Using Particle Counters in combination with Turbidimeters to obtain a better understanding of coagulation and filtration performance.

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CHEMTRAC

Topics

- Coagulation & Filtration Theory
- Nephelometric (90° Light Scatter) Turbidimeter
- Light Blocking Particle Counter
- Particle Volume Distribution – Why It Matters,
- Interpreting NTU & PC Data

Which Has Higher Turbidity?

A

B

Both samples contain mixture of water and iron oxide (hematite)

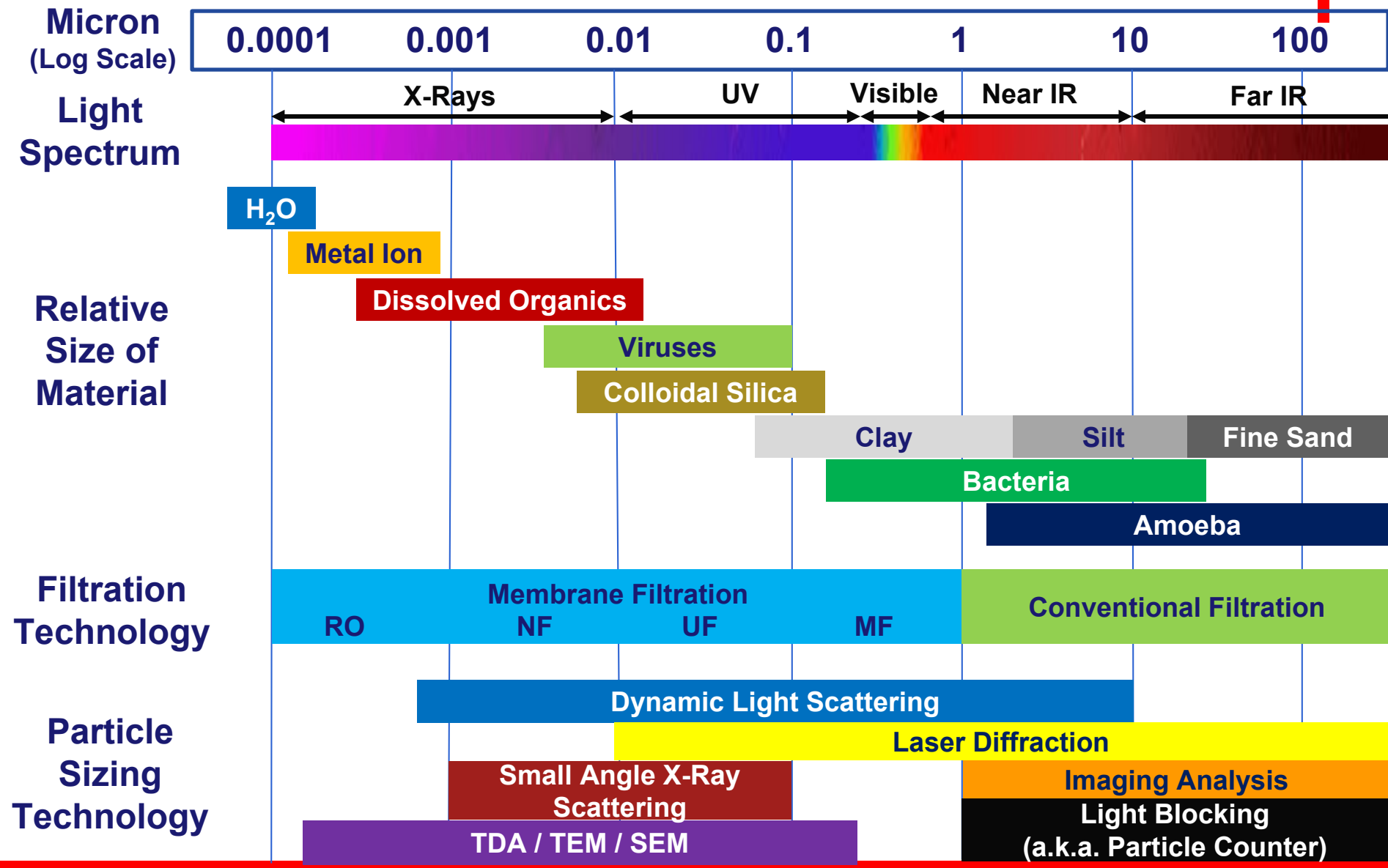
Which Has Higher Solids?

A

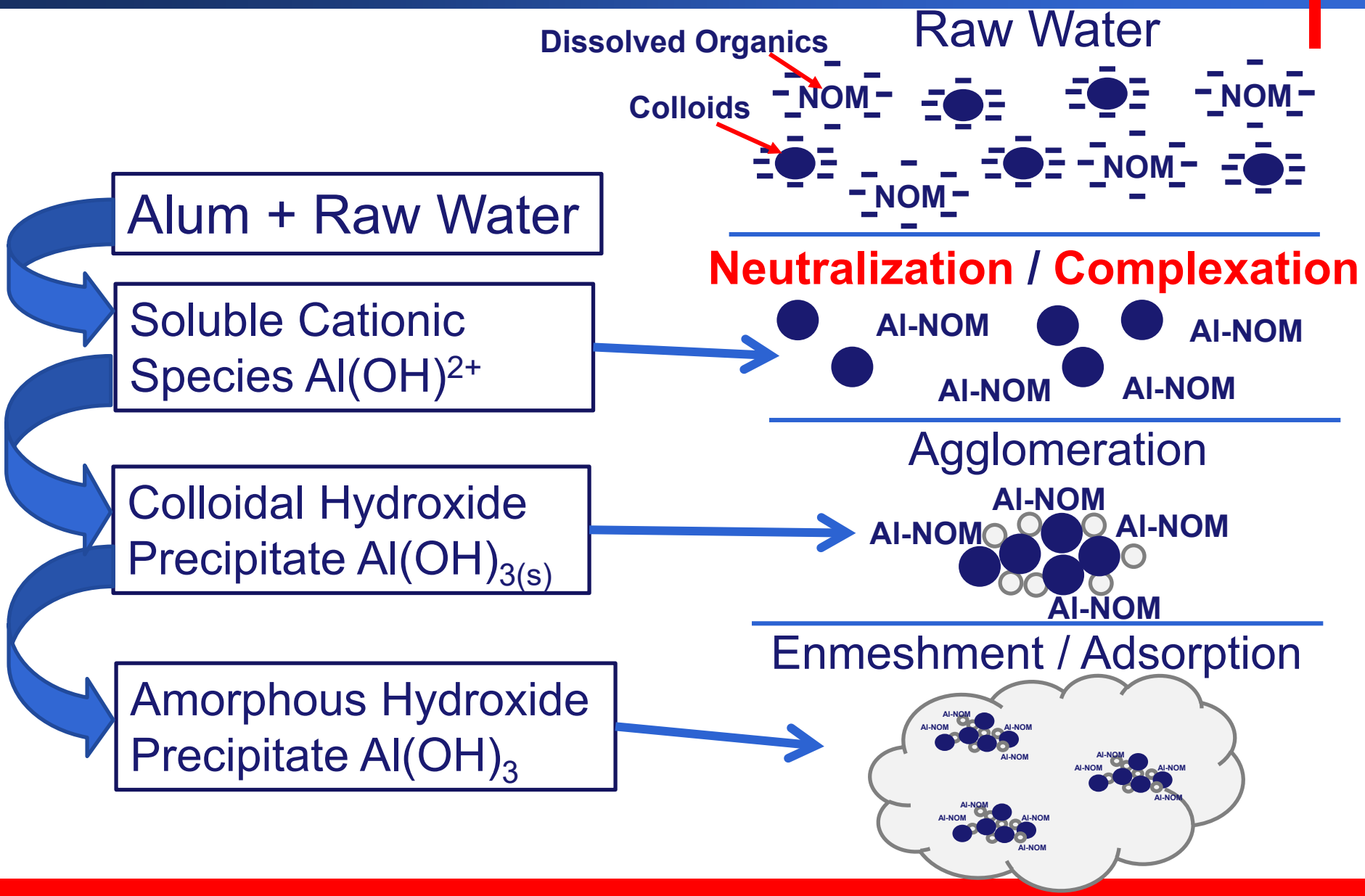
B

Both samples contain mixture of water and iron oxide (hematite)

Particle Size Spectrum



Coagulation Mechanisms



Turbidimeters (Light Scatter)

Turbidity Definition

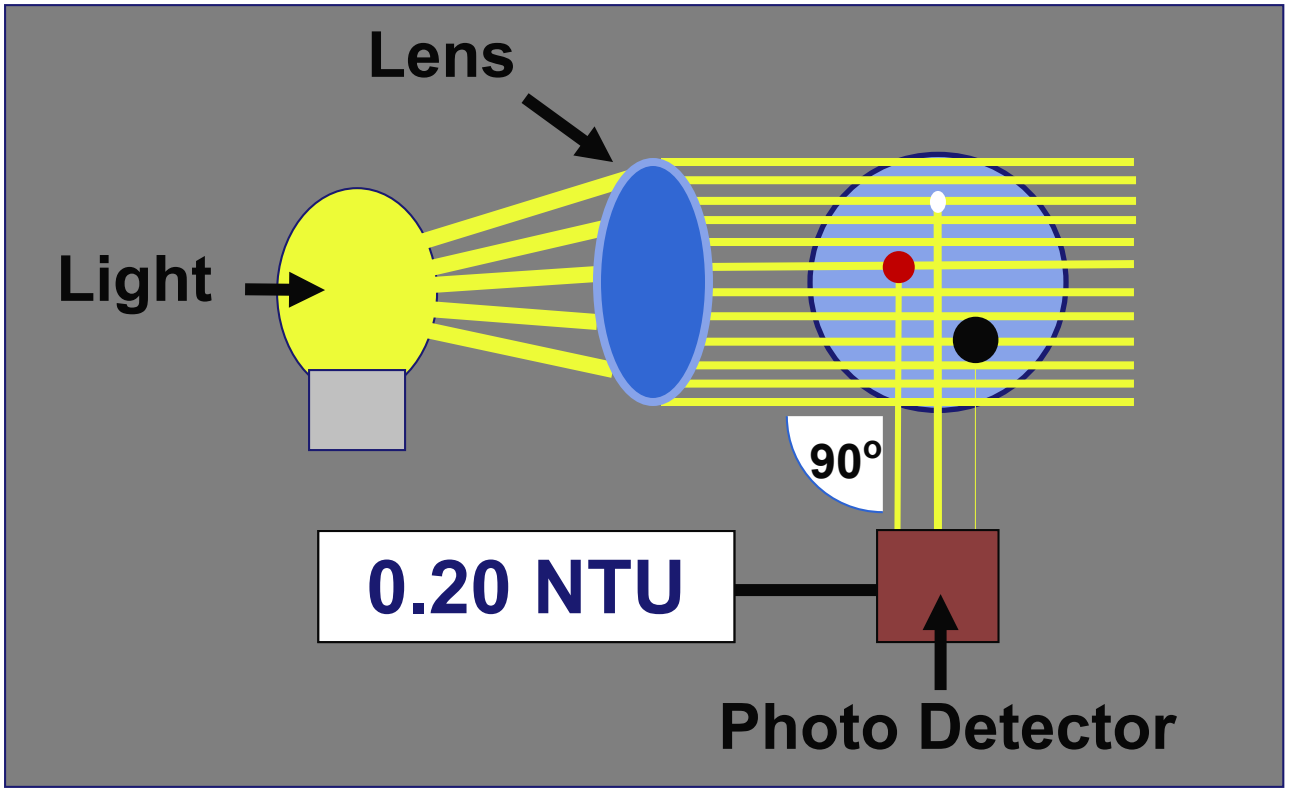
- Turbidity is a measure of water clarity, how much the material suspended in water decreases the passage of light through the water. - EPA
- Turbidity is the measure of relative clarity of a liquid. - US Geological Survey (USGS)

Turbidimeter Definition

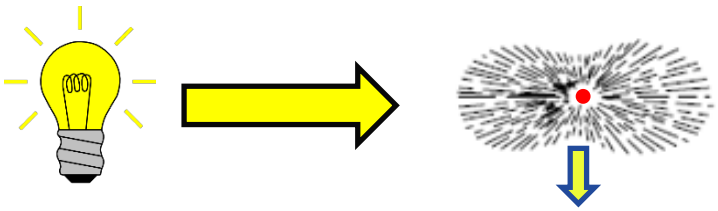
Oxford Dictionary

- An instrument for measuring the turbidity of a liquid suspension, usually as a means of determining the surface area of the suspended particles.

