Feasibility of Using Low-Cost Appliance Turbidity Sensors for Water Quality Monitoring

David Gillett[1], and Alan Marchiori[2]

[1]Department of Chemical Engineering, Bucknell University, Lewisburg, Pa.

[2]Department of Computer Science, Bucknell University, Lewisburg, Pa.

Abstract

Continuous and accurate monitoring of water quality is key to efficient and proactive water resource management. However, the cost and complexity of deploying such monitors limits their use. This research set out to determine if low-cost, off-the-shelf, appliance-grade turbidity sensors (~$3 in volume) have the needed precision and accuracy to be used in water quality monitoring applications. Several different models of appliance-grade turbidity sensors were considered. Tests were run to determine the variation between different units of the same model, the effect of temperature on the measurements, and the ultimately the granularity/precision of these turbidity sensors. The primary conclusion was that these low-cost turbidity sensors, even with device-specific calibration, do not have the precision required to provide useful data for typical water resource management applications. Future work focuses on improving the precision of low-cost turbidity sensors in water resource management applications by changing the geometry of the sensor and applying signal processing techniques.

Introduction and Purpose

Turbidity is a measure of the clarity of a water sample. High turbidity can be indicative of human impact on the environment such as increased algae growth due to fertilizer run-off.

This research set out to see if off the shelf appliance turbidity sensors have the needed precision and accuracy to be used in water quality monitoring.

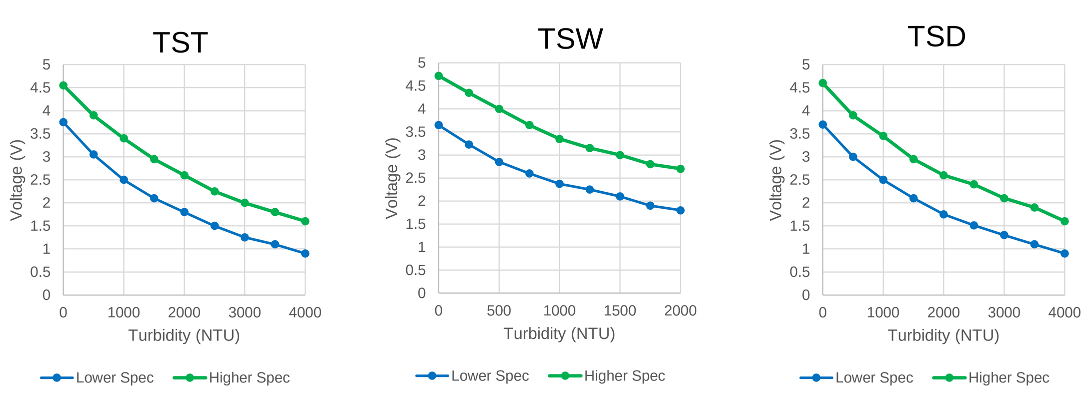


Figure 1: Manufacturer Specification for Voltage to NTU

All NTU values on this poster assume that tap water is 1 NTU and use a trend line through that point to approximate the NTU

