USE OF TREATED MUNICIPAL WASTEWATER IN POWER PLANT COOLING SYSTEMS

David Dzombak, Carnegie Mellon University
Radisav Vidic, University of Pittsburgh

AAEES Conference

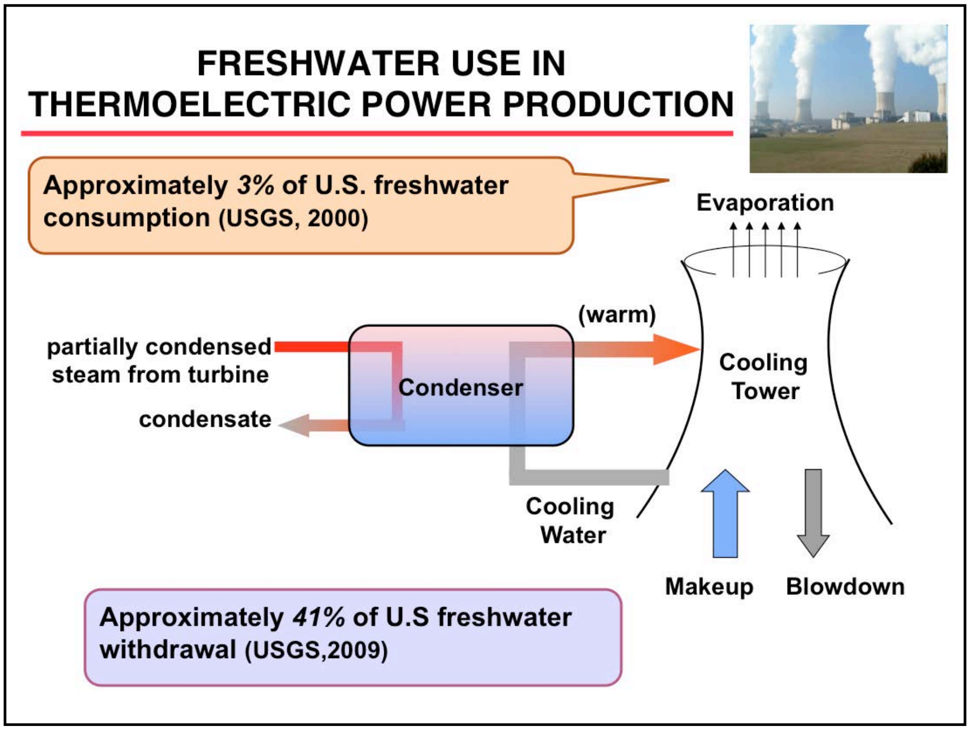
April 25, 2013

OVERVIEW

- Water requirements in thermoelectric power production
- Alternative waters for power plant cooling
- Reuse of secondary treated municipal wastewater for power plant cooling
- Summary

WATER-ENERGY NEXUS

- Water is needed for thermoelectric power production, in acquiring and shipping fuels, and in generating power (primarily for cooling)
- Air cooling is much less efficient and more expensive than water cooling
- In next 25 years, US population will grow by 50-80 million and electricity demand by 30%
- Available surface water supplies are fixed (and largely allocated) and groundwater supplies are depleting



In a thermoelectrice power plant, freshwater is withdrawn to a cooling tower system.

The main function of the cooling water is to cool the steam which is used to generate electricity.

Cooling water becomes warmer after passing through the heat exchanger and then enters a cooling tower.

In the cooling tower, evaporation of the cooling water cools the water for further circulation.

