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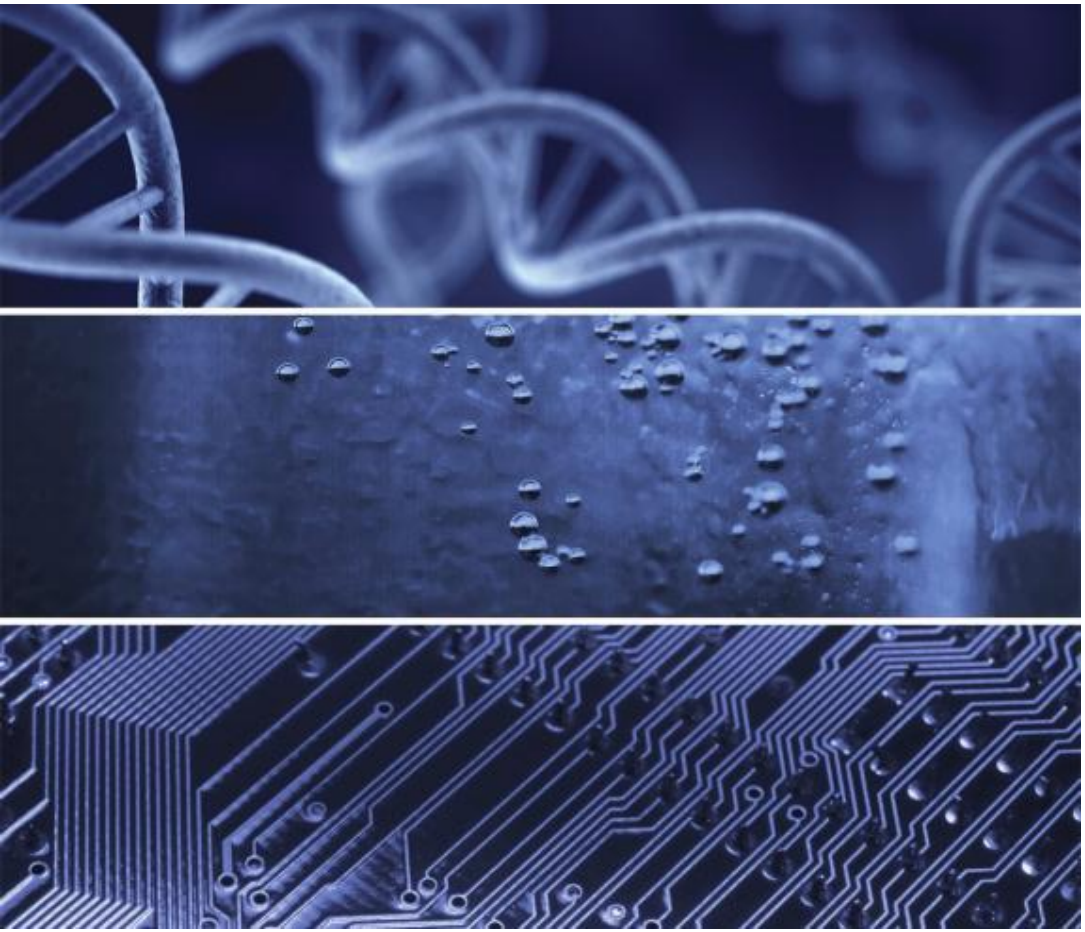

Particle Clean-Up of Various Filter Media in WEC Chemistry via 20 nm Particle Counting