Materials and Methods

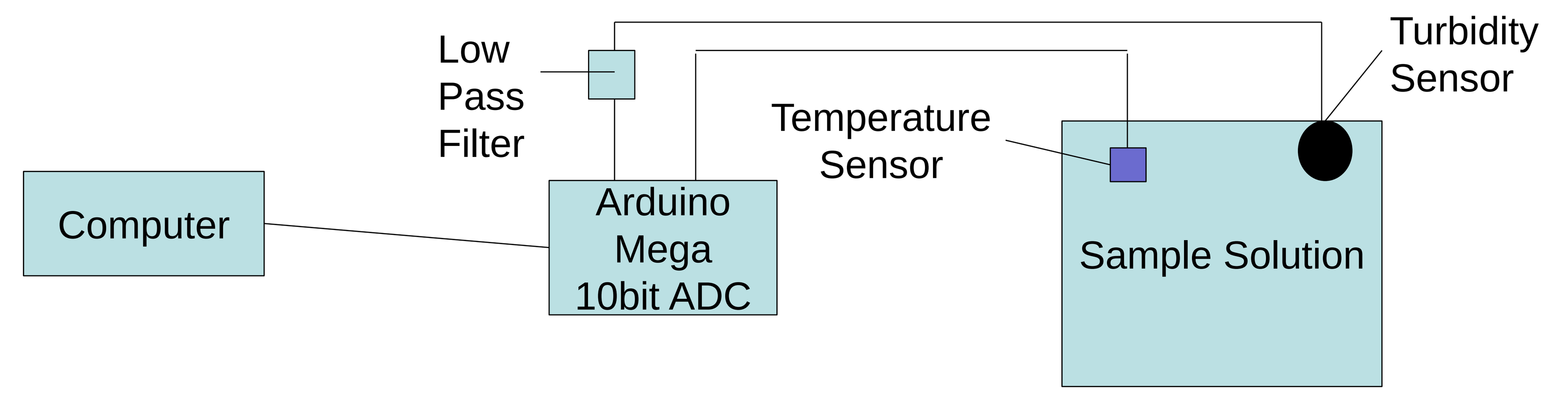
Materials Used

- Arduino Mega (with 10-bit ADC) (Arduino 2017)
- Amphenol Turbidity sensors (TST-10, TSD-10, TSW-10) (Amphenol Advanced Sensors 2014a-c)
- DS18B20 Temperature Sensor (Maxim Integrated Products)
- Basic Electrical Components (Capacitors, Resistors, Wires)

Tests Performed

- Noise Reduction
  - Created an analog low pass filter to minimize the noise in the data
- Temperature Compensation
  - Created a calibration curve to isolate the sensor's temperature from its readings
- Sensor to Sensor Variation
  - Compared sensors of the same model to see out of the box consistency of readings
- Cutting Oil Test
  - Tested each sensor at a variety of cutting oil levels to evaluate the response to turbidity changes

Diagram of The Sensor Setup



Sensor to Sensor Variation

Sensor	Specified Variation (NTU)	Observed Variation (NTU)
TST-10	325	50
TSD-10	305	162
TSW-10	748	348

The tested sensors showed wide variation, but not to the full range allowed by the manufacturer specification. This variation motivated the use of device-specific calibration to greatly improve accuracy.

Sensor Reading

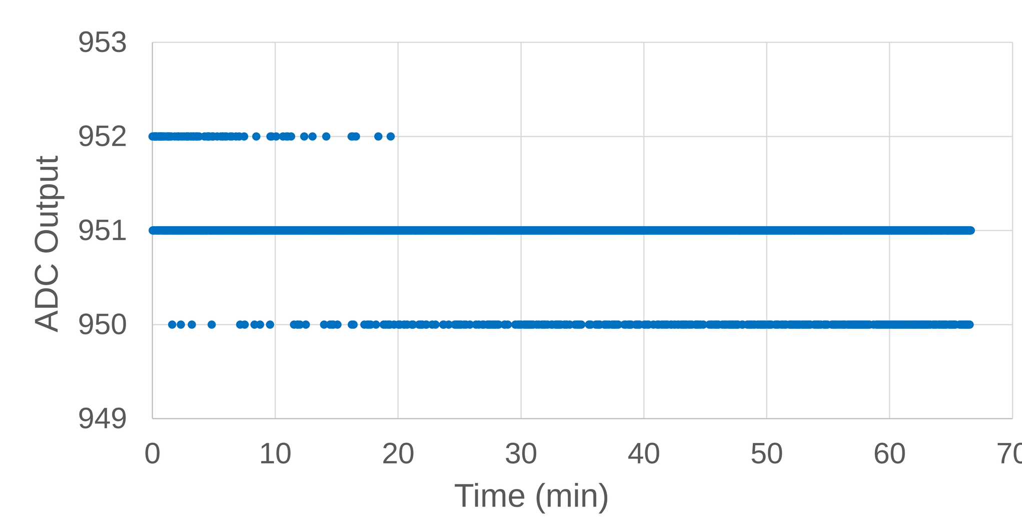


Figure 2: TST-10 Run Post-Noise Reduction

After adding the filter, sensor readings were very consistent +/- 1 count (+/- 4 NTU) over long runs with the tap water sample. This variation is mostly due to the last-bit imprecision of the 10-bit ADC.

