APPLICATION NOTE

Monitoring Microfiltration Processes for Water Treatment

Quantifying Nanoparticle Concentration and Size to Optimize Filtration Processes

PARTICLE CONCENTRATION

PARTICLE SIZE

Introduction

With the increasing demands on water supplies and tighter regulations, much research is being done in to water treatment processes. Subjects of study include improving processes to allow treated water to be used in secondary applications, optimizing filtration processes to remove biological contaminants and reduce membrane fouling, monitoring filter breakthrough to minimize maintenance requirements or contamination, and verifying ability to remove the increasing load of nano-particulates in the waste water stream.

Due to the massive quantities processed, even small improvements in process performance and efficiency have a large impact on resulting water quality and energy consumption.

Numerous technologies exist for monitoring particle size and concentration in the micron size range, but Nanoparticle Tracking Analysis (NTA) is a unique technology that provides greater insight into the sub-micron size range that is so important to many of these advanced water treatment processes.

Detecting and Counting Particles

Both Dynamic Light Scattering (DLS) and NTA measure the Brownian motion of nanoparticles whose speed of motion, or diffusion coefficient (D_t), is related to particle size through the Stokes-Einstein equation.

In NTA, laser light scatters from particles in suspension and a video camera captures the images of those particles moving under Brownian motion. By tracking and quantifying the particles' diffusion, the particle diameter can be determined through the Stokes-Einstein equation. The direct view of the sample also allows visual inspection of the sample for an additional qualitative confirmation. [1,2]

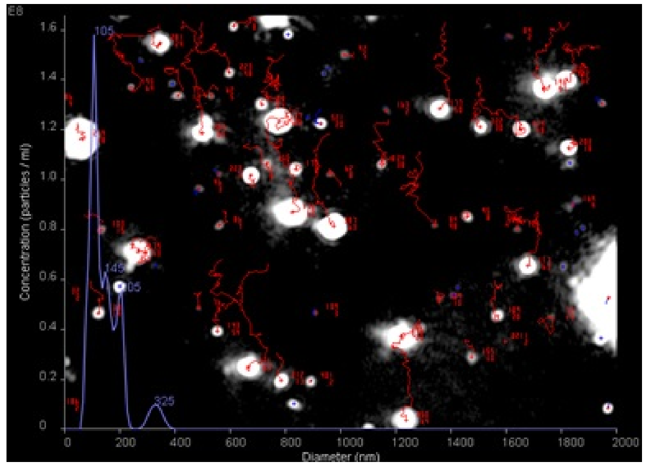

Figure 1: Tracking of particles by NTA software to derive the particle size distribution.

Qualifying Filtration Processes

Ling et al [3] have used NTA to measure particle (50–500 nm) concentration upstream and downstream of a filter in order to determine the filtration efficiency of a model membrane filter for application in the purification and disinfection of drinking water and also the removal of nanoparticles from highly pure chemicals used in industry. NTA measurements were found to be reliable within a certain concentration limit (about 10^8 –10^{10} particles/mL) and that experimental results were comparable with previously published data obtained using an aerosolization method, thus validating the capability of the NTA technique.

Microfiltration (MF) can serve as a pre-treatment for other processes like ultrafiltration, or as a post-treatment for granular media filtration. Qualifying and monitoring the performance of a filtration process is important for optimizing process conditions. One large scale application is for waste water or drinking water treatment.

Subsequent stages of treatment can remove the finer sizes, such as virus and engineered nanoparticles, finally yielding only dissolved materials. Processes include microfiltration (MF), reverse osmosis (RO), and ultraviolet (UV) treatment.

The following example shows the progressively lower concentrations (y axis) and generally reducing size of the peak. Microfiltration proved very effective at removing particles in the 10's to 100's of nanometer range. RO removed most of the remainder. After UV treatment, there was essentially no particles visible to the NTA technique.

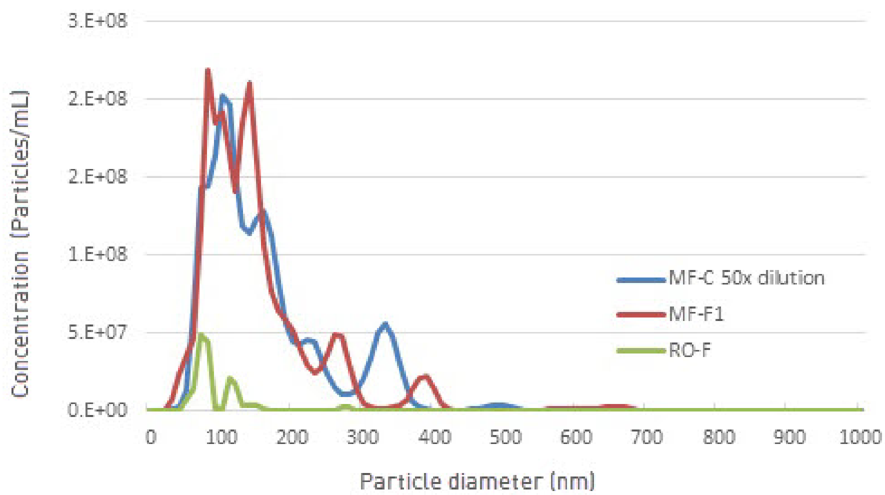

Figure 2: The concentrated retain side of the microfilter (MF-C) was approximately 50 times higher concentration than the inflowing feed water stream (MF-F). Post microfilter, the feed to the RO (RO-F) was an order of magnitude lower again.