Presented at SPCC 2017, Austin, TX
March 28, 2017

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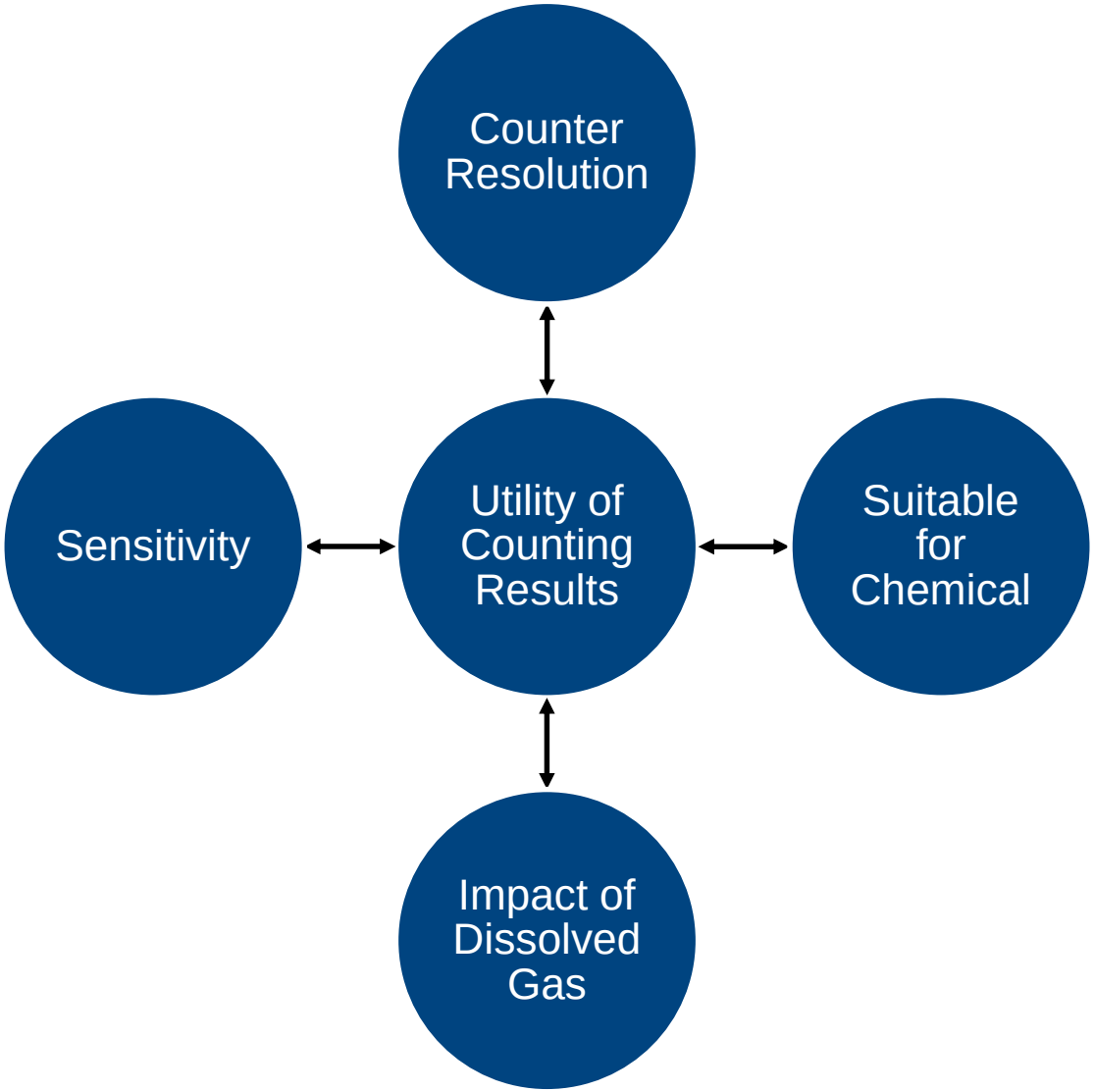
Rationale for Study

- Particle behavior of filters can be affected by the chemical in which they are used
  - Evaluation in actual chemical is needed to show actual performance
- Present-day light scattering particle counters are limited to a minimum size resolution of 30 nm
  - Particle sizes of interest for latest technology nodes are much finer
- Many process chemicals are prone to presence of light scattering bubbles that are counted as particles and skew assessment of behavior
  - Technologies that are less sensitive to bubbles would be preferred

