Energy & Environmental Research Center (EERC)

WASTEWATER RECYCLING USING A HYGROSCOPIC COOLING SYSTEM

2020 Virtual Review for DE-FE0031810

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Christopher L. Martin

PROJECT TEAM

Technical Team and Contacts:

- **Energy & Environmental Research Center**
  Christopher Martin, Ph.D.
- **Baltimore Aircoil Company**
  Yohann Rousselet, Ph.D.
- **Great River Energy**
  Patrick Schwartz, P.E.

Project Sponsors:

- **Department of Energy, National Energy Technology Laboratory**
  Barbara Carney, Project Manager
- **North Dakota Industrial Commission Lignite Energy Council**
  Michael Holmes, Project Manager

PROJECT GOALS AND OBJECTIVES

Technological Goals

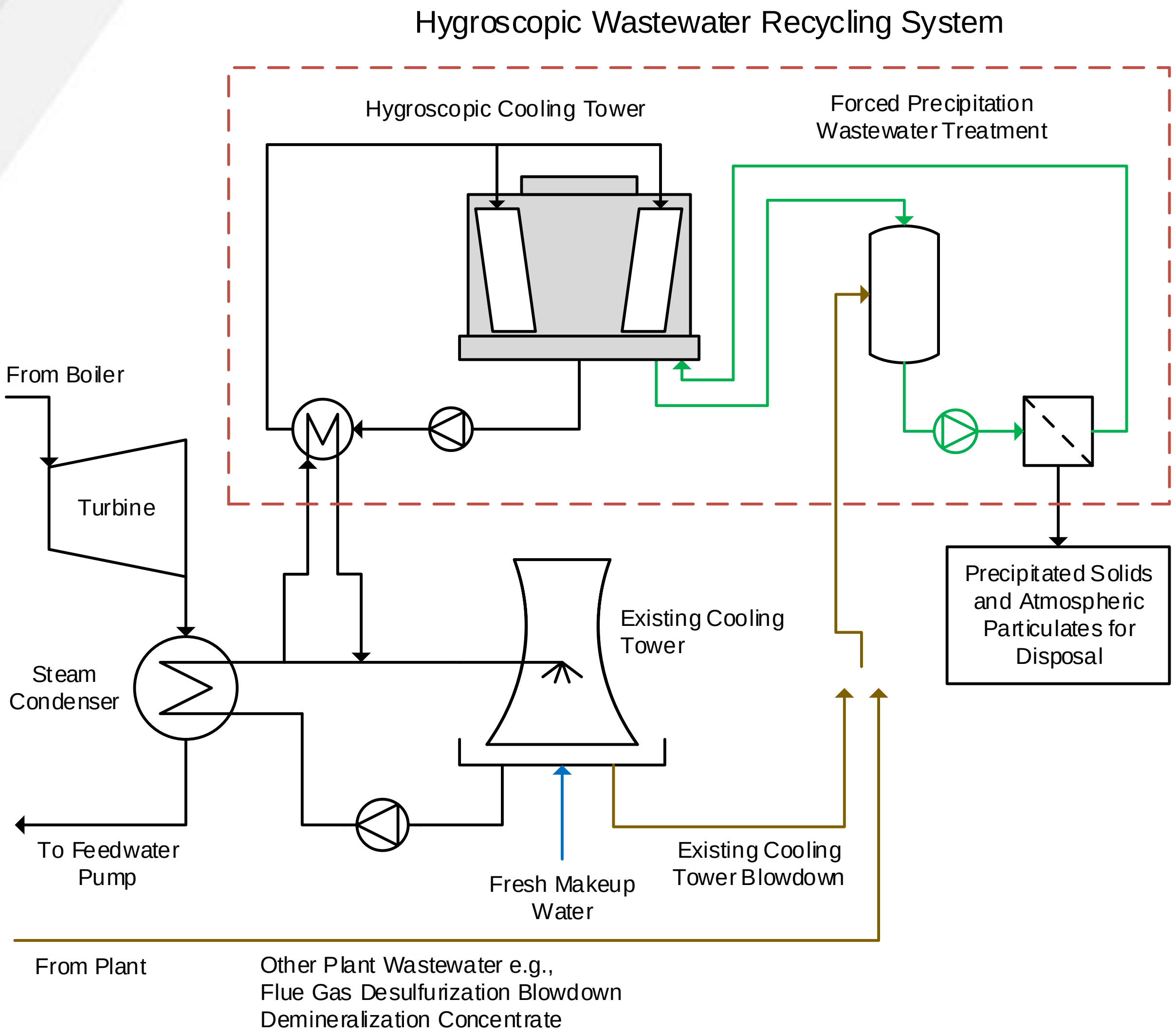
- Improve the water use efficiency of power plants.
- Provide cost-effective zero-liquid-discharge (ZLD) compliance.

