetics, medical compounds, pesticides, industrial chemicals
  - Alkylphenols; polycyclic aromatic hydrocarbons;
  - organohalogenes; triorganotins
Surfactants and Pesticides

- **Surfactants**
  - Alkyl Phenol Ethoxylates (APEO) widely used in industries
  - Nonylphenol ethoxylate is the most common
  - APEOs tend to be degraded to more potent endocrine disrupting compounds during wastewater treatment

- **Pesticides**
  - Largest group of EDCs
  - DDT, dieldrin, 2,4-D, tributyltin, atrazine, metolachlor, cyanazine, alachlor
  - All herbicides, fungicides, pesticides
  - Atrazine the most difficult to remove

- **Other Compounds**
  - Polyaromatics, PCB, flame retardants, phthalates
## Potency of Steroid Compounds

<table>
<thead>
<tr>
<th>EDC</th>
<th>Lowest Observed Effective concentration (LOEC)-Rainbow Trout</th>
<th>WWTP Effluent Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estradiol</td>
<td>1 ng/l</td>
<td>&lt;0.2 – 3 ng/l</td>
</tr>
<tr>
<td>Ethinyl estradiol</td>
<td>0.1 ng/l</td>
<td>&lt;0.2 – 3 ng/l</td>
</tr>
<tr>
<td>Nonylphenol</td>
<td>14,000 ng/l</td>
<td>&lt;80 – 923 ng/l</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>25,000 ng/l</td>
<td>8 – 33 ng/l</td>
</tr>
</tbody>
</table>

German Study – Berlin Ruhlenben WWTP – Hansen et al, 1998)
Zora’a Vineyard (Kibbutz Tzora)

- Hebrew University studied health risks of drift from spray irrigation with reclaimed water
  - no increased incidence of disease in reclaimed water-user & workers compared to other workers.
- 30 km creek system from Jerusalem, secondary, disinfected effluent
- Used since 1960s
- 40 ha vineyard growing sauvignon blanc and cabernet sauvignon for own small boutique winery. Potable water after budding
- The Kibbutz also has a 50 ha almond orchard, 200 ha of olives and a 900 cow dairy from which the off-run water is used directly for cotton growing.
Blowdown/Effluent Treatment

- Passive Treatment
- Active Treatment
Passive Treatment - Constructed Wetlands

- Imitate the environment
- Aerobic, anoxic & anaerobic zones
- Effective at mercury removal to very low levels (0.04-0.09 to <0.008 µg/L)
- Removes COD, BOD, ammonia
- Other ions
  - manganese – boron - selenium
Active Treatment Processes

- Wastewater treatment – particularly higher SRTs (nitrification and BNR/ENR) can provide significant removals.
- Granular Activated Carbon
- Reverse Osmosis
- Advanced Oxidation Processes
  - UV
  - H2O2
  - O3
## Treatment Efficiencies

<table>
<thead>
<tr>
<th>EDC Classification</th>
<th>Coagulation/ Flocculation</th>
<th>Softening/ metal oxides</th>
<th>CL2/ ClO2</th>
<th>UV</th>
<th>Ozone/ AOPs</th>
<th>Activated Carbon</th>
<th>BAC</th>
<th>NF</th>
<th>RO</th>
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</thead>
<tbody>
<tr>
<td>Pesticides</td>
<td>&lt;20%</td>
<td>70-90%</td>
<td>70-90%</td>
<td>&gt;90%</td>
<td>20-90%</td>
<td>&gt;90%</td>
<td>90%</td>
<td>70-90%</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Industrial Chemicals</td>
<td>&lt;20-40%</td>
<td>&lt;20-40%</td>
<td>&lt;20%</td>
<td>&gt;90%</td>
<td>40-90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Steroids</td>
<td>&lt;20%</td>
<td>&lt;20-40%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
<td>70-90%</td>
<td>&gt;90%</td>
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<tr>
<td>Metals</td>
<td>40-90%</td>
<td>40-90%</td>
<td>&lt;20%</td>
<td>&lt;20%</td>
<td>&lt;20-40%</td>
<td>40-70%</td>
<td>70-90%</td>
<td>&gt;90%</td>
<td></td>
</tr>
<tr>
<td>Inorganics</td>
<td>&lt;20%</td>
<td>70-90%</td>
<td>&lt;20%</td>
<td>40-90%</td>
<td>20-90%</td>
<td>70-90%</td>
<td>70-90%</td>
<td>70-90%</td>
<td>&gt;90%</td>
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<tr>
<td>Organometalics</td>
<td>&lt;20-40%</td>
<td>&lt;20-40%</td>
<td>&lt;20-70%</td>
<td>40-90%</td>
<td>20-90%</td>
<td>70-90%</td>
<td>70-90%</td>
<td>70-90%</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>
Conclusions

Coming “Perfect Storm” impacting Power Plants – more cooling towers!
- Reuse growing quickly
- Many different standards/concerns
  - Bacteria, TSS, turbidity, etc.
  - Virus
  - Endocrine Disruptors - Estrogens
  - PPCP
  - Others
- Lots of Impediments to Overcome
- Good History Worldwide
- Public Perception
  - Don’t Underestimate Public Opinion!

Advantages
- History of successful projects
- Reduces pollutant load in discharges
- Saves potable water
- Provides reliable supply
- May save energy
QUESTIONS??

Thank You
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