Integrated turbidity measurement „NTU-Check“

1. Introduction

Turbidity is caused by small suspended (undissolved) particles that show a different refractive index than the surrounding medium. This results in reflexion, absorption and scattering of the irradiated light.

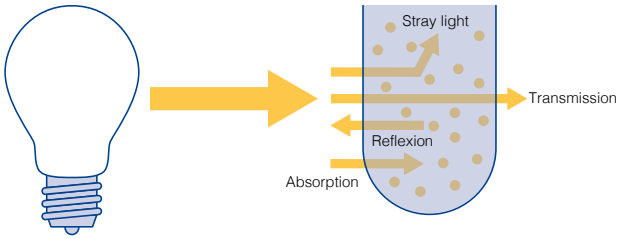

Figure 1: Behaviour of light with suspended solids

Up to a particle specific turbidity value the higher the turbidity gets the more intense the resulting stray light will be. The amount of stray light intensity is influenced by several parameters, e.g. the wavelength of the irradiated light, the particle size and form, the refractive index as well as the color of the test solution.

To better compare turbidity, photometry is the method of choice as it provides objective results. In case a sample with high turbidity is measured, we recommend to use the transmitted light measurement (absorbance measurement) with a measurement angle of 180°. Conversely, if low turbidities have to be detected, a measurement at a 90° angle (nephelometric turbidity measurement) is the more suitable detection method.

2. Measurement methods

As a turbidity reference substance generally formazine is used. The following turbidity units, based on this standard, include a *F* in the abbreviation.

2.1. Nephelometry (stray light measurement)

Recommended measurement range:

1–40 FNU (DIN EN 27027 / ISO 7027 guide value)

Light source and detector are aligned at a 90° angle. The light intensity reflected by the undissolved particles is measured.

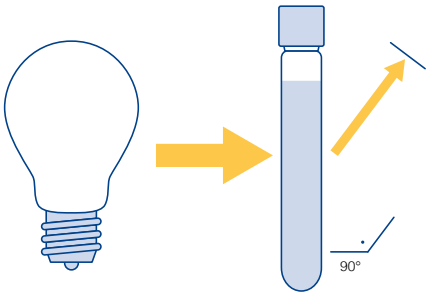

Figure 2: Stray light measurement

The international unit is the nephelometric turbidity unit NTU. Additional units are FTU (formazine turbidity unit) and FNU (formazine nephelometric unit). The latter corresponds to the German unit TE/F (Trübungseinheit Formazin).

Most of the commercially available turbidimeters, the compact photometer PF-12*Plus* as well as spectrophotometers *NANOCOLOR*® *VIS*, *NANOCOLOR*® *VIS* II, *NANOCOLOR*® *UV/VIS* and *NANOCOLOR*® *UV/VIS* II from MACHEREY-NAGEL use methods based on the nephelometry principle. Moreover, our photometers are also able to measure turbidity using the absorbance measurement (transmitted light).

2.2. Absorbance measurement (transmitted light measurement)

Recommended measurement range:

40–4000 FAU (DIN EN 27027 / ISO 7027 guide value)

Light source and detector are aligned at a 180° angle. The reduced light intensity, after the beam has passed the sample, is measured.

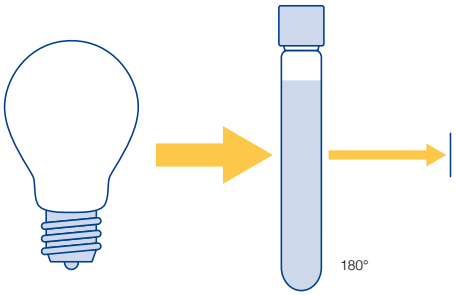

Figure 3: Absorbance measurement

The international unit is FAU (formazine attenuation unit). In Germany, the spectral absorption coefficient SAK [^{1}/m] is the more common measurement unit.

Turbidity measurements based on the detection of transmitted light can be measured with our filter photometers *NANOCOLOR*® 350 D / 400 D / 500 D as well as our spectrophotometers *NANOCOLOR*® *VIS*, *NANOCOLOR*® *VIS* II, *NANOCOLOR*® *UV/VIS* and *NANOCOLOR*® *UV/VIS* II.

