Meeting Green Goals with Zeta Potential and the SZ-100

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Wastewater

- Wastewater contains chemical and particulate contaminants that need to be removed for safety, environmental, and aesthetic reasons.

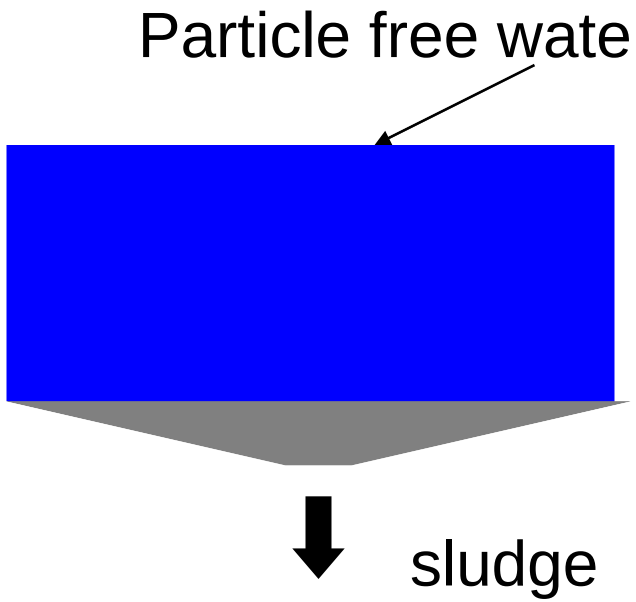
- Today we primarily talk about particulate waste.

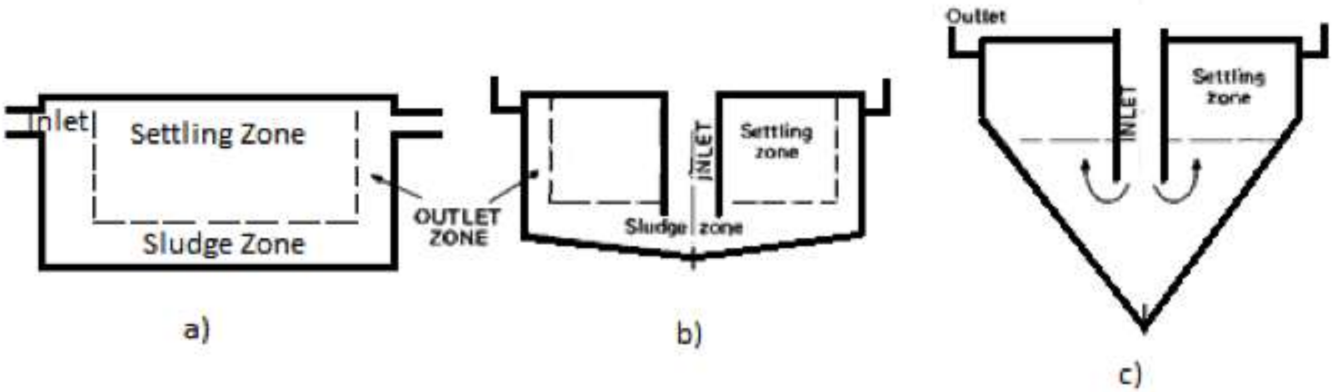
How do we look at particle contamination?

- Suspended particles will appear as haze and can be measured with
  - Turbidity meter – scattered intensity at right angle
  - Total suspended solids (filter and weigh)
- See US EPA: Analytical Method for Turbidity Measurement, Method 180.1
- See the HORIBA U-53 for measuring turbidity

Getting Rid of Particles

- Put them in a giant tank and wait (settling or flotation)
- Filter particles out with filter media





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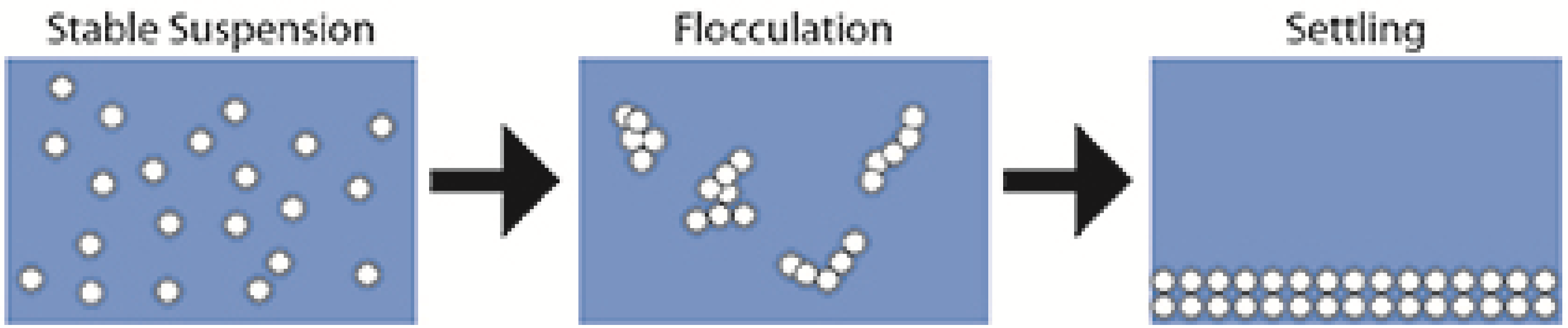
Settling Process

- This is a summary of the desired process in a settling tank (or pond).