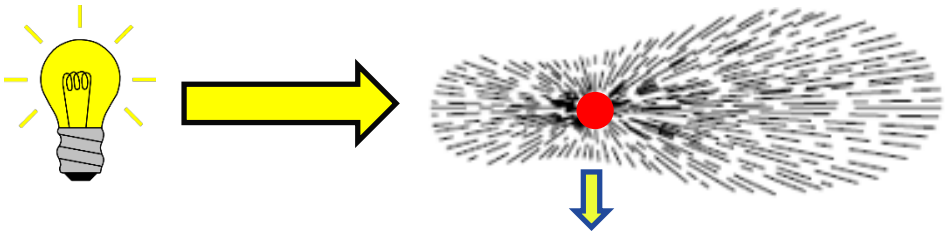
Nephelometric Turbidimeter (90 Degree Light Scatter)



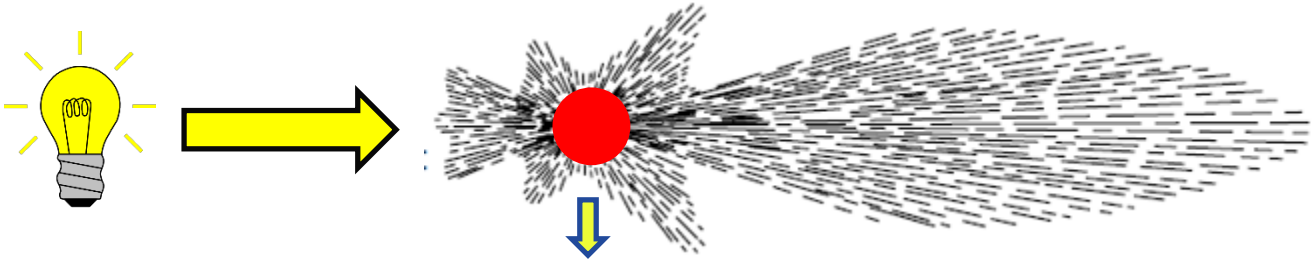
Light Scatter Behavior



Small Particles (<100 nm): Somewhat Symmetric Light Scatter

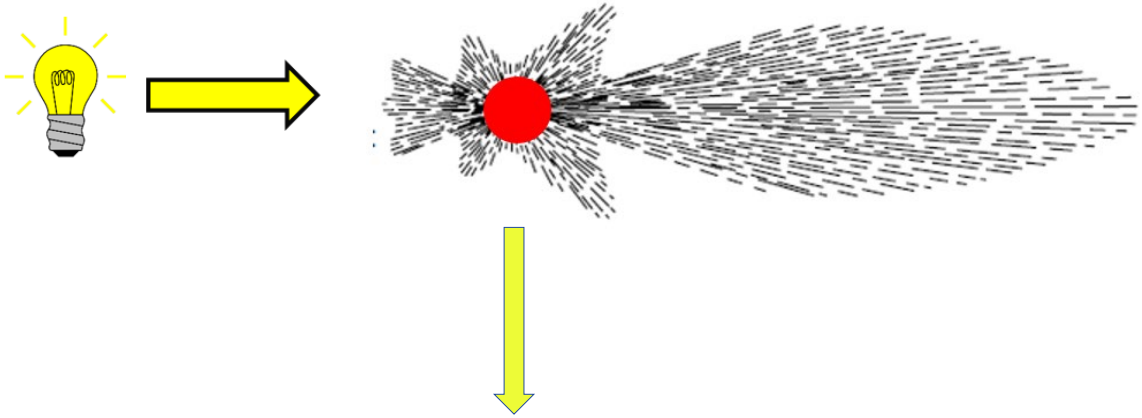


Medium Particles (100 to 500 nm): Increased Light Scatter in Forward Direction

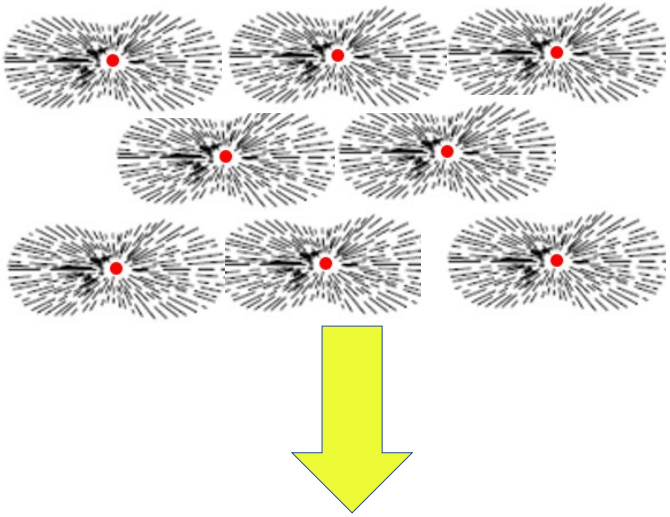


Larger Particles (>500 nm): Extreme Scatter in Forward Direction

NTU Relationship To Solids

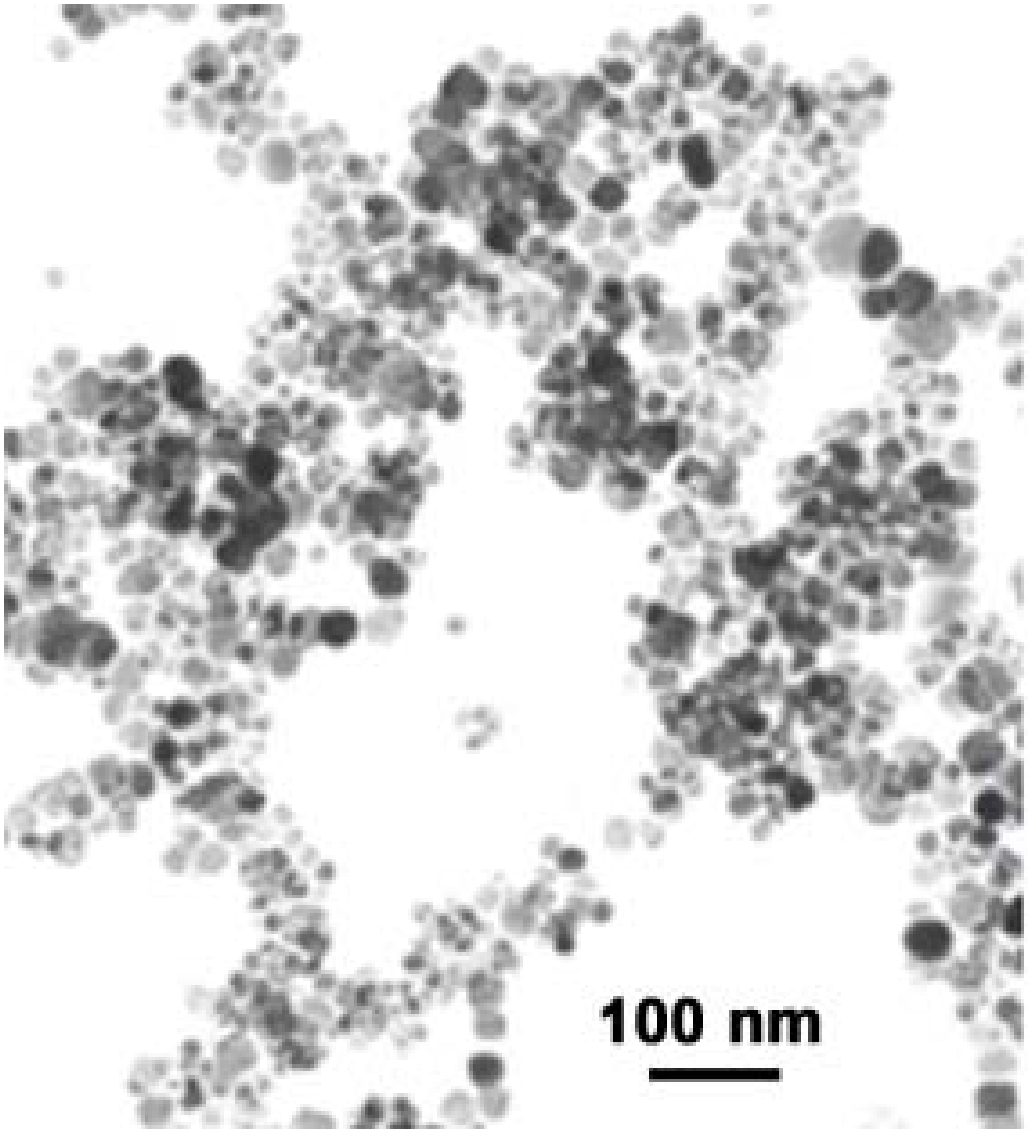


? NTU



? NTU

Iron Oxide - Nanoparticles



Impact of Particle Size On Turbidity

Demosntrating Impact Particle Size Has On Turbidity

Prior to Ultrasonication

Sample contains large agglomerations of iron particles, many larger than >10 micron

Initial Moment After Going Into Bath

The agglomerations of iron particles begin to break apart.

10 Seconds After Going Into Bath

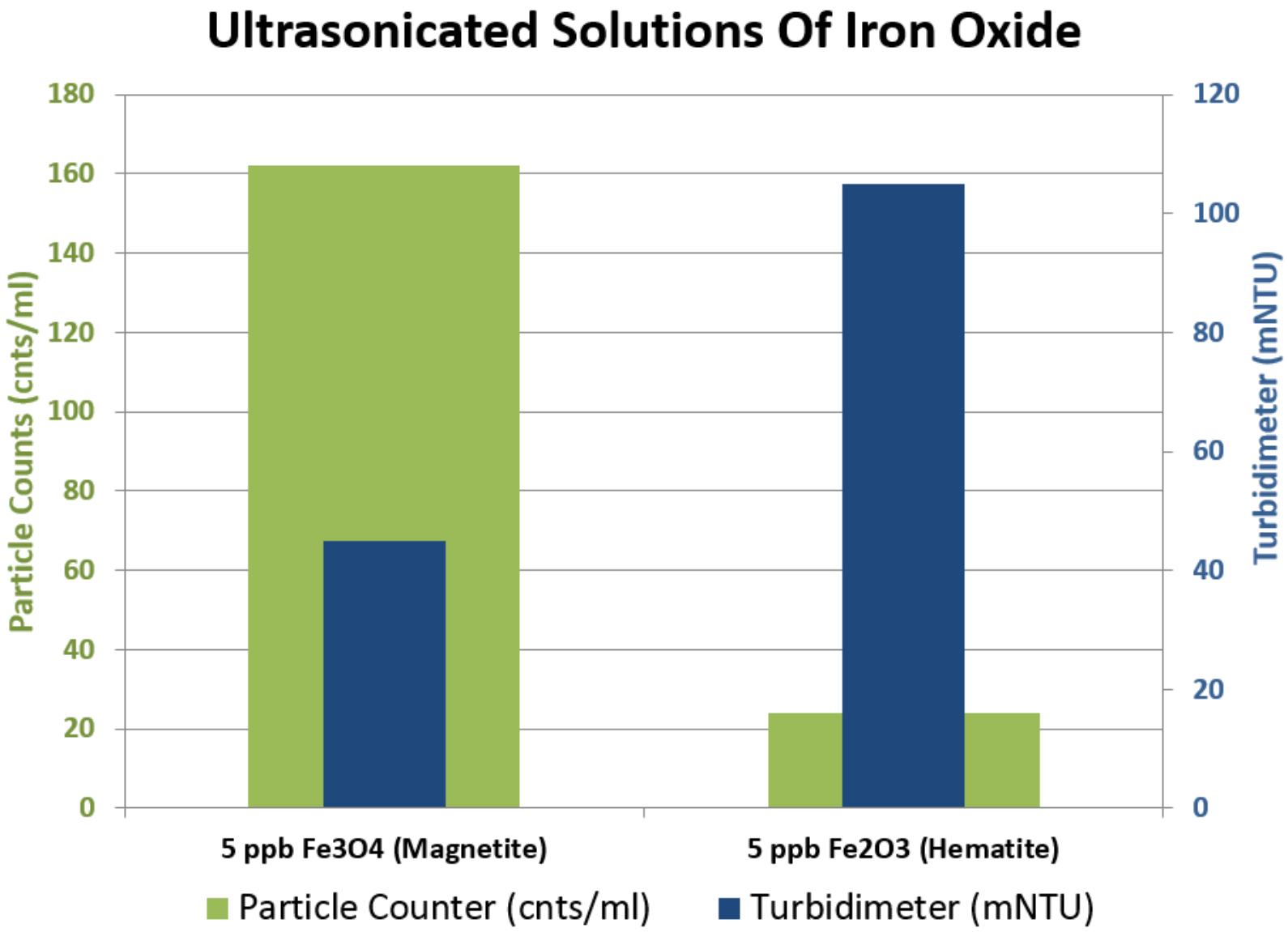
As discrete iron particles are disbursed, more surface area is exposed, increasing light scatter.

