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Landfill Leachate Impacts from Coal Ash and Exploration & Production Wastes

NEW YORK SOLID WASTE ASSOCIATIONS SOLID WASTE/RECYCLING CONFERENCE & TRADE SHOW

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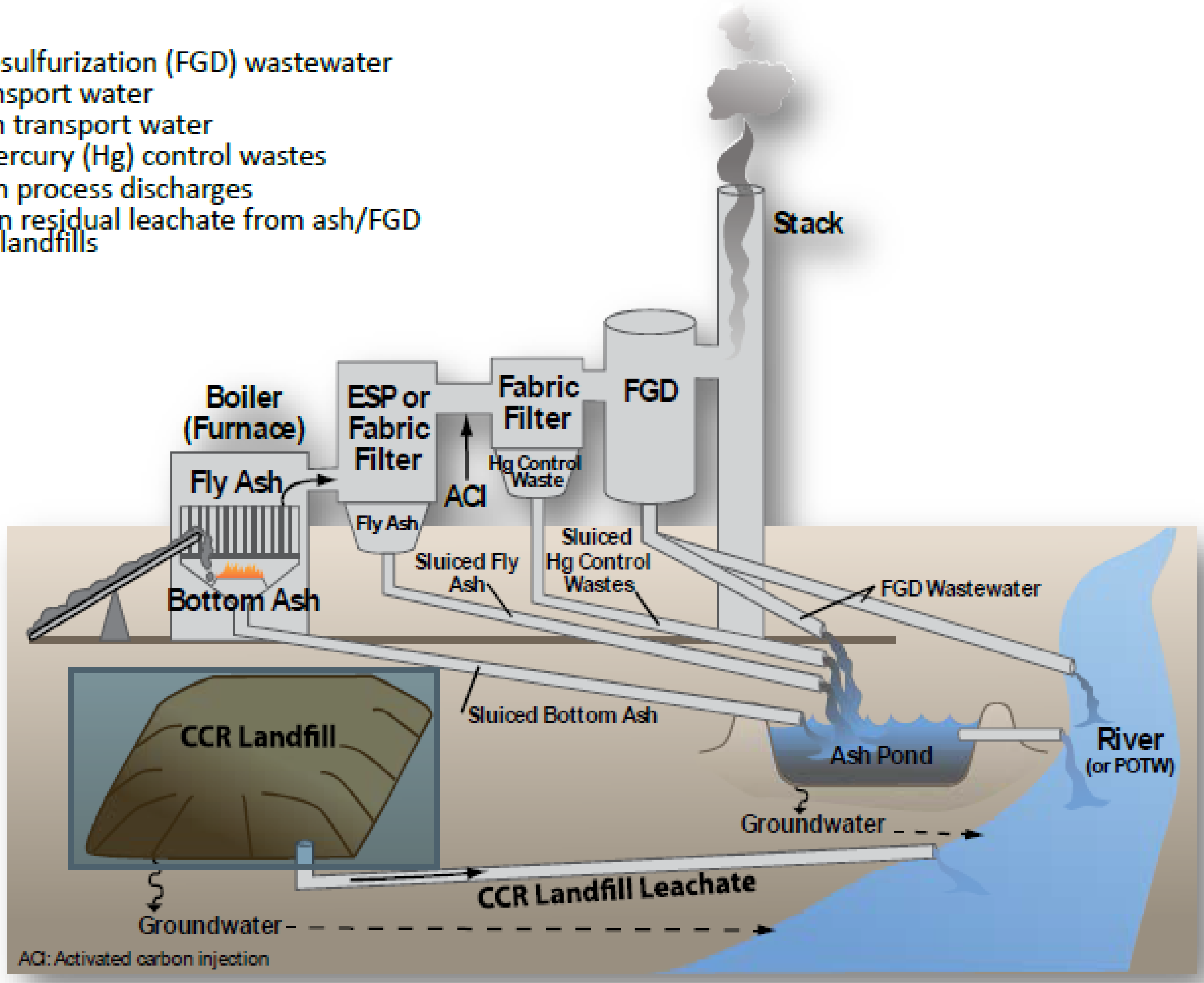
Introduction

- **Mixed Waste and Coal Ash Landfills**
- **E&P Waste Generation**
- **What's in These Wastes - Leachate Concentrations**
- **What are the Impacts on Leachate Composition**
- **Considerations for Treatment Design & Operations**
- **Conclusions**

Coal Fired Power Plant Waste Sources

- Flue gas desulfurization (FGD) wastewater
- Fly ash transport water
- Bottom ash transport water
- Flue gas mercury (Hg) control wastes
- Gasification process discharges
- Combustion residual leachate from ash/FGD ponds and landfills



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CC- Coal Combustion Residuals

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Types of Coal Power Plant Wastes

► Fly Ash

- Ash collected by particulate control equipment
- Fine grained, silt-size
- Spherical, well-graded within the fine fraction
- Class F non-cementing from eastern coal – no cohesion
- Class C self-cementing from western coal
- Dry Density 65 to 90 pcf
- Friction angle 25^o to 45^o ; typical 30^o to 35^o
- Permeability 10^{-4} to 10^{-6} cm/sec ; typical $5x10^{-4}$ cm/sec

