Ivan A. Cooper, PE, BCEE

Power Plant Cooling Towers and Cooling Water Issues

McIlvaine Company Hot Topic Hour - 11 AM EST
February 16, 2012

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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…

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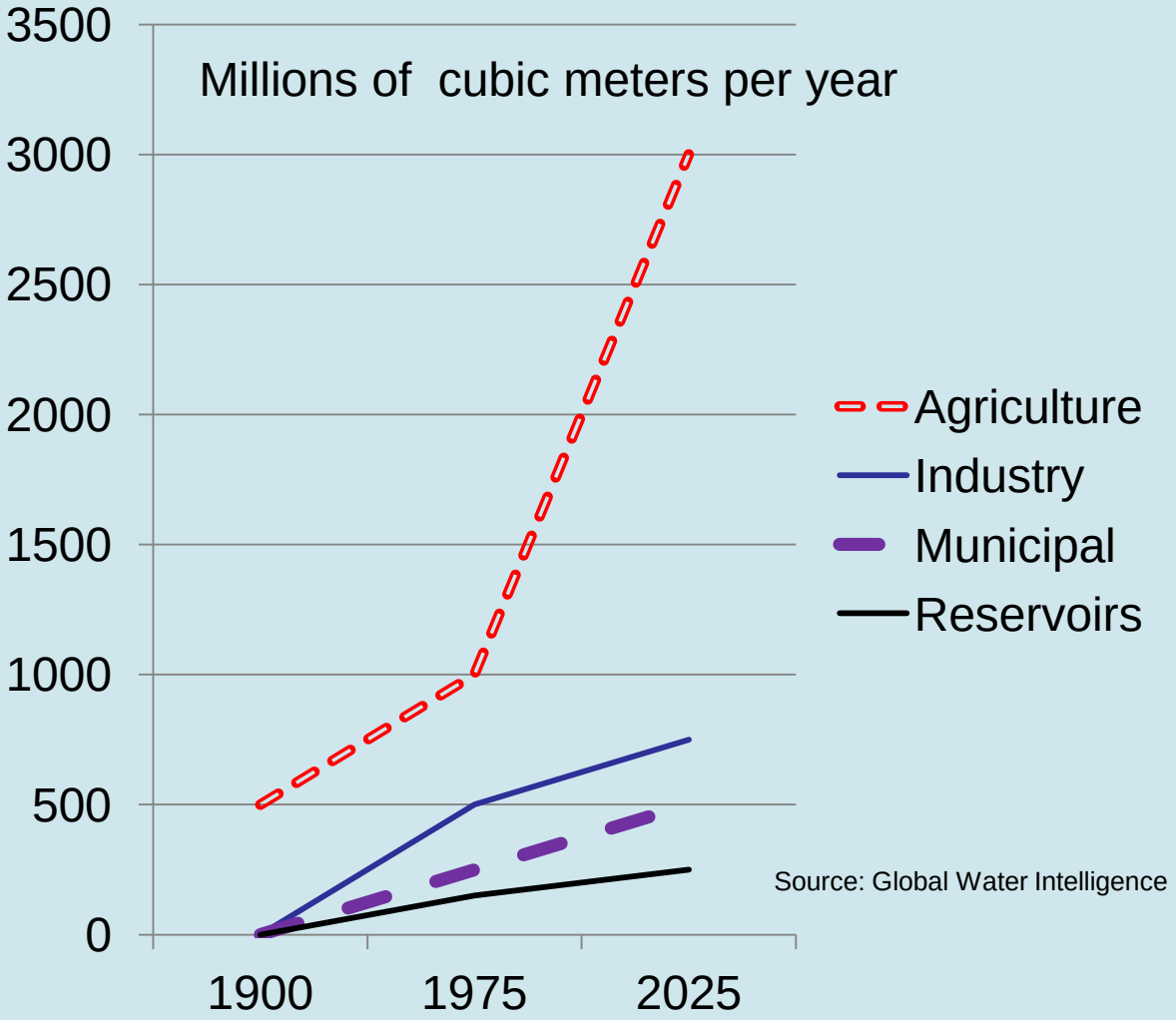
Worldwide Trends

- 2009 – 10 billion m^3/yr
- 2014 – 29 billion m^3/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

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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”

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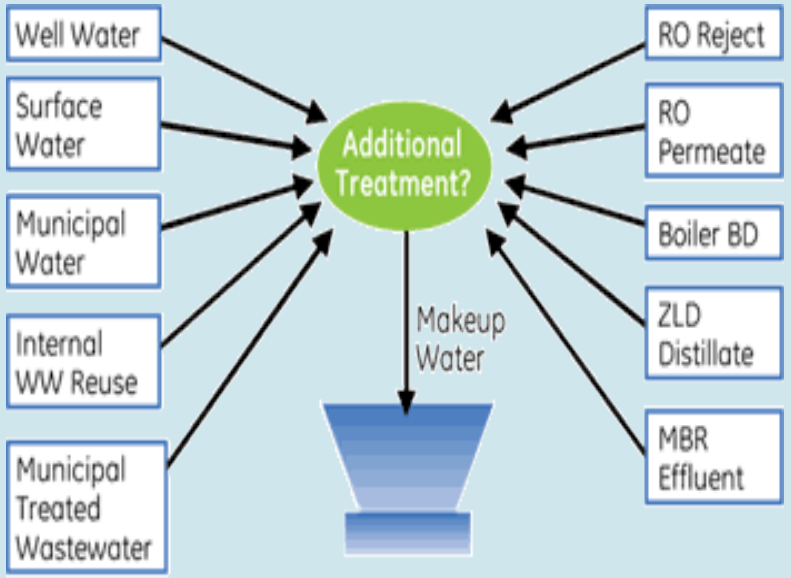
Cooling Tower Sources

