***Even if turbidity – like no other parameter – is full of diversity and particularities for calibration and measurement procedures, it is nevertheless a helpful factor in the measurement of water quality. But it is essential to know how best to measure and interpret it - especially in the lower measurement range. For this reason, WTW has also placed particularly emphasis on user requirements in the drinking water sector for the Turb 430 turbidity measuring instruments.***

# TURBIDITY – A MEANINGFUL PARAMETER FOR DRINKING WATER

Turbidity measurement represents a method appearing quite simple with a very complex background. Its complexity is shown by the fact that possibilities for objective and reproducible measurements were developed just about in the 2nd half of the 20th century.

Turbidity is caused by dispersion of undissolved particles varying in size and form being suspended in the solution. The greatest challenge for correct measurement was given in the development of suitable calibration standards generally reflecting the composition and properties of the turbidity showing a 'linear' correlation. This already presents a singularity: Due to scattered light properties depending on particle size and their number, the linearity over a wide measuring range is not given; on the contrary the measuring ranges are linear within sections. Depending on the degree of turbidity, there are different applicable measuring techniques. Modern turbidimeters such as the WTW Turb 430 Series provide an automatic measurement range changeover.

The Turb 430 IR and Turb 430 T models represent a new generation of portable measuring instruments minimising the stray light effects by means of an intelligent optical system and therefore offering the highest possible precision, especially in the sensitive drinking water range below 1 NTU.

The tolerated turbidity in drinking water must not exceed the value of 1 NTU according to (European) Drinking Water Ordinance of 2001. In drinking water applications turbidity is a measure for the contamination with particles and eventually micro-organisms. In addition, it enables statements on the penetration of dirt, insufficient soil filtration and also impurities from surface water after heavy rainfall or snow melt as frequently seen in late spring.

Througout Europe nephelometric measurements at 90° scattered light with an infrared light source and the measurement unit

'Nephelometric Turbidity Unit (NTU)' has proven to be ideal and has therefore become the established method for drinking water. The measured values are found in the lower end of the measuring range where small deviations and disturbing effects can lead to significant impacts on the reproducibility of results. Modern optical systems, efficient and manifold, are highly advanced in the exclusion of error sources i.e. scattered light. Turb 430 series provide a 'light trap' for this purpose. A measurement, however, is only as good as a reliable calibration.

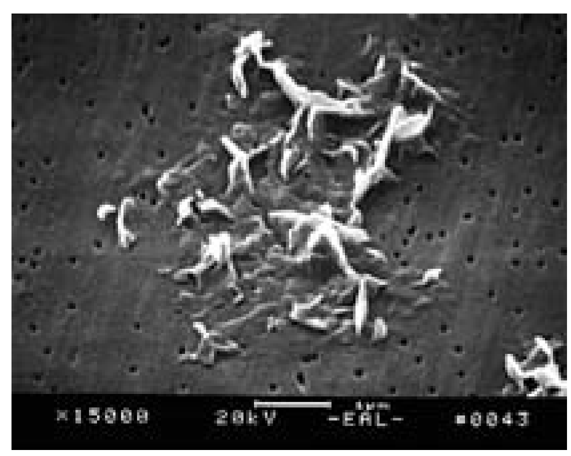
*Turb 430 T and Turb 430 IR: Turbidity measurement in 'drinking water quality'*

## IS THERE A RELIABLE STANDARD AT ALL?

Particularly in the case of turbidity with its wavering appearance as a result of movable particles and irregular size, the calibration factor is of greatest importance. Surprisingly, however, suitable standards are still a controversial and much-discussed topic today: On one hand regarding the stability of the standards over a prolonged period of time and on the other hand taking manufacturing precision and tolerances into account. Formazin was discovered as calibration standard in 1920 and has been specified as the primary standard since the 50s within many national and international regulations, even though formazin are known to show optimal characteristics in many aspects.

