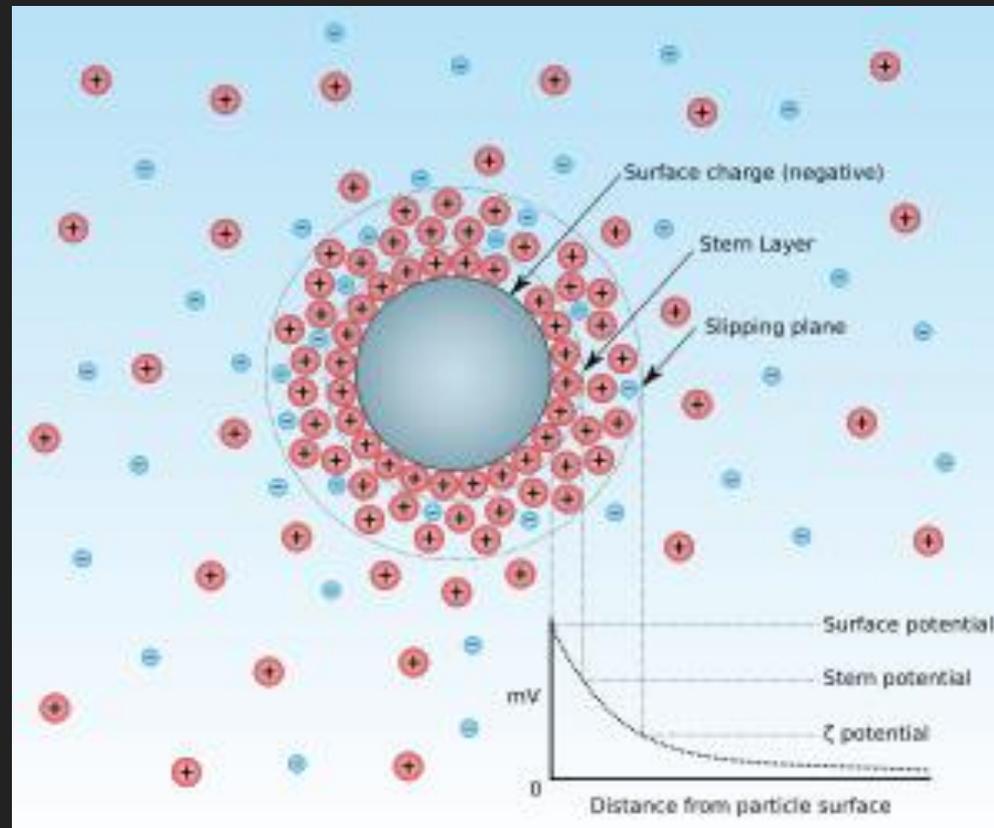


Using Zeta Potential to Optimize Filtration Plants





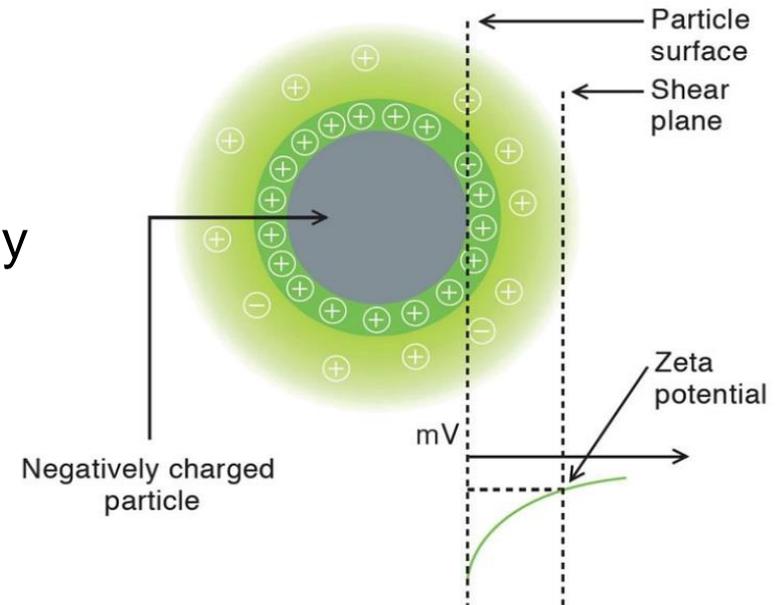
Agenda

1. What is Zeta Potential?
2. Applying Zeta Potential at WTPs
3. Case Study – Great Lakes Direct Filtration WTP
4. Summary

What is Zeta Potential?

What is Zeta Potential (ZP)?

- A measurement of the surface charge on a particle
- Measured by tracking the motion of charged particles in an electric field (electrophoretic mobility, EM) and is usually expressed in millivolts (mV)
- Depends on surface chemistry of particle and solution
- Used to predict clarification and filtration performance at WTPs
- Higher (less neutral) zeta potential yields more stable particles

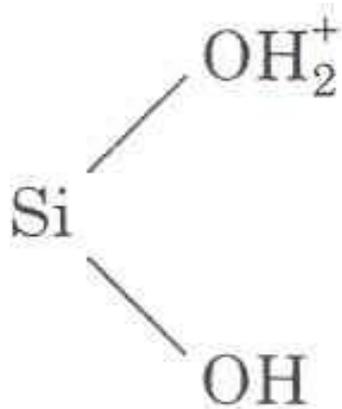


Source: St. Petersburg State University Center for Optical and Laser Materials Research