Stokes Law

- This is why we care about flocculation!
- Particle settling velocity increases by square of particle size. If you double particle size, particles settle four times faster.

$$v = \frac{2(\rho_p - \rho_f)gr^2}{9\eta}$$

v = velocity (down is positive)
ρ_p = density of particle
ρ_f = density of fluid
g = acceleration due to gravity
r = particle radius
η = fluid viscosity

- Gravity increases with r^3. Drag only increases with r. So velocity increases with r^2.
- Larger Particles → Less expensive process

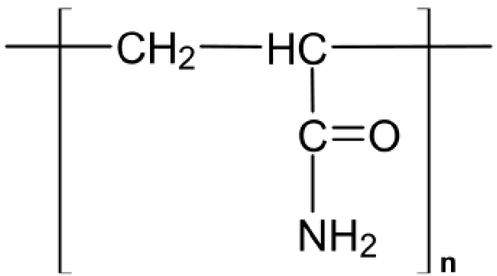
Effect of size on settling

Diameter (micron)	Order of size	Time to settle 1 meter (ρ=2.6 like sand)	Time to settle 1 meter (ρ=1.3 like clay)
1,000 (1 mm)	Coarse sand	1.1 sec	6.1 sec
100	Fine sand	110 sec	610 sec
10	Silt	11000 sec (3.2 hr.)	61000 sec (17 hr.)
1	Bacteria	1.1 $x10^6$ sec. (13 days)	6.1 $x10^6$ sec. (70 days)
0.1	colloids	1.1 $x10^8$ sec. (3.6 years)	6.1 $x10^8$ sec. (19 years)

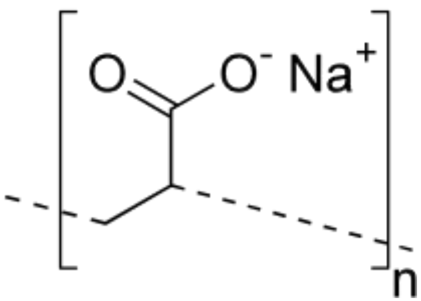
Coagulants

- Alum - Aluminum Sulfate $Al_2(SO_4)_3$
- Ferric Chloride – $FeCl_3$
- Acrylamide-acrylate copolymers are anionic due to the presence of negatively charged carboxylate groups

polyacrylamide



Na-polyacrylate



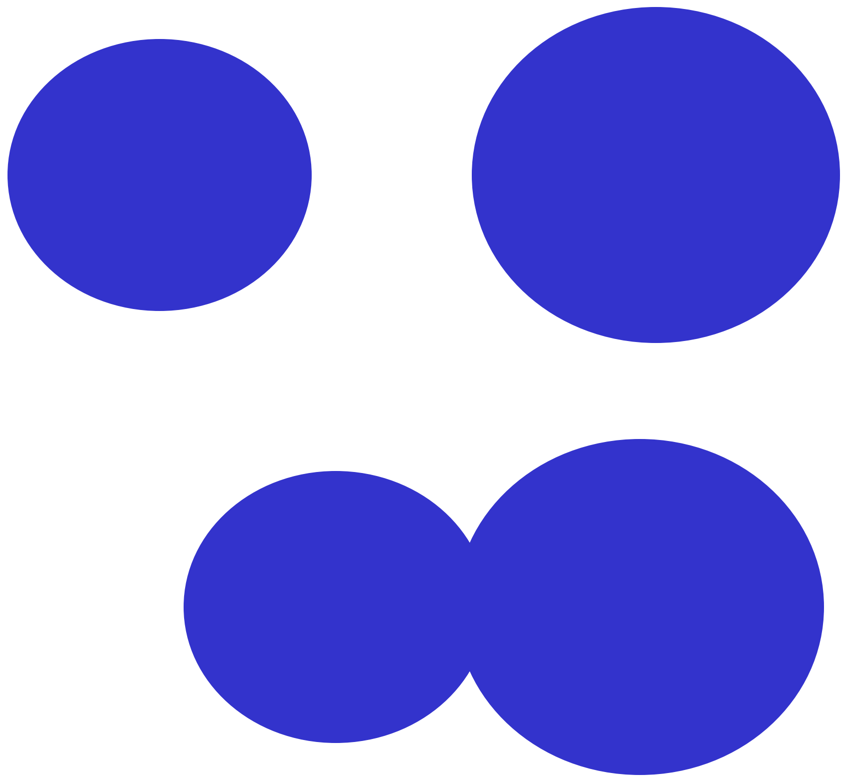
Anionic

"Polyacrylamide" by Roland Mattern - Roland1952. Licensed under Public Domain via Commons - https://commons.wikimedia.org/wiki/File:Polyacrylamide.svg#/media/File:Polyacrylamide.svg

"Sodium polyacrylate skeletal" by Edgar181 - Own work. Licensed under Public Domain via Commons - https://commons.wikimedia.org/wiki/File:Sodium_polyacrylate_skeletal.png#/media/File:Sodium_polyacrylate_skeletal.png

Why will particles flocculate?

Fine particles will tend to flocculate to reduce surface energy.

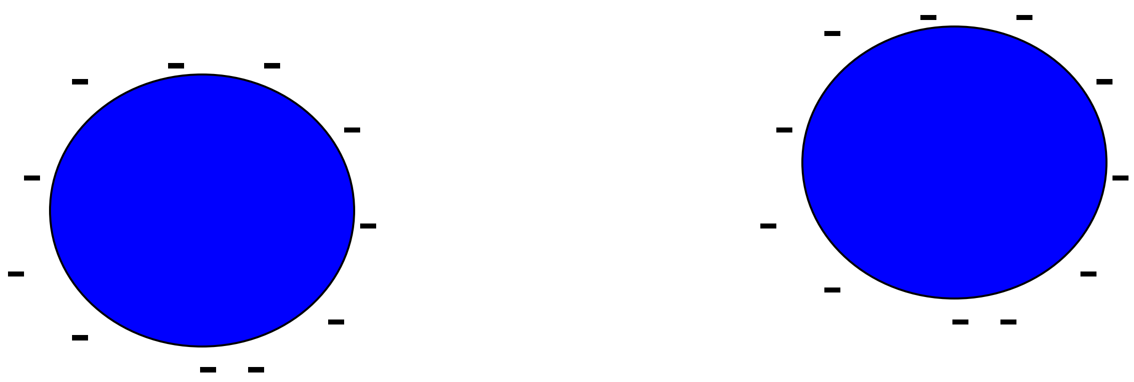


Less surface, lower free energy.

Why don't particles flocculate?

Most particles in aqueous suspension have a surface charge and therefore repel each other; they never touch.

