Waltemode GmbH

Optical or Acoustic
Process measurement of liquids

- **Turbidity**
- **Colour**
- **Oil in Water**
- **Water in Oil**
- **Oil on Water**

#Scatter light Turbidity Measurement

What does turbidity mean?

Turbidity is an optical impression, which describes the characteristic of a transparent product, to scatter light. A focused light beam will be attenuated and scattered in hazy products, so that this product can become practically opaque in bigger layers.

What causes turbidity?

Turbidity is caused by particles in transparent products. A particle is defined as something with a different refractive index as the carrier product. Some examples of particles are minerals, yeast cells, metals, oil drops in water, milk in water, gas bubbles and aerosoles.

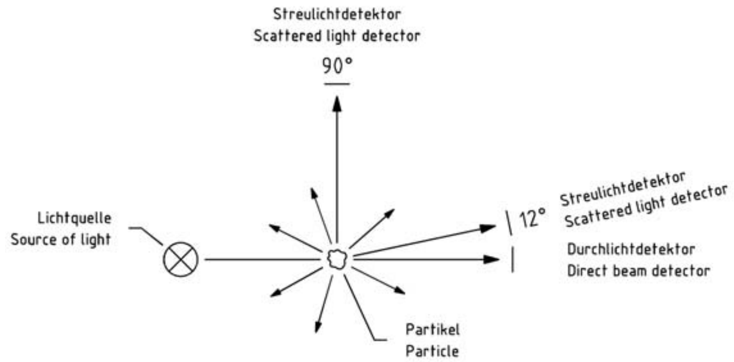
Measurement of turbidity

Turbidity is not a clearly defined magnitude like e.g. temperature or pressure. Turbidity is a subjective impression. For this reason turbidity measurement systems will be typically calibrated by using a comparison's standard such as Formacine and Diatomatious Earth.

Measurement methods

The typical scattered light turbidity measurement methods are:

- Side scattering (90°) The detector is located in a right angle (90°) to the light beam
- Forward scattering (12°) The position of the detector is 12° shifted to the axis of light beam



As shown in the figure above, an intense collimated beam of light is projected through a sample contained within the sensor. The intensity of this light beam is measured by the direct beam detector, located opposite to the light source.
The light, scattered by particles inside the sample is measured by a scatter light detector
Depending on sensor specification, this detector can be located 12° or 90°, displaced from the direct light axis.

The signals caused by scattered and direct light will be amplified and processed by the electronics. The results displayed, is the turbidity value.

$$\frac{\textbf{Scatterd light signal}}{\textbf{Direct light signal}} = \textbf{Turbidity}$$

The particles inside the liquid flow decrease the intensity of direct light, and increase the intensity of the scattered light, i. e. the turbidity rises.
Colour decreases the intensity of direct and scattered light in same ratio I. e. the turbidity value is constant. Lamp ageing and window coatings are compensated as well by this ratio.

Comparing the different measurement methods

The two different measurement methods (12° forward scattering / 90° side scattering) are not comparable.
Even in if you use the same calibration standard to calibrate the systems, different samples will show you different measurement results.
This deviations of the results, is caused by the different particle size distribution inside different samples. The measurement methods will respond different, depending on current particle distribution inside the actual sample.

Very Important:
When comparing measurement results. The same methods must be compared to one another. For example, 90° vs. 90°, 12° vs. 12°. Never 90° vs. 12°.

Context between particle size, measurement method and measurement results

The most common Calibration standard for turbidity is based on Formacine liquid. When using Formacine as calibration standard, defined Formacine suspensions have to show identical measurement results with all different methods 12° and 90°. During observation of a real sample, such as filtrated beer, the different methods will show different measurement results. The measurement results of the 90° side scatter method are typically by factor 3 to 10 above the measurement results of the 12° forward scatter method.
There are typically a lot of small particles left inside the filtrated beer, such as proteins, etc.. This colloidale turbidity will be overvalued with the 90° method, due to the fact that this method is more affected by the quantity of the particles as by particle size. The 12° forward scatter method is affected more by particle size.

90° method: small particles and large particles will cause comparable scatter light intensities.
12° method: small particles / low scatter light intensity; large particles / high scatter light intensity.

