



Cleaning up liquid waste streams at thermoelectric power plants

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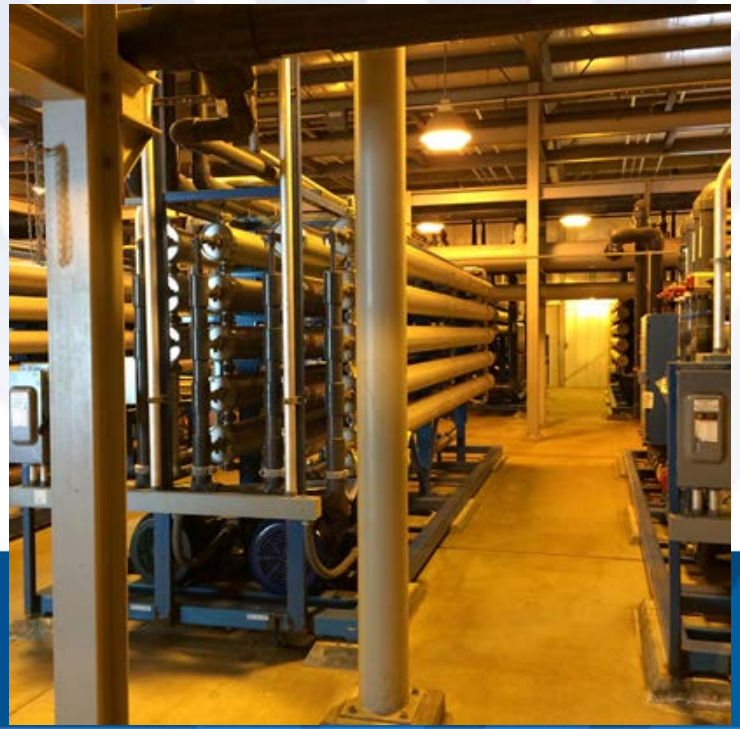
Terminology

- Intake: TSS removal
- Cooling circuit
  - Blowdown
- Boiler feed-TDS removal-Reverse Osmosis
  - RO reject
- Ash pond hydraulic water
- FGD liquids



Ash and FGD disposal methods

Dry handling of FGD solids

And fly ash

Water Balances

	conventional PC [a]	Supercritical ZLD [b]		
	Q	Q	EC	
water circuit	gpm	gpm	µS/cm	notes
river intake	10621	4500	300	
TSS trt only		4500		
RO raw	468	250		
RO Reject	143	90	600	to UG mine to AMD plant
RO Permeate	325	160	0.06	boiler feed
CT makeup	9178	4250	300	
Blowdown	2938	750	2250	to scrubber makeup
CT Evaporation	6240	3500		
FGD water	650	>90%		To stack gas
FGD water		<10%		retained in FGD solids
Service water	325	0		dry handling
Discharge	4056	0		