Temperature Compensation

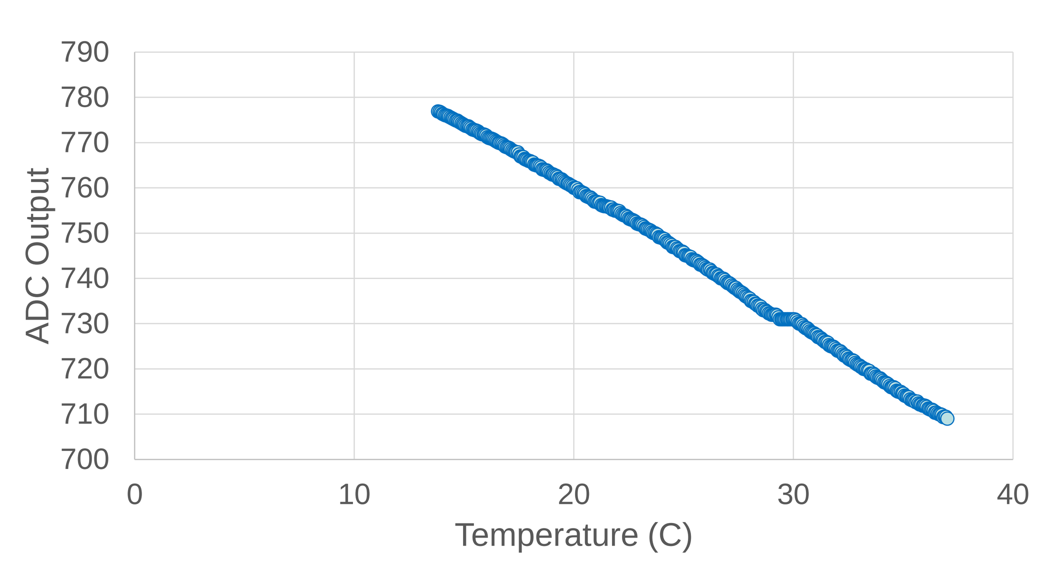


Figure 3: TSW-10 Temperature Compensation (Tap Water)

All the sensor models showed a near-linear trend of decreasing ADC output with increasing temperature. Across all sensor models the ADC output decreased 1-3 counts per degree Celsius (5-15mV).