Types of Coal Power Plant Wastes

- **Bottom Ash**
  - Ash that falls to bottom of boiler
  - Fine to coarse grained, sand size
  - Angular, well-graded
  - Dry Density 65 to 100 pcf
  - Friction angle 25^o to 45^o; typical 35^o to 40^o
  - Permeability 10^{-1} to 10^{-3} cm/sec ; typical $5x10^{-3}$ cm/sec

- **Boiler Slag is similar to Bottom Ash – but more coarse. Not usually a factor in regard to engineering properties – low quantity of total waste**

Types of Coal Power Plant Wastes

► Flue Gas Desulfurization (FGD)

- By-product of scrubber system used to reduce sulfur dioxide – scrubbers utilize lime or pulverized limestone
- Fine grained, silt size; similar to fly ash
- Ranges from no cohesion (synthetic gypsum) to self-cementing; variable depending on system
- Dry Density 65 to 90 pcf
- Permeability 10^{-4} to 10^{-7} cm/sec; depends on Calcium Sulfate (gypsum)or Calcium Sulfite (wet or dry scrubber and/or whether or not there is forced oxidation)

CCR and MSW Leachate Comparison - Background

- Electric Power Research Institute (EPRI, 2006) “Characterization of Field Leachates at Coal Combustion Product Management Sites.”
  - 33 sites in 15 states
  - Varies by coal type and combustion/collection process
  - Constituents are highest in FGD leachate, then in ash landfill leachate, and then in ash impoundment samples.
  - CCR leachates are moderately to strongly alkaline regardless of coal type or process.
- Univ Wisconsin Studies
  - Looked at leachate concentrations & ionic strength
  - High ionic strength caused higher permeability of clay & GCL liners.

CCR and MSW Leachate Comparison

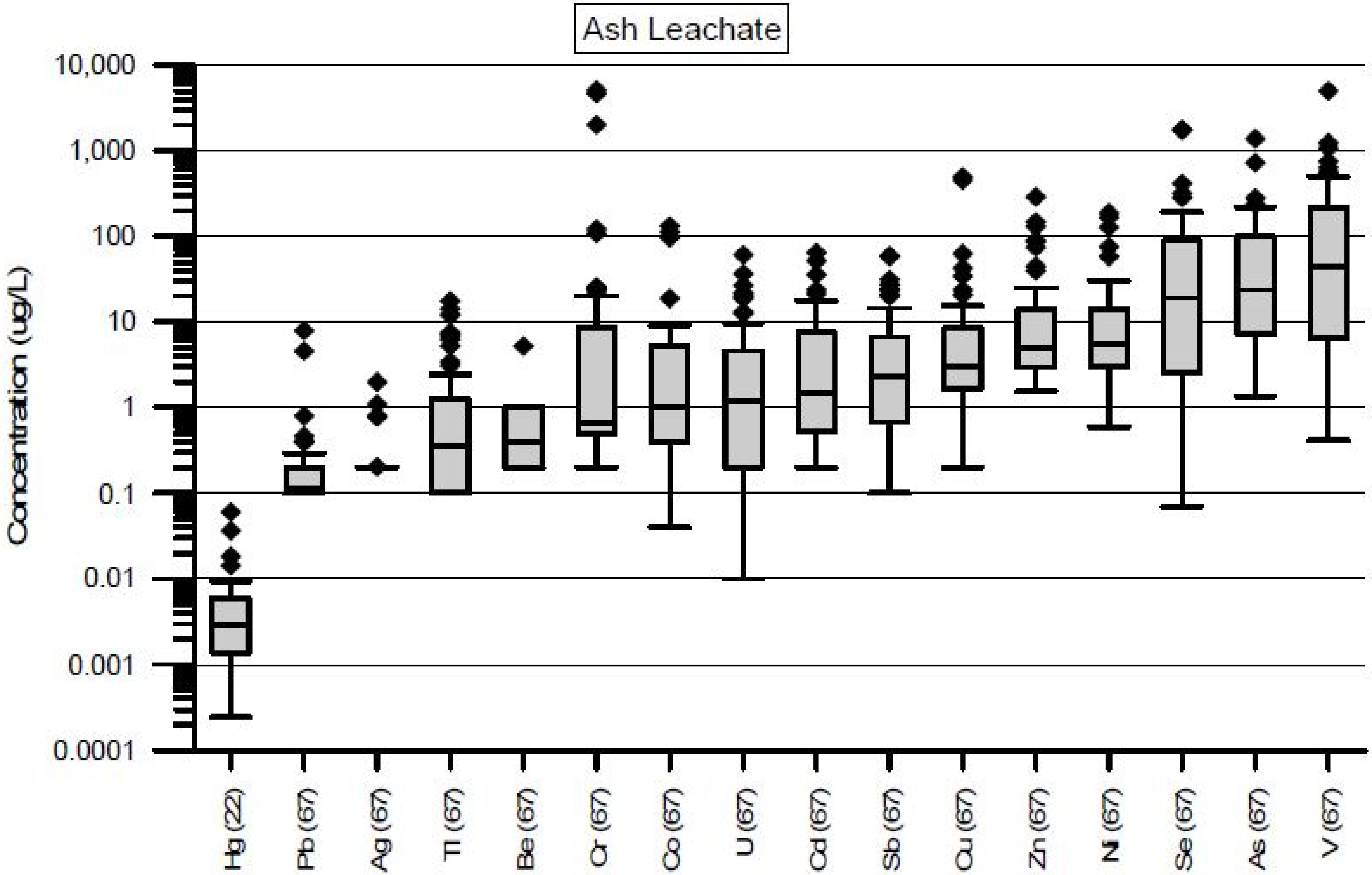
- **Fly ash leachates (39 samples) showed low ionic strength (< 0.2 M)**
- **Fly Ash/Bottom Ash Mixtures. Fly ash/bottom ash leachates (24 samples) also showed low ionic strength (< 0.2 M),**
- **FGD Waste. Flue gas desulfurization (FGD) leachates (5 samples) showed the highest ionic strengths (up to 0.42 M) and the highest magnesium and sodium concentrations (Na ~ 5,000 mg/L),**
- **The highest hydraulic conductivity value was associated with a leachate sample collected from an FGD impoundment where sluice water was recirculated, resulting in a highly concentrated leachate.**
- **• FGD/Fly Ash/Bottom Ash Mixtures. Facilities with blends of FGD waste and ash (8 samples), showed much lower ionic strengths (<0.13 M) than FGD waste alone,**
- **MSW Leachate – Higher ionic strength and variable constituents**

