a) Introduction

The optical impression of a liquid's turbidity is created by small particles in transparent liquids. Consequently, the turbidity is measured by analysing the number of particles in the liquid. Two analysing instruments can be used to measure the turbidity of a liquid: an Automatic Particle Counter (APC) or a turbidimetre or nephelometre. Both of these instruments are able to measure the concentration of solid particulate matter in a liquid and they both are optical analysing instruments, but they differ largely in their technical capacity.

b) Turbidimetre vs. Automatic Particle Counter

The analysing result of a turbidimetre is indicated in the measuring unit NTU (Nephelometric Turbidity Unit). The more turbid a liquid, the higher is its NTU value. Beside the particle population of a liquid (which is equivalent to the collective absorption measured by the turbidimetre), Automatic Particle Counters also analyse the size of each individual particle. Equipped with a volumetric[1] sensor cell, an Automatic Particle Counter detects every single particle, whereas a turbidimetre analyses only the turbidity which is caused by the liquid's particulate matter as a whole. Compared to the analysing result of an Automatic Particle Counter, the NTU value therefore is of minor significance.

Automatic particle counters however do not analyse a single parameter, but two: apart from the particle concentration, they also detect the exact particle size in different size channels. The knowledge of the particle size helps for instance to identify certain types of bacteria or a failure in the system (e.g. break-through of filter membrane in case of a number above-average of very big particles). In general, automatic particle counters are more sensitive than turbidimetre and instantaneously give alert if previously determined limits are exceeded. The use of an automatic particle counter assures simultaneous monitoring and allows an early parameterisation[2] of the filter system. Due to this valuable information, the automatic particle counter in the long term is worth its higher price (compared to that of a turbidimetre).

The following table briefly sums up the features of both measuring instruments mentioned above:

[1] Instead of the in-situ principle which analyses only a small part of the measuring cell.

[2] Parameterisation is the modification of presettings, like the variation of the flow rate or the choice of the flocculation agent. Flocculation agents are used to bundle solid undissolved contaminants in order to improve the process of filtration.

Nephelometre or turbidimetre	Automatic Particle Counter (APC)
• Only measures one single parametre, i.e. the collective turbidity. • Smaller particles < 0.5 micron already cause a turbidity which is neglected by the automatic particle. • The measured turbidity is indicated in NTU (Nephelometric Turbidity Unit); this single parameter is of minor significance (especially when analysing liquids with a low particle population). • The measuring result is a single one-dimensional parameter that does inform about the particle size.	• More expensive than a turbidimetre. • Measures single particles > 0.5 micron. • Indicates the particle concentration and the exact particle size in different size channels. • The knowledge of the particle size helps to identify certain types of bacteria or failures in the system (e.g. filter damage). • The automatic particle counter immediately alerts when previously defined limits are exceeded. • The higher price of the instrument is compensated by the permanent monitoring of the filter plant and of the water quality.

c) Turbidity measurement vs. particle counting: Comparison of analysing results under standard conditions

A comparison of the measuring results clearly shows the differences between the two analysing instruments. In the following example, an automatic particle counters was used to verify the particle population of liquids whose turbidity had been declared before by a turbidimetre. As the diagrams A and B (see next page) show, the sample with a turbidity of 10 NTU contains much more particles per millilitre than the sample with a turbidity below 0.1 NTU.

Durchmesser	kumulativ
> 1.00 µm	11100
> 1.50 µm	6100
> 2.00 µm	3827
> 3.00 µm	2247
> 4.00 µm	1493
> 5.00 µm	880
> 7.00 µm	457
> 10.00 µm	207
> 15.00 µm	87
> 20.00 µm	57
> 25.00 µm	37
> 30.00 µm	27
> 40.00 µm	10
> 60.00 µm	0
> 80.00 µm	0
> 100.00 µm	0

