Turbidity Measurement: Driven by Application

FROM WATER TO WINE
Turbidity – Driven by Application

• **Drinking Water Applications**
  - Quality Control of ponds and water works
  - Food and Beverage Industry
  - Reference measurements for On-line instrumentation

• **Waste Water Applications**
  Reference measurements for On-line instrumentation

• **Industrial Process Control, Production, QC of incoming goods**
  - Filter loads: avoiding breakage of filter
  - Fuel quality
  - Food&Beverage
  - Commercial Fish-farming
  - Cell culture growth
  - ...........

• **Environmental monitoring: Surface Water Bodies**
Measuring Principles

Driven by application requirements
Principles of Turbidity Measurement

Turbidity is an optical property due to scattering and absorption of light

• Solid particles cause light scattering depending on size, shape and colour

• Angles of light scattering are varying with size and particle count: forward, sideward and backscattering.

• Backscattering effects with increasing turbidity => turbidity is non-linear

Scattering effects: particle size

More particles => Backscattering effects
Principles of Turbidity Measurement

What do scattering effects mean to reproducibility and readings

Imagine a piece of paper in the light: being exposed full format or from the side

- Particles are turning and twisting in the solution with changing exposure
- Depending on the orientation of an unevenly shaped particle in the light, the scattering effect will be different:

=> The reading results will vary around a value, it is not comparable to other analytical measurements with „stable“ measurement conditions
Principles of Turbidity Measurement

Nephelometric Measurement at 90° Scattering

Common and best suitable measurement for drinking water applications

- Light beam passing through a cell
- Side scattering of 90° measured with a detector
- Light passing through the cell (transmission 180°) is ignored
Principles of Turbidity Measurement

Transmission measurement at 180°

- Measurement of decreasing light intensity before and after the vial.
- This is the principle of photometric turbidity correction for some parameters.
- It also is used photometrically for Quality Control of e.g. liquids like wall paint.
Principles of Turbidity Measurement

Ratio measurement – combining various detection angles

• Important for values >1500-2000 NTU to include backscattering effects between particles into measurement results of high turbidity levels.

• Computing results algorithmically with the ratio of different (scattering) angles vs transmission:

Manufacturer specific optics => results are not comparable between different systems
Application specific optics: e.g. brewery industry with defined angles (90°, 11°)
Principles of Turbidity Measurement

Different Light Sources

**IR at 860 nm**
- fulfills DIN EN 7027 requirements => European standard for drinking water
- tech. requirements of optical system strictly defined:
  - 860 nm ± 30 nm
  - Detector at 90° ± 2.5°
- eliminates colour effects, less stray light influence

**White light, Tungsten**
- fulfills US EPA 180.1 requirements => US regulations for drinking water:
- tech. requirements are wider
  - light source between 400-600 nm, filament temperature 2200 – 3000 K
  - Detector at 90° ± 30°
- due to absorbance in this wavelength range, the coloration of a sample may disturb

=> Optical systems are depending on standard methods, industries, applications
What is the best choice?

If not defined by requirements of standard methods, the suitable application is matched by: particle size and count + coloration of samples!

<table>
<thead>
<tr>
<th>Measuring task</th>
<th>Optics</th>
<th>IR 90° 860 nm</th>
<th>T 90° 400-600 nm</th>
<th>Forward scattering (IR or T) (e.g. 11-45°)</th>
<th>Ratio (IR or T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Turbidity Level e.g. Drinking Water &lt;1 NTU</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Turbidity Level &gt; 1000-2000 NTU</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Colored samples</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Small Particles</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Big Particles, e.g. cells</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
Calibration & Standards

"Tolerance needs to be accepted!"
Calibration

Brief History:

The Jackson Candle Turbidimeter explains the measurement idea of turbidity measurement:

**Attempting a real world sample image**

- First standards from diatoms in earth (=Kieselguhr) diatoms are algae with silica housing and **multiple** shape and size Prepared from a 1000 ppm stock solution = suspended silica
- Poured from top view in glass tube with candle below
- With increasing particles light turns gradually to a uniform shimmer and final opaque solution. These grades have been marked
- Unit = JTU, Limitation of this „transmission“ < 25 JTU
Calibration since the 1950 until today

**Formazine**
has been found to be best image of real samples in the 1950ties

**Key facts**

- Primary standards DIN/ISO and US EPA
- Hazardous, cancerogene (raw) material
- Stock solution of 4000 NTU, variation of 5-10% depending on raw material and manufacturer
- Freshly prepared dilutions for use within 24 hrs only + dilution tolerance added!
- Unstable by clogging and deterioration of particles => inhomogenous and varying dispersion (stabilized formazine changes in distribution and size too!)
AMCO Clear® Standards (and other polymers)

Offering best and stable real sample image today

Polymer microspheres in ultrapure water retraceable to Formazine

Key facts

- Primary standard acc. US EPA
- Secondary standard acc. DIN ISO
- Not hazardous
- Easy to dispose
- Most modern technique of production: Allows stable and homogenous particle distribution
- Designed and optimized for each optical system: Highest precision reached with specific IR and T calibration standards
## Calibration: Comparing Standards