Kolstad, D (2004) "Hydraulic Conductivity and Swell of Nonprehydrated GCLs Permeated with Multispecies Inorganic Solutions", Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 130, No. 12, December 2004, pp.1236-1249.

Coal Ash Leachate Factors

- **Calcium in fly ash influences pH of the ash–water system.**
- **Mobility of most elements in ash is pH sensitive.**
- **Alkalinity of fly ash attenuates release of Cd, Co, Cu, Hg, Ni, Pb, Sn or Zn.**
- **High alkalinity increases release of oxyanionic species such as As, B, Cr, Mo, Sb, Se, V and W.**
- **Precipitation of secondary phases (ettringite) captures and binds As, B, Cr, Sb, Se and V.**
- **Concentrations of monovalent and divalent ions (chlorides, calcium, also boron)**

Range of Constituents in Ash Landfill Leachate



Univ Wisconsin Study

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CEC Leachate Investigations

- **IL Coal Ash (Flyash/Gypsum/Bottom Ash/FGD Blowdown**
  - Boron 260 to >500 mg/L; minimal heavy metals
- **IN Mixed Waste MSW County LF**
  - Coal Ash and MSW
- **GA MSW Mixed Waste Ash LF**
  - Fly Ash & Bottom Ash as daily cover
- **WV Coal Ash Mixed Waste LF**
  - Fly Ash, bottom Ash, CCR at Power Plant
- **SC Mixed Waste LF**
  - Mostly Coal Ash with Off-spec products and wood pallets
- **PA Coal Ash LF**
  - Power Plant Monofill
- **E&P Wastes and Ionic Strength**
  - 15 sites minimal to 50% E&P Wastes

CEC Leachate Investigations

Site	As, ug/l	Hg, ng/l	Se, ug/l	Cl, mg/l	Na, mg/l	B, mg/l
ELGs	6/8	119/242	NA	NA	NA	NA
IN	143 - 421	910 – 9,220	165 - 408	3,590 – 10,100	Not Reported	Not Reported
GA	23.6 – 63.6	Not Reported	25 – 50	3,200	3,510 – 3,900	Not Reported
WV	110 – 1,600	Not Reported	41 – 110	180-400	180-400	1.9
SC	50 – 4,830	<2	20 – 80	Not Reported	60 – 3,140	Not Reported
PA	5 – 1,330	Not Reported	<5 – 1,330	9.25 – 1,090	14.8 – 3,700	0.07 – 3.69
Ash Leachate	0.8 – 1,300	0.5 - 80	0.08 – ~2,000	Not Reported	Not Reported	Not Reported
E&P (15) Sites	ND	ND	ND	630 – 8,224	429 – 4,005	Not Reported