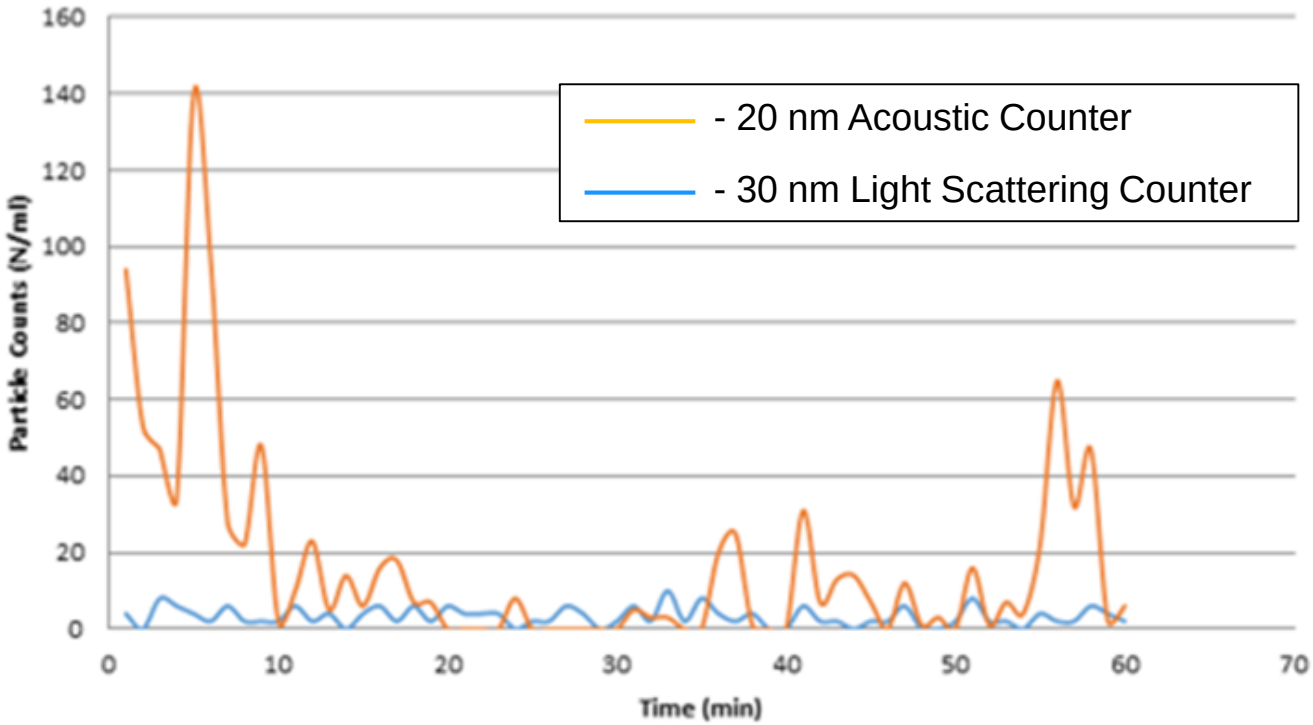
Our study explores the use of an alternate counting technology enabling counting in chemicals down to 20 nm, with diminished impact of bubbles

> Can it show differences among different filter types?

Factors Impacting Particle Counting Operations

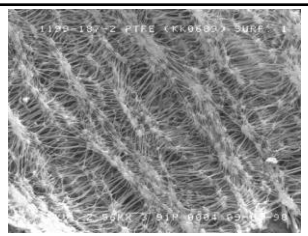
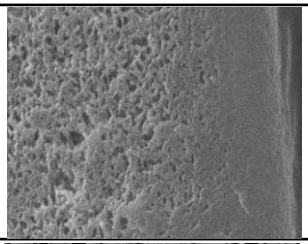
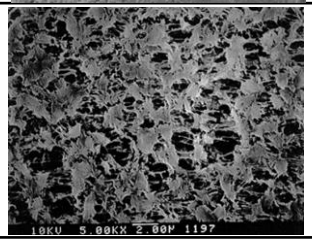
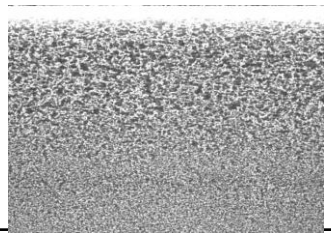