Chemistry of Particles

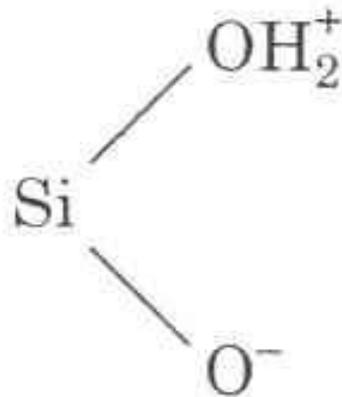
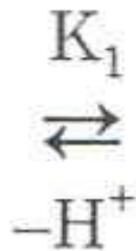
- Many types of particles in water sources:
 - Clays, minerals, algae, organic debris
- All have similar surface chemistry
 - OH⁻ (hydroxyl) groups
- Surface charge is pH dependent
 - Negative at neutral to high pH, less negative at low pH
- Natural organic matter behaves similarly

ALUMINUM SILICATE (CLAY) IN WATER



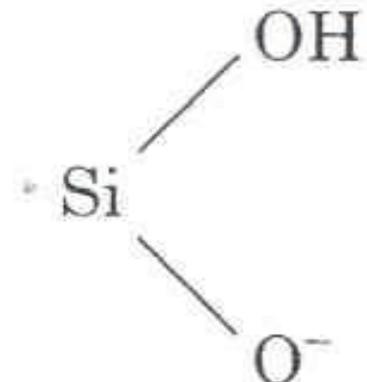
Low pH

(+) particle charge



Neutral pH

no charge



High pH

(-) particle charge

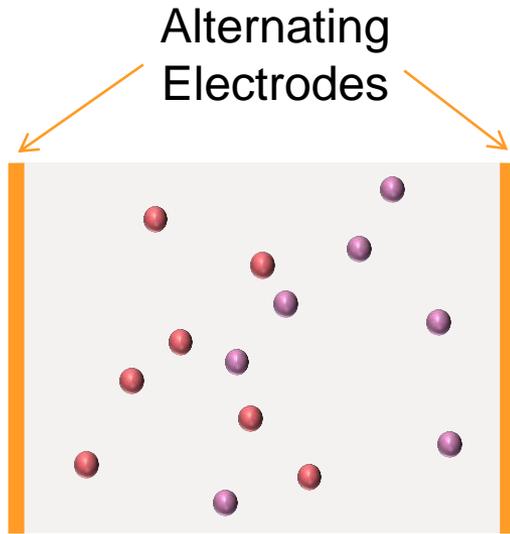
How do We Measure Zeta Potential?



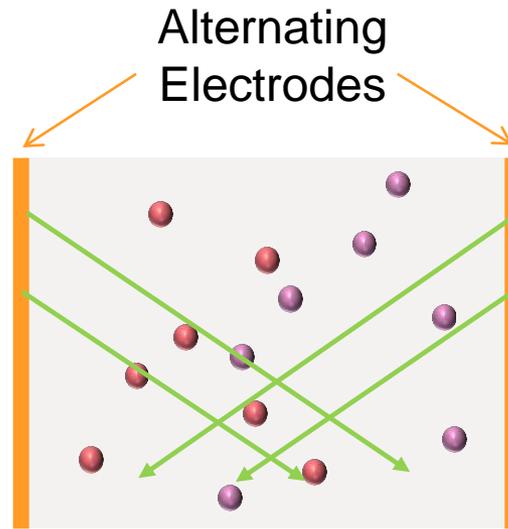
MODERN ZETA POTENTIAL ANALYZER

- 1 travel case, 1 sample cell, 1 button analysis
- Electrophoretic Mobility (EM) measured by tracking particle movement with laser light scattering

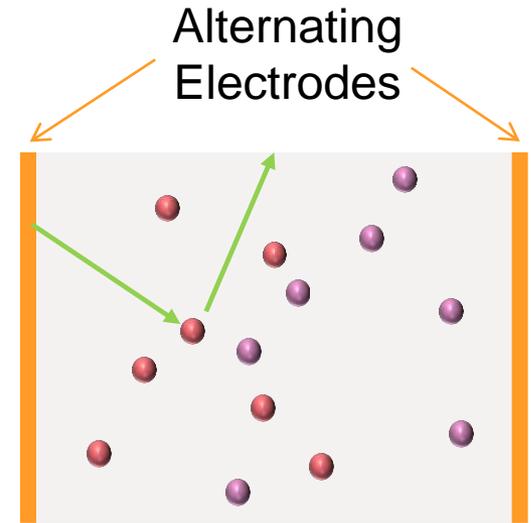
How Does the ZP Analyzer Actually Work?!



Distance Between Electrodes



Laser light sources send multiple light beams into the cell, with photodetectors on other side.



Changes in the frequency of scattered light by the moving particles are converted to a velocity.