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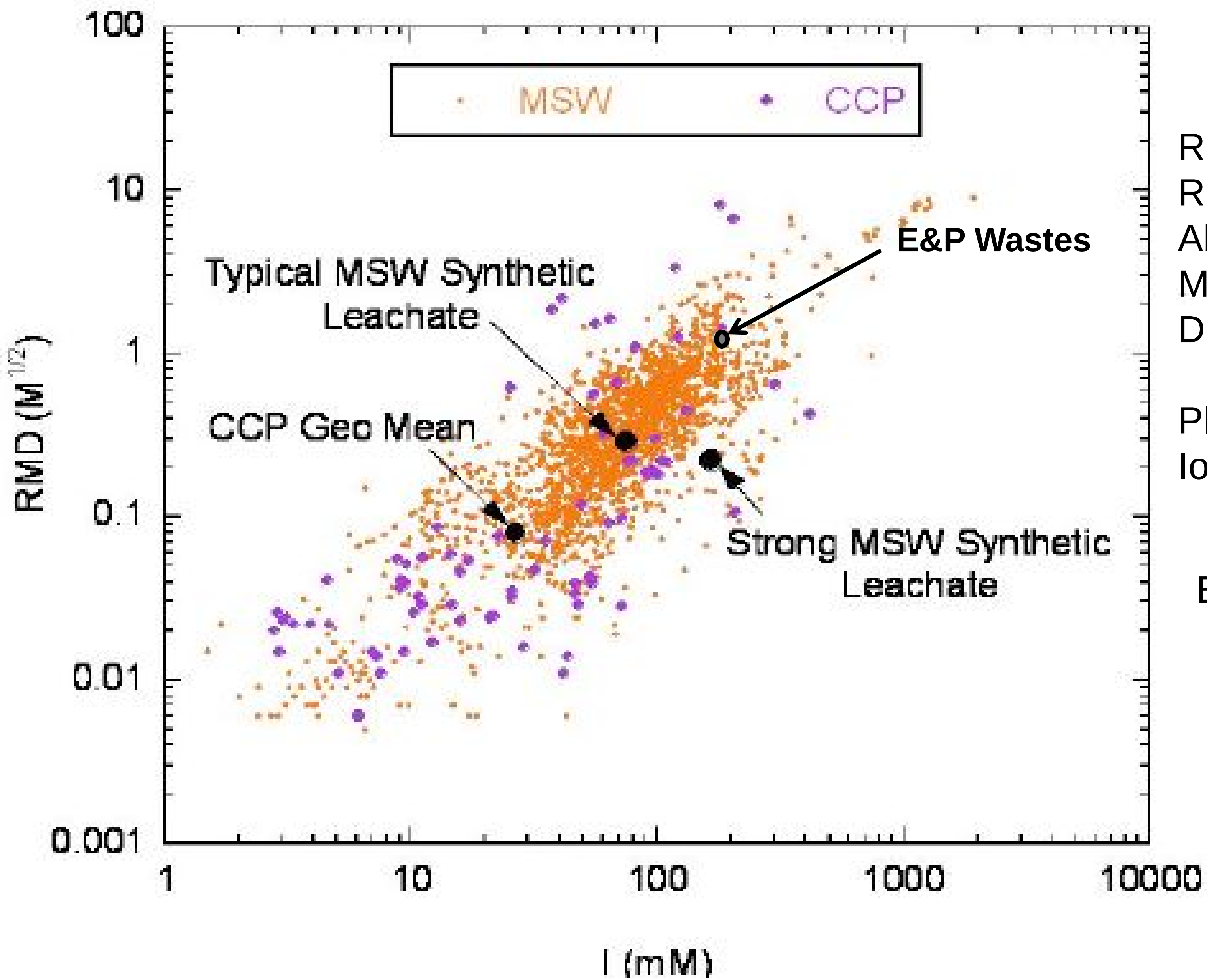
Comparison of Ionic Strengths



RMD = Relative Abundance of Mono and Divalent ions

Plotted against Ionic strength

EPRI 2006

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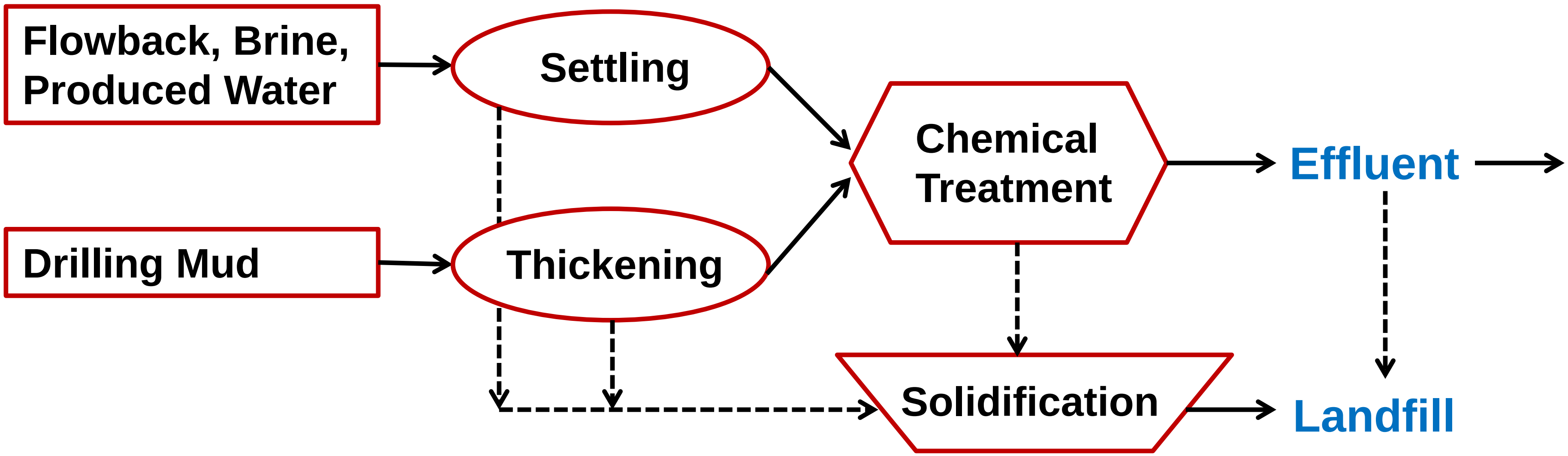
E & P Background