- 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



Cooling towers can use many sources of lower quality water with proper pretreatment design and chemical treatment

Figure 8: Cooling Tower Makeup Water Reuse Sources

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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

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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

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US Water Reuse Regulations/Guidelines

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

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Unrestricted US Urban Reuse Regulations

State	Date	Regulation – (Other Parameters in Regulations)
FL	Nov 2009	5 mg/l TSS; 20 mg/l CBOD5; C.T. - 300 ft setback, minimize drift
CA	Jan 2009	2.2 MPN/100 ml (7 day)
TX	Nov 2009	5 mg/l BOD; 3 NTU; 20 CFU/2100 ml
AZ	Jan 2001	<2NTU; 23/100 ml
CO	Nov 2007	126/100 ml (class 2 /class 3)
VA	Jan 2010	14/100 ml FC
WA	Dec 2010	2.2/100 ml; BOD,30 mg/l
OR	Jun 2009	Oxidized. Filtered, NTU, bacteria
NC	2008	14/100 ml FC; TSS 5 mg/l; BOD 10 mg/l
MA	2000	0/100 (median); no test over 14/100 ml FC

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

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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

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Treatment - Reclaimed CT Water

- **Recirculated Cooling**
  - Treatment for cooling tower cycles of concentration
    - Filtration/backwash
    - Lime softening
    - Alum precipitation
    - Ion Exchange
    - Membranes
    - pH control
  - Solids/sludge management

Blowdown

- Chemical
- MF/UF
- RO
- AOP
  - UV
  - H_20_2
  - O_3

Case Study Examples

Usage of Reclaimed Water	Number of Facilities
Cooling Tower makeup	46
Cooling Ponds	2
Air Scrubbers	2
Injected to Increase Pressure at Geothermal Fields	2
Boiler Feed Water	1
Cooling Tower Makeup and Scrubber Water	1

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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

Reclaim Water Cooling Tower Recirculation pumps

Panda Plant Aerial View

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

El Segundo, CA

- **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.

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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;
  - organohalogens; triorganotins

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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

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Potency of Steroid Compounds

EDC	Lowest Observed Effective concentration (LOEC)-Rainbow Trout	WWTP Effluent Concentrations
Estradiol	1 ng/l	<0.2 – 3 ng/l
Ethinyl estradiol	0.1 ng/l	<0.2 – 3 ng/l
Nonylphenol	14,000 ng/l	<80 – 923 ng/l
Bisphenol A	25,000 ng/l	8 – 33 ng/l

German Study – Berlin Ruhlenben WWTP – Hansen st al, 1998)

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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.

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Blowdown/Effluent Treatment

- Passive Treatment
- Active Treatment

Passive Treatment - Constructed Wetlands

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

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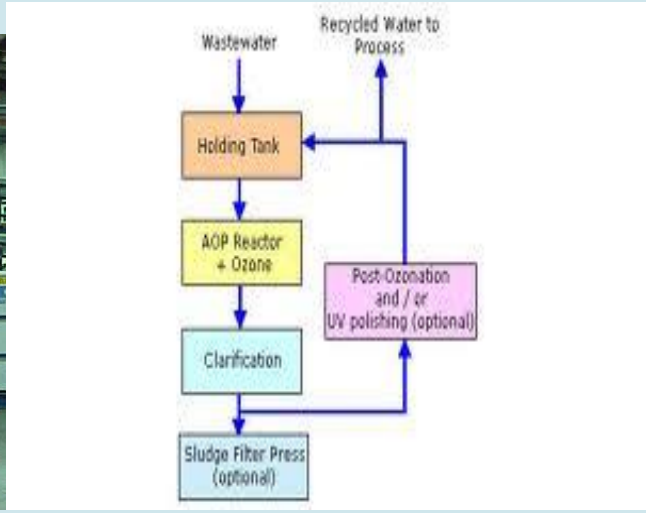
Active Treatment Processes

- Wastewater treatment – particularly higher SRTs (nitrification and BNR/ENR) can provide significant removals.
- Granular Activated Carbon
- Reverse Osmosis
- Advanced Oxidation Processes
  - UV
  - H202
  - O3



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Treatment Efficiencies

EDC Classification	Coagulation/ Flocculation	Softening/ metal oxides	CL2/ ClO2	UV	Ozone/ AOPs	Activated Carbon	BAC	NF	RO
Pesticides	<20%	70-90%	70-90%	>90%	20-90%	>90%	90%	70-90%	>90%
Industrial Chemicals	<20-40&	<20-40%	<20%	>90%	40-90%	>90%	>90%	>90%	>90%
Steroids	<20%	<20-40%	>90%	>90%	>90%	>90%	>90%	70-90%	>90%
Metals	40-90%	40-90%	<20%	<20%	<20%	<20-40%	40-70%	70-90%	>90%
Inorganics	<20%	70-90%	<20%	40-90%	20-90%	70-90%	70-90%	70-90%	>90%
Organometalics	<20-40%	<20-40%	<20-70%	40-90%	20-90%	70-90%	70-90%	70-90%	>90%

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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

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QUESTIONS??

Thank You

ivan_cooper@golder.com