Measuring Zeta Potential with Electrophoretic Light Scattering

ZP Analyzer measures **particle velocity**, used to calculate **ELECTROPHORETIC MOBILITY**:

$$U_E = \frac{V_p}{E f}$$

Where

U_E = Electrophoretic Mobility

V_p = Particle Velocity

$E f$ = Electric Field Strength

When

$E f$ = Applied Voltage

ZETA POTENTIAL is related to the **ELECTROPHORETIC MOBILITY** by Henry's Equation:

$$U_E = \frac{2 \varepsilon z f(k a)}{3 h}$$

U_E = electrophoretic mobility

z = zeta potential

ε = dielectric constant

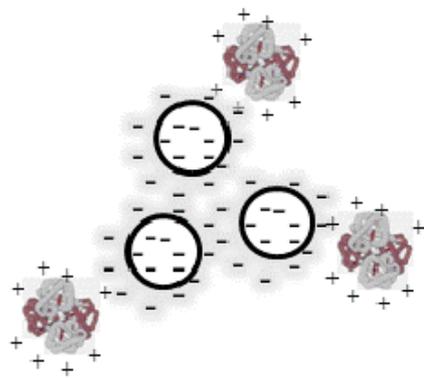
h = viscosity

$f(k a)$ = Henry's function

Using Zeta Potential to Optimize WTPs

Why Do We Coagulate?

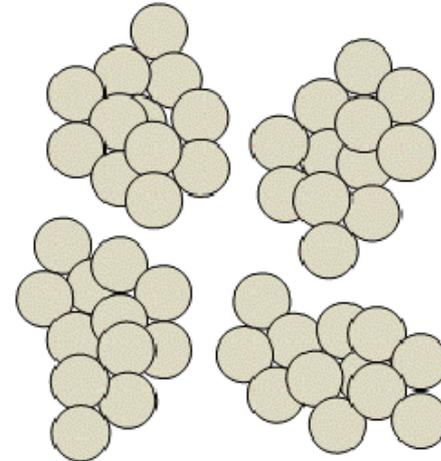
- **Condition raw water particles** so they can be removed by clarification and filtration
 - Remove turbidity and pathogens
- **Convert NOM to a solid phase** for removal by clarification and filtration
 - Remove color
 - Remove DBP precursors
 - Increase UV transmittance to improve UV disinfection



Charge neutralization



Coagulation



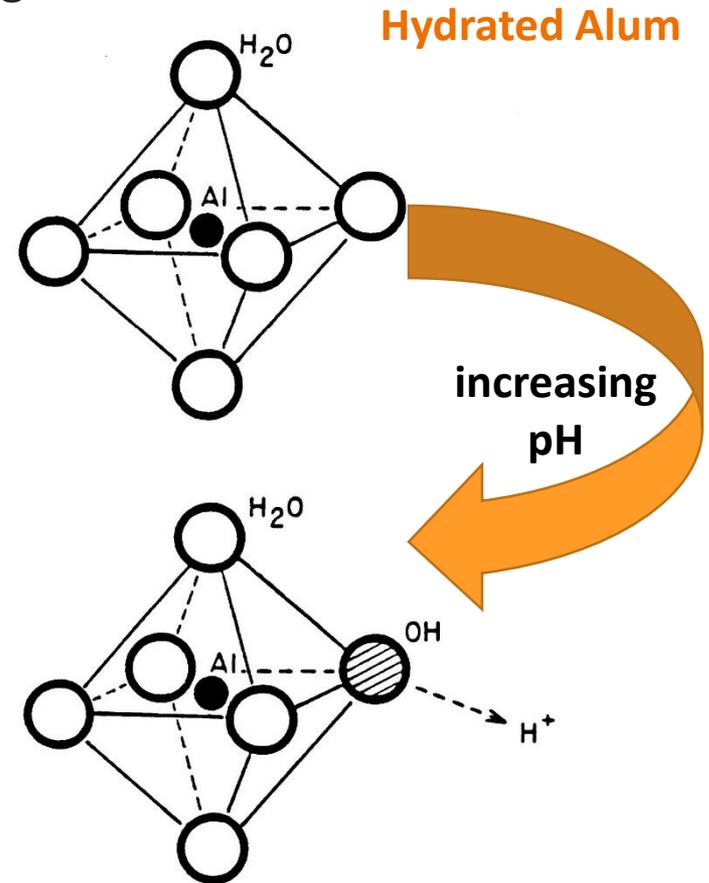
Flocculation

Chemistry of Coagulants

- Charge of dissolved coagulant species and floc surfaces are pH dependent
- More positive at low pH
- Goal is near neutral ZP for ideal coagulation conditions

	Low pH	High pH
NOM & Particle Charges	Less Negative	More Negative
Coagulant Charge	More Positive	Less Positive

IDEAL COAGULATION CONDITIONS
"ENHANCED COAGULATION"



NOM Related Coagulant Demand

- Must satisfy charge demand of NOM before particle charge changes

Water	Turbidity (NTU)	TOC (mg/L)	SUVA ¹	Dose to neutralize (mg/L as Al)
1	16	2.5	2.2	0.8
2	0.8	2.8	3.0	1.5
3	0.7	6.1	4.5	4.2

1. SUVA = UVA/DOC; indicator of how well coagulation will work

Coagulants used:

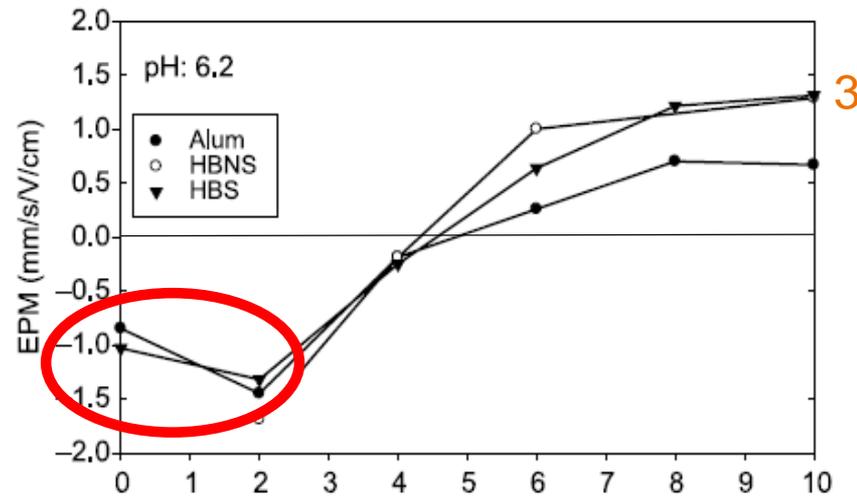
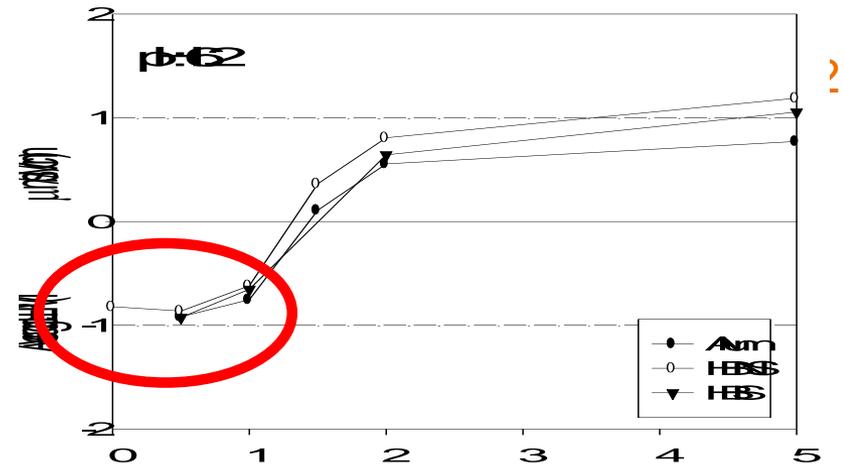
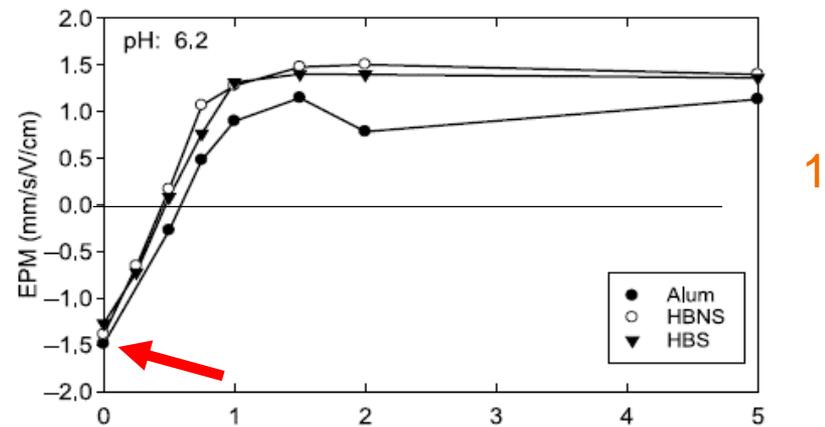
Alum

High-basicity no-sulfate PACl (HBNS)

High-basicity PACl with sulfate (HBS)