- Unconventional gas/oil E&P ongoing in NE U.S. for 10 years, very hot and heavy the last 5 years, but recently slowed, and now picking up.
- Large tonnages of solids, semi-solids and solidified liquids have been disposed in landfills over the recent past years.
- There is a large and “accurate” database for E&P chemical composition, waste types placed, tonnages and percent of overall total, and leachate analyses.
- Collectively, these data allow us to evaluate if E&P wastes are, or have the potential to, impact leachate quality.

E&P Wastes

- **Evaluate 14 landfills in PA, WV & OH accepting E&P waste + 5 “control landfills”.**
- **Quantify E&P waste types disposed.**
- **Determine leachate parameters of interest.**
- **Evaluate effect these parameters may have on leachate chemistry.**
- **Assess potential impact the changes in leachate chemistry may have on leachate treatment.**
- **Determine other areas needing research/evaluation.**

E&P Return Waste Generation



Process Liquid
Solids

Source: Countess, et al, 2014

Volume and Types of E&P Wastes Being Generated

- **In 2014-2015, 1.5 to 2.0 million tons of E&P waste is disposed annually in tri-state area (PA, OH, WV).**
- **Wastes include:**
  - **Solids – drill cuttings, frac sand**
  - **Semi-Solids/Liquids – spent muds, sediment, produced water, brine, drilling/fracing fluids**

Volume and Types of E&P Wastes Being Generated

- E&P wastes are 5% to 10% of total waste tonnage being disposed annually in tri-state area
- Nineteen landfills in this study
  - 10 different companies/authorities
  - Started accepting E&P wastes 2011-2012
  - At 10 sites E&P is 10% to >50% of total tonnage (avg. 25%)
  - At 4 sites E&P is 2% to 10% of total tonnage
  - Ranging from 10,000 to 165,000 TPY
  - Study showed liquid wastes accepted for solidification very minor
- Five "control" landfills in this study
  - Accept no E&P waste
  - In same region as study sites

What's In E&P Waste

- **What's Available (Source: Countess, et al, 2014)**

Concentration	Parameter
> 10 g/kg	Al, Ca, Ba, Fe, Na
1-10 g/kg	K, Mn, Mg, Sr
0.1-1 g/kg	B, Br, Li, P, Pb, Si, V, Zn
< 0.1 g/kg	Numerous
???	Organics

- **What Can Leach**
  - **Numerous TCLP & SPLP results**
  - **Ba, Ca, K, Na, Mg, Mn, Sr, V, chlorides, sulfates**

Impacts on Leachate Composition

Evaluations Performed

- Inter-Site (are parameter concentrations different between sites, do differences correlate to tonnages/percentages of E&P waste?)
- Intra-Site (for each site, are parameter concentrations different pre- versus post-E&P acceptance?)

Analysis for Each Landfill

- Looked at Ba, K, Na, V, TDS, chlorides and sulfates
- Evaluated quarterly data from 2007 thru 2015 (2^{nd} Qtr.)
- Separated data into pre-E&P waste acceptance and post-E&P waste acceptance
- Developed time series plots and descriptive statistics for each parameter
- Performed t-Test, 2-sample unequal variance at 95% confidence for pre- versus post-E&P