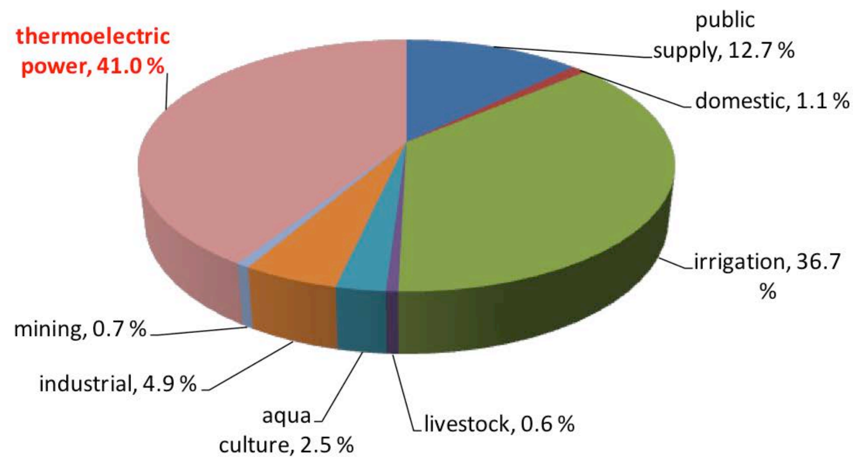
Because evaporation takes pure water from the system, continuous injection of makeup water and rejection of blowdown are necessary to maintain cooling water quantity and quality.

And the ratio of the total solid concentration in the cooling water to the makeup water is defined as cycles of concentration.

The situation is that, …..

So there is abundant of freshwater use for thermoelectric power plant and the demand is increasing.

2005 FRESHWATER WITHDRAWALS IN US



Source: USGS (2009) *Estimated use of water in the United States in 2005*. Circular 1344

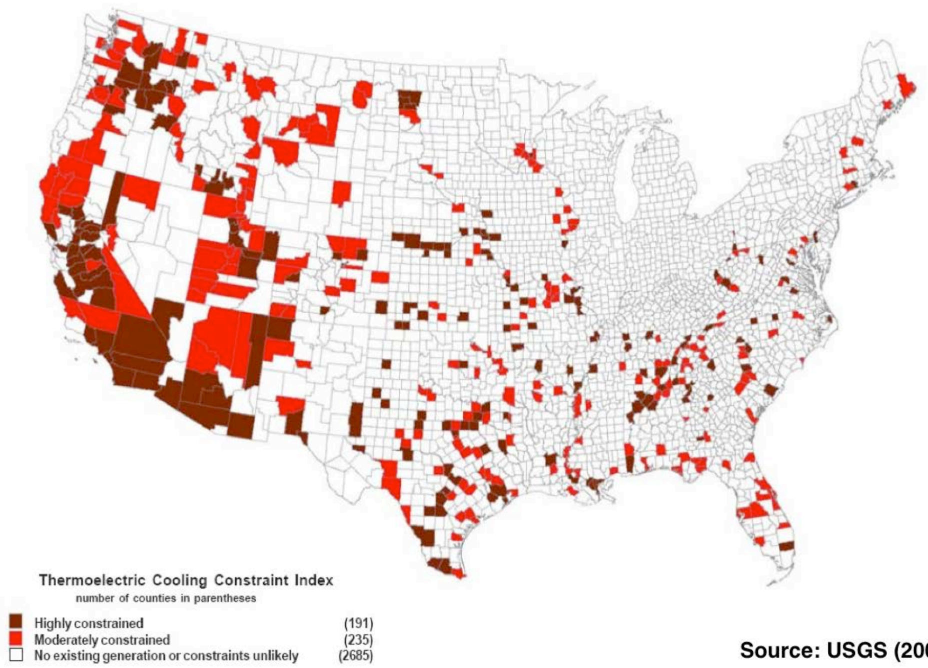
POWER PLANT COOLING TECHNOLOGY BY GENERATION TYPE

- Once–through cooling: 25-30 gal/kwh
- Recirculating cooling: 0.6 – 1.2 gal/kwh
- Across all types of power plants, 43% are water once-through and 42% are water recirculating

Plant type	Recirc water (%)	Once-through water (%)	Dry (%)	Cooling Pond (%)
Coal	48.0	39.1	0.2	12.7
Nuclear	43.6	38.1	0.0	18.3
All	41.9	42.7	0.9	14.5

Source: USDOE/NETL, 2009

LIMITATIONS IN WATER AVAILABILITY FOR POWER PLANT COOLING



Source: USGS (2004)