### Formazin

Before new compounds such as the industrially manufactured 'submicron' polymers became possible in the modern era, with freshly produced formazin out of two raw materials a substance was found that enabled a relatively comparable calibration for turbidity measurement when used immediately. It is very important, that the formazin standard for the calibration is freshly prepared: Today an initial concentration of 4000 NTU/FNU can be diluted to the relevant required concentrations.



*Formazin standard*

A formazin solution consists of differently sized particles which however agglutinate and sediment quickly and therefore no reproducible distribution of the particles in the solution can be obtained. This leads to a slow drift of the standard: Whoever calibrates with drifted standards will inevitably obtain deviating meaning incorrect measurement results. Incidentally, this drift behaviour applies to practically all types of formazin to a greater or lesser degree, even if they are 'stabilised'. It is, therefore, extremely difficult to compare measurement results in respect of accuracy and resolution, especially between different instrument models and instrument manufacturers at a time. The following points must be considered:

*"in reality tolerances of 3-5 percent can occur between different manufacturers of raw material and ready-to-buy formazin itself."*

- in reality tolerances of 3-5 percent can occur between different manufacturers of raw material and ready-to-buy formazin itself.
- the individual batches can perform great tolerances, even when theoretically only 1% percent is stated in many regulations.
- there is no uniform and stable distribution of the particles, which are subject to constant regrouping. Comparable conditions cannot be provided for the settling behaviour and the particle size; therefore only freshly manufactured formazin solutions with immediate calibration can be used for the comparability of different instruments.
- dilution errors: there is often an additional fault given by the preparation of the desired calibration standards in various concentrations.

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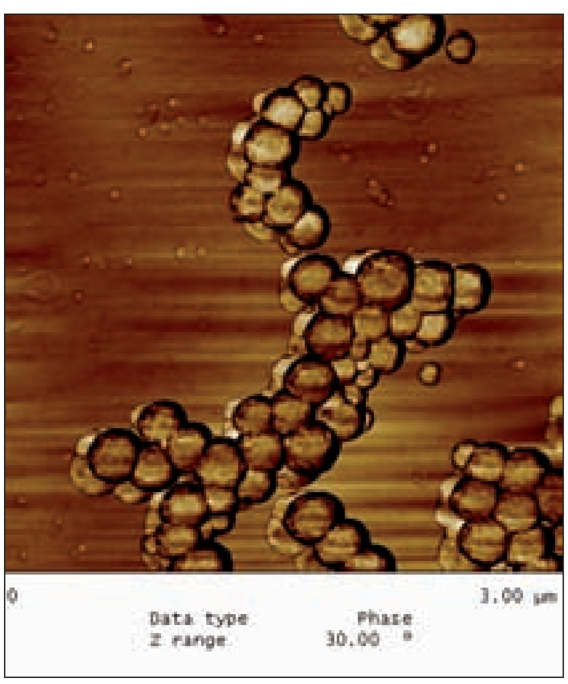
In practise, this means a deviation of ± 5-7 % can occur! By the way: it should be mentioned that the starting substances for formazin are also deemed to be hazardous and therefore requires appropriate disposal. Avoiding these unpleasant side effects, WTW is offering a new generation of polymer standards traceable to formazin.

## AMCO CLEAR® STANDARDS – ACCURATE AND NON-TOXIC

AMCO Clear® standards consist of a suspension of linked polymer microspheres with a defined size between 0.02 and 0.203 µm and an average size of 0.121 µm in ultrapure water. Due to the consistency of the polymer size, a homogeneous composition is ensured. Meanwhile, the AMCO Clear® standards have become accepted by the US EPA as the primary standard. In the DIN ISO they are documented by comparing measurement results but still quoted as secondary standards traceable to formazin.