"Kinetically Stable"

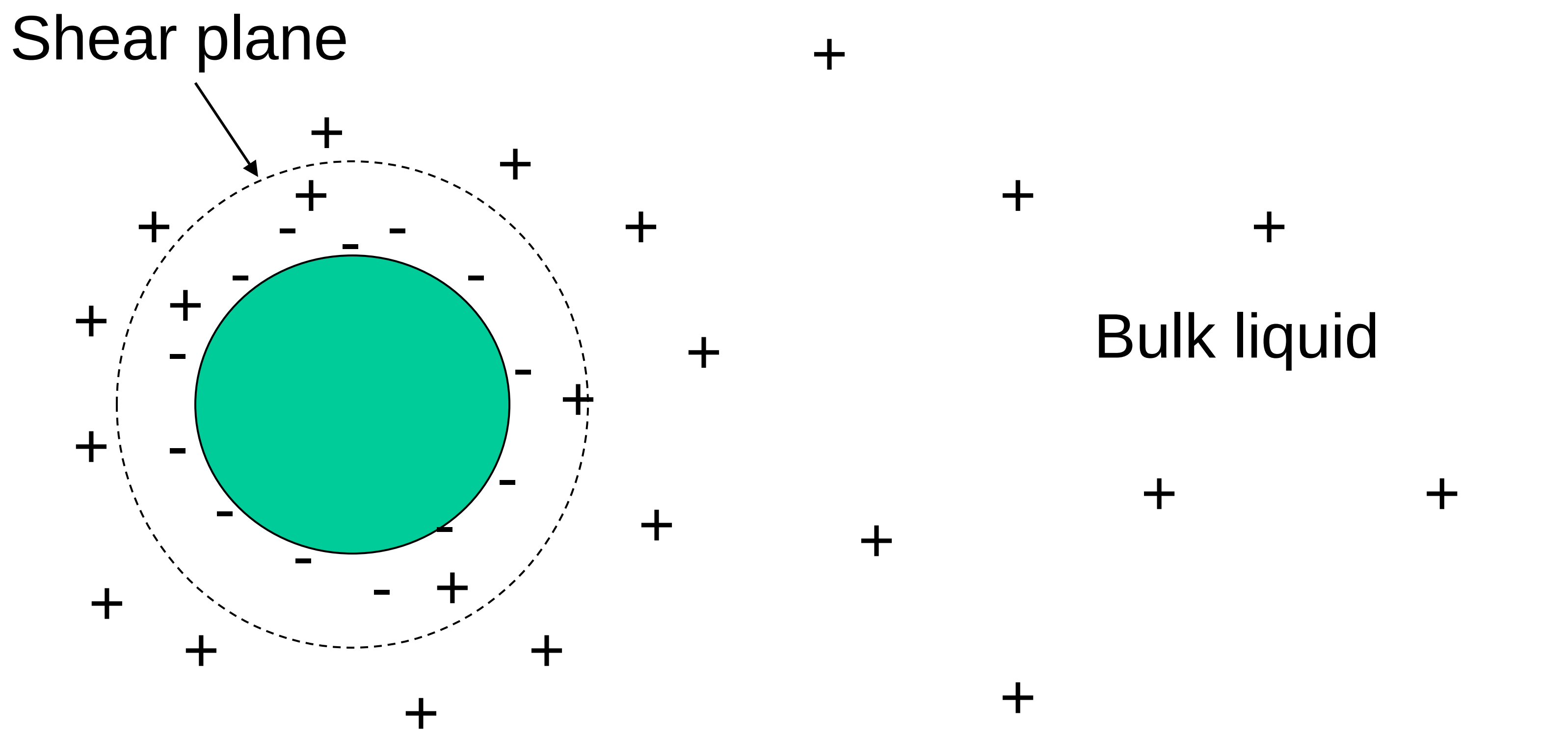


Jar Test

- Fill identical beakers with identical amounts of waste.
- Keep one as a control (or blank).
- Add varying amounts of coagulant.
- Evaluate results. Do small particle wastes become cloudy (indicating formation of larger flocs).
- Inexpensive
- Operator Dependent, can be time consuming

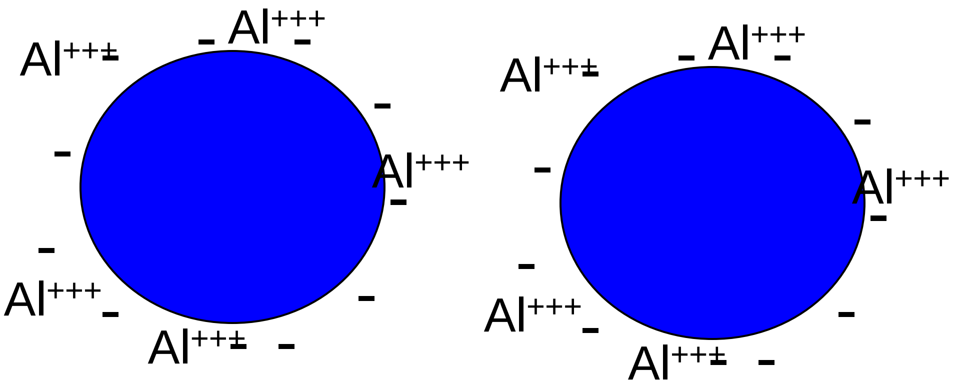
What is Zeta Potential?

- Zeta potential is the charge on a particle at the shear plane.

