Susanne Gollor
Senior Product Manager

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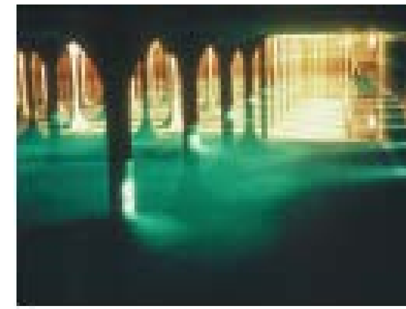
Turbidity Measurement: Driven by Application

FROM WATER TO WINE

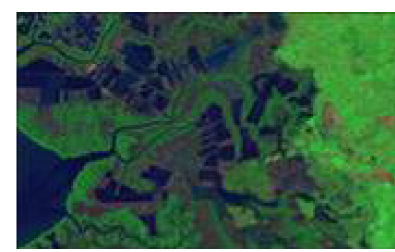

Turbidity – Driven by Application



- **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**

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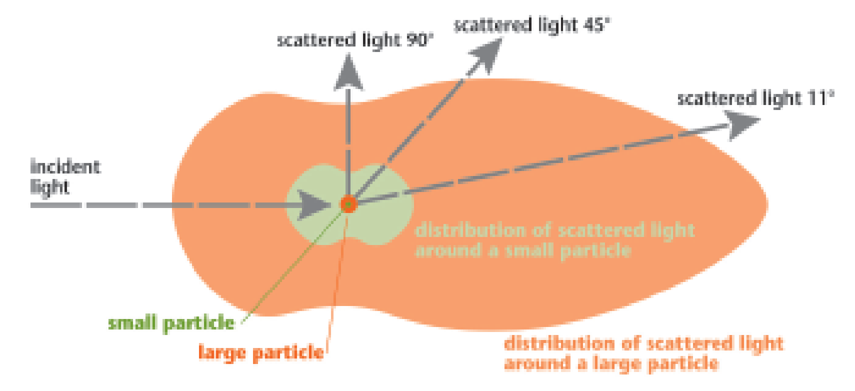
Measuring Principles

Driven by application requirements

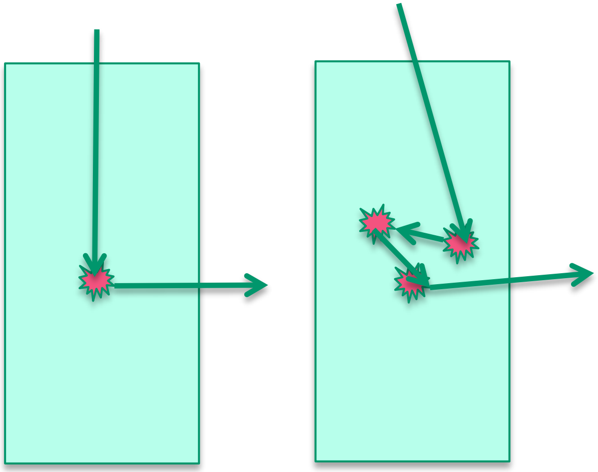
Principles of Turbidity Measurement

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

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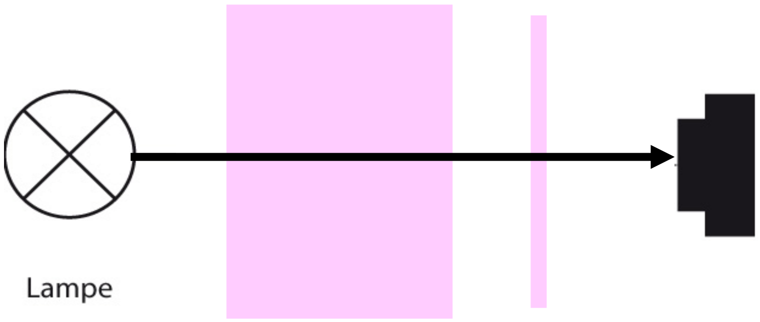
Principles of Turbidity Measurement

What do scattering effects mean to reproducibility and readings

Imagine a piece of paper in the light: being exposed full formate 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:

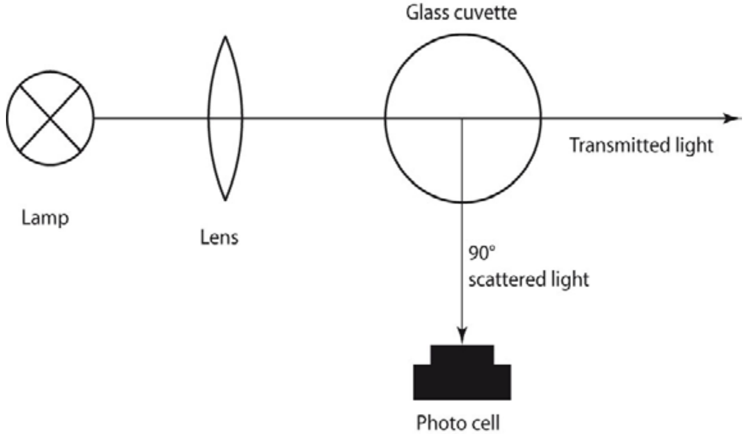
  => The reading results will vary arround a value, it is not comparable to other analytical measurements with „stable“ measurement conditions