After Ultrasonication

Iron particles now disbursed as discrete submicron particles which dramatically increases turbidity.

Magnetite & Hematite

PC vs NTU Response

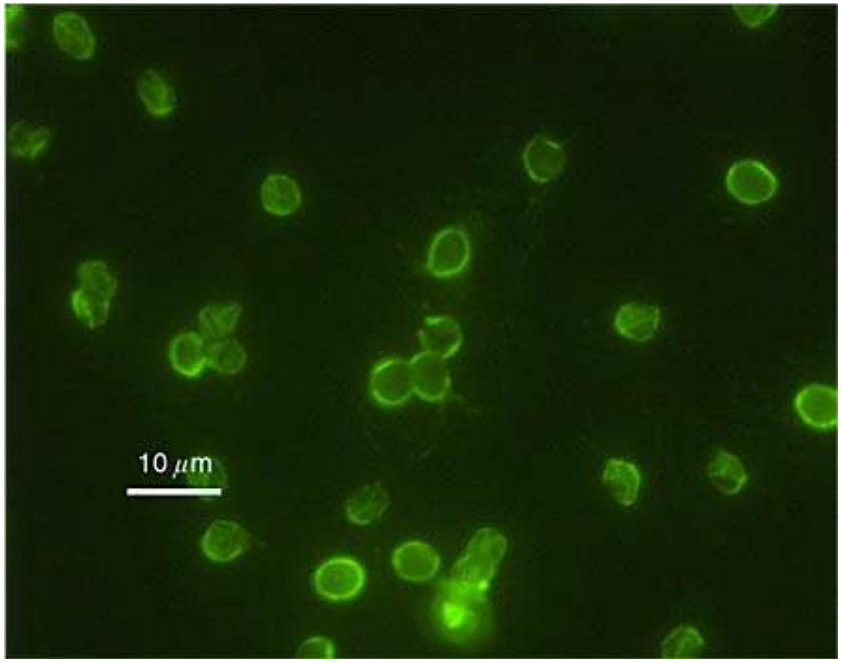


Turbidity (Light Scatter) Summary

- A qualitative measurement that determines clarity of the water, which is impacted by both number and size of particles.
- 10 ppb of 5 micron particles will have a lower NTU than 10 ppb of 0.5 micron particles.
- Does not reliably correlate to suspended solids post coagulation due to changing distribution of particulate (post coagulation).
- Offers affordable means of submicron particle detection.

Particle Counters (Light Obscuration)

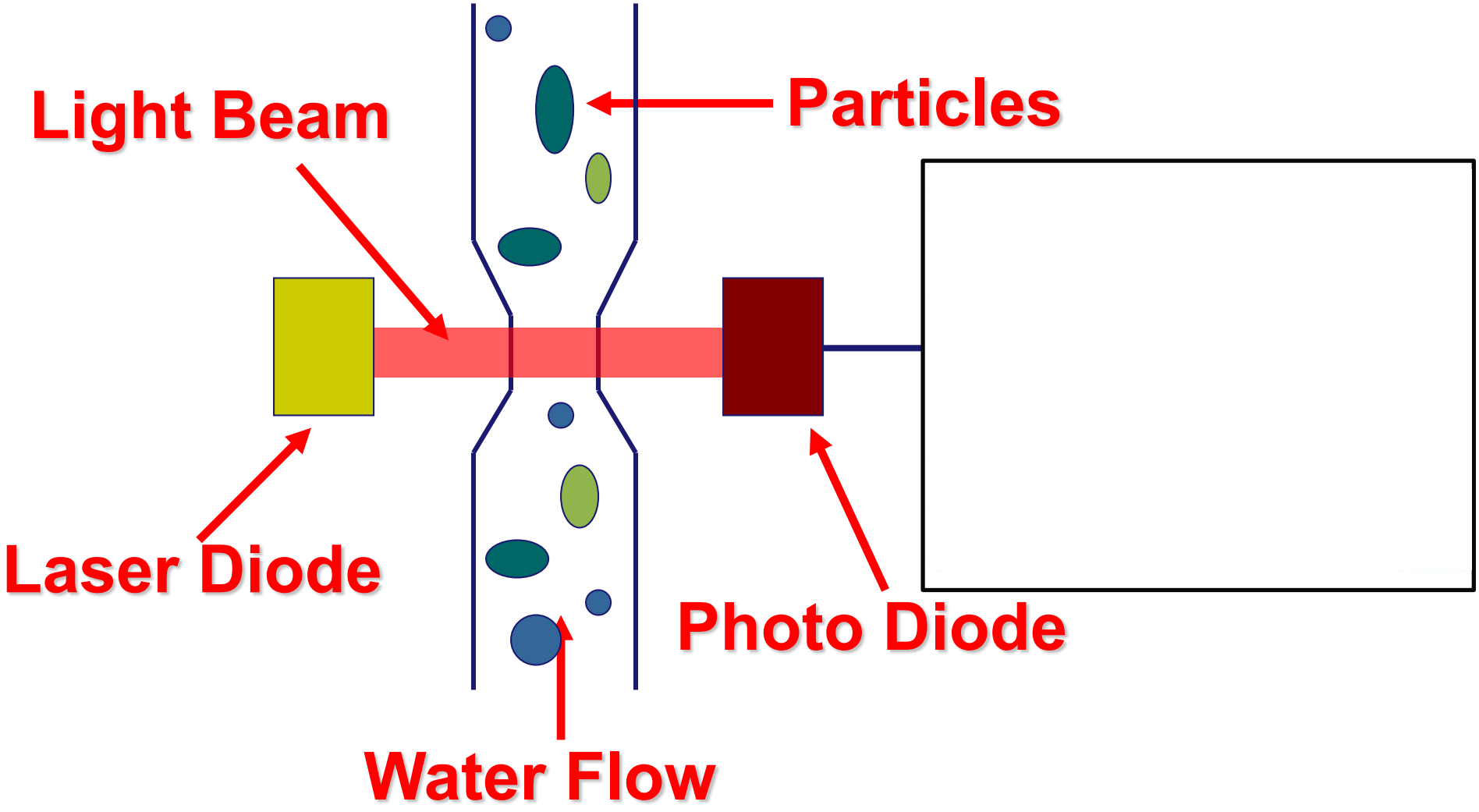
The Rise of Particle Counters



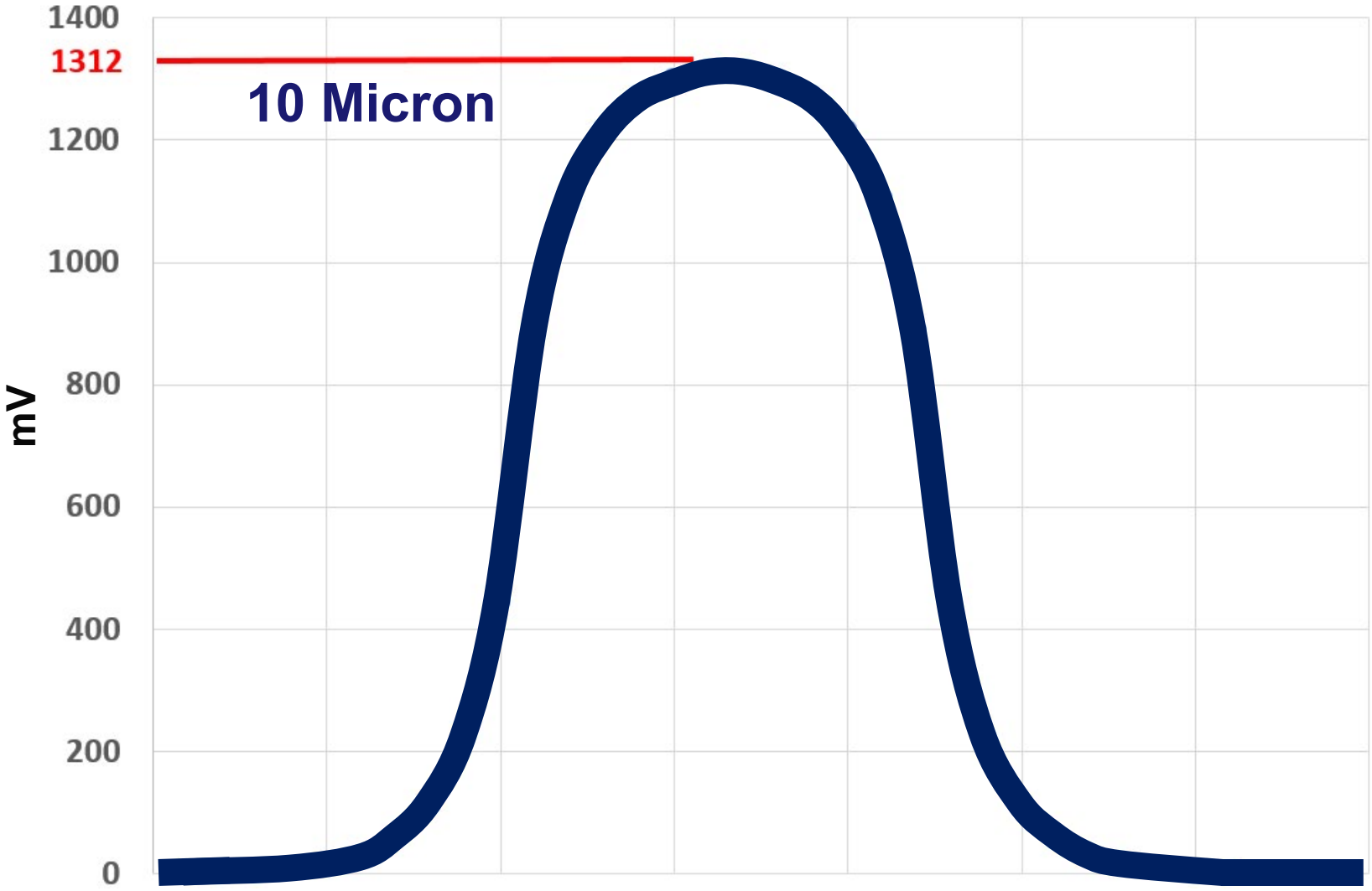
- Two major crypto outbreaks in the US occurred in the early 90's which led to intense interest in particle counters in the drinking water industry as a way to hep guard against future outbreaks.