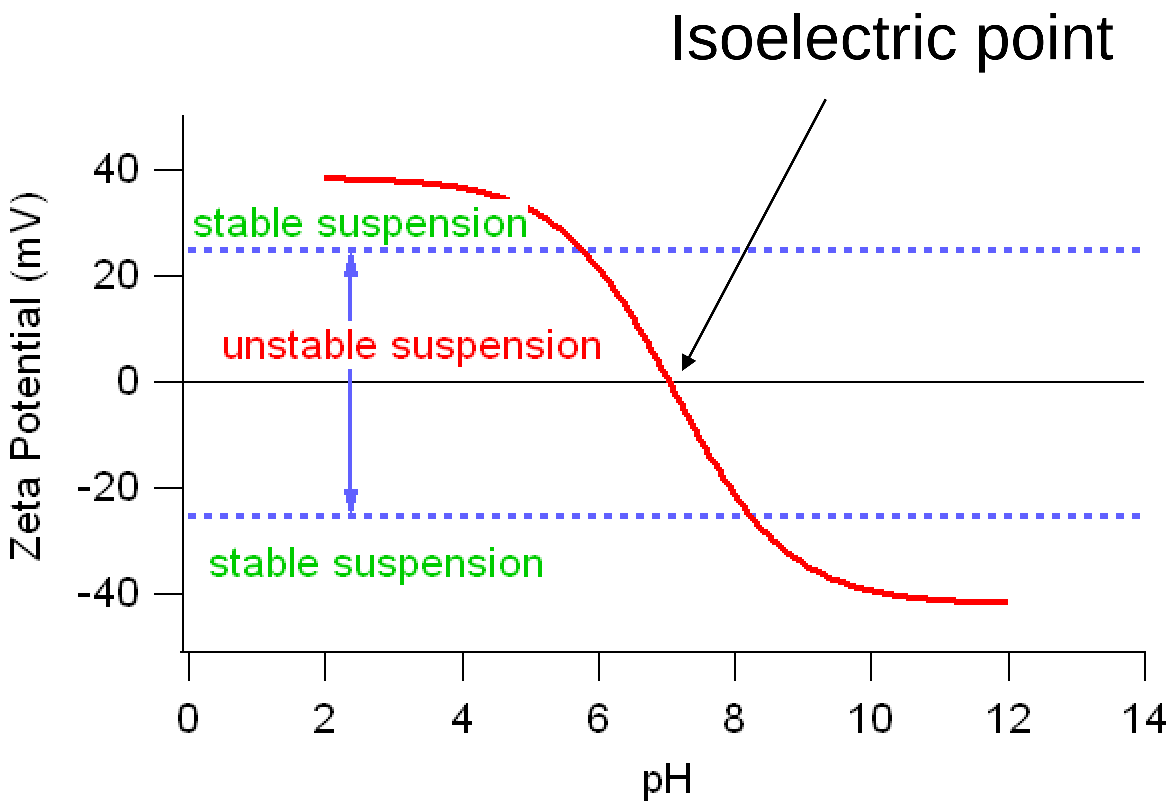


How do we suppress charge effects?

- If we can "turn off" the particle charge, then the particles will flocculate and more rapidly settle (or be more easily filtered).
- We can do this with coagulants and flocculants.
  - Multivalent ions: Ca++, Al+++
  - Polyelectrolytes: acrylamide/acrylic acid copolymers



Isoelectric point



X-axis can also be Ca++ or other ion concentration.

What is the Isoelectric Point?

- The Isoelectric Point is the point at which the zeta potential (surface charge) is zero.
- Achieved by the addition of
  - potential forming ions
  - Specific adsorption of charge modifying agents –the coagulents and flocculants mentioned earlier.
- This is what we need to control the system.

How to Measure Zeta Potential:

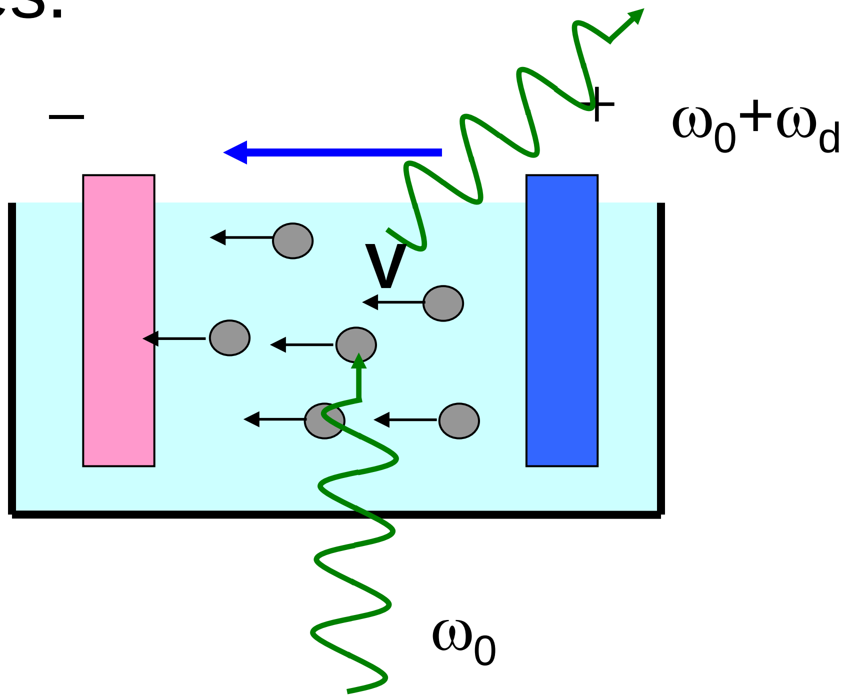
- Acoustic techniques (use sound to probe particle response)
- It is much more popular to use light scattering to probe motion of particles due to an applied electric field. This technique is known as electrophoretic light scattering.
- Used for determining electrophoretic mobility, zeta potential.