2.3. Measuring method

In order to evaluate the correct method of choice, a previous knowledge of the particle size and the concentration can be helpful. The following general rules can be applied:

- Absorbance measurement: Average or high turbidity concentration (approx. 40–400 FAU), e.g. for the determination of the solid content in activated sludge.
- Stray light measurement: Low turbidity concentration (approx. 1–40 FNU), e.g. for the analysis of sewage effluents.

2.4. Wavelength

Due to their three-dimensional structure, turbidity particles show an absorption at almost all wavelengths. An undesired additional absorption of colors in the visual range can be avoided by performing the measurements in the infrared (IR) and the near-infrared (NIR) area, respectively. The attenuation of the transmittance is a degree for particle concentration which causes the turbidity.

The photometric analysis of turbidities is generally performed at a wavelength of 860 nm (DIN EN 27027 / ISO 7027).

The EPA norm requires measurements using a tungsten broadband light source (white light) at a wavelength range of 400–600 nm. However, applying turbidity measurements in this spectral range can cause color interferences.

2.5. Turbidity values

Turbidity plays a major role in evaluating various waters, e.g. drinking water, industrial waste waters, boiler feed water and more. Turbidities are also of particular importance in the quality assurance in the beverage industry (fruit juice production, breweries, etc.). In the waste water area, turbidity measurements provide a good opportunity to evaluate the efficiency of filtration and cleaning processes. Typical turbidity values can be seen in table 1.

Sample	Turbidity [NTU]
Drinking water	0.02–0.5
Formazine stock solution	4 000
Sewage influent	70–2 000
Sewage effluent	2–40

Table 1: Typical turbidity values

2.6. Turbidity measurements with *NANOCOLOR*®

2.6.1 Overview

Both, nephelometry and absorbance measurements can be performed with our filter and spectrophotometers.

Photometer	Measuring method	Method number	Turbidity unit [wavelength]
NANOCOLOR® *VIS*, *NANOCOLOR*® *UV/VIS*	Nephelometry	3-07	1–1000 NTU / FNU [λ = 860 nm]
PF-12*Plus*	Nephelometry	9-06	1–1000 NTU / FNU [λ = 860 nm]
NANOCOLOR® *VIS* II and *NANOCOLOR*® *UV/VIS* II	Nephelometry	3-07	0,1–1000 NTU / FNU [λ = 860 nm]
NANOCOLOR® *VIS*, *NANOCOLOR*® *VIS* II, *NANOCOLOR*® *UV/VIS* and *NANOCOLOR*® *UV/VIS* II	Absorbance	3-05 [50 mm cuvette]	2–400 FAU [λ = 860 nm]
		3-06 [50 mm cuvette]	1–100 FAU [λ = 550 nm]
		1-92 [50 mm cuvette]	1–100 FAU; 0,5–40 ^{1}/m [λ = 620 nm]
		3-10	0–750 mg/L TSS [λ = 860 nm]
NANOCOLOR® 350 D / 400 D / 500 D	Absorbance	1-92 [50 mm cuvette]	1–100 FAU; 0,5–40 ^{1}/m [λ = 620 nm]
		3-10	70–750 mg/L TSS [λ = 690 nm]

Table 2: Turbidity measurements with *NANOCOLOR*® photometers

2.6.2 Automatic turbidity measurement for tube tests – NTU-Check

Our spectrophotometers and the compact photometer PF-12^{Plus} allow you to automatically check for turbidity when running *NANOCOLOR*® tube tests, displaying the turbidity in NTU. This function safely detects measurement errors due to turbidity, thus increasing overall measurement and result safety.

You can activate / deactivate the NTU-Check in the settings (menu) of your photometer.

If you activate the NTU-Check, a nephelometric turbidity measurement is run time-shifted whenever you measure a tube test. You can enter an individual NTU limit. If the turbidity is exceeding your selection, the measurement value and the NTU result will be displayed in red (on the spectrophotometers) or with an exclamation mark (on the PF-12^{Plus}) as a visual warning.

3. FAQ

Is the cuvette condition relevant?

The cuvette has to be free of scratches and dirt.

Which cuvette type is the best for performing turbidity measurements?