Project Objectives

- Survey wastewater streams; determine optimal use parameters for hygroscopic recycling.
- Determine the fate of bulk and trace constituents entering with the wastewater.
- Analyze solid by-products; determine appropriate disposal options.
- Prepare a techno-economic analysis of the concept.

Coal Creek Station host site.

POWER PLANT WASTEWATER RECYCLING



- This project will test the feasibility of using the EERC's hygroscopic cooling technology to eliminate power plant wastewater by recycling the water fraction to augment the plant's cooling load, while collecting the dissolved solids as a precipitated by-product for reuse or disposal.
- The concept improves the water use efficiency of existing plants while mitigating regulatory issues associated with wastewater discharge.

HYGROSCOPIC COOLING

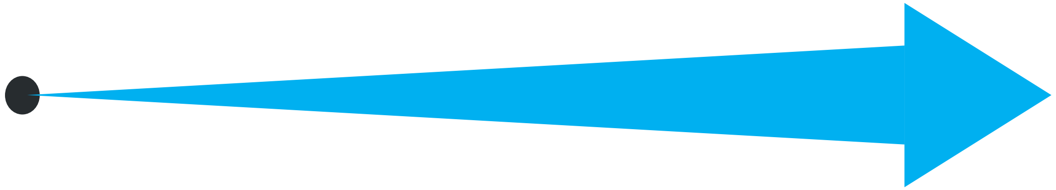
- **Fundamental Concept:** achieve water savings by substituting a liquid desiccant for pure water as a cooling tower working fluid.
- Water conserved via two mechanisms:
  - Increased sensible heat transfer under cool ambient temperatures.
  - Blowdown is eliminated, all makeup water is evaporated for cooling, and dissolved solids are collected as a precipitate.
- Concept previously demonstrated using potable water as makeup. Key differences with power plant wastewater include:
  - 10 to 100 times higher quantity of total dissolved solids (TDS).
  - Different slate of dissolved species, e.g., Na_2SO_4-dominated versus $CaCO_3$.

Demonstration site for a hygroscopic cooling system using potable water makeup.

QUALITATIVE ZLD COMPARISON

	Disposal-Only ZLD	Hygroscopic Wastewater Recycling	Thermomechanical ZLD
Example Systems	Evaporation ponds, injection wells	This project	Mechanical vapor compressor/evaporator; thermal brine crystallizer
Water Recovery	No	Indirectly by displacing makeup cooling water	Yes, typically high quality
Input Energy	Low, limited to pumping energy	Primary energy input is waste heat from the plant’s condenser cooling circuit; some electricity needed for tower pump and fan	High-quality thermal or mechanical energy to drive phase change

Lower operational costs, but a suitable site is necessary.