How to Measure? With the SZ-100

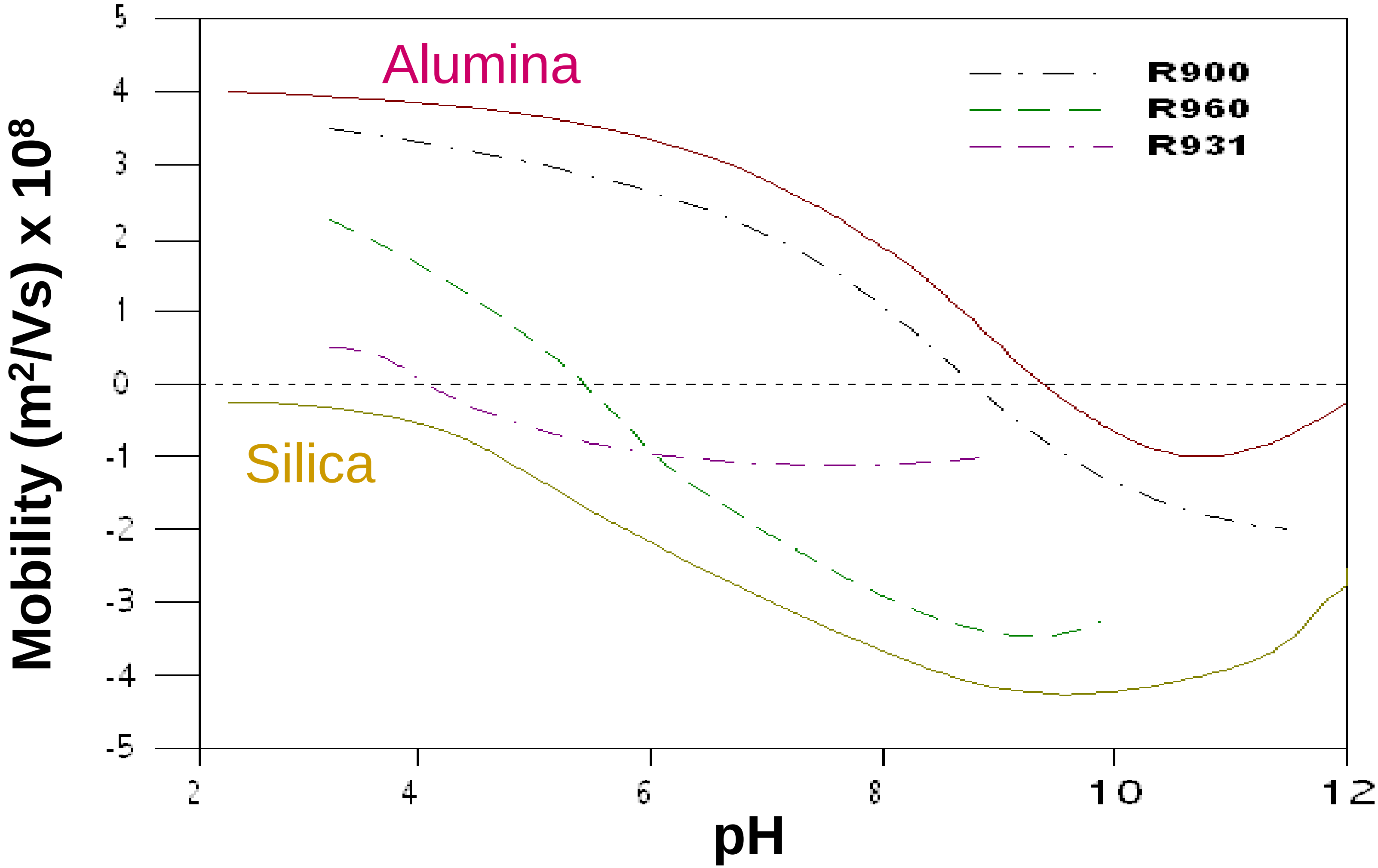
- Single compact unit that performs size, zeta potential, and molecular weight measurements: the SZ-100

How to determine zeta potential

- Apply an electric field and probe response of particles to applied field.
- You need to see Doppler shift in scattered light due to particle motion with respect to fixed electrodes.