The rinse of the RO filter showed progressively higher concentrations of background material, but particles were below the NTA detection limit. Other tests showed a slight increase in total bacteria concentration across these same samples and a definite increase of total protein and carbohydrates.

Studying Membrane Fouling

Low-pressure membrane techniques, like microfiltration (MF) and ultrafiltration (UF), are a popular option for later stages of water treatment, offering many advantages compared to conventional filtration processes due to high water quality effluent, reliability in operation and a small footprint [4]. As tertiary treatments, they are promising techniques for advanced removal of particles, pathogens and, in combination with chemical coagulation, by size exclusion due to the membrane pores.

The main drawback of low-pressure membrane processes is membrane fouling as it increases chemical cleaning frequency and operational costs while reducing membrane life time. A study was carried out by Schulz, et. al. [5] to assess the fouling behavior of treated domestic wastewater by sizing and counting its submicron constituents with Nanoparticle Tracking Analysis (NTA) and to look for a link between colloidal loads and filtration performance of low pressure membranes. The findings showed that the pre-treatment processes of pre-ozonation and subsequent coagulation has to be optimized to minimize the fractions that cause membrane fouling and maintain good filtration performance.

A further test [6] was carried out comparing pre- and post-filtration nanoparticle concentrations. Both these were done in lab experiments and pilot-plant experiments, where the NanoSight system was run continuously for two months taking a measurement every 15 minutes.

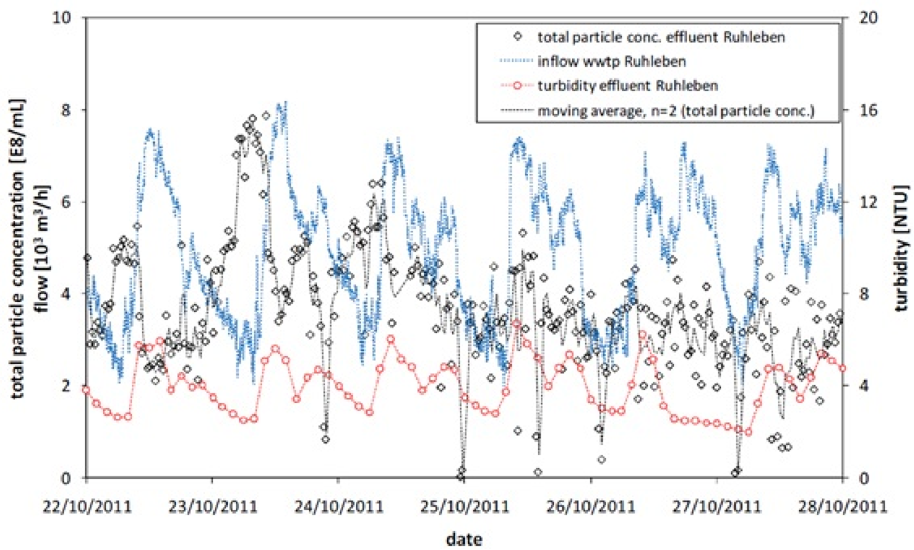

Figure 3: Daily variation of wastewater inflow and corresponding total particle concentration (by NTA) and turbidity in the effluent. [6]

Part of the conclusion was, "Particle analysis by Nanoparticle Tracking Analysis (NTA) was obtained to give reliable and reproducible information about the concentration and size distributions of the colloidal fraction in the tested treated domestic wastewater. A consistent detection of variations in colloid concentration can be carried out in a range between 1x10E8 and 2x10E9 particles/mL even in organic-rich matrices."

Conclusion

Nanoparticle Tracking Analysis is a technique with proven application in qualification and monitoring of filtration processes. The large scale of many of these applications can lead to significant cost savings when the process is optimized. Membrane fouling can be reduced with appropriate use of coagulants or other pre-treatment, which also benefits from process optimization to reduce chemical usage and to monitor incident nanoparticle concentrations.

References

[1] ASTM E2834-12 Standard Guide for Measurement of Particle Size Distribution of Nanomaterials in Suspension by Nanoparticle Tracking Analysis (NTA)

[2] Malvern white paper WP150312 "NTA: Principles and Methodology"

[3] Ling T Y, Wang J and Pui DYH (2011) Measurement of filtration efficiency of Nuclepore filters challenged with polystyrene latex nanoparticles:

experiments and modeling, Journal of Nanoparticle Research, DOI: 10.1007/s11051-011-0529-2,Online First™

[4] Wintges, T., Melin, T., Schafer, A., Khan, S., Muston, M., Bixio, D. and Thoeye, C. (2005): The role of membrane processes in municipal wastewater reclamation and reuse. Desalination 178, 1-11.

[5] Schulz M, Godehardt M, Boulestreau M, Ernst M, Miehe U, Lesjean B and Jekel M (2011) Analysis of nanoparticles in treated domestic wastewater for improved understanding and prevention of membrane fouling, 6th IWA Specialist Conference on Membrane Technology for Water & Wastewater Treatment, 4-7 October 2011 Eurogress Aachen, Germany

[6] Schulz M (2012) Submicron particle analysis to characterize fouling in tertiary membrane filtration, Diplomarbeit, Technische Universitat Berlin, Institut fur Technischen Umweltschutz Berlin, April 2012

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