Impacts on Leachate Composition

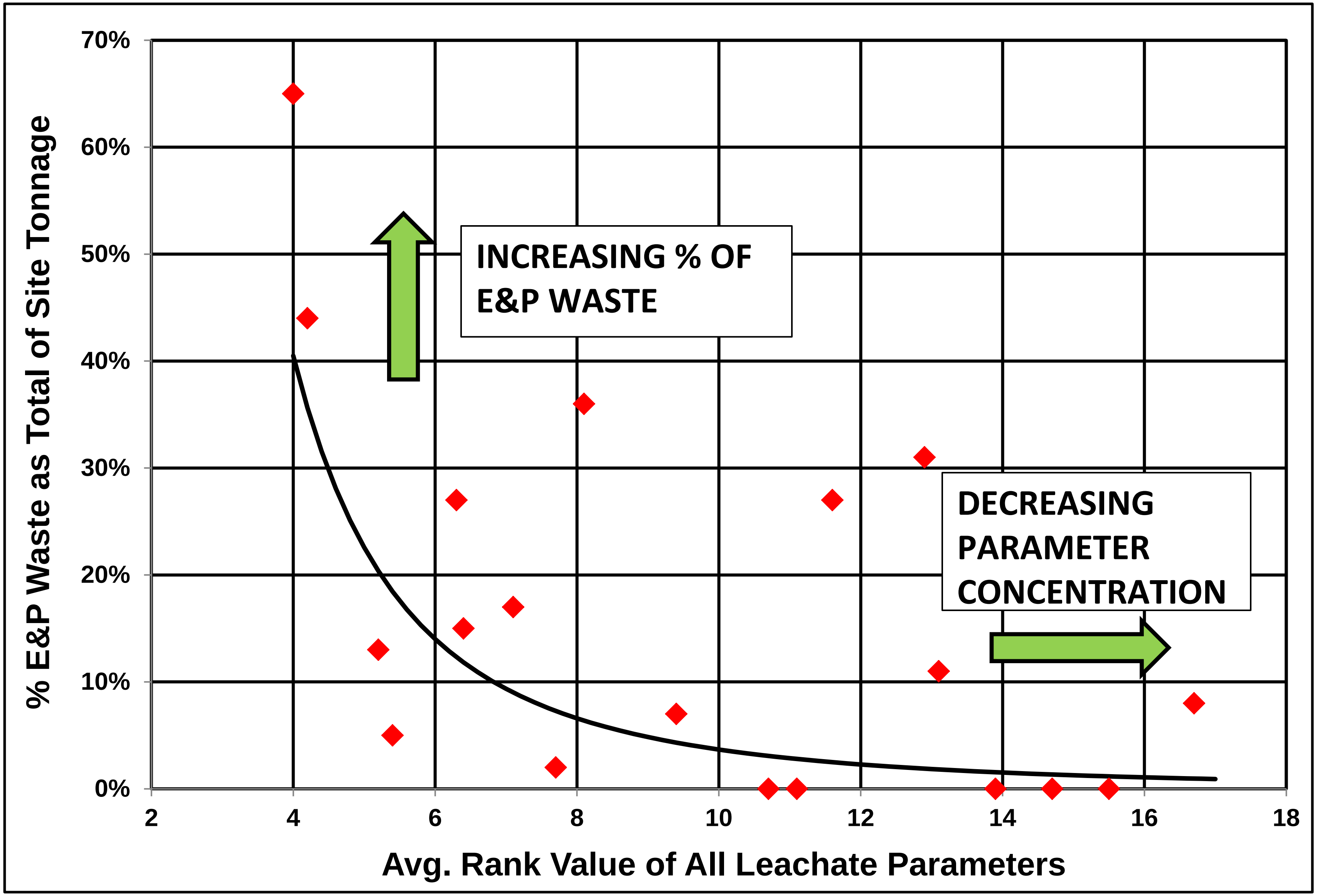
► Inter-Site Comparison

- For each parameter evaluated, ranked the sites from highest average concentration to lowest
- Calculated an average rank for each site

► Key to Following Tables

- RED TEXT – Site disposes 10% to >50% E&P Waste
- GREEN TEXT – Site disposes 1% to 10% E&P Waste
- BLUE TEXT – Site disposes no E&P Waste (Control)
- The lower the rank value – the higher the average concentration of that parameter