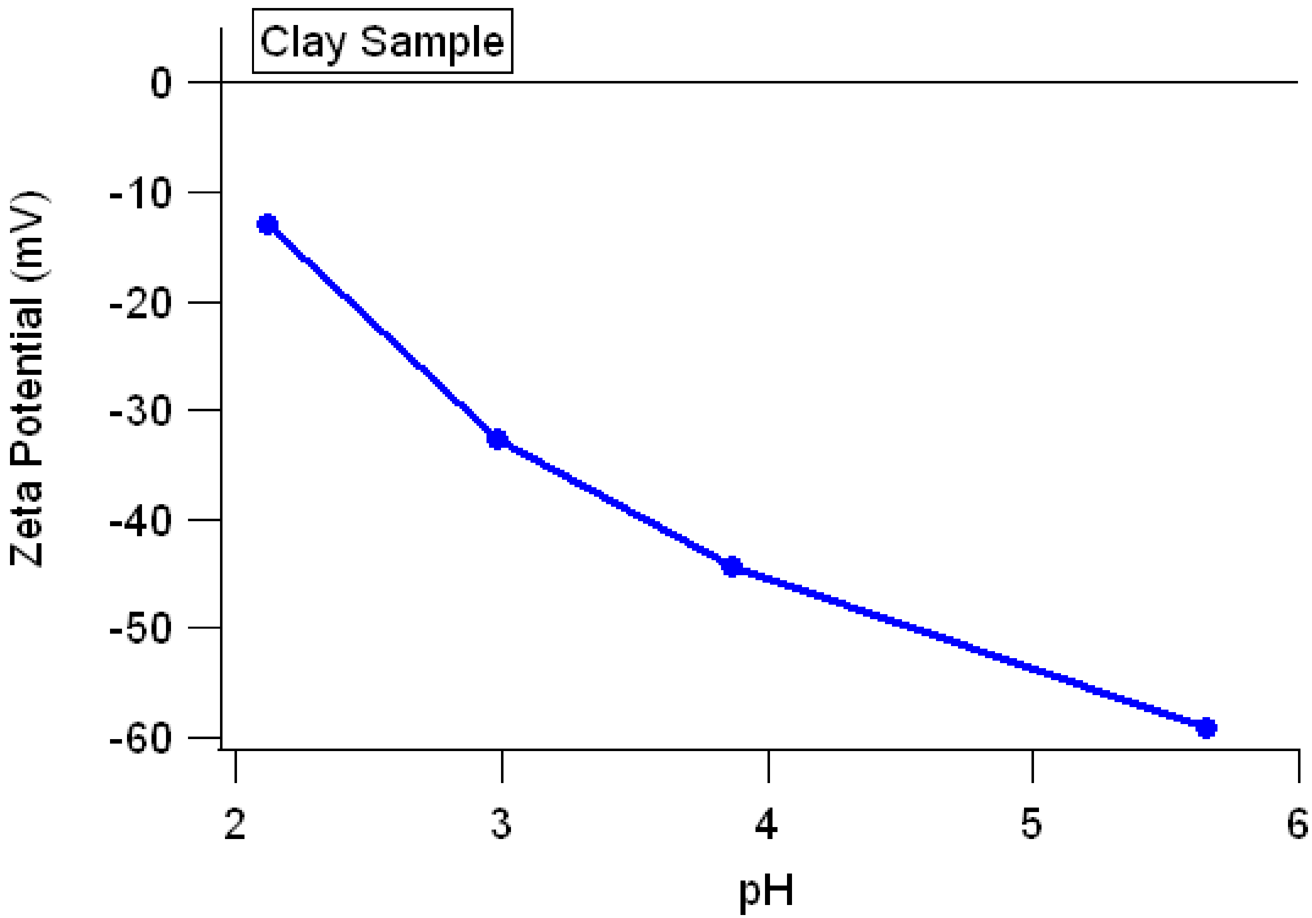


TiO_2 Grades



Surface matters, not bulk material

Clay



To flocculate this clay so it settles, pH must be quite low. You will need a lot of acid.