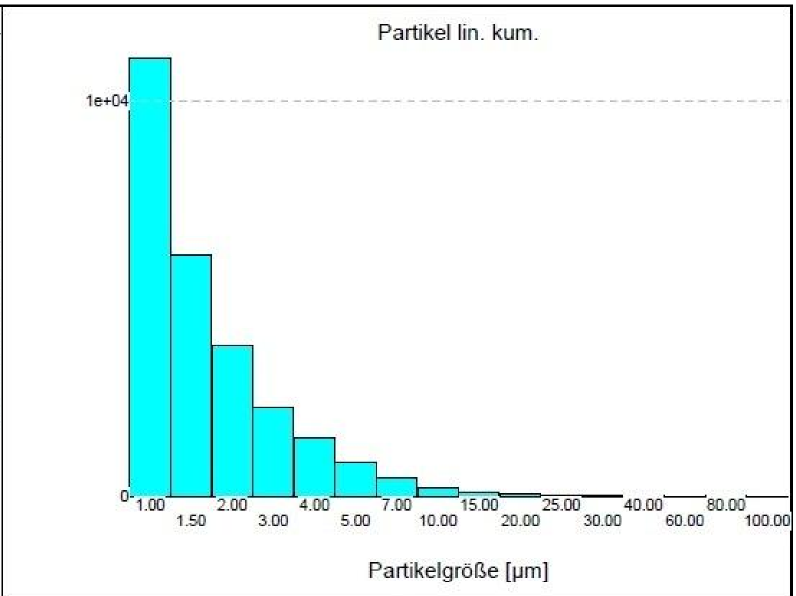

Diagram A: Particle analysis result of a sample with a turbidity below 0.1 NTU

Durchmesser	kumulativ
> 1.00 µm	5312686
> 1.50 µm	292560
> 2.00 µm	36197
> 3.00 µm	10230
> 4.00 µm	5470
> 5.00 µm	2827
> 7.00 µm	1173
> 10.00 µm	517
> 15.00 µm	203
> 20.00 µm	93
> 25.00 µm	50
> 30.00 µm	27
> 40.00 µm	7
> 60.00 µm	3
> 80.00 µm	3
> 100.00 µm	0

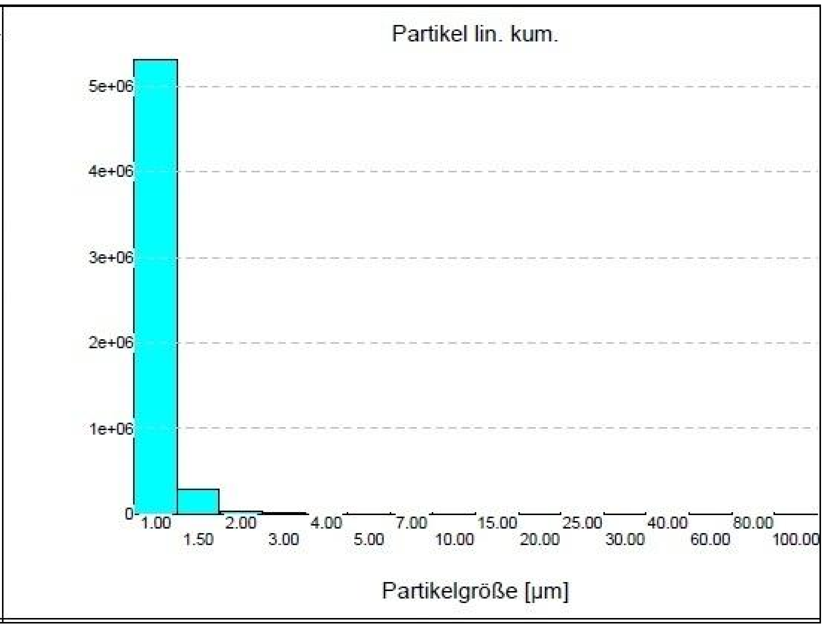

Diagram B: Particle analysis result of a sample with a turbidity of 10 NTU

Whilst the turbidimetre indicates only one single parameter, the measuring result of the Automatic Particle Counter contains detailed information on the particle size distribution, i.e. the particle quantity in the different size classes.

In the size class > 1 µm, the Automatic Particle Counter (APC) measures 500 times more particles in the turbid sample of 10 NTU than in the sample of a turbidity below 0.1 NTU. In the cumulative size class > 10 µm, the difference between the two measuring results is only 50%: the APC measures 517 particles per millilitre in the turbid sample and 207 particles per millilitre in the clear sample. In the size class > 30 µm, the APC counts 27 particle per millilitre in both samples. With its information on the particle size distribution, the Automatic Particle Counter gives a more multifaceted result than the turbidimetre.

d) Turbidity measurement vs. particle counting: Comparison of analysing results in case of filtration supporting additives

The sensitivity of Automatic Particle Counters in comparison to turbidimetres is even more obvious when filtration supporting additives are added to the liquid in order to improve the filter efficiency rate. By attaching and bundling dissolved contaminants, these additives enable a very efficient filtration. This application example is best qualified for the comparison of test results, because the exact time and amount of the added contaminants are known and determined. Thus, the measured data can easily be checked and compared. In the following example, Powdered Active Carbon (PAC) was used as filtration supporting additive. PAC is mainly used if flocculation is impossible. Contrary to filtration supporting additives, flocculation agents bundle only undissolved and solid particles. Dissolved contaminants however can be filtered only by the use of filtration supporting additives.

The diagrams C and D show the influence of PAC on the results of the contamination analysis of the Automatic Particle Counter (diagram C) and of the turbidimetre (diagram D).