Source: Pernitsky and Edzwald 2006



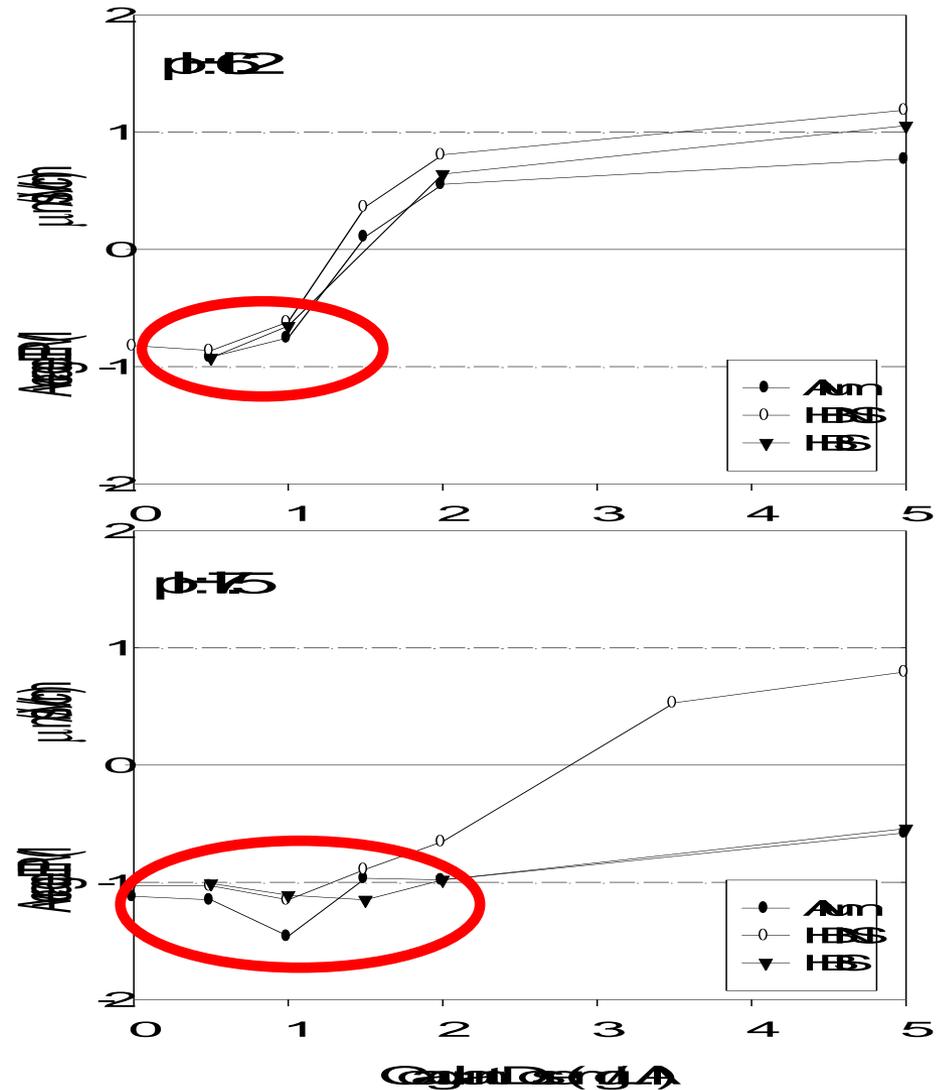
1

2

3

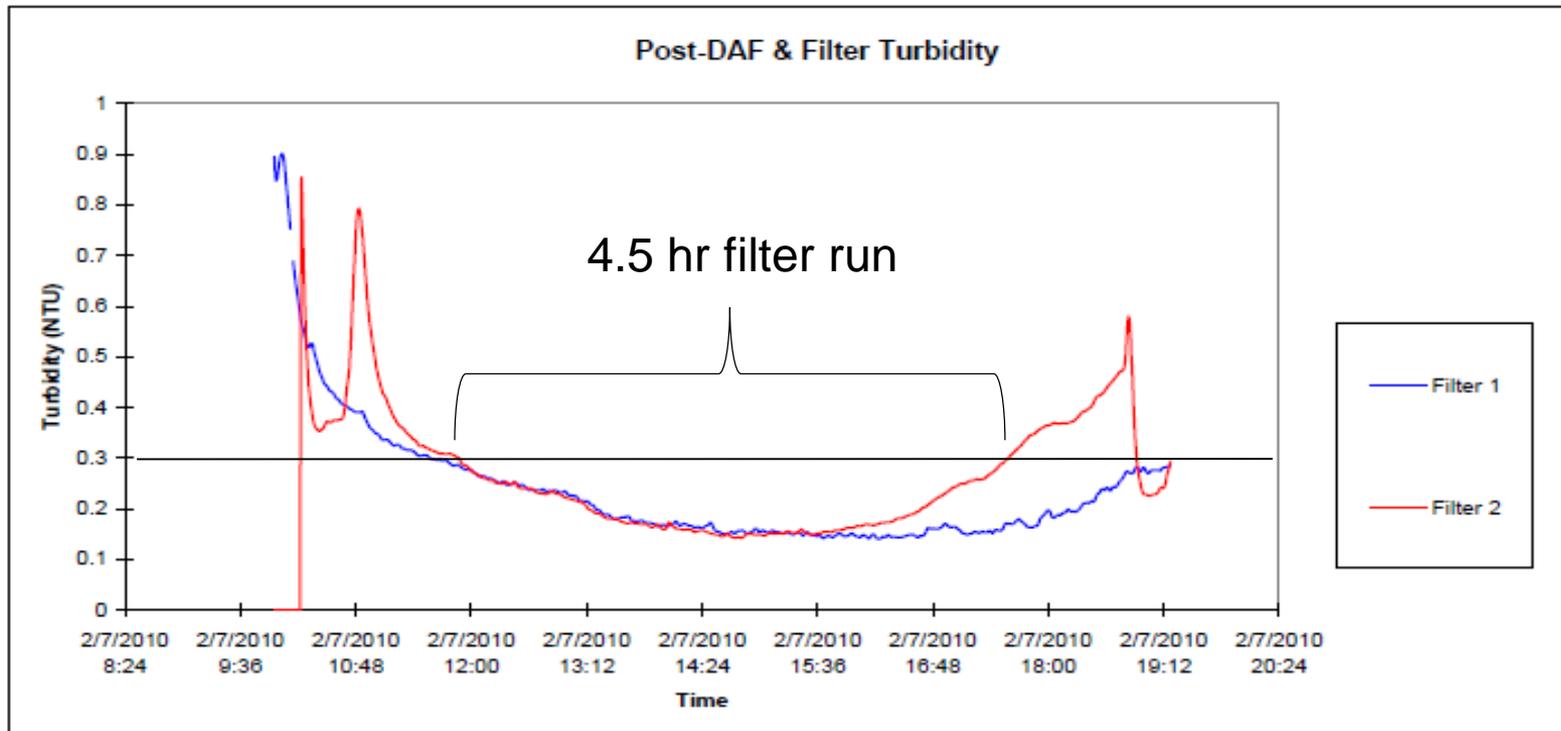
pH-Related Coagulant Demand

- Water #2 from previous slide with low TOC and moderate SUVA
- At high pH, coagulant demand much higher
- Coagulant selection critical at high pH