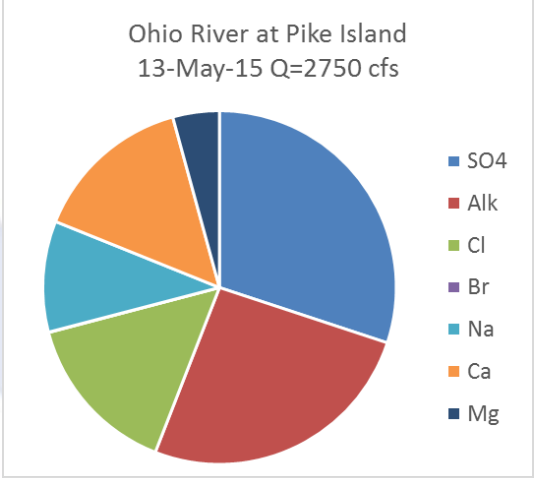
[a] 780 mW conventional

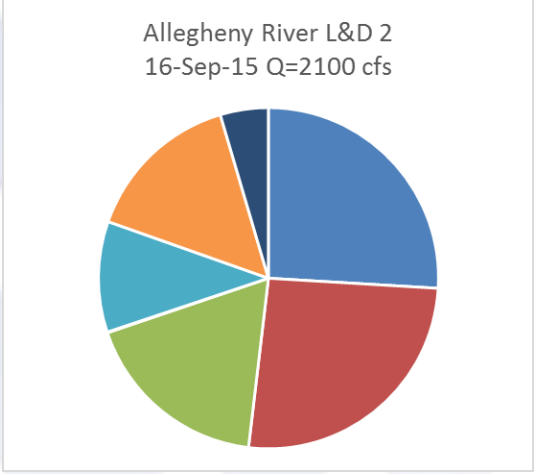
[b] 780 mW supercritical/ZLD

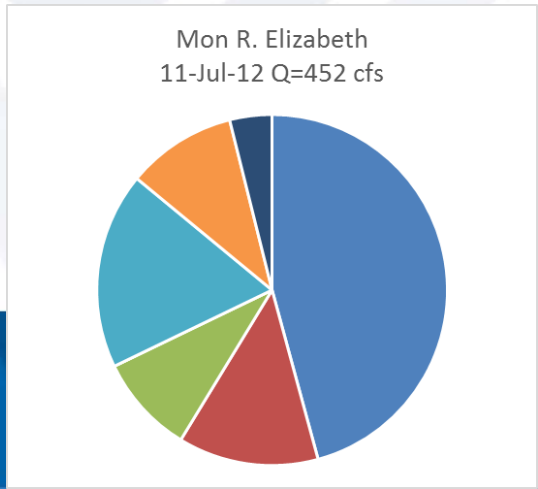
Just below gypsum saturation

Low Flow WQ

	units	Ohio Pike Island 13-May-15	Monongahela Elizabeth PA 11-Jul-12	Allegheny Highland Pk. 16-Sep-15
Q	cfs	2750	452	2100
T	°C	19	29	25
EC	µS/cm	337	649	313
pH		7.7	7.4	7.8
TDS_{sdc}	mg/L	182	345	198
SO4	mg/L	63	169	59
Alk	mg/L	54	48	59
Cl	mg/L	31	34	41
Br	mg/L	0.1	BDL	0.2
Na	mg/L	21	67	24
Ca	mg/L	31	37	34
Mg	mg/L	9	14	10
Fe	mg/L	0.0	0.0	0.0
Mn	mg/L	0.5	0.0	0.0
Al	mg/L	0.0	0.0	0.0
Acid	mg/L	1.2	0.1	0.3







System water: volume/chemistry

water circuit	gpm	µS/cm		notes
river intake	10621	300	µS/cm	
RO Reject	143	600	µS/cm	to UG mine to AMD plant
RO Permeate	325	0.06	µS/cm	boiler feed
Blowdown	2938	2250	µS/cm	to scrubber makeup
FGD water	650	>20,000	mg TDS/L	Ca, SO4, Cl, Br, Hg
Ash hydraulic	325	<3,000	mg TDS/L	As, B, Se, TDS, SO4, Hg
Discharge	4056			

Water Treatment-Physics

- Gibbs Free Energy
  - $\Delta G = \Delta H - T\Delta S$
  - *H*=enthalpy-constant
  - *T*=temp-constant
  - *S*=entropy-not constant
- So: if *H* and *T* are constant,

  Δfree energy= Δentropy

Partitioning of free energy in saline water treatment

Free energy=water potential:

$\Psi = \Psi o + \Psi m + \Psi p$

- *o*=osmotic potential-free energy **depression** caused by solutes
- *m*=matric potential-free energy **depression** caused by sorption forces
- *p*=pressure potential-free energy **increase or decrease** due to +/- pressure on closed system
- Temperature also increases free energy