Background Information on Testing



- Early testing with an acoustic counter in litho solvent suggests finer particle detection than previously possible in chemical
- This was viewed as an indication that this counter ought to be able to allow more discrimination among filters rated 20 nm and finer
- Current study explores chemical more broadly applied in the industry

Various Filter Media for Aqueous Chemicals

Material	Flow-ΔP	General compatibility	Wettability	Min. avail. rating	Appearance in SEM
HDPE	★★★	★★★★	-phobic	2 nm	
Nylon 6,6 asym.	★★★	★★	-philic	5 nm	
PTFE	★★★★	★★★★★	-phobic	5 nm	
HAPAS*	★★★★★	★★★	-phobic	5 nm	

*HAPAS: highly asymmetric polyarylsulfone

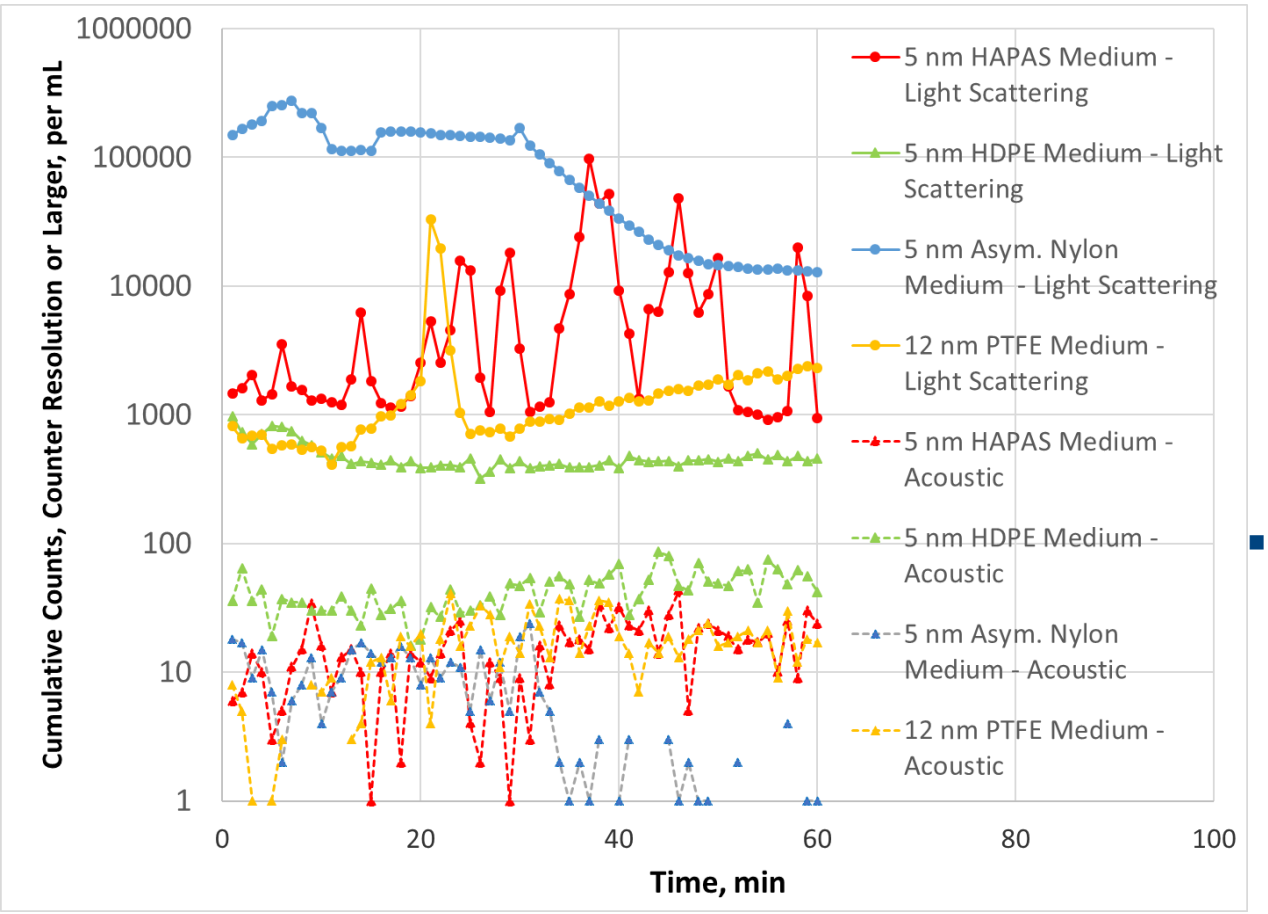
Selection of Candidate Model Chemistry

- Tetramethylammonium hydroxide (“TMAH”) selected as model chemical
  - Occurs widely for various applications
    - Cleaning chemistries
    - Silicon etchant
    - Photolithography developer
  - Also serves as a model for alkaline chemistries in general and alkylammonium type cleaning chemistries in particular
- TMAH is used and filtered under various concentrations in actual application
  - Moderate concentration of 2.5% was selected to model various applications and to allow safe handling
  - Diluted 25% TMAH was filtered for use in the work