Depending on the turbidity measurement, different cuvette types can be used. Transmitted light measurements can be performed with both, round and rectangular cuvettes (180° measurement). Nephelometric turbidity measurements only work with 16 mm OD round tubes (90° measurement).

How can I preserve a sample that has to be analyzed in terms of turbidity?

Since the particles might coagulate or flocculate, turbidity measurements are ideally performed right after sample taking, otherwise false measurement values can result.

Which additional parameters can influence the turbidity measurement?

The sample has to be completely free of air bubbles or else false high measurement values can result. Bubbles can be eliminated by warming-up the sample to 30 °C approx. Another method would be to use an ultrasonic bath (Note: Ultrasonic treatment may alter the particles shape and size leading to a change of the result).

Do I have to calibrate my photometer to perform a turbidity measurement?

Yes, the instrument has to be calibrated. The calibration is already implemented in the factory settings. We recommend to control the calibration of the used device with NIST-traceable turbidity standards (e.g. *NANOCONTROL* NANOTURB) every 6 months. With these solutions the device can also be recalibrated if necessary.

Can the measured turbidity unit easily be converted into the corresponding mass concentration of the suspended substance?

No, there is no linear correlation between the turbidity value and the solid content [ppm]. Such a mathematical recalculation would afford the exact knowledge of the optical properties, size and form of the analyzed suspended solids.

Which parameters are relevant for the influence of the turbidity?

a) Matrix

The intensity of the emitted light beam is influenced by the particle size and form. In order to ensure an acceptable comparability of the measured turbidity values we recommend to mix the turbid samples with a magnetic stirrer prior to measurement performance.

b) Wavelength

The correlation between the measured absorbance and the wavelength is shown in the following spectrum (figure 4) for a 50 NTU standard (correlation can vary for other samples).

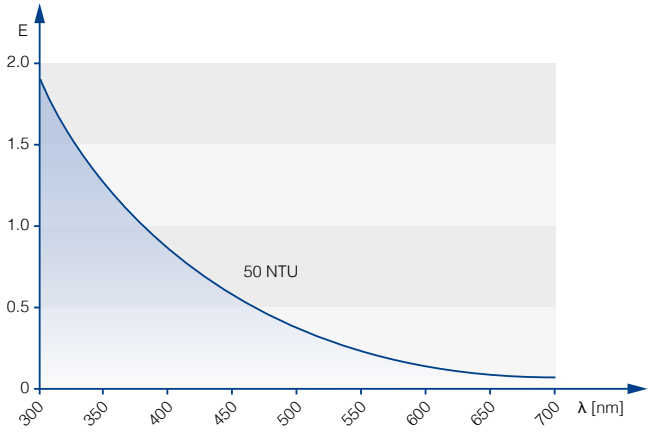

Figure 4: Correlation between the absorbance and the wavelength for a 50 NTU standard

We recommend to adjust a general threshold value of 10 NTU for our NTU-Check function. This ensures a maximum measurement safety for all our *NANOCOLOR*® tube tests.

c) Factor

In case a sample is turbid the measured value will be affected by the additional particles. Depending on the measurement direction of the used test, false high or false low measurement readings may be the consequence. Tests based on a negative measurement direction will show lower results with turbid samples. To which extent the result will differ from the true value (without turbidity) depends on the wavelength and the corresponding factors, as shown in the following example.

Example:
A turbidity in a COD sample, measured at a wavelength of 620 nm, results in an additional absorbance of 10 mE. Now this sample is analyzed with 2 different *NANOCOLOR*® COD test kits, COD 1500 [Test 0-29] and COD 4000 [Test 0-11]. The tests have the following factors:

Test 0-11
F = 5600

Test 0-29
F = 1740

The concentration is calculated with the formula c = E x F. Therefore, the turbidity leads to the following measurement errors, resulting in false high readings:

Test 0-11
F = 5600 → Δc = 0.01 x 5600 = + 56.0 mg/L

Test 0-29
F = 1740 → Δc = 0.01 x 1740 = + 17.4 mg/L

4. Approach guide after detection of undesired turbidity in the sample

If you detect a noticeable turbidity (NTU > 10) with the NTU-Check function, a plausibility control of the measured value is recommended. Depending on the measured parameter there are different approaches:

4.1. Dilution (generally applicable)

In general, we initially recommend to consider the possibility of diluting the sample. For dilutions, distilled water can be used. Exceptions are the parameters COD and BOD_5. For COD we recommend to use COD-free water. For BOD_5 the corresponding dilution water has to be used. By diluting the sample, the concentration of the undesired interfering substances, e.g. turbidities, is decreased and therefore cannot influence the measurement anymore. Please pay attention to the valid measurement range of the test kit of choice since it may change after the dilution step. In such a case, a test with a lower measurement range has to be considered. The optimum parameter concentration lies within the 20–80 % measurement range of the used test kit.