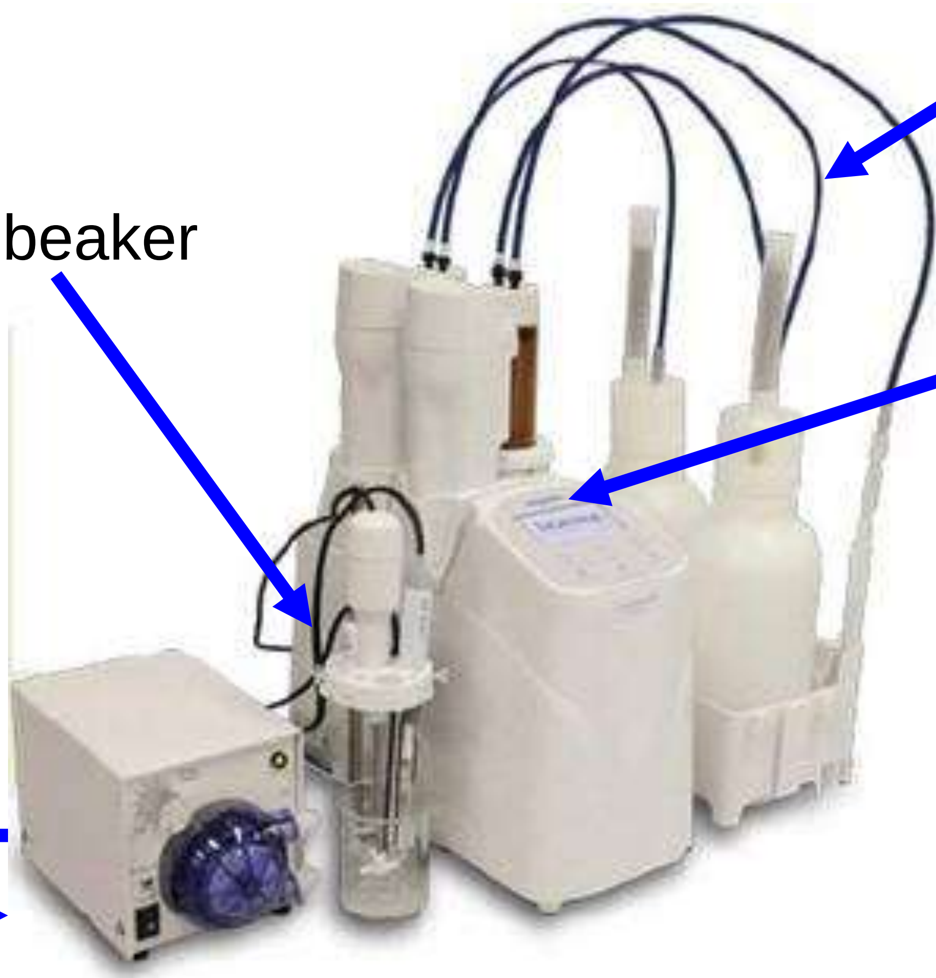
Autotitrator Accessory

Acid/Base bottles

Sample beaker

Precision dosing

Connect
to
instrument



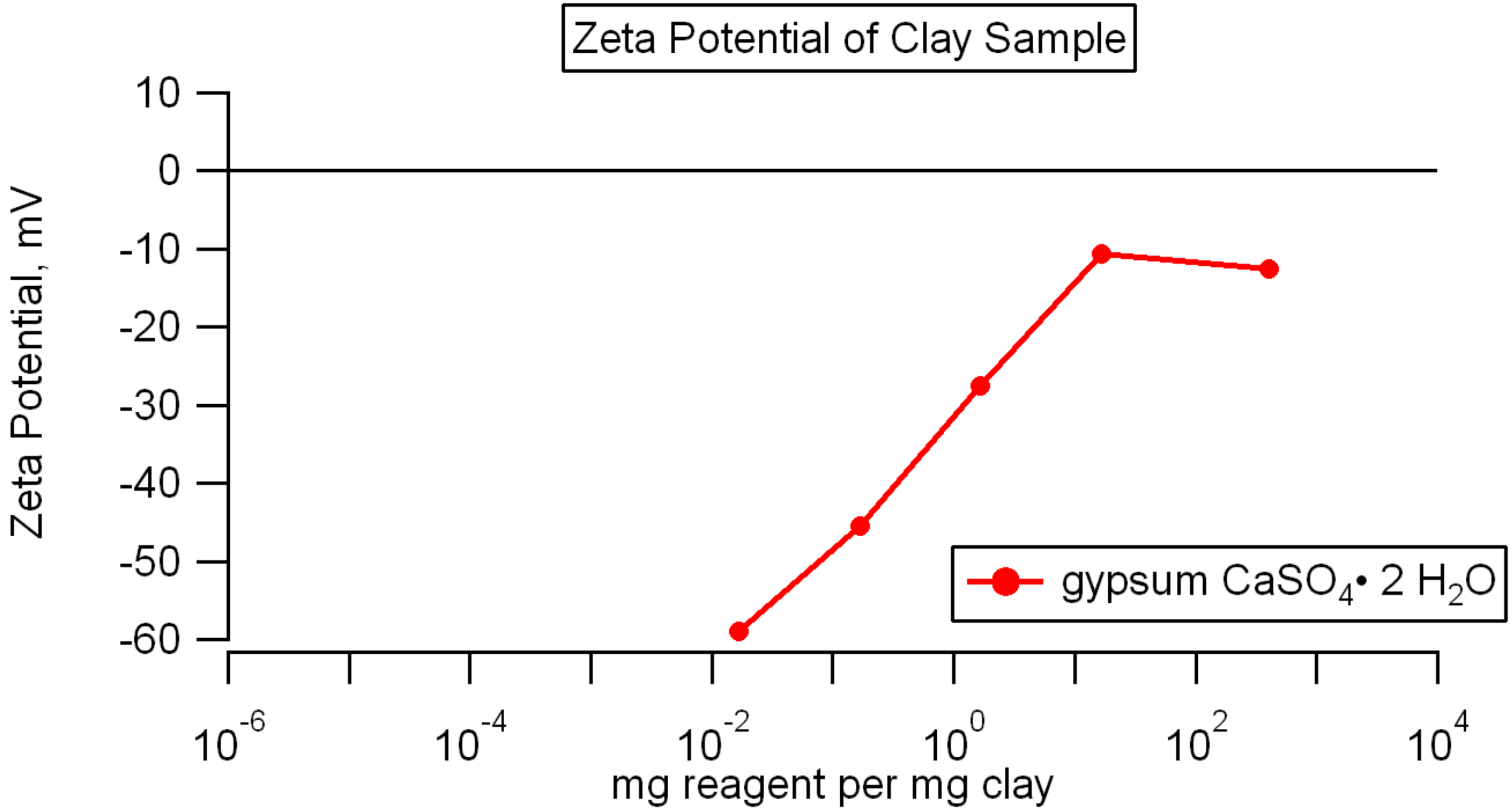
Complete SZ-100 for Zeta Potential

HORIBA

Industrial Control of pH

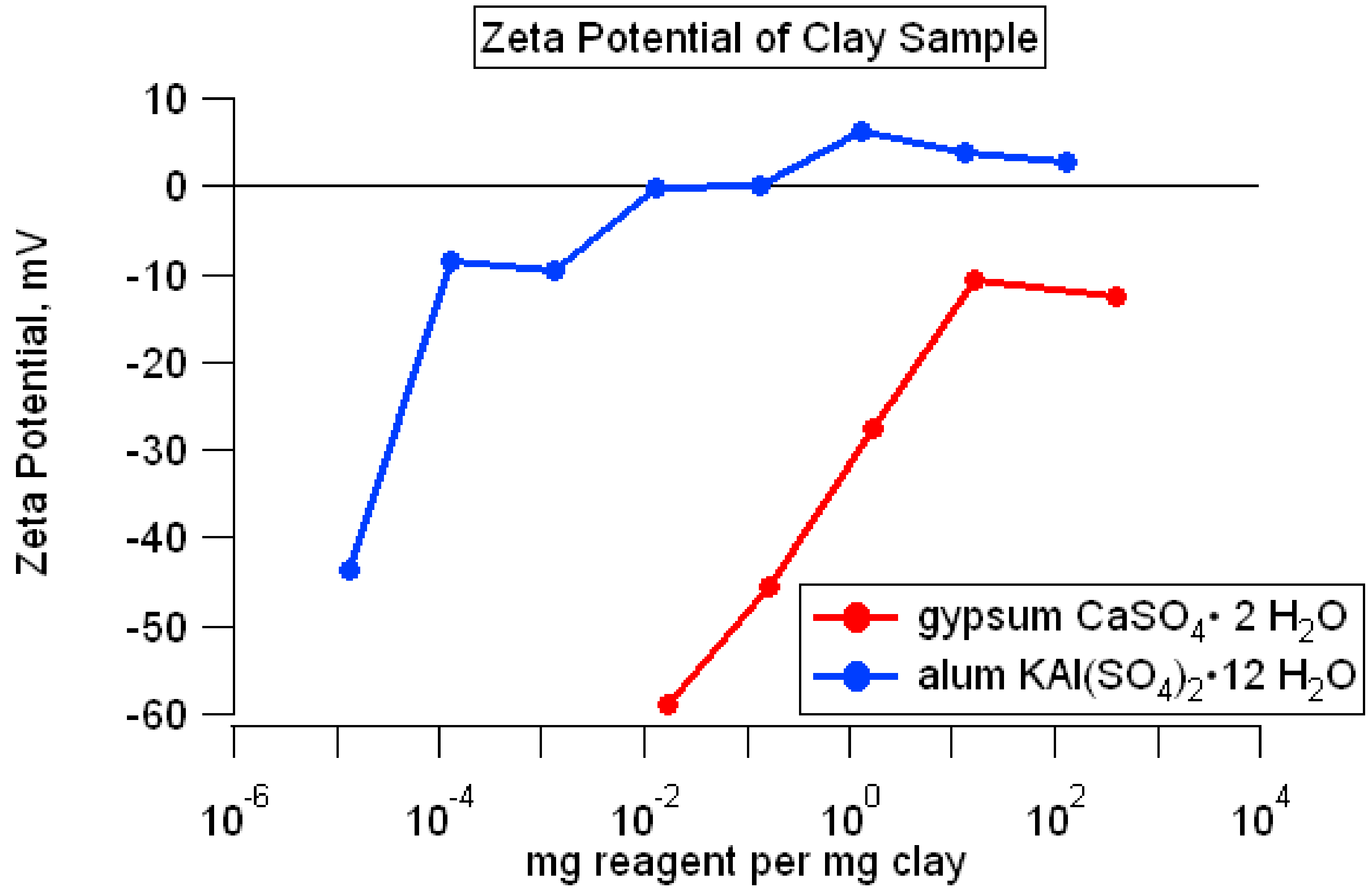
- Once you know your target pH, how do you control it in real time?
- pH controller for industrial use (HP-480 series), transmitter, 4-20 mA signal to valve to control flow of acid/base.