Test Set-up and Operation

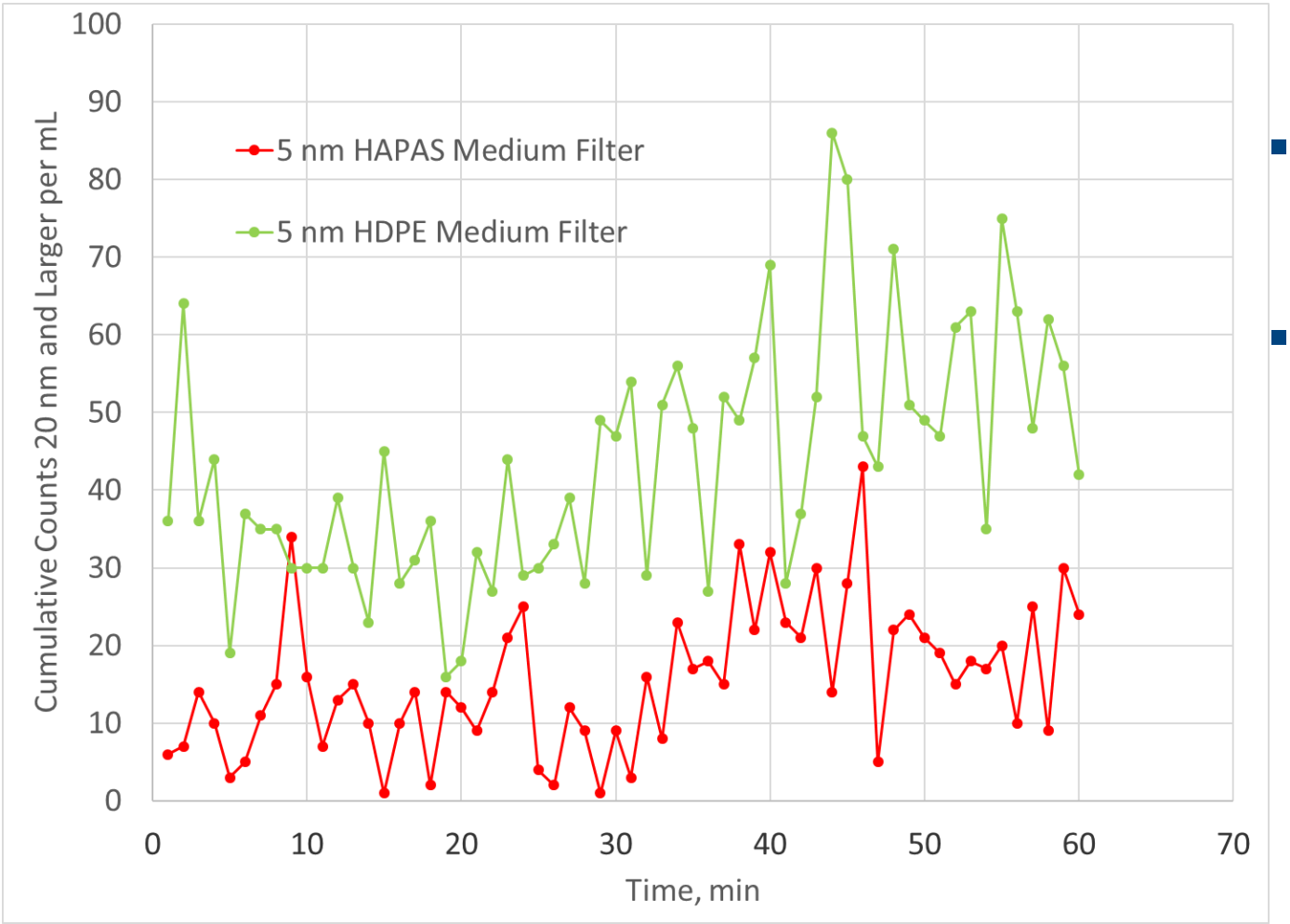
- Recirculative test system set-up with reservoir, pump, insertion point for filter, and side stream to particle counters
  - Effluent sidestream split to two counters
    - Acoustic (shown), 20 nm res.
    - Light scattering, 30 nm res.
  - Limited testing with UPW in single-pass, with UPW system providing pressure,
- Low backpressure used to mimic actual operational condition often occurring
- Filter capsules used for all tests
  - Flow rates selected based on size, typically in range 0.3 – 1 LPM
- Counts monitored over one hour period

Relative Behavior Found for Various Filters Evaluated with Either Counter Type in TMAH