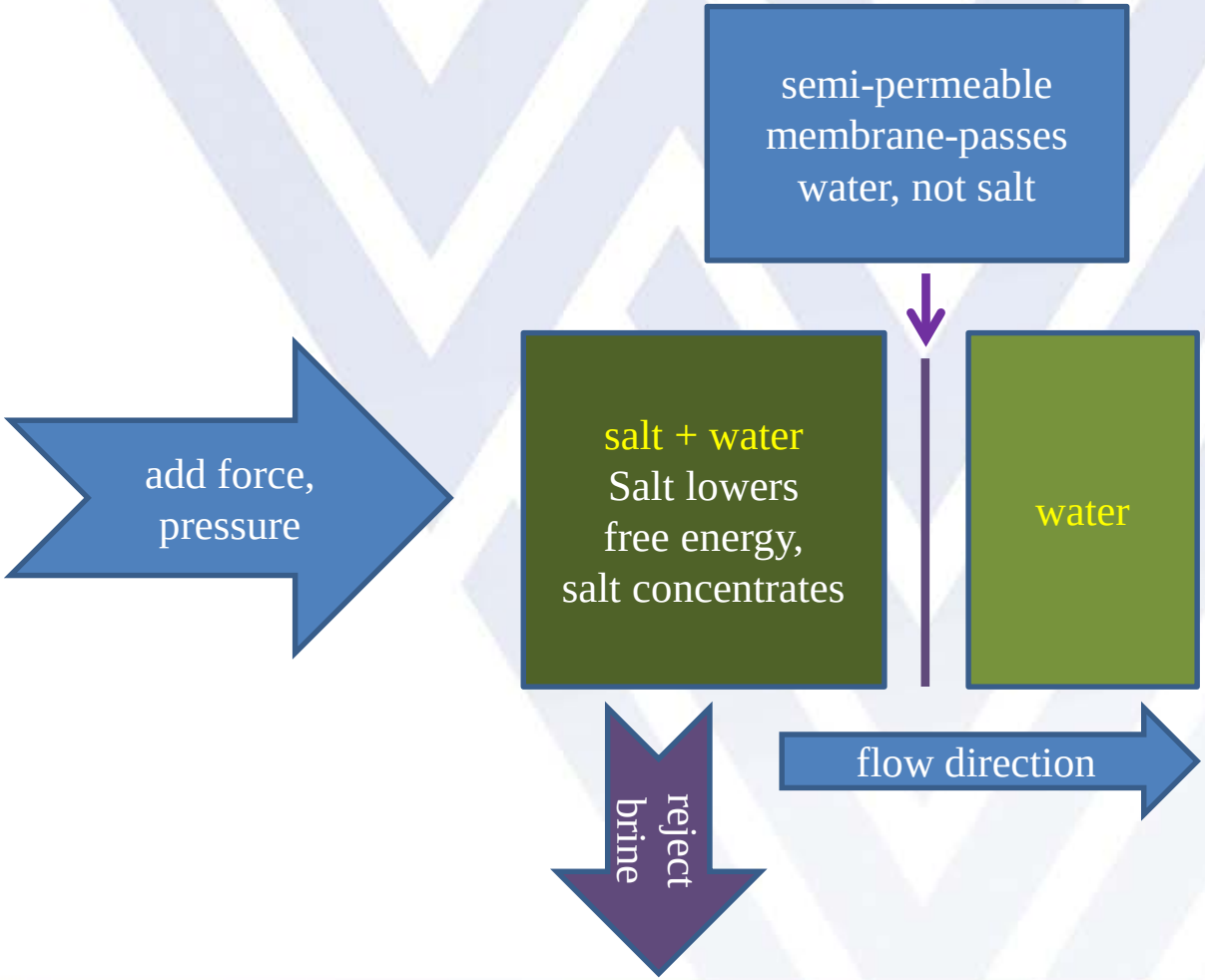
REVERSE OSMOSIS, NANO FILTRATION

If water is near the salt solubility limit, the reject rate will increase or membranes will clog

as salt concentration increases in the left cell the amount of force required to overcome free energy depression also increases.

Also, salt concentrations will eventually exceed the solubility limit and cause membrane clogging.

$CaSO_4$:	**2,505 mg/L**
Na_2SO_4:	195,000 mg/L
NaCl:	360,000 mg/L
Na_2CO_3	215,000 mg/L



As, Se in ash pond water

Ashpond water	Result	Units
Arsenic, As (total)	20.83	µg/L
Arsenic, As (dissolved)	19.46	µg/L
Arsenate, As^{+5}	16.91	µg/L
Arsenite, As^{+3}	6.52	µg/L
Selenium, Se (total)	33.67	µg/L
Selenium, Se (dissolved)	33.38	µg/L
Selenate, Se^{+6}	10.27	µg/L
Selenite, Se^{+4}	23.40	µg/L

sorbs to FeOOH

Treatment options

liquid	Q gpm	target contaminants	treatment methods
river intake	10621	suspended solids	Lamallar separators, clear wells
Boiler feed	325	all ions, low concentrations	RO
RO Reject	143	all ions, modest concentrations	LS, NF/RO
Blowdown	2938	Ca, Mg, CO3, SO4	LS, RO
FGD water	650	Ca, SO4, Cl, Br, Hg	LS, RO
Ash hydraulic	325	As, B, Se, TDS, SO4, Hg	FeOOH, Evaporation, wetlands

Lime Softening: $Ca, Mg\,SO_4 + Na_2CO_3 = Ca, Mg\,CO_3\,(s) + Na_2SO_4$

Thank you and always know your route in advance