Cutting Oil Tests

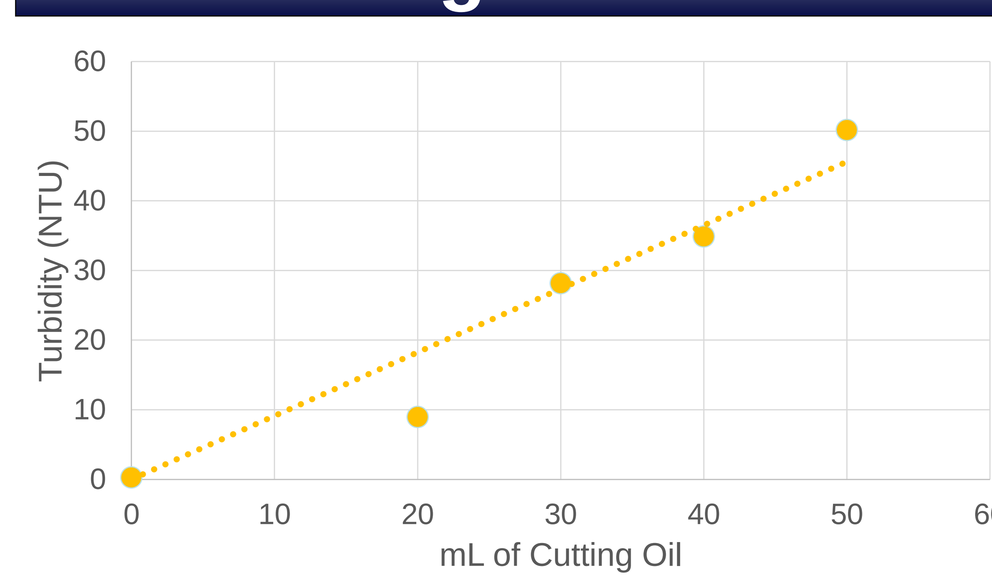


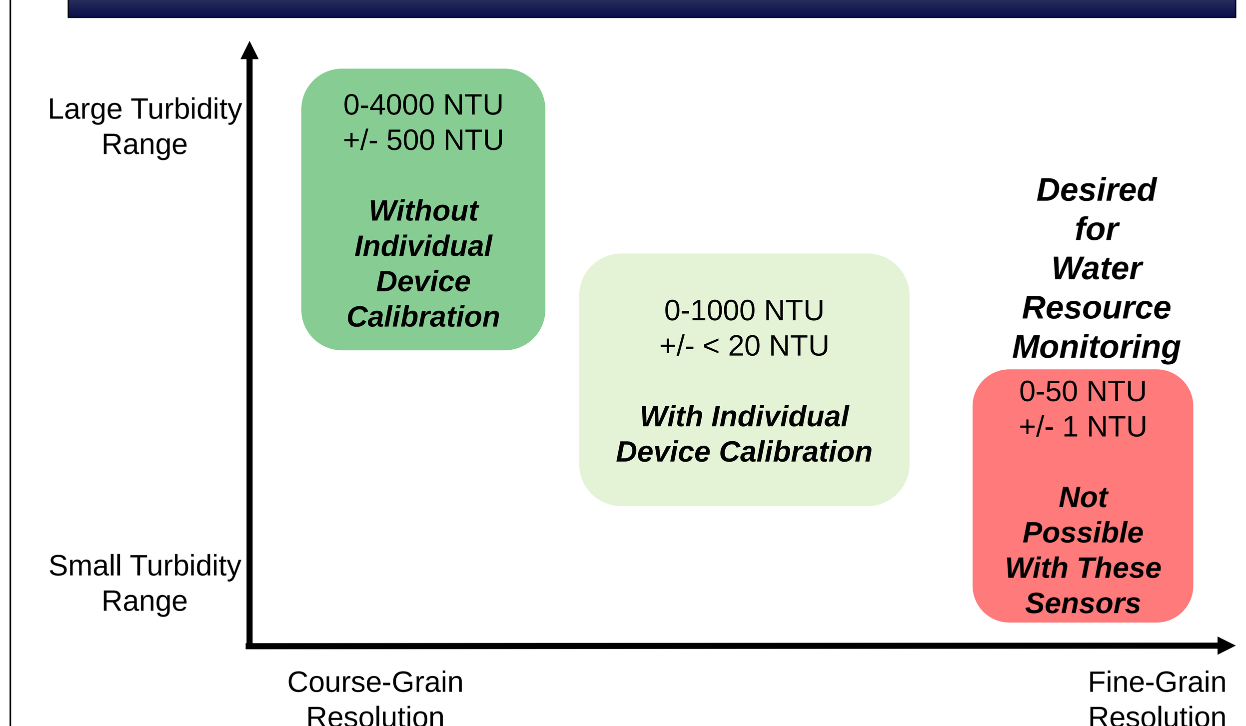
Figure 4: TSD-10 Cutting Oil Test in 1L of Tap Water Cutting oil can be used in water to increase turbidity (Lambrou 2009)

All the sensor models showed an increase in turbidity as cutting oil content increased. The solutions showed some variation in NTU over time. More stable solutions will be investigated in the future.

Discussion

- After the addition of a simple low-pass filter (Fcutoff = 822 Hz), the noise in the data was greatly reduced.
- The data showed that the individual sensors performed consistently over time and can be corrected with linear temperature compensation
- The specified variation of voltage to NTU yields accuracy in the range of +/- 350 NTU if no device-specific calibration is performed.
- The accuracy can be greatly improved with specific-device calibration and temperature calibration +/- < 20 NTU (15x improvement)
- Ultimately, even with the benefit of specific-device calibration these sensors do not have the accuracy needed for typical water quality applications (+/- 1 NTU)

Conclusion



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