The addition of PAC and the increasing contamination can clearly be seen in the measuring results of the Automatic Particle Counter in upstream position (diagram C). The particle counter in downstream position measuring a low particle concentration indicates that the added carbon particles have been effectively filtered. The improved filter efficiency after re-flush (backwashing) is also documented on the graph. The reduction of the PAC concentration diminishes the filter efficiency which leads again to higher particle measuring results of the particle counter in downstream position.

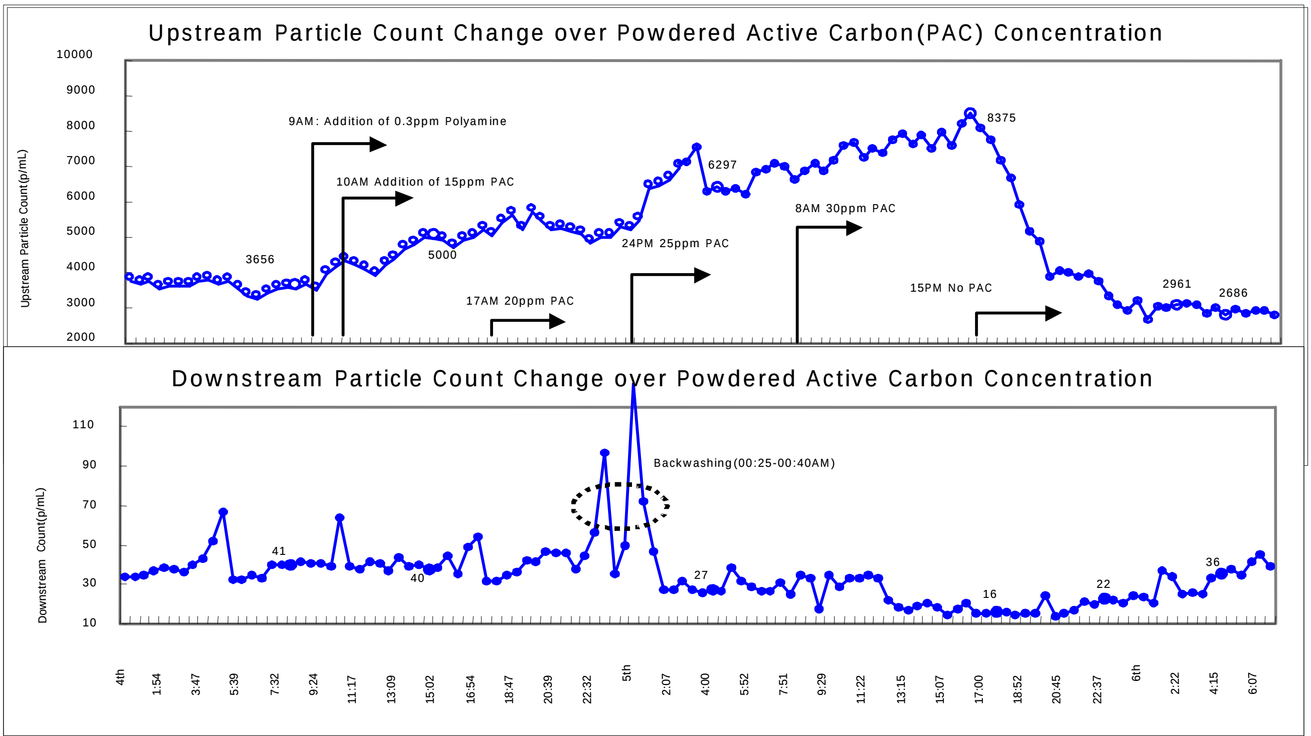

Diagram C:
Measuring result of an Automatic Particle Counter in combination with filtration supporting additives

The turbidimetre also measures an increasing turbidity when the PAC addition is stopped (diagram D). The instrument in downstream position also shows the moment of backwashing by indicating a momentary rising of the turbidity. The addition of PAC, however, nearly does not have any influence on the measured turbidity. The turbidimetre does not clearly show neither the increase of upstream contamination, as it is documented by the Automatic Particle Counter, nor the decreasing downstream contamination due to the additive.

Merely automatic particle measurement is sensitive enough to provide reliable data for the control and the parameterisation of the filtration plant.