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



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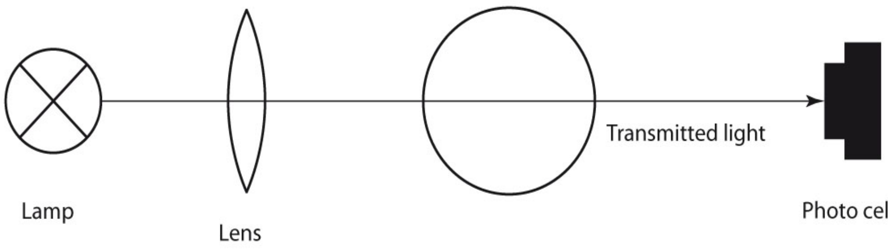
Principles of Turbidity Measurement

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.

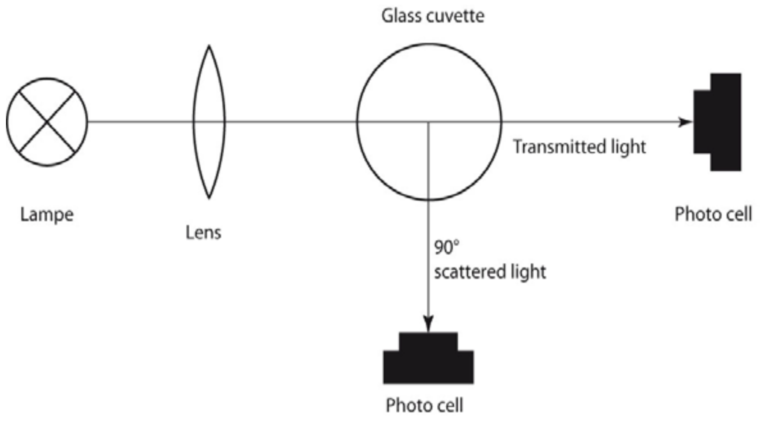
Principles of Turbidity Measurement

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!

Optics / Measuring task	IR 90° 860 nm	T 90° 400-600 nm	Forward scattering (IR or T) (e.g. 11-45°)	Ratio (IR or T)
Low Turbidity Level e.g. Drinking Water <1 NTU	x	x		
High Turbidity Level > 1000-2000 NTU				x
Colored samples	x			x
Small Particles		x		
Big Particles, e.g. cells	x		x	

Calibration & Standards

"Tolerance needs to be accepted!"

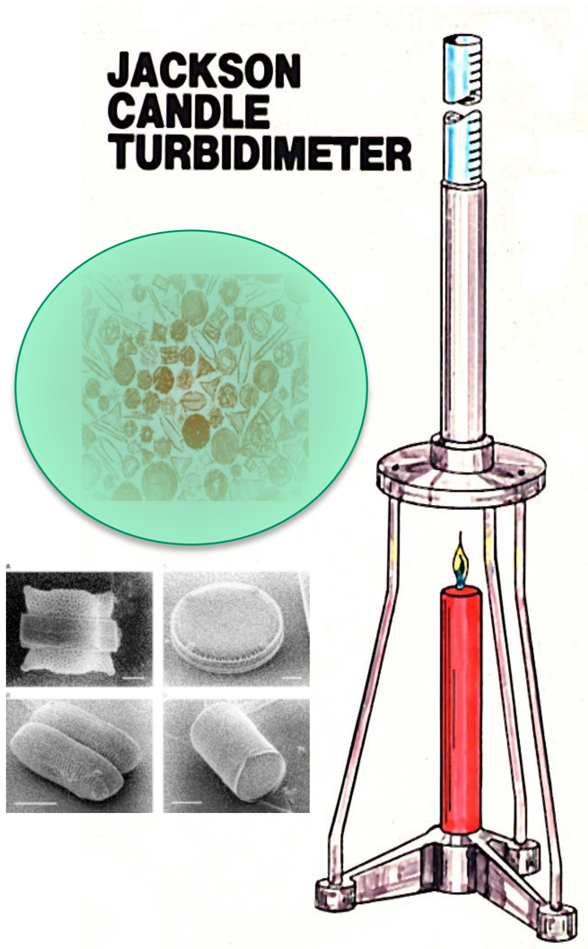
Calibration

Brief History:

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

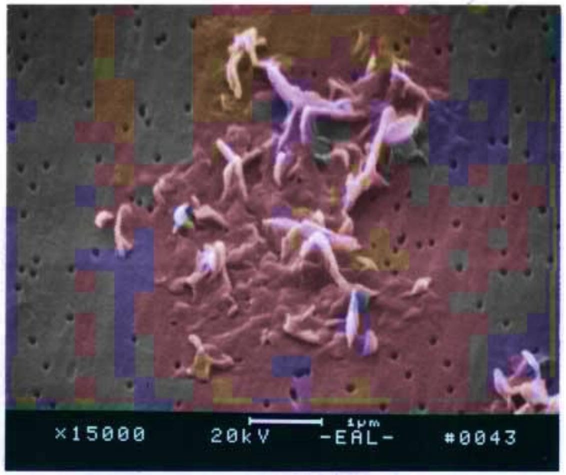
Attempting a real world sample image

- 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

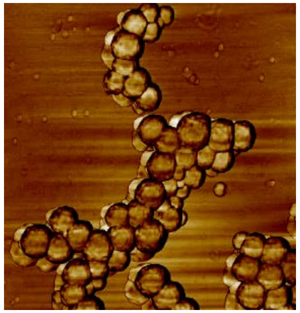
- Primary standards DIN/ISO and US EPA
- Hazardous, cancerogene (raw) material
- Stock solution of 4000 NTU, variation of 5-10% depending on raw material and manufacturer
- Freshly prepared dilutions for use within 24 hrs only + dilution tolerance added!
- Unstable by clogging and deterioration of particles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

Calibration today – Polymers!

AMCO Clear® Standards (and other polymers)

Offering best and stable real sample image today

Polymer microspheres in ultrapure water retraceable to Formazine



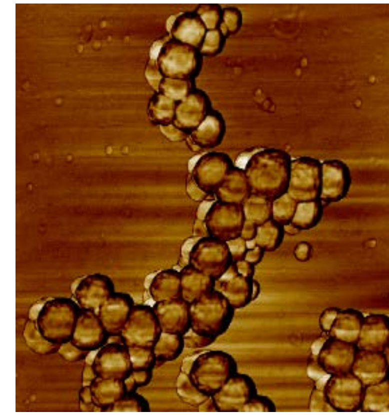
Key facts

- 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)

AMCO Clear® Standards	Formazine / stabilized Formazine
Non hazardous	Formazine raw material is rated carcinogenic and hazardous
Hihgly precise: ±1% from Batch to Batch W/o dilution faults	Formazine stock solution varies depending on manufacturer 3-5% adding dilution faults => total up to 10% deviation
Stable particle distribution and particle size	Drift of particle size and shape => values drift accordingly. Stabilized Formazine standard “Re-Suspension” => Change in size and distribution
Easy to dispose	Formazine to be disposed separately
Longterm stability min. 12 months	Formazine Standards change within 24 hours, stabilized solution also drift (see above)



Polymers

Formazine

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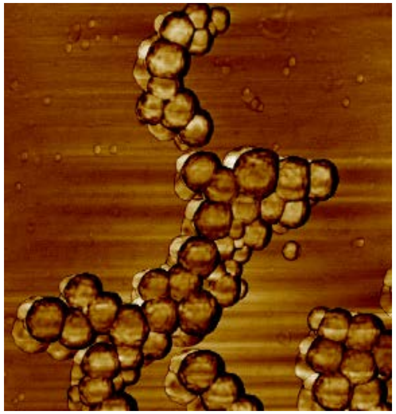
Calibration:

One Point Calibration – Usefull or Not?

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

=> Saving time with one-point vs. three-point calibration is linked to a loss of measurement range.



Polymers

Formazine

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Measurement & FAQ

How to achieve highly precies measurements?

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 precies measurements?

- **Correct Sampling with instant measurement:**
  - Homogenous Samples
  - No settlement of samples, re-suspend softly
    rapid settlment 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!**

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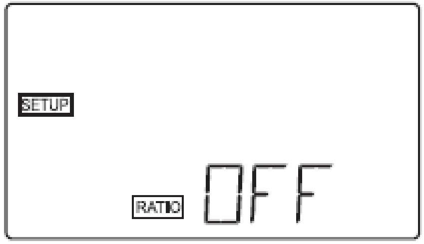
(Erratic) Expectation on Measurement Results

Conclusion of Measurement Principles & Calibratio

Turb® 430



- **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
  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

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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 then 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

Most reliable portable in Drinking Water

Turb 355 IR/T

> 1 NTU

Labor

Turb 550 IR/T

Flow through

Turb 555 IR/T

0.02-10.000 NTU
Flow through

On-line

VisoTurb®

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Turb® 430 Series – Portable & more

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-S
    (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!

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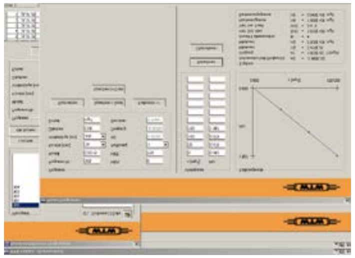
The “Swiss Army Knife” – pHotoFlex® Turb

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 NH_3, CO_2
- AQA and GLP-compliant documentation
- Barcode-Support via optinal LabStation

Electrochemical pH/ORP functionality

- Automatic buffer recognition
- Automatic temperature control

For more information:

www.WTW.com

WTW Customer Care Center
Email: TechInfo.WTW@xyleminc.com
Telefon: ++49 881 183-321