Photo Credit: H.D.A Lindquist, U.S. EPA

Particle Counter (Light Blocking)

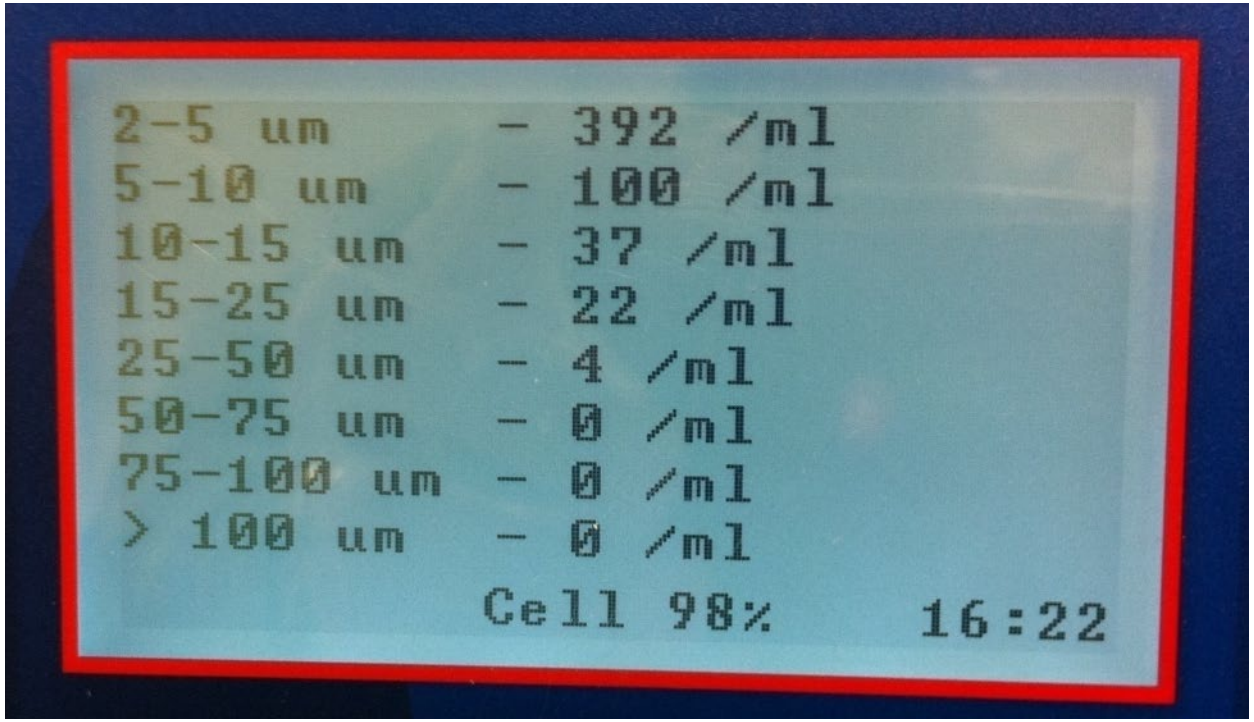


Particle Sizing

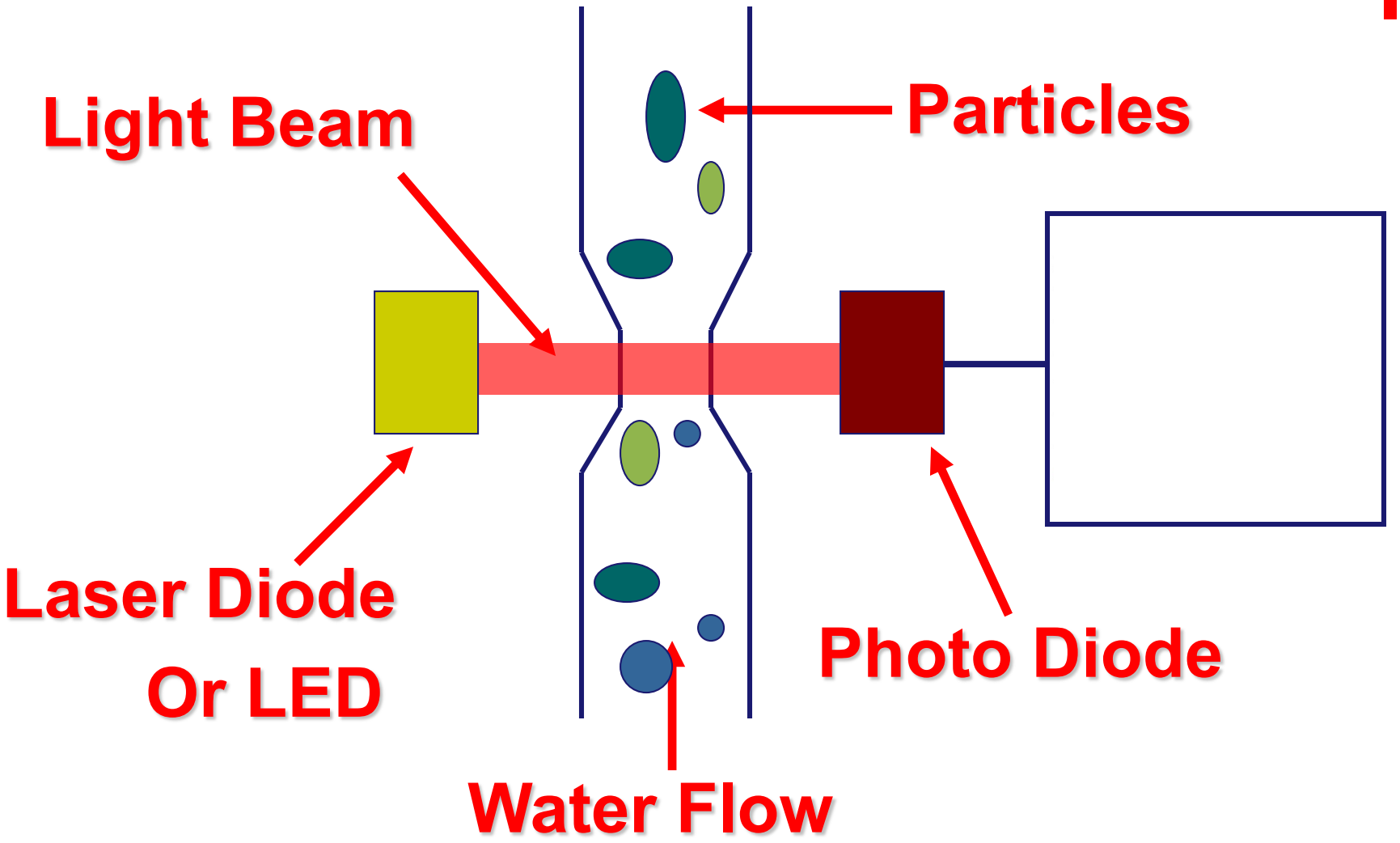


Particle Counts

- Multi-Size channel view showing counts in each size bin.



Coincidence Error

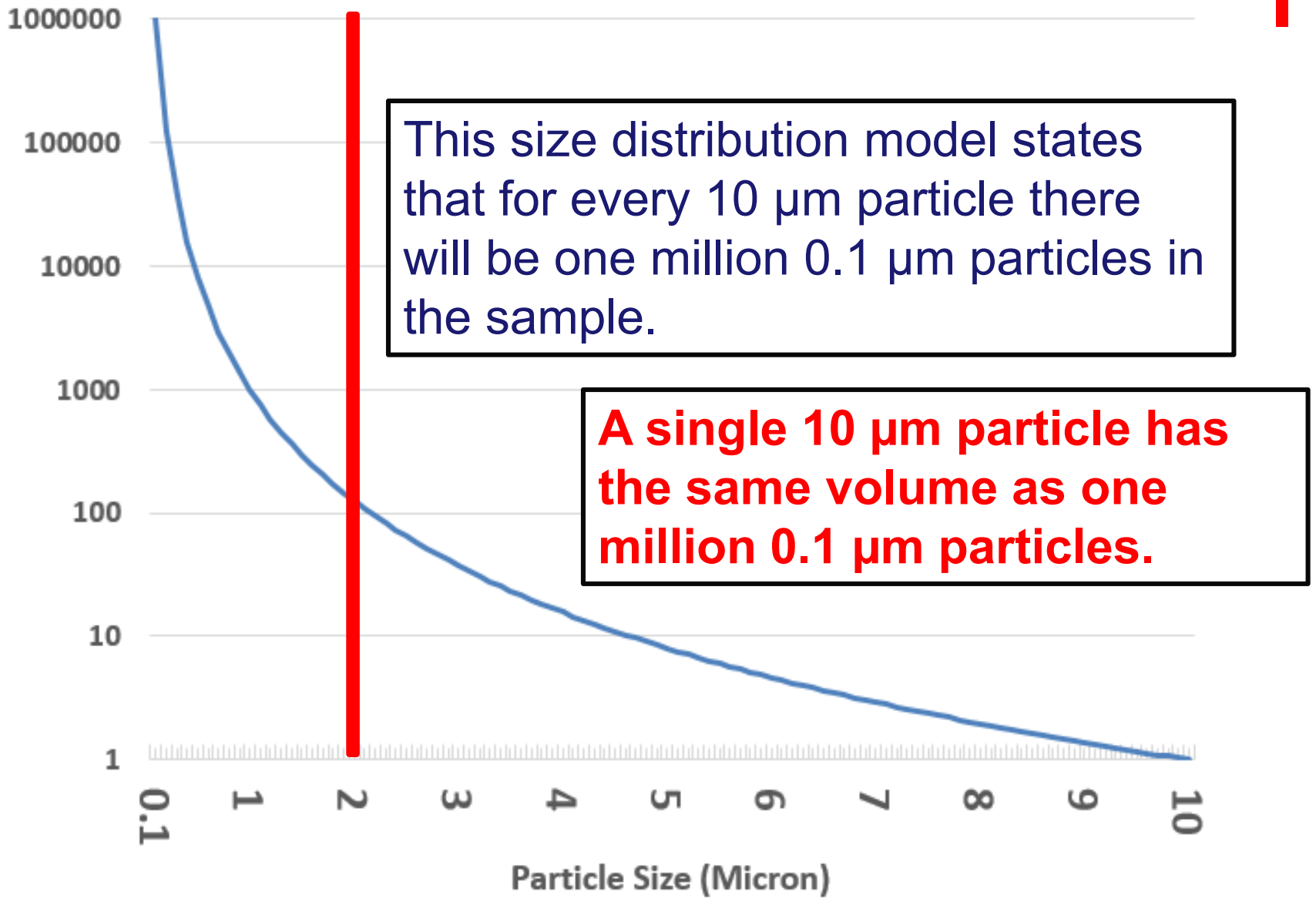


What Is More Important?

Particle Count (How Many?)

Particle Volume (How Much?)

Idealized Size Distribution



This size distribution model states that for every 10 µm particle there will be one million 0.1 µm particles in the sample.

A single 10 µm particle has the same volume as one million 0.1 µm particles.

Particle Size vs Volume

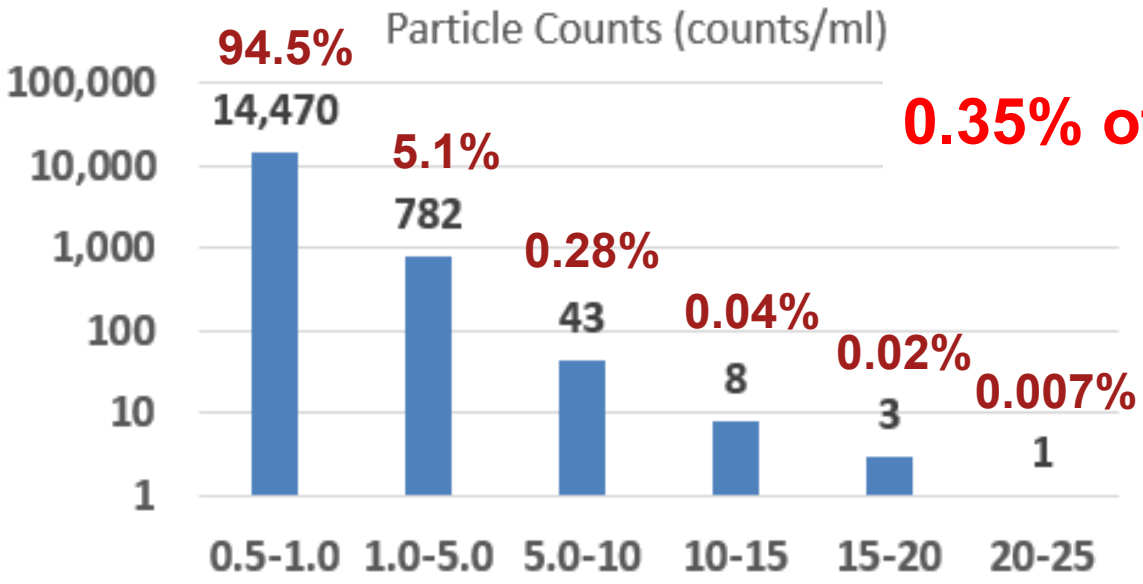
0.1 micron = 0.0005 μm^3 → **0.0005 ppt***