ALTERNATIVE WATER SOURCES FOR THERMOELECTRIC POWER PRODUCTION – FOR RECIRCULATING SYSTEMS

- Treated municipal wastewater
- Mine drainage
- Industrial process waters
- Saline groundwater
- Seawater

SOME NON-SEAWATER ALTERNATIVE SOURCES OF COOLING WATER

Municipal Wastewater

Ash Pond Water

Abandoned Mine Drainage

1. Municipal waste water effluents are a complex mixture of human waste, suspended solids, debris and a variety of chemicals that come from residential, commercial and industrial activities.
2. Mine drainage refers to the outflow of acidic water from abandoned metal or coal mines. Passive treated system for AMD includes Wetland, alkalinity producing pond, anoxic limestone drains, limestone ponds, etc.
3. Ash is the byproduct from coal combustion. The fly ash travels with flue gas and portion of the fly ash is captured in wet scrubbers together with sulfur dioxide. Then enter a pond for settling.

REUSE OF TREATED MUNICIPAL WASTEWATER IN THE COOLING SYSTEMS OF THERMOELECTRIC POWER PLANTS

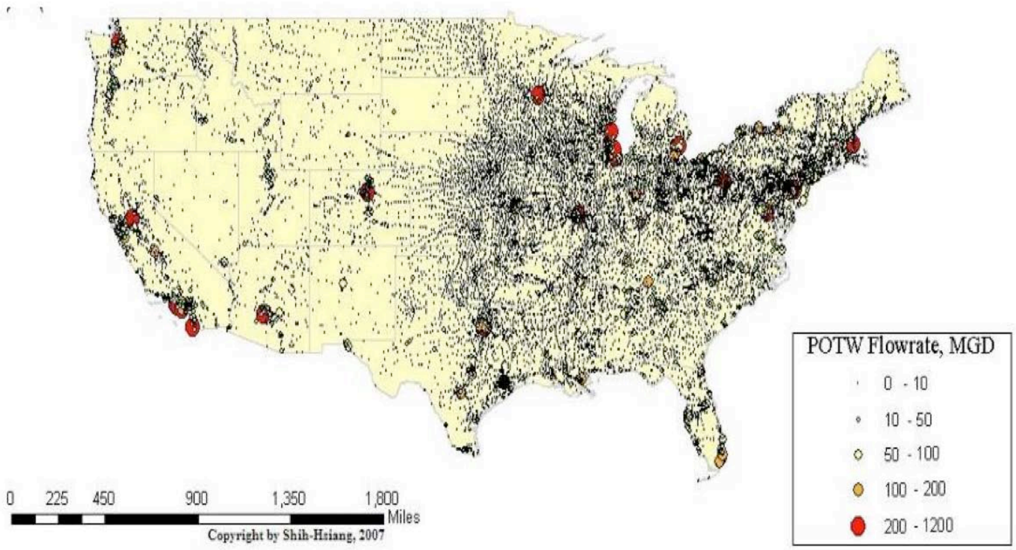
- 11.4 trillion gallons of municipal wastewater collected and treated annually in U.S.
- Experience with use of treated municipal water for power plant cooling in arid west; e.g., Burbank, Las Vegas, Phoenix
- Significant additional treatment beyond secondary treatment (e.g., clarification, filtration, N and P removal)

REDHAWK AND PALO VERDE POWER PLANTS

- Redhawk: 530MW, natural gas
- Palo Verde: 4000 MW, nuclear
- Use treated municipal wastewater from Phoenix
- RPS: 6.5 MGD
- PVNGS: 68 MGD
- Additional treatment at power plant: chlorination, pH adjustment, phosphorus removal, membrane filtration

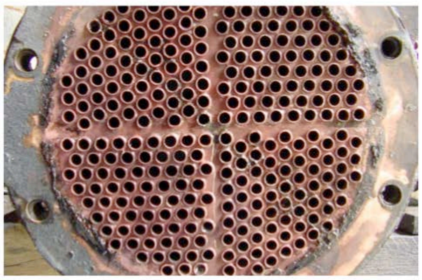
INVENTORY OF AVAILABLE WASTEWATER

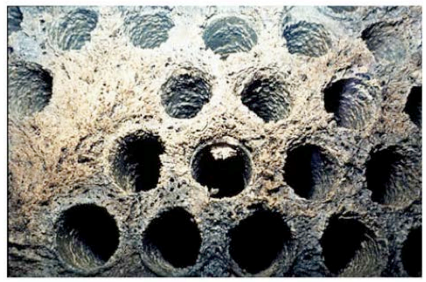
GIS-based tool developed to assess availability of secondary effluent from publicly owned treatment works (17864 POTWs in lower 48 states).