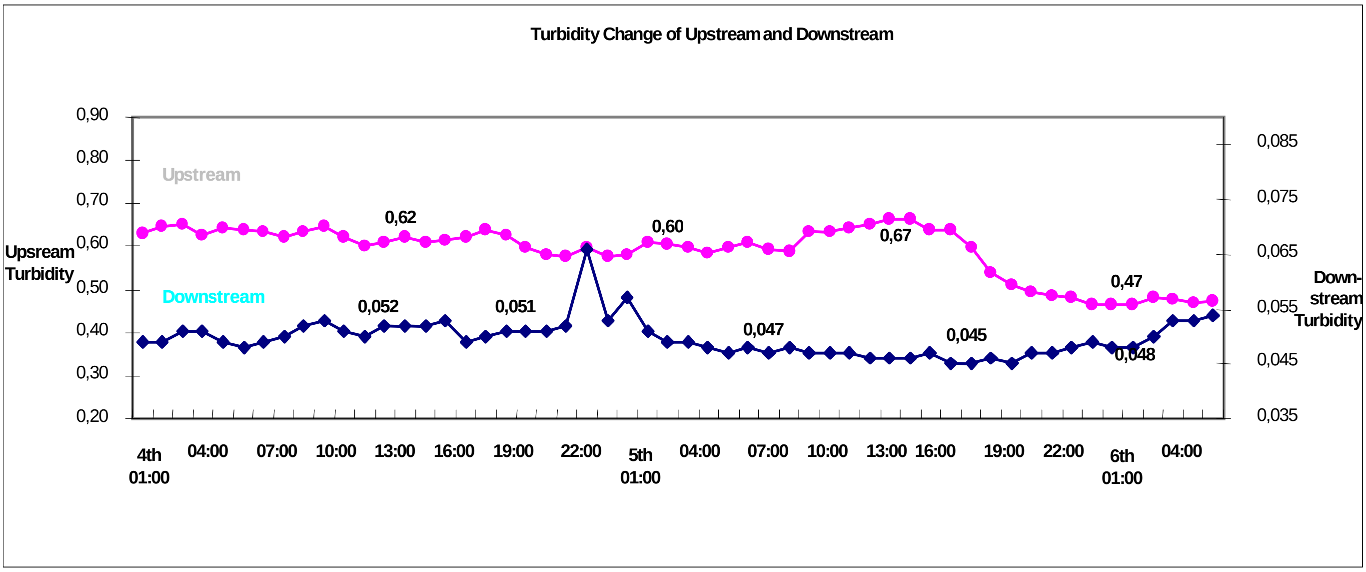

Diagram D: Measuring result of a Turbidimetre in combination with filtration supporting additives

e) Application Report of PAMAS WaterViewer in comparison with turbidimetres

The PAMAS WaterViewer, a particle counting system for multiple measurement points, is designed as permanently running system with an automated sensor flushing unit (SFU). At different locations PAMAS WaterViewers were installed to monitor the filtration process and the influence of backwash. The results proved that the Automatic Particle Counter is more sensitive than the turbidimeter.

- Waste Water Processing – Application in Austria: During a six-week test period, a PAMAS WaterViewer particle counter was used to permanently monitor the filtrate of a membrane unit for waste water processing. The results proved the advantages of this highly sensitive method of particle counting. The automatic particle analysis provides detailed information about the filtration process. The automated sensor flushing keeps the system running unattended even in case of iron oxides, manganese oxide, or micro organisms, all of them possibly blocking optical instruments. In our example, the WaterViewer was used as integrity check in Waste Water Processing. The particle counter permanently measured the effluent to guarantee for water quality.

- Process Water Filtration – Application in Finland: Back-flushing and normal operation can be identified by the particle concentration pattern for the different particle sizes. The PAMAS WaterViewer is sensitive enough to detect even single particles passing the sensor. It can be used as an easy-to-handle tool for permanent monitoring of the filtration process. The analysing results provided by the WaterViewer help to optimise the filtration process, saving energy, time and money.

- Rapid Sand Filter – Application in Northern Europe: Rapid sand filters are very commonly used in many Northern European Countries. Water highly contaminated with particles is filtered to remove most of the particle load. Depending on the water source the filters are re-flushed every few hours or some days. Again the automated sensor flushing unit of the PAMAS WaterViewer proved to keep the system running unattended – even in presence of solved iron which tends to build up oxide layers, typically blocking optical instruments.

- Tap Water Filtration – Application in South Korea: In South Korea particle counters delivered by PAMAS are used by many drinking water suppliers. Besides checking the floc size in flocculation basins, they use the particle counter to control the filtration process for different types of filters.

f) Conclusion

Automatic Particle Counters are more sensitive than turbidimetres and therefore are qualified to be used in filtration and water purification plants. Due to their advanced sensor technology, newly developed PAMAS particle counters are able to detect single particles of a minimum size of only 0.5 micron. The information about the particle size distribution, i.e. the exact number of particles in the different size classes, gained by the Automatic Particle Counter enables a more efficient plant operation than in case of a nephelometre.