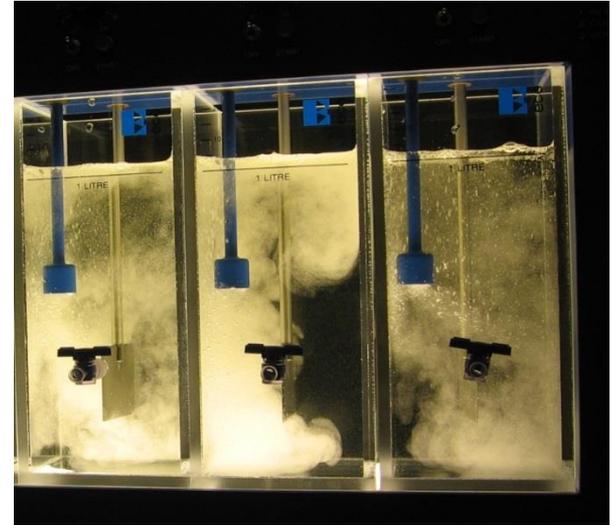
Symptoms of Sick Filters

- Filters cannot maintain turbidity < 0.3 NTU
- Long ripening times; early breakthrough
- Poor clarifier performance (but only sometimes)



Troubleshooting Coagulation Chemistry

- Jar tests work for some plants, but...
 - Often lots of scatter in turbidity data
 - No indication of NOM removal
 - No indication of filter performance
 - Time intensive
 - Qualitative results based on visual observations



- **ZETA POTENTIAL TO THE RESCUE!**
 - A direct measure of particle charge
 - The best available tool for troubleshooting difficult coagulation optimization problems
 - selection of coagulant
 - proper dosing
 - optimization of process



Ideal Operating Conditions

- In general, most WWTPs that measure zeta potential, target between -4 and -1
- Increasing past this range can cause issues downstream due to too much coagulant in effluent

Average Zeta Potential	Degree of Coagulation
0 to +3	Maximum
-4 to -1	Excellent
-10 to -5	Fair
-20 to -11	Poor



CASE STUDY

Great Lakes Direct Filtration WTP

Direct Filtration Plant Troubleshooting

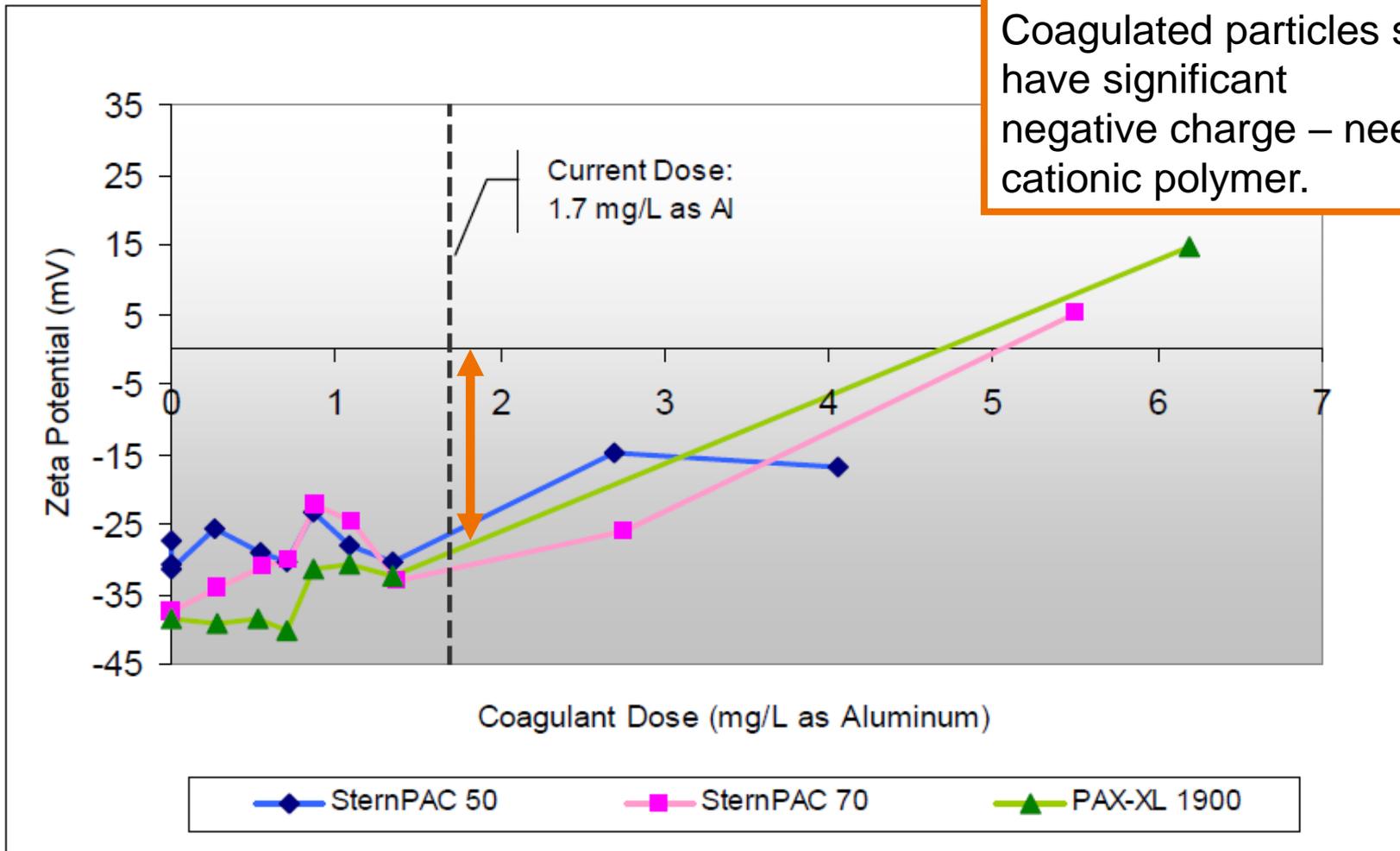
- Low turbidity, moderate NOM source water (Lake Huron)
- Direct Filtration Treatment Process:
 - PACl coagulant
 - Sand/anthracite filter
 - No clarification



