When is an NTU not an NTU? New Reporting Procedures by USGS and ASTM Address Turbidity Data Comparability and Storage Issues

by Chauncey Anderson

and

G. Douglas Glysson, US Geological Survey
Acknowledgements

Funding from: USGS Office of Water Quality

Major assistance from:

Mike Sadar (Hach Corp.)
John McDonald (YSI Environmental)
Kemon Popacosta (GFS Chemicals, Inc.)
USGS- Andy Ziegler, Richard Wagner, Jim Eychaner, Mark Uhrich, Office of Surface Water
Take Home Messages

There is no such thing as “The Correct Turbidity”!

Consistency, Consistency, Consistency!

USGS & ASTM will report and store data with new reporting units based on instrument type (Oct. 1, 2004)
Outline

1. Problem / Definition
2. Measurement & Technology
3. Comparisons among instruments
4. USGS & ASTM response
   • Reporting Units
   • Data Storage
Problem: Large differences among instruments and users

(Gray and Glysson, 2002)
Definition of Turbidity

“...an expression of the optical properties of a liquid that causes light rays to be scattered and absorbed rather than transmitted in straight lines through a sample.” (ASTM International, 2003a)

- Suspended material
  - clay, silt, finely divided organic matter, plankton, other microscopic organisms

- Dissolved material
  - organic acids and dyes
Measurement

Light Source
(White Light Tungsten Filament or near-IR LED)

Sample Cell

BACKSCATTER DETECTOR (Optional)

90° DETECTOR (Required)

FORWARD SCATTER DETECTOR (Optional)

TRANSMITTED DETECTOR (Optional)
Technology

- Single detector, white light (standard nephelometry)
- Multiple detectors (ratiometry)
- Near-IR nephelometry
  - Non-ratio (single detector)
  - Ratio (multiple detectors)
- Surface Scatter
- Backscatter
- Attenuation / Transmission
- Static (benchtop) vs Dynamic (submersible)
Effect of Color

White-light, ratio (Hach 2100AN)

White Light, non-ratio (Hach 2100A)

Data from Pavelich, NWQL
Effect of Light Source & Detectors

- YSI 6026 (near IR)
- Hach 2100P (White Light, Ratio)
- Hach 2100N (White Light, non-ratio)

\[ x = y \]
# New Reporting Units

<table>
<thead>
<tr>
<th>Detector Geometry</th>
<th>Light Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>White or broad band</strong> (400-680 nm)</td>
</tr>
<tr>
<td></td>
<td><strong>Near-IR or Monochrome</strong> (780-900 nm)</td>
</tr>
<tr>
<td><strong>Single-Beam Light Source</strong></td>
<td></td>
</tr>
<tr>
<td>Single Detector Nephelometry (90°)</td>
<td><strong>NTU</strong> — Nephelometric Turbidity Unit</td>
</tr>
<tr>
<td></td>
<td><strong>FNU</strong> — Formazin Nephelometric Unit</td>
</tr>
<tr>
<td>Multiple Detector Nephelometry (90° and other angles)</td>
<td><strong>NTRU</strong> — Nephelometric Turbidity Ratio Unit</td>
</tr>
<tr>
<td></td>
<td><strong>FNRU</strong> — Formazin Nephelometric Ratio Unit</td>
</tr>
<tr>
<td>Single Detector Backscatter (30°)</td>
<td><strong>BU</strong> — Backscatter Unit</td>
</tr>
<tr>
<td></td>
<td><strong>FBU</strong> — Formazin Backscatter Unit</td>
</tr>
<tr>
<td>Single Detector Attenuation (180°)</td>
<td><strong>AU</strong> — Attenuation Unit</td>
</tr>
<tr>
<td></td>
<td><strong>FAU</strong> — Formazin Attenuation Unit</td>
</tr>
<tr>
<td><strong>Multiple-Beam Light Source</strong></td>
<td></td>
</tr>
<tr>
<td>Multiple Detector Nephelometry (90° and other angles)</td>
<td><strong>NTMU</strong> — Nephelometric Turbidity Multibeam Unit</td>
</tr>
<tr>
<td></td>
<td><strong>FNMU</strong> — Formazin Nephelometric Multibeam Unit</td>
</tr>
</tbody>
</table>
Remaining issues

- New instruments continually being developed
- Still have large variability within some categories
- Databases
- Education
Where to from here?

- USGS National Field Manual Ch. 6.7 (http://water.usgs.gov/owq/FieldManual)
- USGS historical data won’t be migrated to new pcodes unless specific information on instrument is available.
- FAQ
- ASTM Round-Robin
Conclusions

There is no such thing as “The Correct Turbidity”!

Consistency, Consistency, Consistency, Consistency!

USGS & ASTM will report and store data with new reporting units based on instrument type (Oct. 1, 2004)
Turbidity-- Considerations

- Currently no federal regulations apply to natural waters
- Turbidity isn’t an inherent physical property & is affected by many factors
- Technological advances that account for these factors also reduce comparability
- Techniques matter (static/dynamic, calibrants used)
Effect of Particle Size and Density

Upper Squaw Creek, 3-Sisters Wilderness, Oregon, August 2003

Turbidity

Subsample #
1  2  3  4  5

White-light, Ratio (Hach 2100P)
White-light, Non-ratio (Hach 2100N)
<table>
<thead>
<tr>
<th>Properties of water matrix</th>
<th>Effect on Measurement</th>
<th>Direction of effect</th>
<th>Instrument designs to compensate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Absorption of light beam</td>
<td>Negative (-)</td>
<td>• Near-IR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Multiple detectors</td>
</tr>
<tr>
<td>Particle Size:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Large</td>
<td>$\lambda$ – Dependent</td>
<td>+ (Near IR)</td>
<td>• White Light</td>
</tr>
<tr>
<td>• Small</td>
<td>- (White)</td>
<td></td>
<td>• Near IR</td>
</tr>
<tr>
<td>Particle Density</td>
<td>Increases</td>
<td>Negative (-)</td>
<td>• Multiple Detectors</td>
</tr>
<tr>
<td></td>
<td>forward &amp; back scattering</td>
<td></td>
<td>• Backscatter</td>
</tr>
</tbody>
</table>
Factors affecting measurements

- Particles
- Color
- Light source
- Number and configuration of detectors
- Particle settling
- Mechanical & Sample problems
Comparison of new YSI turbidity probe with Hach 2100AN
Sites number 1-71

Turbidity (NTU)

Site Number

Hach 2100AN
YSI 6136
Which Instrument Do I Use?

- Based on Study Objectives
- Decision Tree to help users decide which instrument type to use
Data Storage

- **USGS Database**
  - New parameter codes for **turbidity**
  - Historical data will not be migrated without specific knowledge of instruments used
  - New method codes to designate each instrument (make, model, mode of op.)
Calibrants

• Reference Solution
  – Scratch Formazin (4000 TU)

• Calibration Solutions
  – Diluted scratch formazin or commercial standards
    (StablCal™, AMCO AEPA-1™ polymers)

• Verification Standards
  – Solids, gels
FAQ

• EPA Role/Response?
• What about FTU?
• Polymer vs Formazin?
• Why do some units contain “formazin” in name and some don’t?
• Can USGS just do this w/o EPA?
• What’s the best instrument to use?