KEY TECHNICAL CHALLENGES WITH THE USE OF IMPAIRED WATERS

- Precipitation and scaling
- Accelerated corrosion
- Biomass growth

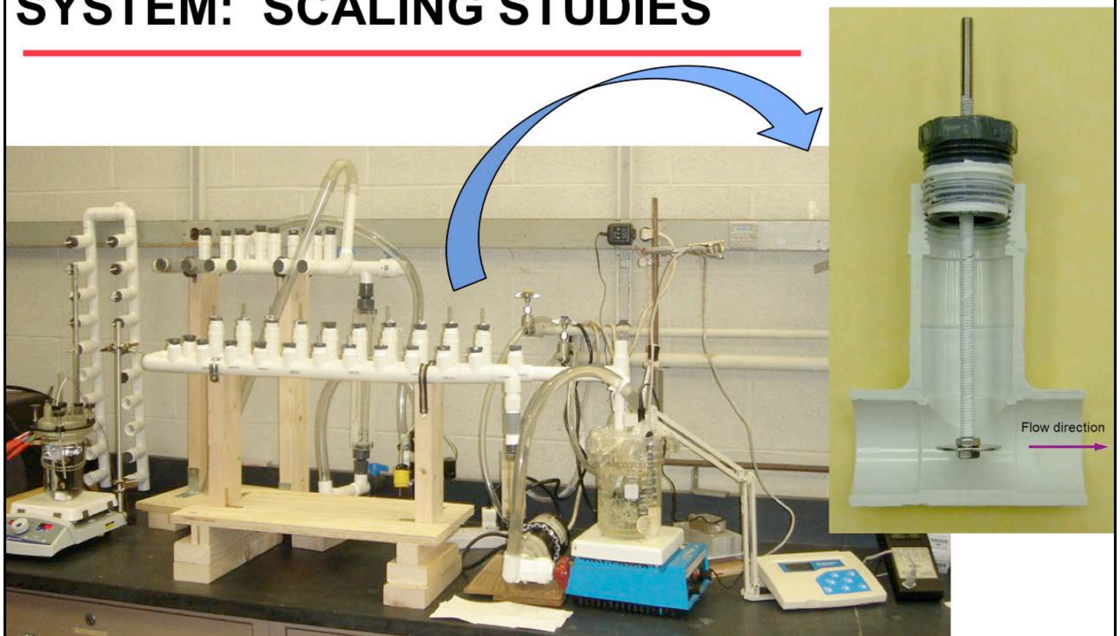




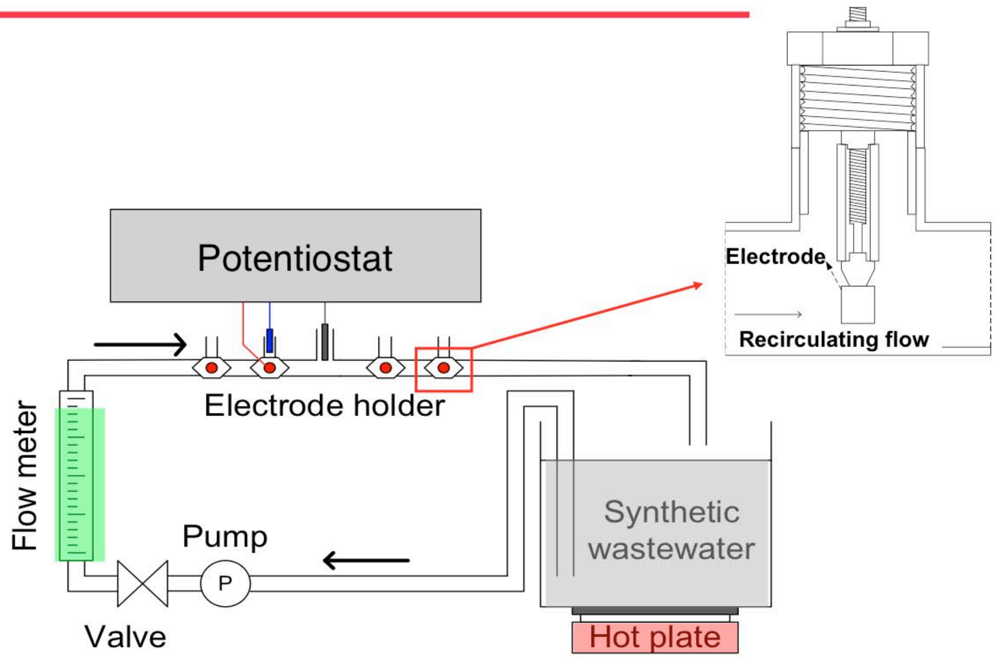
CARNEGIE MELLON – UNIV PITTSBURGH USDOE PROJECT GOALS

- Evaluate feasibility of controlling corrosion, scaling, and biofouling through different combinations of phys/chem/bio treatment
- Evaluate performance, costs, and environmental impacts of different treatment combinations
- Develop methods of measuring corrosion, scaling; evaluate mechanisms

BENCH-SCALE WATER RECIRCULATING SYSTEM: SCALING STUDIES



BENCH-SCALE WATER RECIRCULATING SYSTEM: CORROSION STUDIES



PILOT SCALE COOLING TOWERS

Franklin Township Municipal Sanitary
Authority, Murrysville, PA

PILOT SCALE COOLING TOWERS

PILOT SCALE COOLING TOWERS

MILD STEEL FROM PILOT B2 AFTER 21-d EXPOSURE (before/after acid cleaning)

SCALE DEPOSITION COUPONS FROM PILOT-SCALE TESTS

(a) (b) (c)

Test coupons in the pilot-scale tests: (a) MWW on day-58; (b) MWW_NF on day-50; (c) MWW_pH on day-58

SUMMARY: SCALING AND CORROSION

- Various strategies for controlling scaling and corrosion to acceptable levels (inhibitors; pH control; removal of PO_4, NH_3, organic matter)
- Tradeoffs: e.g., PO_4 reduces corrosion, but increases scaling; lower pH reduces scaling, increases corrosion
- Determining optimal approach requires testing and modeling

SUMMARY: BIOFOULING