2 micron = 4.2 μm^3 → **4.2 ppt***

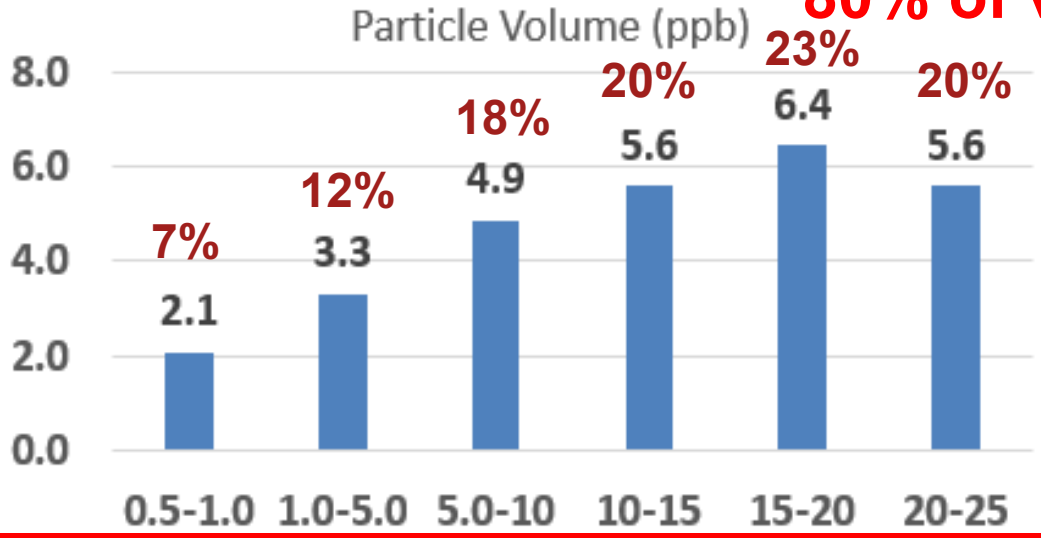
10 micron = 524 μm^3 → **524 ppt***

* At concentration of 1 count per mL

Real World Filter Effluent Data



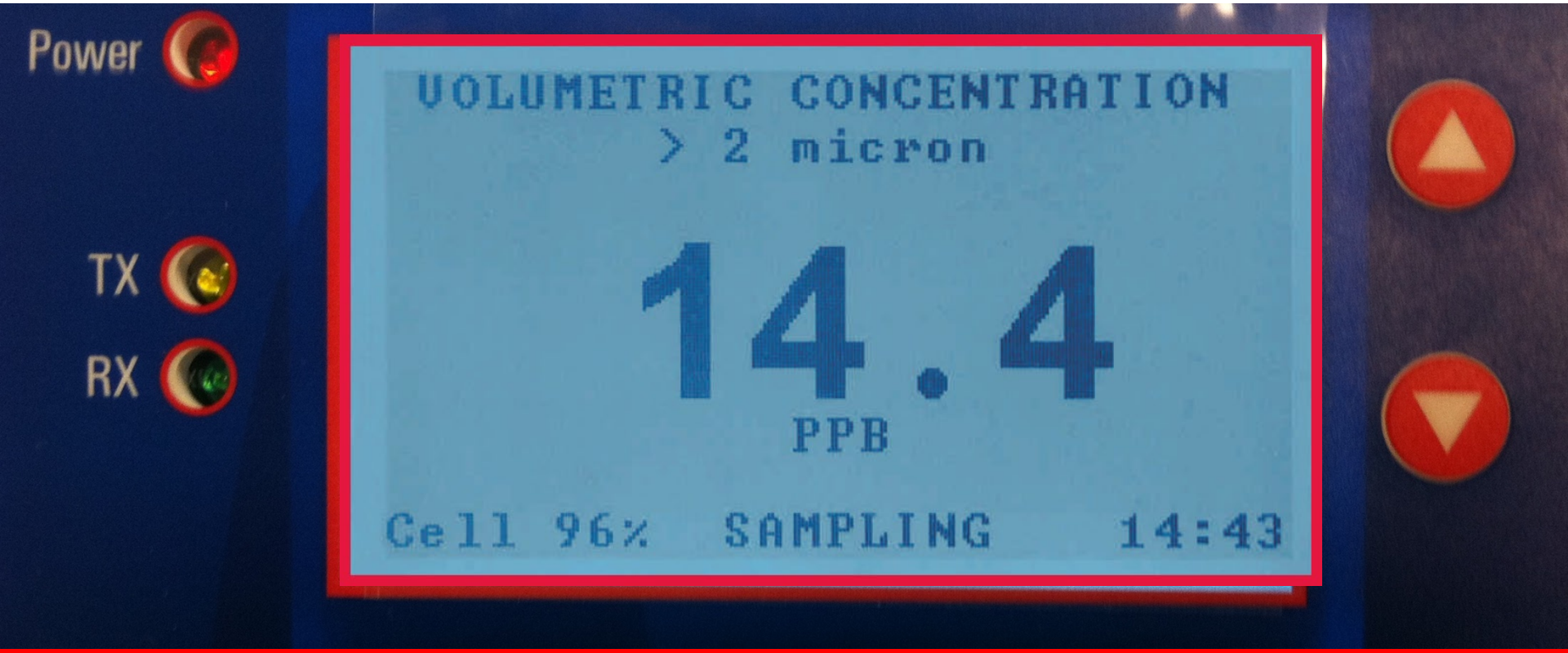
0.35% of counts >5 um



80% of volume >5 um

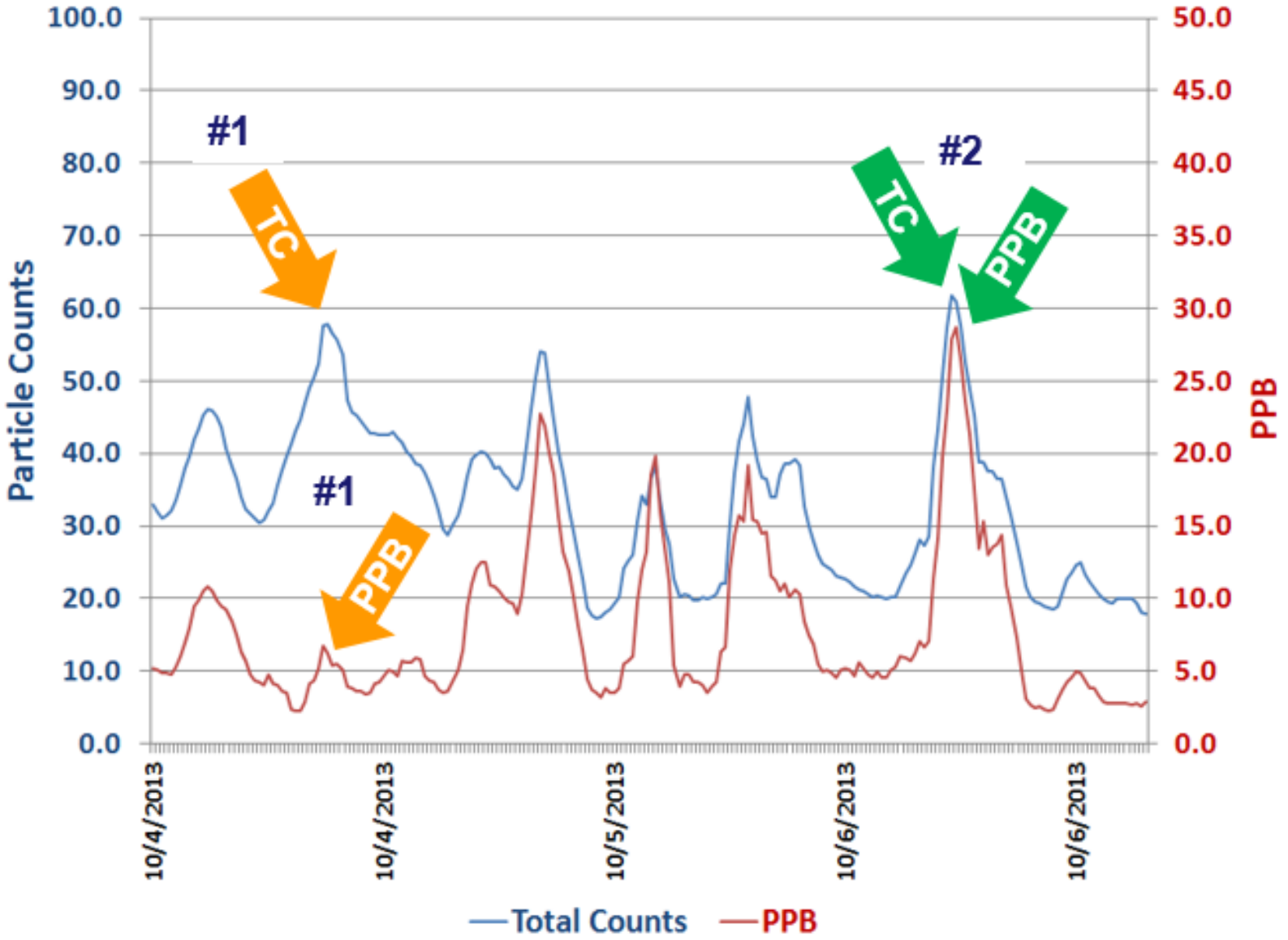
Particle Volume Readout

- An important feature of some online particle counters is a volumetric concentration readout