Other Additives: Gypsum



Note log scale

Other Additives: Alum vs Gypsum



To flocculate clay so it settles, choose alum at 0.01 g alum/g clay. Too much or too little and floculation is not ideal.

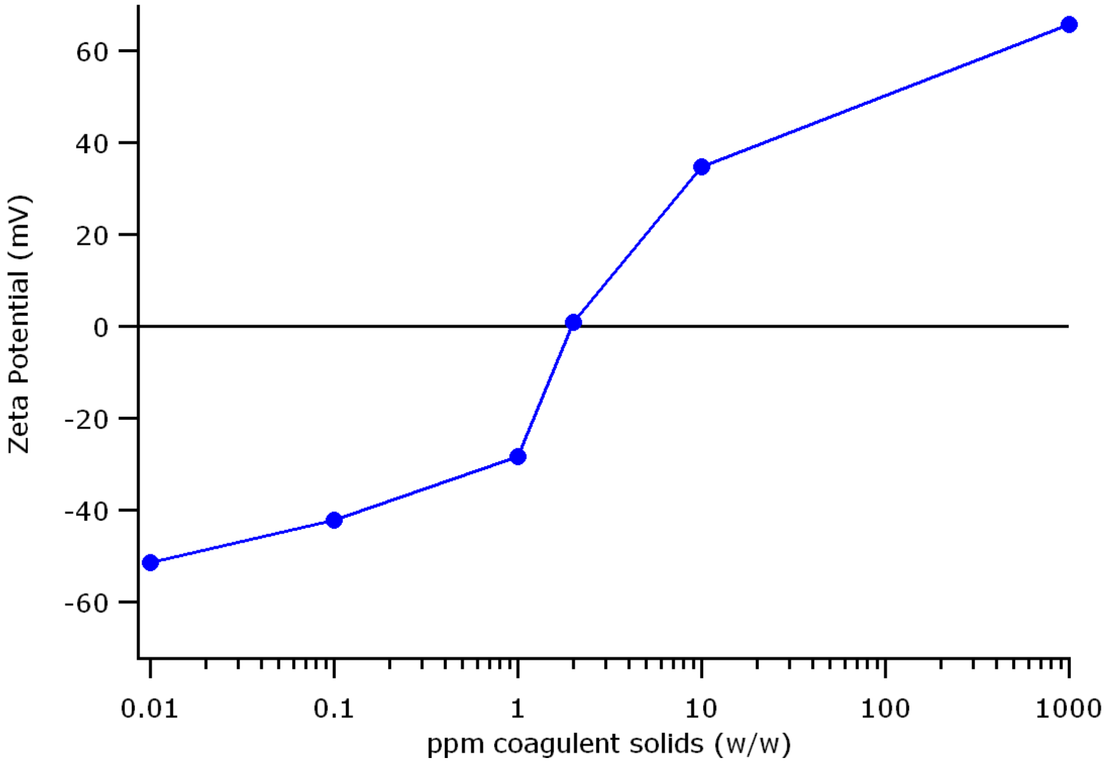
What about refinery waste?

Oil in Water such as the OCMA-350 (fast)

EPA Method 1664 oil and grease in water. Extract with hexane. (slow, but required)

Refinery Wastewater

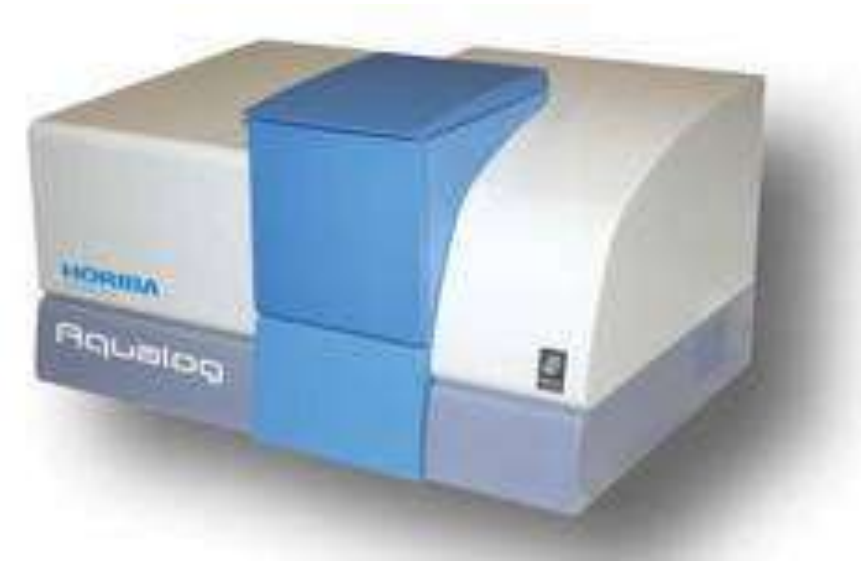
- Water full of oil droplets (and a bit of H_2S!)
- Unknown (proprietary) coagulent.



Note the strong positive charge if you add too much coagulent

Another water analysis option: The Aqualog

- The only true simultaneous absorbance-fluorescence system available
- For CDOM (colored dissolved organic matter)



Zeta Potential Conclusions

- Determining Zeta potential gives the chemist a tool for understanding what different treatment options are doing to the particles.
- Understanding is necessary for optimization.

Q&A

Ask a question at labinfo@horiba.com

Keep reading the monthly HORIBA Particle e-mail newsletter!

Visit the Download Center to find the video and slides from this webinar.

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Thank-you