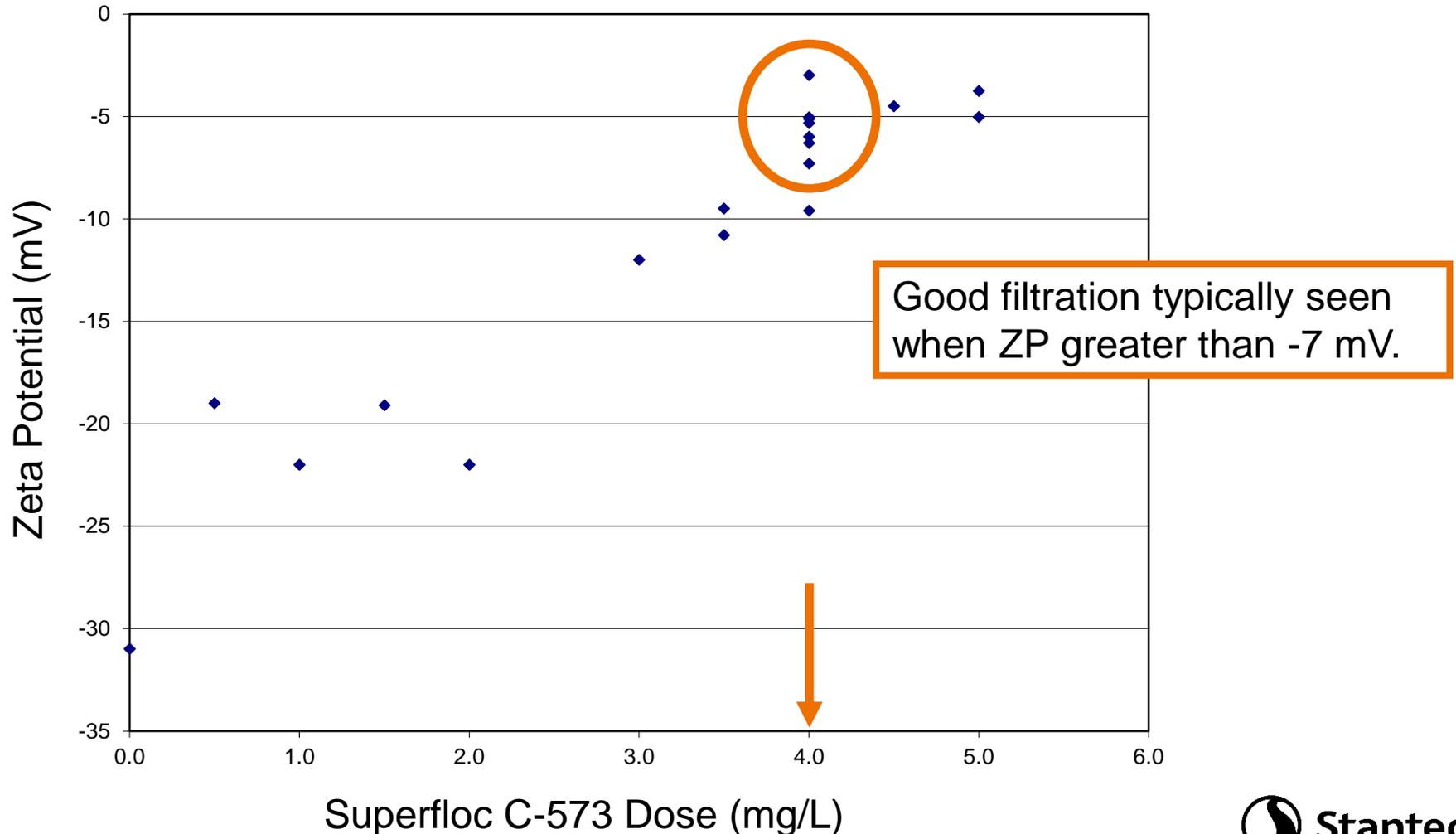
- Experiencing very short filter run times
 - Low coagulant dose → early turbidity breakthrough
 - Higher coagulant dose → good turbidity, but high headloss and short runs