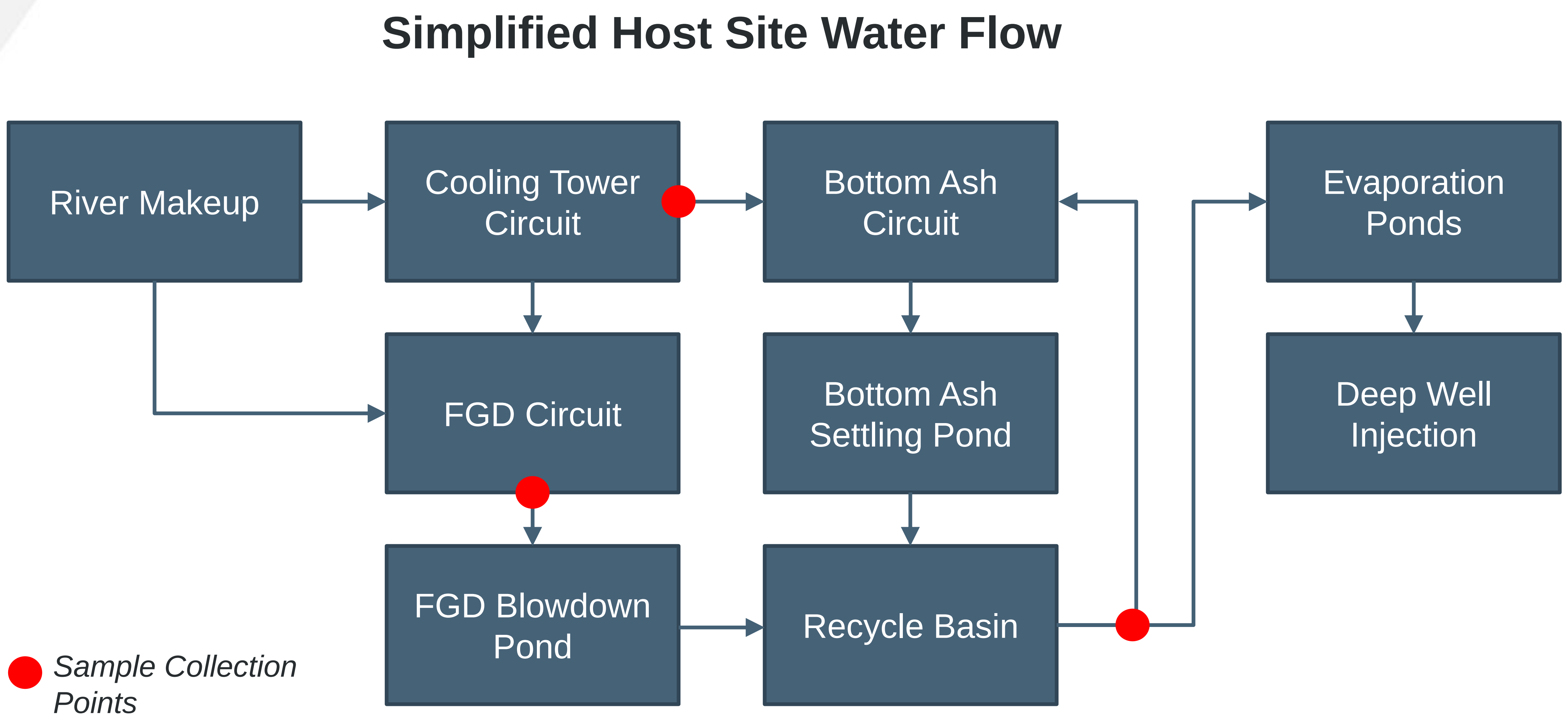


Increasing usefulness of recovered water along with increasing operational cost.

PROJECT UPDATE

- Wastewater samples collected at the host site and analyzed.
- Laboratory evaluation of wastewater–desiccant interactions has been completed.
- Design of the small pilot system is under way, and key components are on order.
- In discussion with host site regarding test setup.

SAMPLE COLLECTION



WASTEWATER ANALYSIS

- Samples were analyzed for major species and elements regulated under the Resource Conservation and Recovery Act (RCRA).
- Prevailing anion in these streams is sulfate with cations of Na^+ and Mg^{2+}.
- RCRA element analysis (next slide) suggests that steady-state, precipitated solids would classify as nonhazardous.

	Cooling Tower Blowdown	FGD Blowdown	Recycle Basin
pH	7.29	5.33	7.79
Alkalinity, as HCO_3	75	26.5	239
Alkalinity, as $CaCO_3$	61.5	21.7	196
Ca, as Ca	712	391	734
Mg, as Mg	313	8030	1190
Sr, as Sr	6.43	1.02	13.6
Na, as Na	898	4280	1680
K, as K	59.6	492	176
Li, as Li	0.9	3.4	1.3
Si, as SiO_2	92.0	102.7	55.6
Cl, as Cl	227	1240	440
F, as F	5.8	150	6.5
Br, as Br	< 1	420	130
Sulfate, as SO_4	4200	34,900	8800
Nitrate, as NO_3	< 5	< 5	< 5
Nitrite, as NO_2	< 5	< 5	9.8
P, as PO_4	< 6.1	16	< 6.1
B, as BO_3	12	278	81
Total Organic Carbon	42.2	63.6	26.9
Total Dissolved Solids	6920	57,600	14,800

Concentration values in mg/L.

RCRA ELEMENT ANALYSIS

Measured Concentration, mg/L

RCRA Metals	Cooling Tower Blowdown	FGD Blowdown	Ash Pond Recycle
As	0.0346	0.0285	0.108
Ba	0.5	0.17	0.31
Cd	< 0.01	< 0.01	< 0.01
Cr	< 0.05	< 0.05	< 0.05
Pb	< 0.005	< 0.005	< 0.005
Hg	< 0.0001	0.00473	< 0.0001
Se	0.014	0.45	0.017
Ag	< 0.05	< 0.05	< 0.05