Site Overall Ranking



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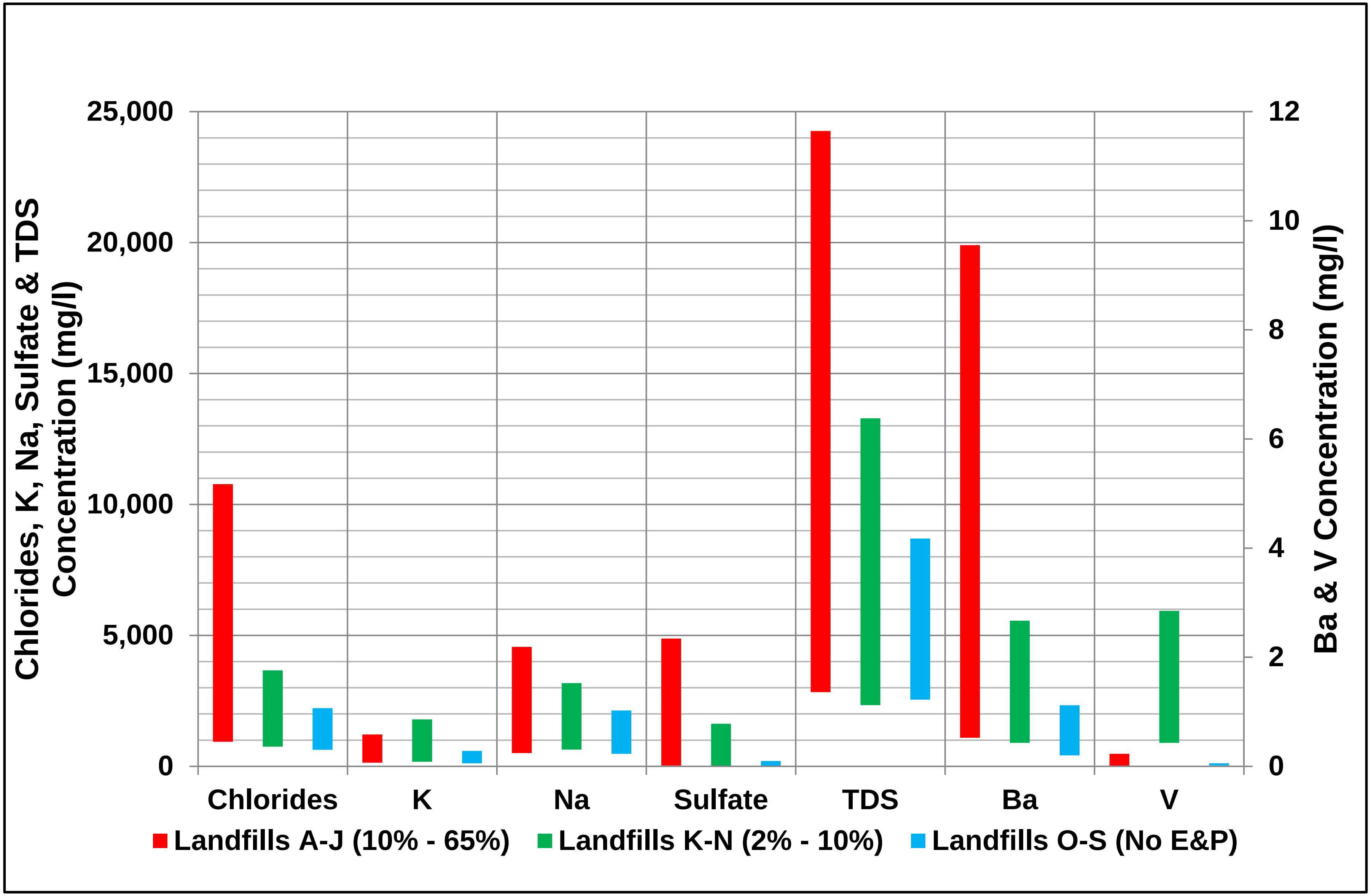
Leachate Concentration Ranges

Leachate Parameter	Landfill A-J Conc. (mg/l) (10%-65% E&P)	Landfills K-N Conc. (mg/l) (2%-10% E&P)	Landfill O-S Conc. (mg/l) (No E&P)
Ba	0.5 – 9.0	0.4 – 2.2	0.2 – 0.9
K	137 – 1,080	176 – 1,618	115 – 476
Na	506 – 4,055	639 – 2,538	475 – 1,656
V	0.01 – 0.22	0.01 – 2.42	0.01 – 0.04
Chlorides	939 – 9,835	753 – 2,913	630 – 1,588
Sulfates	30 – 4,848	5 – 1,618	18 -187
TDS	2,832 – 21,433	2,337 – 10,951	2,547 – 6,152

- **Inter-Site Comparison Conclusions**
  - In general – landfills disposing higher % and/or tonnages of E&P waste have higher concentrations of select parameters.

Leachate Concentration Ranges



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Impacts on Leachate Composition

- **Intra-Site Comparison**
  - For each site and each parameter
    - Separated leachate data into pre-E&P waste acceptance and post-E&P waste acceptance
    - Analyzed for statistical significance of differences of average concentrations
    - Performed t-Test, assuming 2-sample unequal variance, 95% confidence
    - Prepared time series plots