Zeta Potential Analysis of Existing Conditions

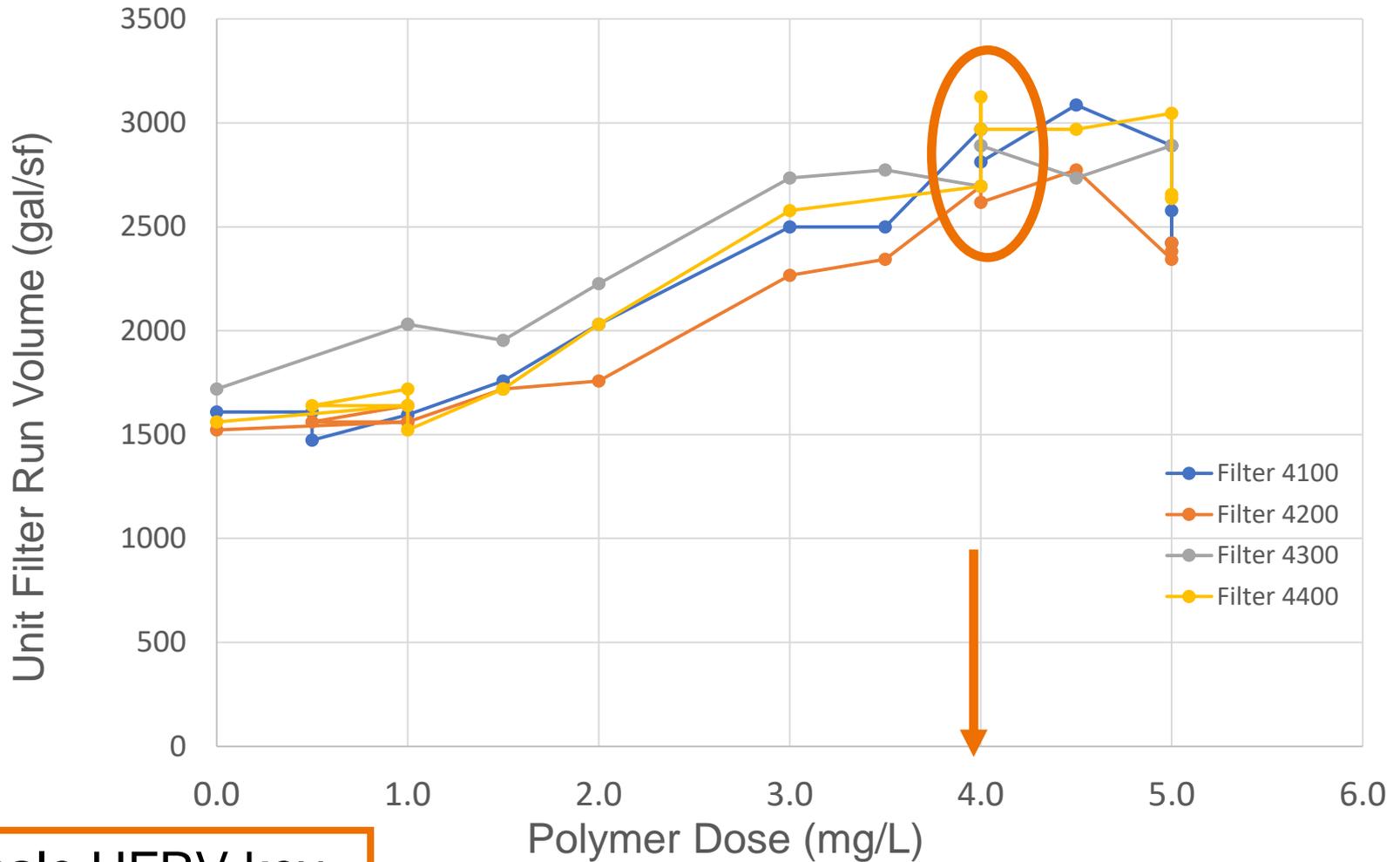
Coagulated particles still have significant negative charge – need cationic polymer.



Using Zeta Potential to Evaluate Polymers for Charge Neutralization



Do Full-Scale Results Agree with Jar Tests and ZP Theory?



Full-scale UFRV key performance indicator

Conclusions and Summary

ZP Analysis at Other WTPs

Utility	Type of WTP	Zeta Potential Target (mV)	Reference
Calgary, AB	Conventional (Actiflo)	-5 to +5	Kundert, 2014
Epcor (Edmonton, AB)	Conventional with seasonal Direct Filtration	-5 or greater	James et al., 2015
Tittesworth, UK	Conventional	-10 to +3	Sharp et al., 2015
Various Great Lakes, ON	Conventional	-7 or greater	Waller et al., 2012
Muskoka, ON	Direct Filtration	-5 or greater	Pernitsky et al, 2010
Halifax, UK	Conventional	-10 to +5	Sharp et al., 2005
Fort Collins, Colorado	Conventional	-5 to +5	Morfesis et al., 2009
Adelaide, Aus	Conventional	-10 to -5	Holmes et al., 2015
Waterford, NY	Conventional	Zero, +/- 5	Riddick, 1961
ASTM	Generic Standard	-5 to +5	ASTM, 1987
Laboratory	Algae Settling and DAF	-10 to +2	Henderson et al., 2008

Summary

- All particles and organics have negative charge in water
- Ideal coagulation occurs at ZP values > -7 mV
- ZP provides a direct measure of particle charge
- ZP more precise for selecting coagulant dose than jar testing
- Using ZP analyzer reduces jar test time and “judgement” decisions
- ZP can be a very useful tool for controlling coagulant dose
- ZP is the best tool for solving difficult coagulation/filtration problems
- Coagulant dose & pH impact ZP and are equally important for proper coagulation

QUESTIONS

Acknowledgements

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