### AMCO Clear® Standards (1) vs Formazin (2)

<table>
<thead>
<tr>
<th>AMCO Clear® Standards</th>
<th>Formazine / stabilized Formazine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non hazardous</td>
<td>Formazine raw material is rated carcinogenic and hazardous</td>
</tr>
<tr>
<td>High precision ±1% from Batch to Batch W/o dilution faults</td>
<td>Formazine stock solution varies depending on manufacturer 3-5% adding dilution faults =&gt; total up to 10% deviation</td>
</tr>
<tr>
<td>Stable particle distribution and particle size</td>
<td>Drift of particle size and shape =&gt; values drift accordingly. Stabilized Formazine standard “Re-Suspension” =&gt; Change in size and distribution</td>
</tr>
<tr>
<td>Easy to dispose</td>
<td>Formazine to be disposed separately</td>
</tr>
<tr>
<td>Long-term stability min. 12 months</td>
<td>Formazine Standards change within 24 hours, stabilized solution also drift (see above)</td>
</tr>
</tbody>
</table>
One Point Calibration – Usefull or Not?

Since the calibration is non-linear, with an one-point calibration, the range will be tightened close around the calibration point.

=> Saving time with one-point vs. three-point calibration is linked to a loss of measurement range.
Measurement & FAQ
Most important precondition is precise calibration:

- **Warm up times** for lab meters such as Turb 555
- **Vials w/o scratches**: scratches cause straylight
- **NO Silicon oil must be used**
  => additional straylight source
- **Unmarked vials allow higher precision!**

  Optimal position while calibrating via turning: Search lowest value then mark
  => Light beam passes through one and the same position
  => Eliminates influence of glass inhomogenities and scratches in measurements

- **Application notes for lowest values below 1 NTU – Drinking water**:  
  Perform calibration of 0.02 NTU Standard (or deionized water) and sample measurement in one and the same marked vial: 
  This result in excellent accuracy of low range value measurement
How to achieve highly precise measurements?

• **Correct Sampling with instant measurement:**
  - Homogenous Samples
  - No settlement of samples, re-suspend softly
    rapid settlement measurement does an averaging only
  - Temperature of sample: not too cold or standardized
  - No condensation

• **Sample handling and disturbing influences:**
  - Air bubbles from sampling, temperature or by agitation
  - Temperature changes
  - Condensation (Temp!)
  - Finger prints!
  - Scratches
  - Fluff

• **Choose matching optics & light source acc. to application requirements!**
Conclusion of Measurement Principles & Calibration

- **Comparing instruments**
  Just the same freshly prepared Formazine standards for calibration allow comparison of results within instrument group of nephelometric measurement 90°!

- **Measurement Methods**
  Ratio, forward and 90° measurements result in different measurement values and cannot be compared.
  Attention: Some models read only in Ratio mode above 40 NTU!

- **Precision in comparison to other analytical methods**
  Due to formazine and sample properties measuring results and reproducibility are limited overall up to ±5-10%

- **With limitations of measurement principles in mind:**
  Excellent for quality control and indication of (environmental) disturbing factors
Summary

- Turbidity measurement principles are not comparable to physical or electro-/chemical measurement principles, where clearly defined quantities or concentrations of substances are reacting and can be analyzed subsequently. E.g. pH, Ammonium, Chlorine, COD…

- For turbidity measurement, various optical systems can be selected matching different application requirements and purposes: E.g. does color rarely influence the measurement with IR lamp negatively in comparison to tungsten lamp.

- Formazine – beside using harmful material – is less accurate than modern polymer particles with a production accuracy of +/- 1% like the well proven AMCO Clear® standards.

- Turbidity is an indicator parameter: E.g. in drinking water, particles stand for a platform of bacterial growth, meaning a potential hazardous bacterial contamination.

- The comparison of measurement results from different instrument models is only given when all instruments are calibrated with one and the same freshly prepared formazine standards.

- For drinking water and low values ≤ 1 NTU the accuracy can be increased by following an improved calibration and measurement handling together with instrument specific or other polymers.
WTW Turbidimeters

Reliable for Drinking Water and best Price/Performance ratio
## WTW Turbidimeters

### Portable (+Lab)
- **Turb 430 IR/T + Sets**
- **Turb 355 IR/T**
  - Most reliable portable in Drinking Water
  - > 1 NTU

### Labor
- **Turb 550 IR/T**
  - Flow through

### On-line
- **VisoTurb®**
  - 0.02-10,000 NTU
  - Flow through
Lab Precision 2 Go!

Applications from 0.02 – 1100 NTU (IR & Tungsten)

- Acc. DIN/ISO und US EPA
  Highly precise in Drinking Water

- Setting of calibration intervals

- AQA:
  - Storage of calibration interval and protocol
  - GLP-compliant Data management with LSdata PC-Software
    (Data filter, ID), LabStation optional for lab use

- Highly precise AMCO Clear® Polymer Standards for best results

Best portable meter offering lab quality functions and results!
The “Swiss Army Knife” – pHotoFlex® Turb

pHotoFlex Turb – the real “Multi”!!!!

Full Turb 430 IR functionality
• Drinking water suitable turbidity measurement

Photometric Measurement
• Via undetachable smart adapter for 16 / 28 mm vials => wide measurement ranges achieved
• Intuitive operation
• more than 200 Programs for commercial test kits
• Combined programs pH + test kits for NH3, CO2
• AQA and GLP-compliant documentation
• Barcode-Support via optimal LabStation

Electrochemical pH/ORP functionality
• Automatic buffer recognition
• Automatic temperature control
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