- Secondary-treated wastewater has high potential for biofouling
- Addition of chlorine as a biocide impaired effectiveness of antiscalants and accelerated corrosion
- Chloramine found to be an effective biocide and much less corrosive than chlorine

ISSUES WITH THE USE OF IMPAIRED WATERS FOR POWER PLANT COOLING

- Optimization problem: Extent of pretreatment before use and chemical addition for control
- Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) of the alternatives
- Regulatory issues
- Social acceptance issues

SUMMARY

- Water needs for thermoelectric power production are substantial: 41% of all freshwater withdrawal.
- With increasing population and growing economy, increasing electricity demand
- Alternative water sources are needed for cooling in electric power production
- Impaired waters can be alternative water sources, but are more costly and complex to manage

ACKNOWLEDGMENTS

- Carnegie Mellon students: M.K. Hsieh, I. Chowdhury, R. Theregowda, M. Choudhury
- Univ Pittsburgh students: S.H. Chien, H. Li, Y. Feng, W. Liu, B. Niblick
- Univ Pittsburgh faculty: A. Landis, J. Monnell
- Franklin Township Municipal Sanitary Authority, Reliant Energy, St. Vincent College
- U.S. Dept of Energy, National Energy Technology Laboratory (DE-FC26-06NT42722, DE-NT0006550)

ADDITIONAL INFORMATION

http://cooling.ce.cmu.edu/
http://www.waterreuse.pitt.edu/
http://www.waterreuse.pitt.edu/Publications.asp


FTMSA