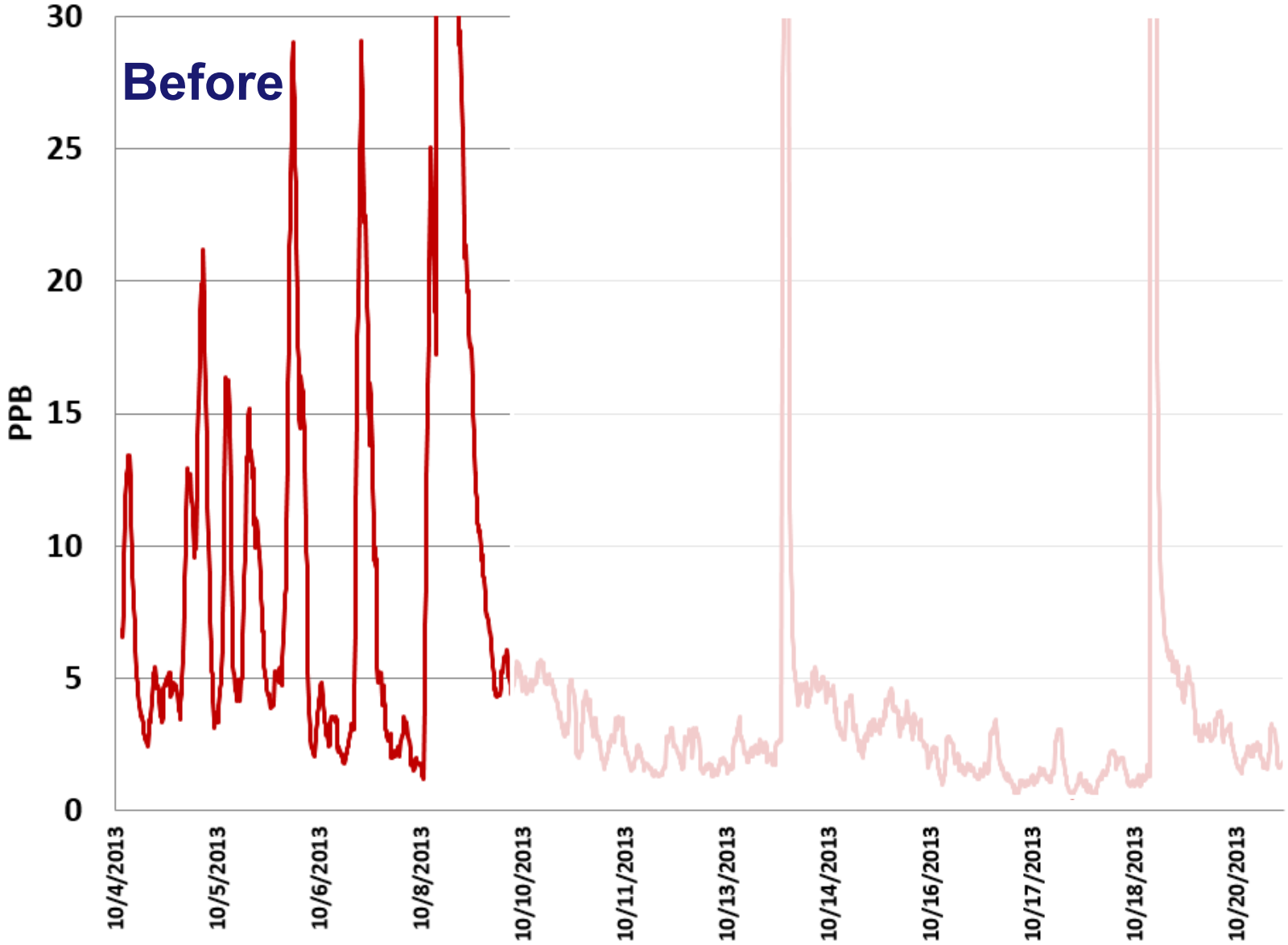


Biologically Active Filters

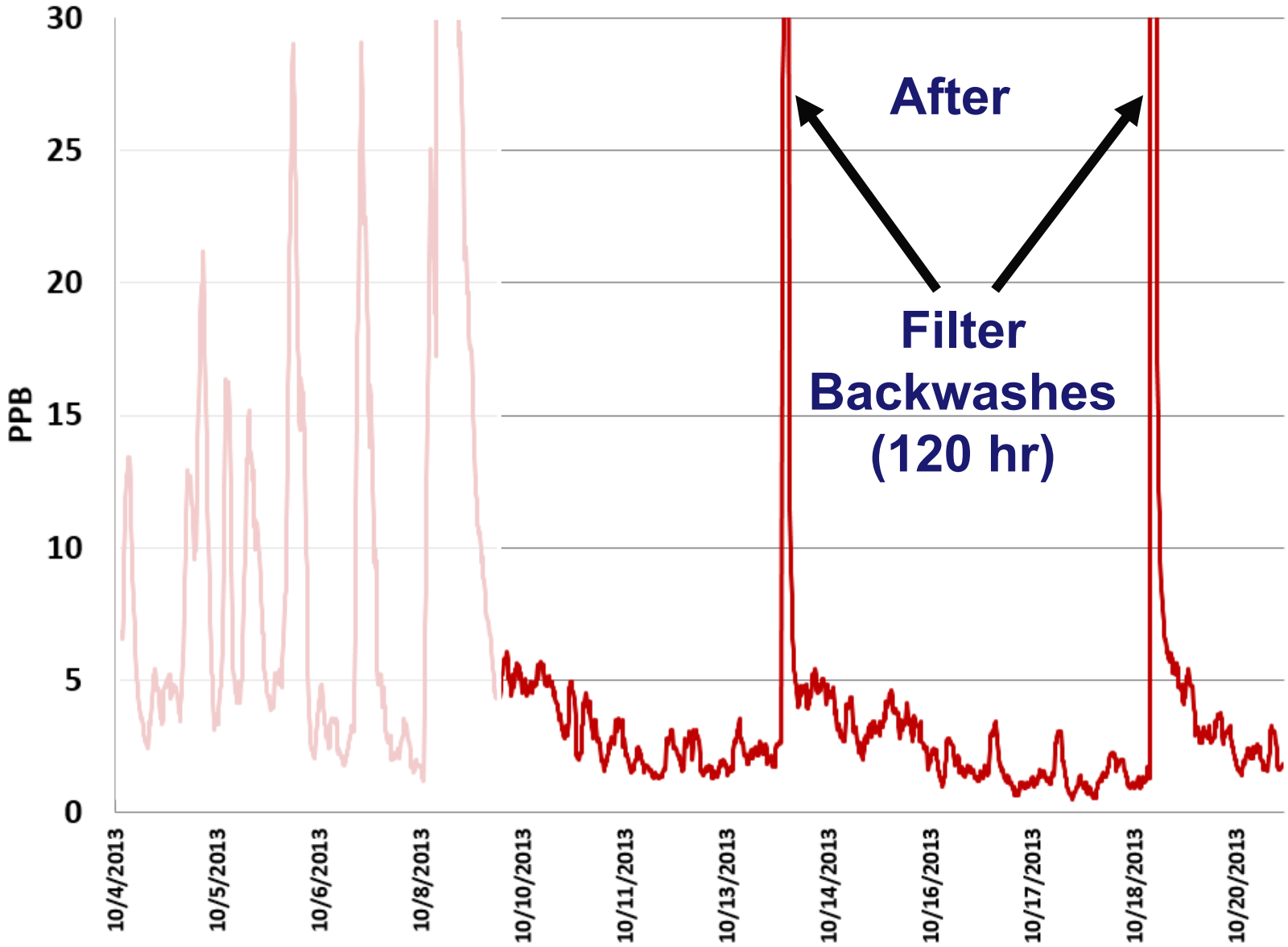
Total Counts with PPB



Before Chlorine Addition

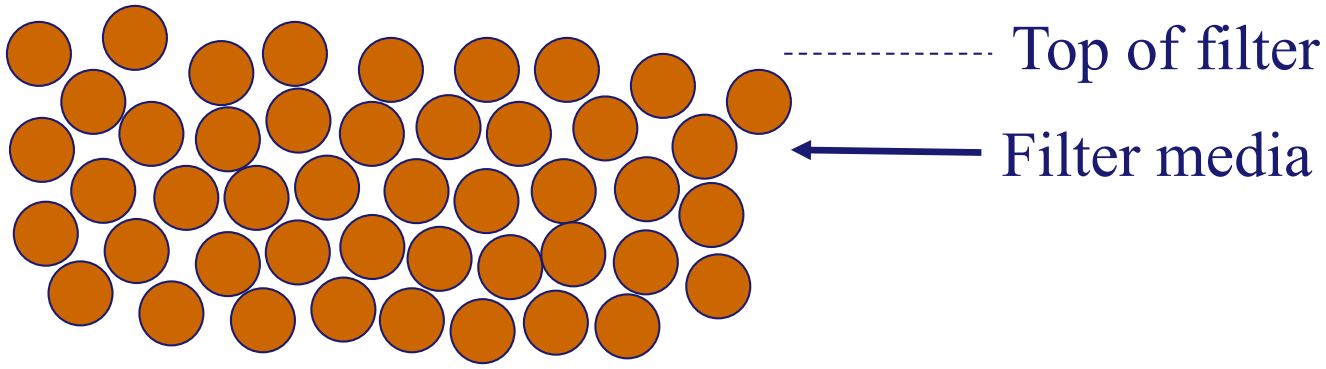


After Chlorine Addition



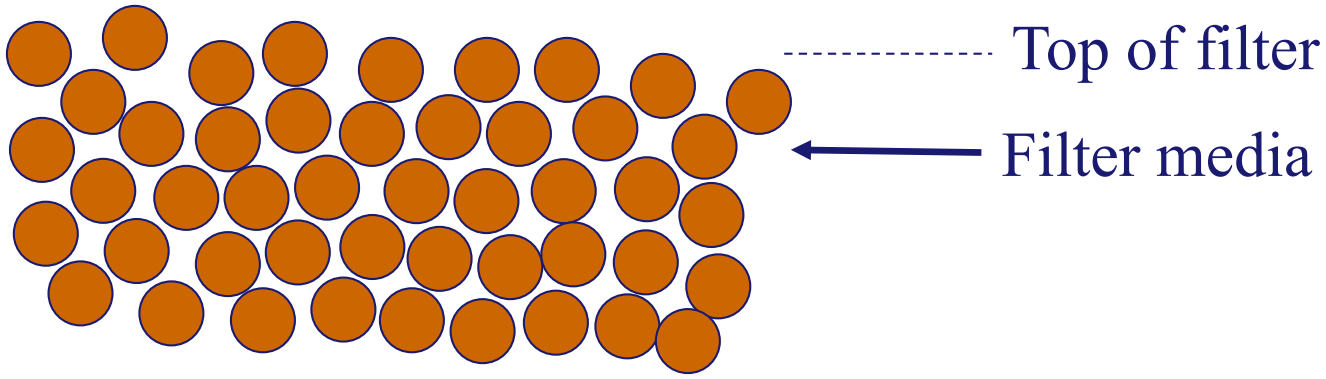
Particle Detachment

Surface Removal (Straining)



- Large floc particles lead to rapid head loss, shorter filter run times.

Attachment Filtration

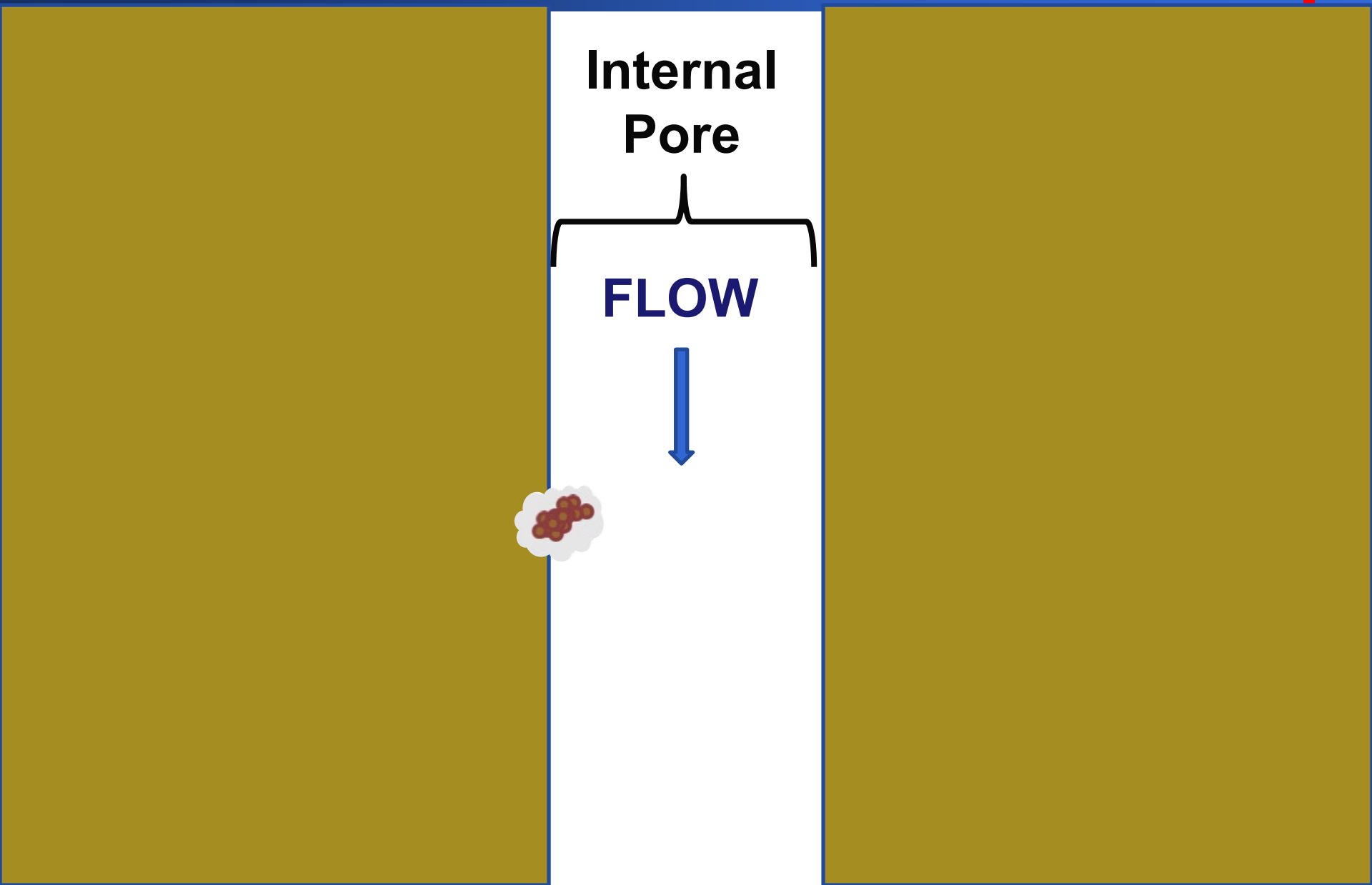


- Smaller floc particles allow more of the filter media to be utilized, allowing for longer filter run times

