Application note | AN037

Turbidity units - a cloudy issue

We are used to using interchangeable units of measure. For example,

- Concentration units: mg/L ≈ ppm (parts per million),
- Conductivity units: Siemens = mhos,
- Salinity units: practical salinity units (psu) ≈ ppt salinity.

What about turbidity – are turbidity units of NTU exchangeable with units of FNU?

The precise answer is no. While the standards used are the same, strictly speaking, the units are not equivalent.

- Turbidity units: NTU ≠ FNU

For turbidity results, the use of a particular reporting unit can give information about the type of meter or sensor used to generate the readings. Therefore, different units (such as NTU or FNU) can indicate different meter types and different test methodologies.

For example, in North America, it is common to measure turbidity in potable and waste waters using meters with a white light source (such as a tungsten lamp or white LED) and a 90-degree detector angle to measure the scatter of light in the sample. EPA Method 180.1 is an example of this methodology. The reporting units are nephelometric turbidity units (NTU). Therefore;

- NTU units indicate a reading from a meter using a white light source and a 90-degree detector.

In Europe and Asia/Pacific regions of the world, for example, it is common to use an infrared light source and a 90-degree or 180-degree detector angle to measure light scatter or attenuation in the sample. (The detector angle chosen depends on how turbid is the sample). ISO 7027 is an example of this methodology. The reporting units are formazin nephelometric units (FNU) for the 90-degree readings and formazin attenuation units (FAU) for the 180-degree readings. Therefore;

- FNU units indicate a reading from a meter using an IR light source and a 90-degree detector.
- FAU units indicate a reading from a meter using an IR light source and a 180-degree detector.

thermo scientific

All of these readings are taken using turbidity meters, so why are the units different? Why not use the same units throughout?

The turbidity value of a sample depends on the optical properties of both the sample and the meter.

The optical properties of the sample may include color and particle density, size, and shape, while the optical properties of the meter may include the wavelength of the light source, the spectral bandwidth, the angle of the detector, etc. The more turbidity causing substances in the sample, the more that readings between different meter types can vary. Therefore;

- Turbidity ↔ optical properties of the sample + optical properties of the meter.

Table 1. Common turbidity units and associated meter properties

Common turbidity units and associated meter properties			
Meter property	NTU	FNU	FAU
Light type	White	Infrared	Infrared
Light wavelength	400 – 680 nm	780 – 900 nm	780 – 900 nm
Detector angle	90°	90°	180°
Signal type	Nephelometric scatter	Nephelometric scatter	Attenuation
Example method	EPA 180.1	ISO 7027	ISO 7027

A new system of turbidity units, which describes every type of turbidity sensor and meter available for sale (as of September 2011), has been developed. Tables of this information have been adopted by:

- The United States Geological Society (USGS), published in the USGS Field Manual at (http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html), and
- The American Society for Testing and Materials (ASTM), published in ASTM Method D7315 at (http://www.astm.org/Standards/D7315.htm).

The naming convention is logical and easy to decode. For example, "N" indicates a nephelometric 90-degree detector angle and "T" indicates a white light source. Therefore, the units of NTU indicate a 90-degree nephelometric reading and a white light source. See Table 2 below for a key to the units.

Table 2. Key to turbidity units per USGS and ASTM

Key to turbidity units per USGS and ASTM			
Letter	Property	Example unit	Meter indicated
N	Nephelometric scatter, 90° detector angle	NTU	90° detector angle, white light
T	White light	NTU	90° detector angle, white light
F	Infrared light	FNU	infrared light, 90° detector angle
R	Ratio-metric[1], dual detectors, primary at 90°, secondary at angle ≠ 90°	FNRU	Infrared light, 90° detector angle (primary), ratiometric (2nd detector angle ≠ 90°)
A	Attenuation[2], detector at 180°	FAU	Infrared light, 180° detector
B	Backscatter[3], detector at <90°	FBU	Infrared light, detector at <90°

1 Ratio-metric: an instrument algorithm that uses a combination of detector readings to generate the turbidity reading. The nephelometric detector serves as the primary detector and one or more other detectors are used to compensate for variation in incident light fluctuation, stray light, instrument noise, or sample color.

2 Attenuation: the amount of incident light that is scattered and absorbed before reaching a detector which is centered at 180° relative to the incident light beam.

3 Backscatter: the amount of incident light that is scattered and detected at an angle of less than 90° relative to the incident light beam. Back scatter signals are less intense and are good for higher turbidity measurements.

Note: While USGS and ASTM have adopted this naming convention for turbidity units, not all manufacturers and other standard bodies have done so. Consult your meter manual to determine the actual light source and detector geometry for your equipment. Report units as required by your testing method.

Table 3. A Brief History of Turbidity Units.

A Brief History of Turbidity Units	
Timeline	History in Standard Methods for the Examination of Water and Wastewater
1900	JTU, Jackson Turbidity Unit. The Jackson Candle Turbidimeter visual method is used to measure light attenuation. The JTU is related to the ppm-silica scale, based on suspensions of diatomaceous earth in distilled water.
1926	Formazin standard developed.
1955	TU, Turbidity Units, replaces the ppm units and the silica scale in Standard Methods.
1971	FTU, Formazin Turbidity Unit. Formazin adopted as the primary turbidity standard. Attenuation readings are still common.
1975	NTU, Nephelometric Turbidity Unit. Nephelometric readings are preferred for low turbidity samples.
1989	The JTU visual method is removed from Standard Methods.