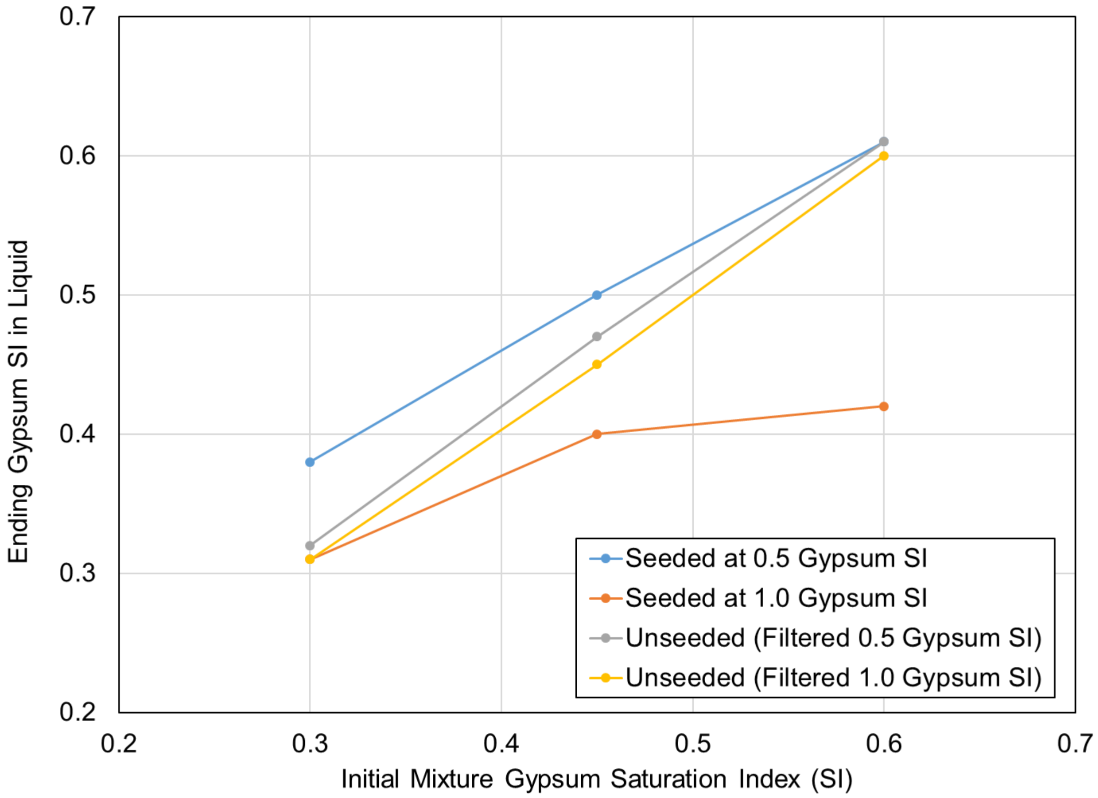
Calculated* Maximum Leachate Concentration of Residual Solids, mg/L (20:1 dilution)

RCRA Metals	Cooling Tower Blowdown	FGD Blowdown	Ash Pond Recycle	EPA Regulatory Limit
As	0.250	0.0247	0.365	5
Ba	3.61	0.148	1.05	100
Cd	0.0723	0.00868	0.0338	1
Cr	0.361	0.0434	0.169	5
Pb	0.0361	0.00434	0.0169	5
Hg	0.000723	0.00411	0.000338	0.2
Se	0.101	0.391	0.0574	1
Ag	0.361	0.0434	0.169	5

* Less than values used in the leachate concentration calculation.

WASTEWATER–DESICCANT INTERACTIONS

- A series of laboratory, batch-mixing experiments was completed to determine design parameters for the small pilot system, including:
  - The saturation index (SI) range for spontaneous nucleation of dissolved solids within the desiccant working fluid.
  - The desaturation approach to equilibrium conditions and the kinetics of precipitation.
- Additional lab-scale tests, and modeling, were done to evaluate the density separation gradient of particulates within the desiccant.



Precipitation test results for mixtures of plant wastewater (from the recycle basin) and the desiccant working fluid. These results bound the expected level of desaturation using seed particles and the initial conditions necessary to create effective seeds.

SMALL PILOT SYSTEM

- The key evaluation metric for this process is the ability to operate on a continuous, rather than batch, basis. A small pilot system will be used to evaluate sustainable dissolved solids control.
- Pilot testing will be done at a host site power plant to have continuous wastewater and waste heat access.
- System sizing specifications include:
  - 2 gpm (7.6 lpm) maximum wastewater treatment flow.
  - 200 gpm (760 lpm) corresponding condenser water heat source flow.
  - 3 to 7 kg/hr solids production rate based on the measured dissolved solids.

Existing condenser cooling circuit access points at the host site; these connections are planned to be used for the pilot system.

CONCLUDING REMARKS

Strategic Alignment

- Hygroscopic wastewater recycling could be retrofit to existing power plants that are unsuitable for conventional ZLD options, such as an injection well or evaporation pond. Furthermore, operation of the hygroscopic system would be synergistic with plant needs by providing cooling while displacing cooling water makeup.
- Laboratory testing thus far supports the evaluation of this concept by having identified key design parameters for a continuous, small pilot system.

Next Steps

- Proceed with fabrication of the small pilot system.
- Plan to set up the pilot at the host site in the second calendar quarter of 2021 for testing.

Christopher L. Martin
Principal Engineer
cmartin@undeerc.org
701.777.5083 (office)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

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