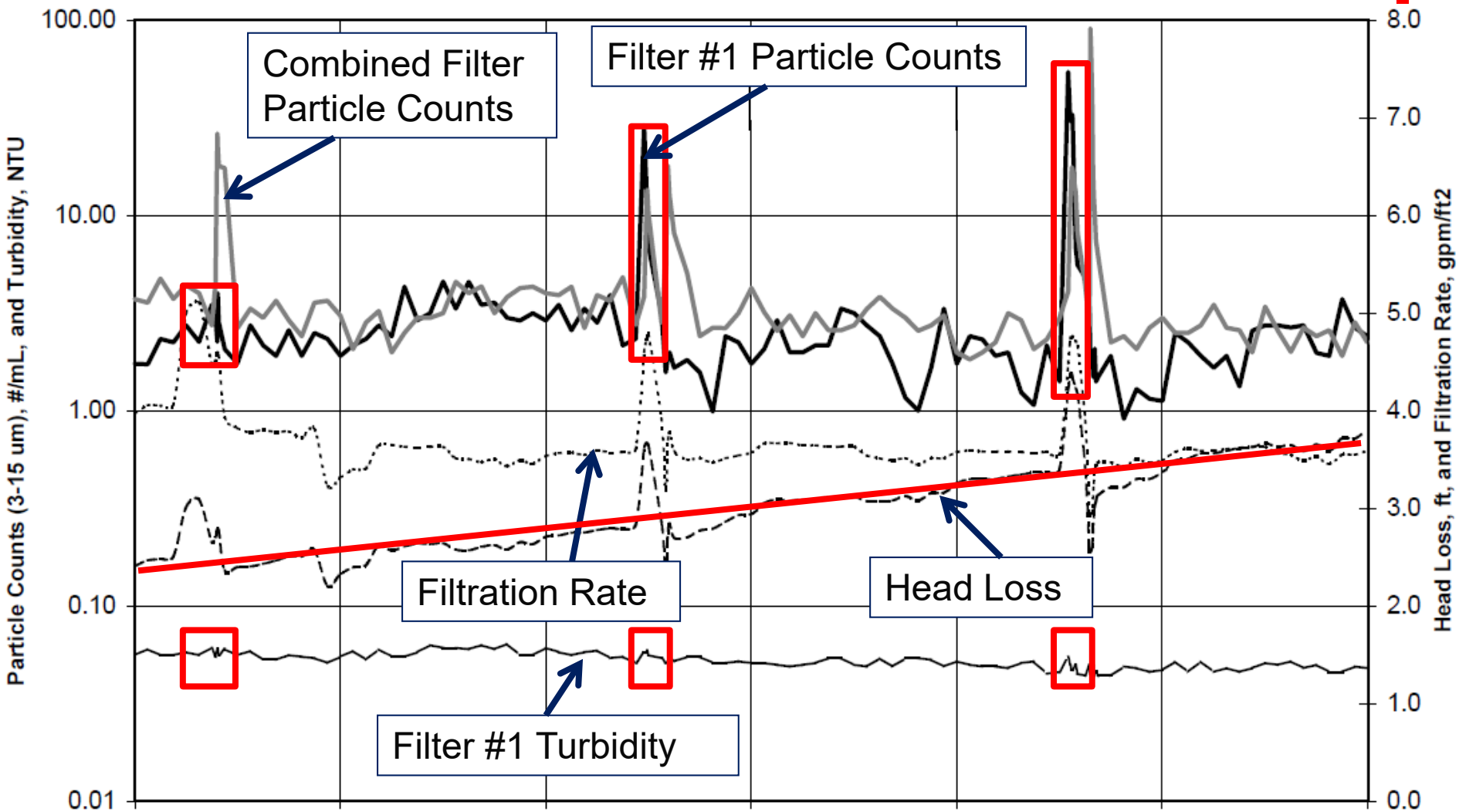
Attachment Filtration Mechanism

- Particles attach to filter media by way of electrostatic forces / van der Waals forces
  - Enhanced with metal hydroxide (coagulant) or polymer (filter aid).
- Particles are “stored” and not “trapped”.
- Probability of detachment & breakthrough increases as solids loading and internal pore velocity increases.