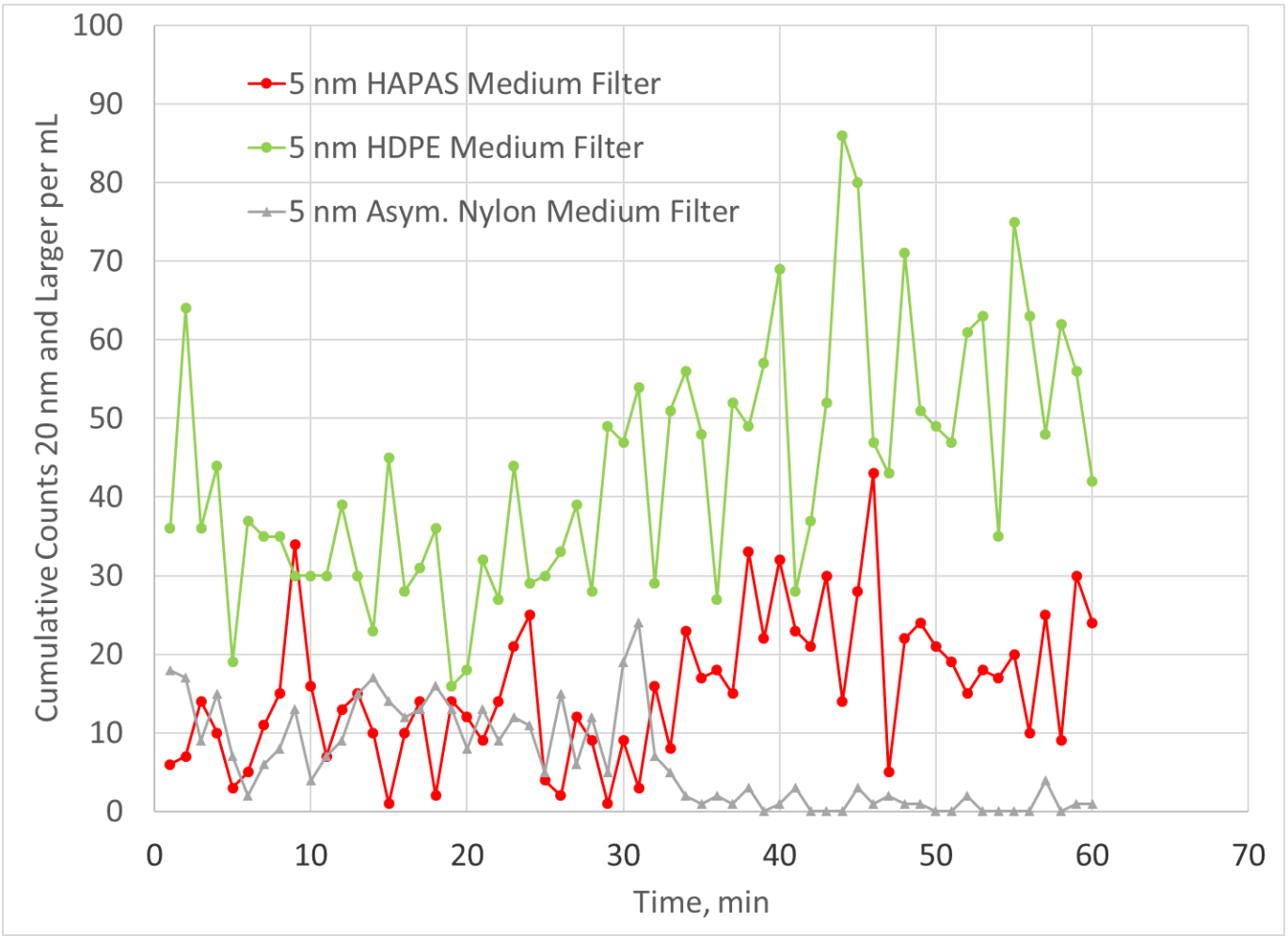
- Higher counts detected using 30 nm light scattering counter
  - Contrary to expected *lower* counts at larger size
  - High ≥30 nm counts suggest *extreme* presence of air bubbles
    - Wide variation among samples
- Generally more consistent counts detected with 20 nm acoustic counter
  - Differences detected among samples but in a narrower range
    - More in line with expectations for filters rated at 12 nm or finer

Focus on HAPAS and HDPE Media Filters in TMAH via Acoustic Counting



- Focus shifted to comparison via acoustic counting
- Clear difference seen in effluent particles detected
  - Lower levels found for filter using HAPAS medium

Acoustic Counting Comparison Including Filter with Asymmetric Nylon Medium



- Here the curve for the nylon medium filter is added
- This filter actually shows the lowest ultimate count level
  - Nylon medium filter exhibited *highest* counts with light scattering counter

(It is noted nylon not suitable for *extended* service in high pH)

Conclusions, Path Forward, Acknowledgments

- An acoustic particle counting methodology allows particle counting in chemical at smaller minimum size than for currently available light scattering counters
- Testing was conducted in 2.5% TMAH as a suitable model chemical, with four filter types evaluated
- Methodology was capable of showing differences among filters with different media
  - Results very different from those obtained via light scattering counting, likely due to impact of desorbed gas
- Further study using different WEC-relevant chemicals, different filters, and alternate test conditions appears warranted to validate the counter over a broader application space

The authors gratefully acknowledge the extensive test work conducted by Mai Nguyen and Ibrahim Mohamed-Ali of Pall