All *NANOCOLOR*® photometers offer the possibility of recalculating the displayed measurement value by entering a dilution. Afterwards the correct value and the corresponding dilution will be documented (please consult the corresponding user manual for further information).

4.2. Prefiltration (only for dissolved substances; not applicable for sum parameters)

For the determination of dissolved substances (ions) in samples showing high turbidity, a prefiltration is recommended. Depending on the degree of turbidity and/or the particle size, respectively, different filters should be applied:

Finely dispersed turbidity:

- use membrane filtration kit 0.45 µm
- use membrane filtration kit GF/PET 0.45 µm

Medium fine dispersed turbidity:

- use glass fibre filters, e.g MN 85/90 BF
- use membrane filtration kit GF/PET 0.45 µm

Coursely dispersed turbidity:

- use qualitative filter paper, e.g. MN 615, if necessary, a fine filtration with 0.45 µm syringe filters can be additionally applied afterwards

4.3. Correction value

Turbid samples that are to be analyzed for sum parameters (e.g. total-P, TN_b, etc.) cannot be filtered. In these cases, we recommend to perform a correction value for each measurement. A detailed description of the correction value determination is included in the corresponding user manual of the photometer or can be requested if necessary. An automatic correction value performance is integrated in our photometers.

For some parameters (e.g. COD and AOX) the correction value determination cannot be used since the color giving reagent is already predosed in the tube.

Generally, all sample colors and turbidities will be destroyed during the digestion process in the heating block. Turbidities that still remain after the heating process, e.g. after a COD digestion, may be related to flocculated mercury chloride. If measured too quickly, this turbidity can lead to measurement discrepancies. In case the turbidity value exceeds 10 NTU, we recommend to wait with the measurement until the particles have settled down. A positive impact on a faster flocculation of suspended particles can be achieved by placing the tube again into the heating block for approx. one minute at 50 °C. In addition, too high chloride concentrations sometimes are not masked completely and therefore also lead to false measurement values.

Ordering information

Photometers

Spectrophotometer *NANOCOLOR*® *VIS* II — REF 919 650.1

incl. manual (quickstart guide), touch pen, protective covering, power supply with country-specific adapters, USB cable, USB stick, calibration cuvette, certificate, and cleaning cloth

Spectrophotometer *NANOCOLOR*® *UV/VIS* II — REF 919 600.1

incl. manual (quickstart guide), touch pen, protective covering, power cable, USB cable, USB stick, calibration cuvette, certificate, and cleaning cloth

Compact photometer PF-12*Plus* — REF 919 250

for evaluation of *VISOCOLOR*® *ECO* tests and *NANOCOLOR*® tube tests, incl. software DVD, manual, *VISOCOLOR*® *ECO* test instructions for compact photometer PF-12*Plus*, 4 batteries, 4 empty test tubes, funnel, beaker, syringe, USB cable, calibration cuvette, certificate, and cleaning cloth in rugged case

Accessories

NANOCONTROL NANOTURB — REF 925 702
Turbidity standard for turbidity calibration (1–1000 NTU)

Distilled water — REF 918 932

COD-free water — REF 918 993

Qualitative filter paper MN 615 — REF 431 005
(e.g. Ø 55 mm)

Glass fibre filter MN 85/90 BF — REF 406 005
(e.g. Ø 55 mm)

Membrane filtration kit GF/PET 0.45 µm — REF 916 01
2 syringes 20 mL and 25 CHROMAFIL®
membrane filters GF/PET 0.45 µm

Membrane filtration kit 0.45 µm — REF 916 50
2 syringes 20 mL and 25 CHROMAFIL®
membrane filters 0.45 µm

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