WTW offers this new generation of polymer standards with the corresponding certificate to be traced back to formazin for all instruments of the Turb 430 series. AMCO Clear® polymers standards have several important advantages for the calibration resulting in precise measurement:

- Higher accuracy and reproducibility given by stable distribution of particles in the solution. There is no regrouping of the particles in the solution, therefore the particles remain identical in composition and size!
- a shelf life of 12 months, whereas formazin should only be used freshly prepared. Studies with AMCO Clear® standards have shown a stability of at least 12 months. At the same time, the drift behaviour was significantly below the described uncertainty of ±5-7 for the primary formazin solution.
- ready-to-use standard solutions in the required concentrations without pretreatment or the shaking. This, on the opposite is required for 'stabilised' formazin in order to resolve some settlement or agglutination. The ready-to-use AMCO Clear® calibration standards are optimised for the respective optical system of the instrument and can therefore only be used with the specified instrument model.)
- constant and reproducible production results within the 1% percent limit whereas formazin is within 3-5% including the variation between different manufacturers
- AMCO Clear® standards are non-toxic and can be simply disposed. At least the raw materials of formazin are stated to be toxic.




*Particle size and structure of AMCO Clear® microspheres versus formazin*

## FINALLY CALIBRATED, BUT WHAT IS ACTUALLY MEASURED?

Almost all instruments have a menu-guided calibration procedure – so does the new Turb 430 models from WTW. Following the menu guidance, the required calibration standards are placed one after the other, done! In addition, for turbidity measurements in the range below 1NTU/FNU, the accuracy can even be increased by performing a dedicated application method. However, it cannot be expected, that turbidity results can be measured showing an accurate nth decimal, reproducible over a prolonged period of time. Often the 'digital resolution' given on the display is mistaken for the actual practiable and metrologicial reasonable resolution: similar to the 10th decimal digit on a pocket calculator. But, how often it is really of interest? The limits of the resolution can easily be followed:

**Gravity** - leads to settlement of particles. The total amount of particles is then being reduced in the optical path, which is resulting in a smaller turbidity value.

**Movement of the particles** - resulting in different orientation versus the light source. Depending on its shape, the same particle reflects a different size for the detector, influencing the total result.

**Scattering behaviour of the particle** - changes depending on the orientation and correlates with other particles.

**Fluctuating values** - are actually the natural consequence of this particle movement. However, the display of result will balance after a short period of time. Often deviations are simply buffered by the instrument showing an average value of internal multiple measurements.

Not all solutions can be measured – i.e., there are liquids such as milk showing a variety of compounds with a completely incalculable and non-reproducible scattered light behaviour. Additionally, in the case of nephelometric measurement a high concentration of various substances results in a backscattering due to the particle density. This creates reverse effects within the measurement and misleading results. For higher turbidity values, e.g. 2000-4000 NTU onwards, other methods of measurement such as ratio modes can be useful.

Besides the procedural characteristics of turbidity measurement, still some error sources remain being overlooked at times. When the sample is too cold, it can lead to condensation on the cuvette and therefore to incorrect measurement results. Furthermore, during heating of the sample, tiny gas bubbles occur, not directly to be noticed and thereafter causing inexplicable turbidity values. In cases where the sample remains too long in the light beam, convectional movements can lead to fluctuating values on the display. Different measuring results caused by glass inhomogenities and scratches can be prevented by marking the glass accordingly.

*Drinking water cisterns*

## CORRECT INTERPRETATION!

The turbidity itself is a very expressive parameter, particularly because it is a measure for grade, quality and cleanliness of the drinking water. It also allows conclusions on the bacterial and contaminant load. It can be an invaluable parameter within certain steps of production processes representing an in-house process control based on experience ensuring i.e. a constant composition of a product, as reported by a paint manufacturer! In other words, if the possibility of slightly fluctuating values and potential tolerances of turbidity measurement are accepted knowing that the second or third decimal digit can be unconsidered, it is a meaningful parameter. Due to the procedural diversity with an infrared or tungsten lamp, nephelometric with 90°, transmission, with 180°, or a ratio method, the turbidity measurement provides an inexhaustible tool depending on local standard regulations or application area.