At a particle size of approx. 0.3 µm (Formacine) both methods will show approx. equal scatter light intensities.
The combination of both measurement results informs about the tendency of the particle size distribution.
Measurement value 90°, above the measurement value 12°, average particle size smaller as 0,3 µm.
Measurement value 90°, below the measurement value 12°, average particle size larger as 0,3 µm.

particle size	result 90° scatter light	result 12° scatter
larger 0,3 µm	lower value	higher value
smaller 0,3 µm	higher value	lower value

Context between particle size, measurement method and measurement results

Example filtration control:

90° side scatter:

Small particles (e.g. proteins, colloides, etc.) within the filtrated beer will be monitored perfectly by the using the 90° instrument. A filter breakthrough will be monitored delayed with this technology due to the fact that this is typically a slow process at witch you will see first just a few large particles within the filtrate. The total amount of particles will be raised minimally; therefore the measurement value will be raised minimal as well.

12° forward scatter:

Small particles (e.g. proteins, colloides, etc.) within the filtrated beer can be monitored well by the using the 12° instrument. The beginning of a filter breakthrough will be monitored immediately due to the large particles (e.g. DE, yeast cells, etc.) within the filtrate. The few large particles will be monitored immediately and the measurement value will rise sharply. This is also a mass related measurement principle which will allow calibration in mg/l if necessary.

Typical Measurement units

ppm:	**P**arts **p**er **m**illion	FNU[1]:	**F**ormacine **n**ephelometric **u**nit
FTU:	**F**ormacine **T**urbidity **U**nit	mg/l:	Milligram per liter
TEF:	**T**rübungs**e**inheiten **F**ormazin (German for FTU)	gr/l:	Gram per liter
EBC:	**E**uropean **b**rewery **c**onvention	% TS:	Percent total solids
NTU[1]:	**N**ephelometric **t**urbidity **u**nit		

The dependencies on the different measurement units

1 FTU = 1 TEF = 1 NTU[1] = 1 FNU[1] = 0,25 EBC

[1] Nephelometry describes the method of side scatter turbidity measurements, these units are used at 90° side scatter turbidimeter only.

Based on comparisons measurements, by using a 12° forward measurement system we have found the following dependencies.

1 FTU = 1 TEF = 0,25 EBC = 2,05ppm = 2,05 mg/l = 0,00205 g/l = 0,00000205 % TS

* At a specific particle weight of 1 kg/dm, 1mg/l particles in 1 kg of water will correspond to 1 ppm.

Typical ranges

The original design of scatter light turbidimeters was used for the detection of low turbidities. The resolution of these instruments is suited easily in ranges lower as 0.1 ppm (approx. 0.05 TEF / FTU / FNU / NTU or approx. 0.01 EBC) and better. The maximum range is in ideal case lower as 200 ppm, but there are as well systems available with a range of more as 8000 ppm.

When, which measurement method

The 12° forward scatter method:
The forward scatter method is typically used at low turbidities and produces nearly mass related measurement results. Main applications are quality control, filtration control, oil in water, etc..

The 90° side scatter method:
The side scatter method is typically as well used at low turbidities. This principle of measurement will produce measurement results related to the number of particles inside the product.
The main application is the observation of small, well distributed particles e.g. beyond a filter. The second typical application is the monitoring of potable water as well as waste water according ISO7027 or according to the US- FDA requirements.
The measurement results of a 90° scatter light system has to be handled with care, due to the fact, that a turbidity caused by many large particles can show a similar measurement result as a turbidity caused by the same quantity of small particles.

The combined 12°/ 90° forward- / side- scatter method:

The 12° measurement method shows higher sensitivity with large particles. The 90° measurement method shows higher sensitivity with small particles. The most common application for the combined systems is filtration control. A filter break through is recognized early, with the 12° forward scattered instrument. Some particles inside the filtrate will raise the 12° measurement value significant.

The 90° side scattered method shows only a small increase of the measurement values in case some big particles pass the filter. A filter break through would be shown very late, due to the fact that the number of particles will not raise significant in case the filter starts to break.

Please note:
The combination of forward- and side- scatter turbidity measurement does not replace a particle size analysis, but it can provide a tendency of the particle size distribution.