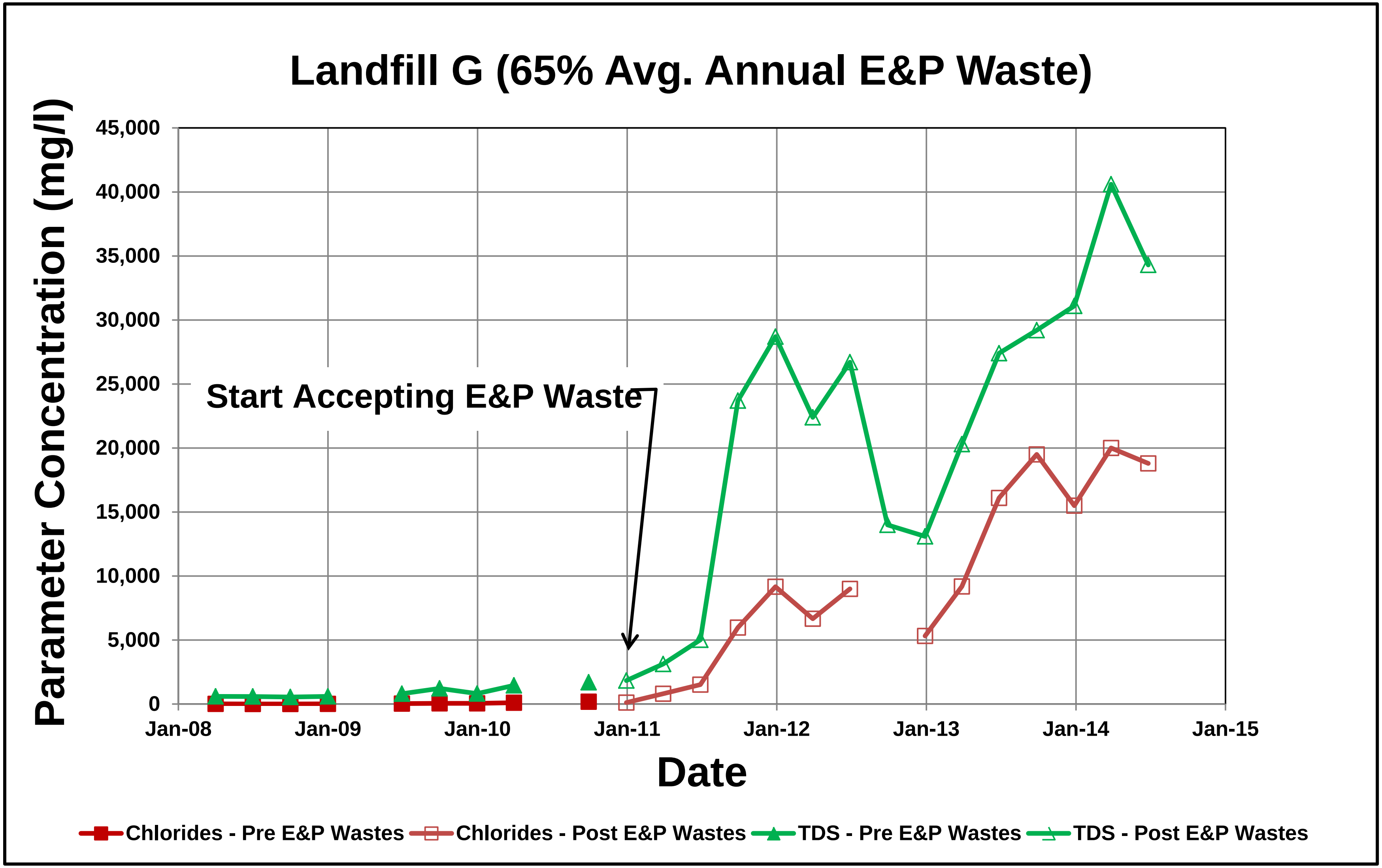
Impacts on Leachate Composition

- **Pre-E&P vs Post E&P, t-Test Significance**

Landfill	Ba	K	Na	V	Chlo.	Sulf.	TDS
A							
B			Yes		Yes		Yes
C	Yes	Yes	Yes		Yes		Yes
D		Yes			Yes		Yes
E					Yes		Yes
F	Yes	Yes	Yes			Yes	
G	Yes	Yes	Yes		Yes		Yes
H							
I					Yes		
J			Yes		Yes		Yes
K	Yes			Yes			
L			Yes		Yes		Yes
M		Yes	Yes	Yes			Yes
N	Yes	Yes	Yes		Yes		Yes
TOTAL	5	5	8	2	9	1	9

- **"Yes" indicates Post-E&P Avg. Concentration is Statistically Significantly Higher than Pre-E&P Avg. Concentration**

Impacts on Leachate Composition



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Impacts on Leachate Composition

- **Intra-Site General Conclusions**
  - Sites disposing moderate to high percentages of E&P wastes over multiple years may experience large increases in concentrations of Na, Chlorides, TDS
  - Sites accepting E&P waste may see increases in other metals (Ba, K, V)
  - Increases range from minimal to dramatic

What May Be Impacts To Landfills and Leachate from CCR and E&P Wastes?

- **FGD -** Highest hydraulic conductivity and ionic strength values (77 samples) were associated with one specific FGD site with recirculated leachate – mostly low hydraulic conductivity
- **Fly ash leachates** (39 samples) showed low ionic strength gives low predicted GCL hydraulic conductivity values
- **Fly ash/bottom ash leachates** (24 samples) also showed low ionic strength results in low GCL hydraulic conductivity
- **FGD/Fly Ash/Bottom Ash Mixtures.** Facilities with blends of FGD waste and ash (8 samples), showed much lower ionic strengths (<0.13 M) than FGD waste alone
- **MSW** alone had higher ionic strengths – higher clay/GCL conductivity
- **E&P Wastes** in LF – High mono and divalent ions – Na, Cl, Ca,

Considerations for Treatment Design & Operation

► **Coal Ash and E&P Waste (some similarities!)**

- Stabilization of wastes prior to disposal
- Minimize leaching potential of wastes
- Monofilling
- Recirculating leachate may exacerbate TDS increases

► **Leachate Treatment**

- Need for pretreatment prior to discharge to POTW
- Impact of increased TDS on settling in SBRs, MBRs may see increased fouling
- TDS concentrations may not impact nitrification if <5,000 mg/L
- “Pickling” of bacteria
- Scale deposition

Conclusions

- **Wide range of ionic strengths**
- **CCR wastes have lower ionic strength than mixed ash in MSW landfills**
- **Significant variability**
- **Treatment Considerations –**
  - Bench tests recommended because leachate concentrations are highly variable.
  - Chemical precipitation or advanced technologies?
  - Organics not investigated

Questions?

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