Detachment

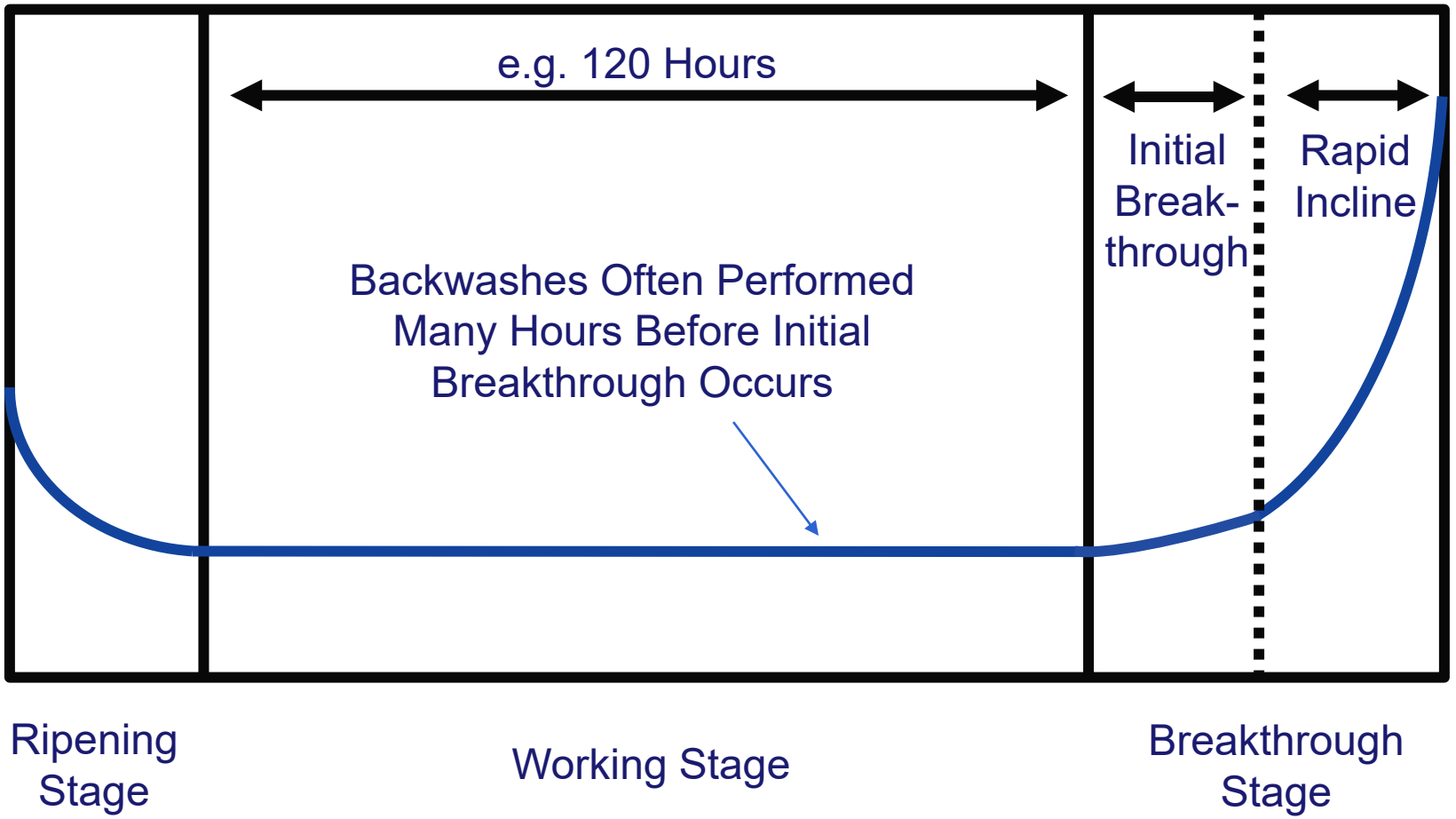


Impact Of Flow Rate Changes

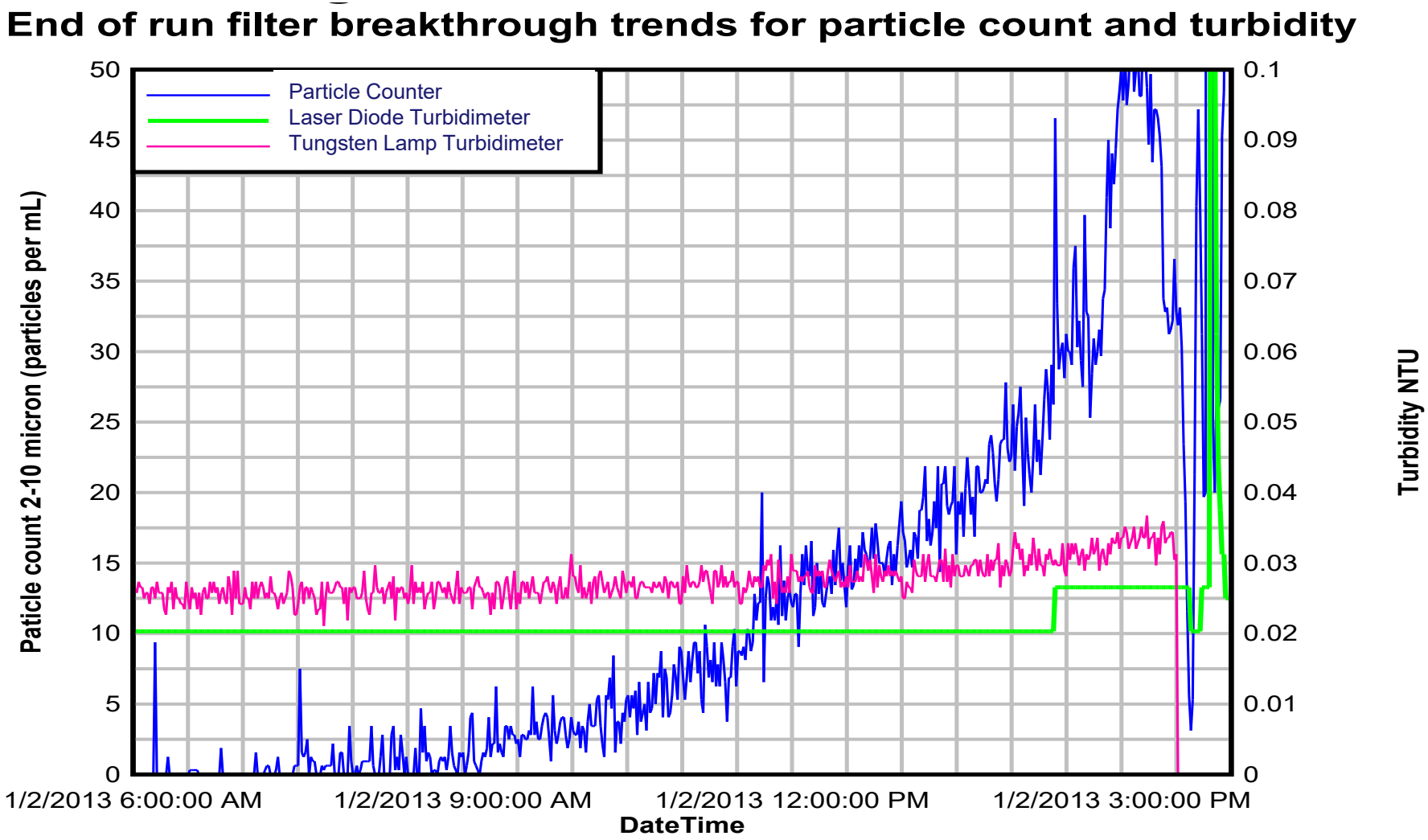


End of Filter Runtime
Particle Breakthrough

Filtration Stages

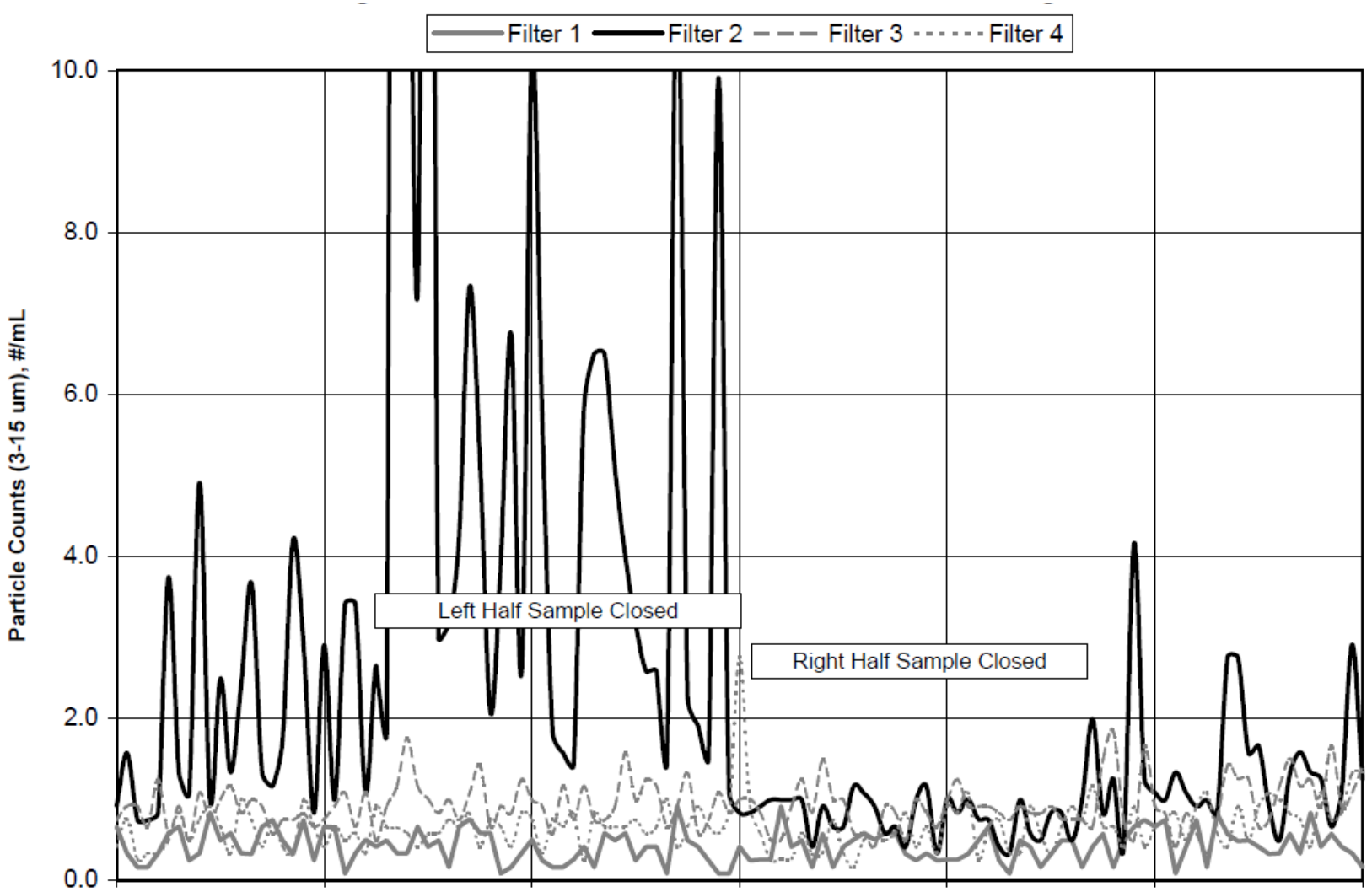


End of Filter Run Breakthrough



Filter Integrity

Early Warning Of Filter Problems

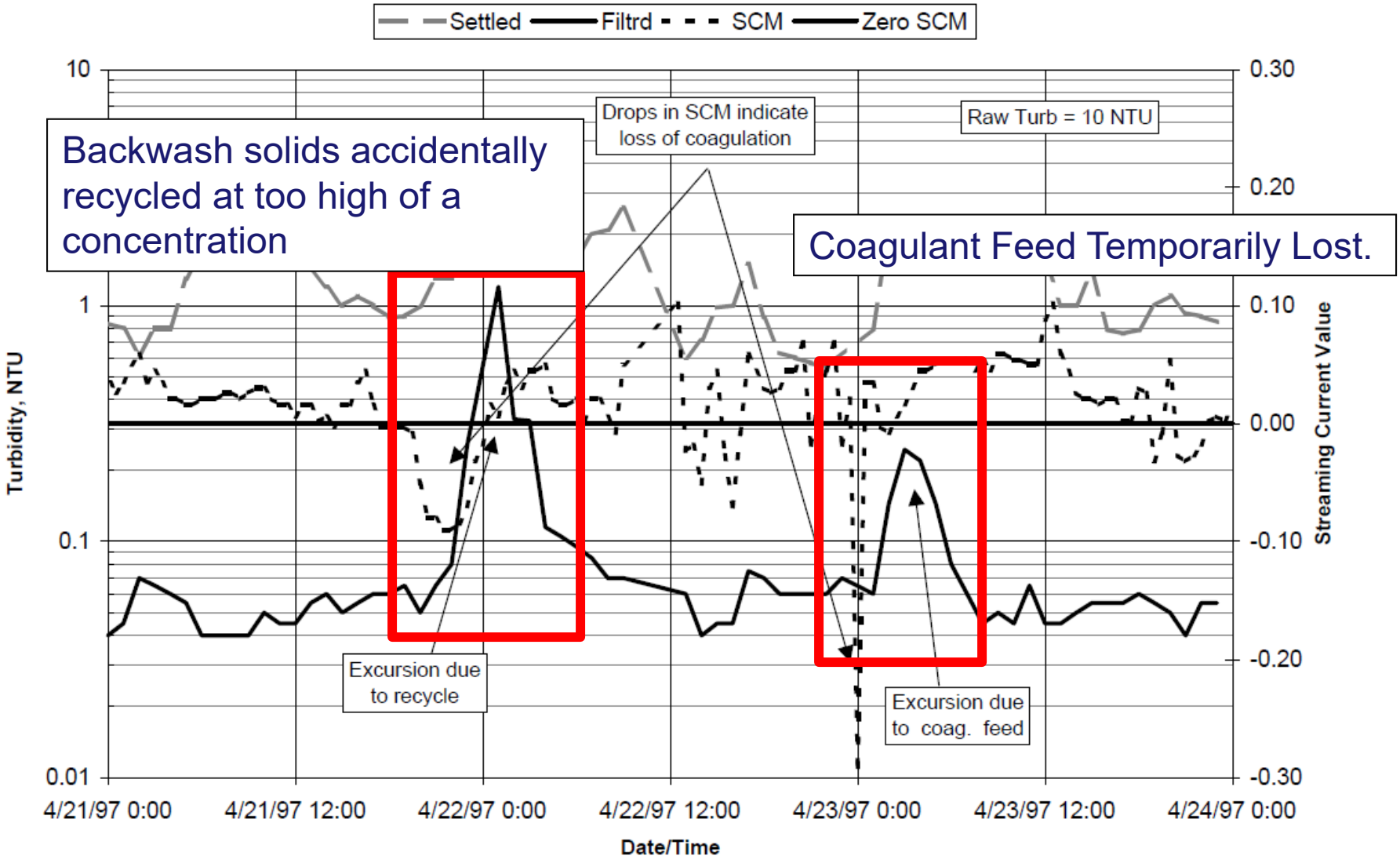


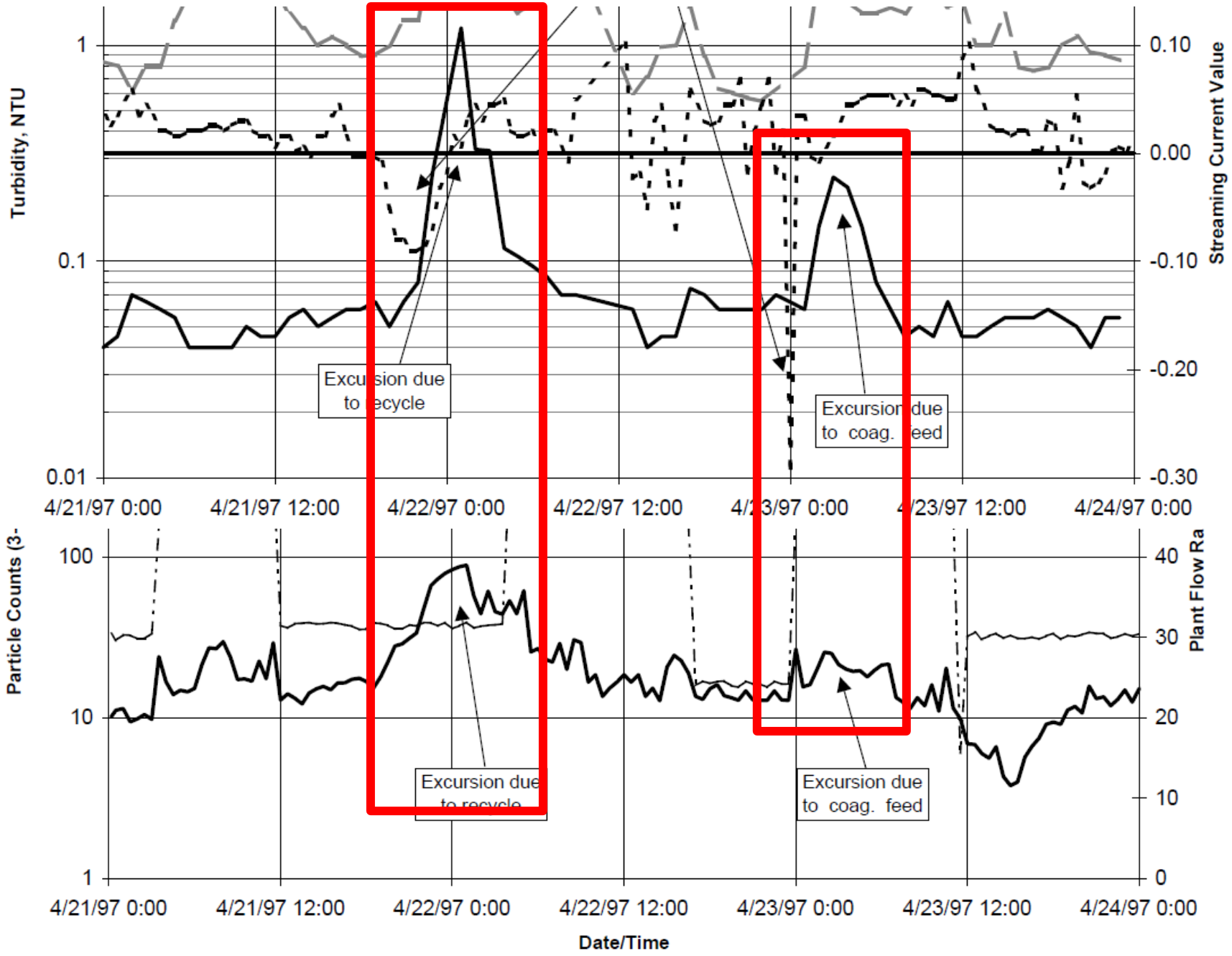
Depression in media caused by damaged underdrain

Coagulation Upsets

Coagulation Upsets

Figure 14 - Wyckoff WTP Coagulation Upset - Turbidity and SCM




Turbidity, NTU
1
0.1
0.01
Streaming Current Value
0.10
0.00
-0.10
-0.20
-0.30
Excursion due to recycle
Excursion due to coag. feed
4/21/97 0:00
4/21/97 12:00
4/22/97 0:00
4/22/97 12:00
4/23/97 0:00
4/23/97 12:00
4/24/97 0:00
Particle Counts (3-
100
10
1
Plant Flow Ra
40
30
20
10
0
Excursion due to recycle
Excursion due to coag. feed
Date/Time

Getting The Full Picture

	Turbidity	Particle Counts	TSS
Baseline	0.04 NTU	10 cnts/ml	<1 ppb

Getting The Full Picture

	Turbidity	Particle Counts	TSS
Baseline	0.04 NTU	10 cnts/ml	<1 ppb
#1 Event	0.30 NTU	30 cnts/ml	30 ppb
#2 Event	0.10 NTU	120 cnts/ml	60 ppb

The Takeaway

- Turbidimeters offer affordable detection of submicron particulate, very informative in terms of coagulation performance. But the reduced response to larger particles has potential implications in regards to early detection of filter performance issues.
- Particle Counters offer affordable, very sensitive detection of larger particles. These larger particles can signal the beginning of the end of a filter run, a developing filter integrity issue, or excessive biological shedding.
- Only when particle counters and turbidimeters are used together do we have the most complete picture of coagulation & filtration performance.

Questions?

References

- *Turbidity Science*, Michael J. Sadar, Hach
- *Monitor Water Filtration Processes For Optimum Particle Removal*, John Gregory, University College London
- *Particles Contributing To Turbidity*, EPA Guidance Manual Turbidity Provisions
- http://www.hielscher.com/nano_01.htm; Ultrasonic Devices To Disperse Nanomaterials
- Deep Bed Filtration: Modeling Theory and Practice, G. Keir; V. Jegatheesan; S. Vigneswaran
- *Particle Counting In Real World Water Treatment Plant Operations,* Thomas M. Ginn,Jr., P.E.; G. Ricky Bennett; Gregory D. Wheatley; Cobb County-Marietta Water Authority