Turbidimeter

June 12, 2011

Abstract

AguaClara needs a reliable and simple method for candidate communities to monitor the turbidity of their water supply. Portable turbidimeters cost $400 or more and thus are too expensive to provide to a large number of candidate communities. The goals of providing candidate communities with turbidimeters is to determine the source water turbidity range and hence the type of water treatment that will be required. For example, if the source water turbidity never exceeds 10 NTU, then it may not be necessary to provide flocculation and sedimentation. The turbidimeter should be very inexpensive (less than $20). It should have an error of less than 50%. One possible approach is to use a Jackson style turbidimeter (a long tube that you fill with water until you can't see the candle below the end of the tube). Instead of a candle you could use a waterproof LED in the bottom of a PVC pipe. Preliminary tests with a submersible LED display during the spring of 2011 were very promising.

students 3 FT

skills some fabrication and experimentation

1 Introduction

Additional experiments can be done using the same test apparatus as was used during the spring of 2011 (Figure 1).

- Determine the effect of particle aggregation on turbidity measurements. Reduce particle aggregation by adding 2 mg of humic acid per 100 mg of clay. Prepare a stock solution that contains both humic acid and clay and add it incrementally to the suspension in the test apparatus to obtain turbidity as a function of optical resolution depth (Figure 1). Compare with the results for clay (Figure 2). Determine if the addition of humic acid causes a significant change in response of the AguaClara turbidimeter. If the AguaClara turbidimeter is very sensitive to
- Test fine rectangular grid patterns rather than words on the LED display
- Determine the influence of line thickness and line spacing on the LED display

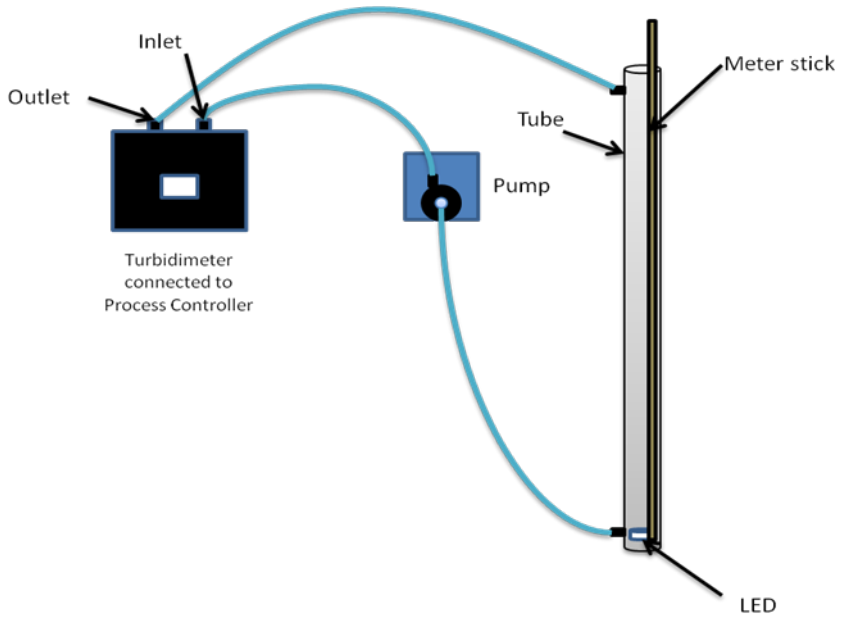

Figure 1: Test apparatus used to simultaneously measure the turbidity using an online meter and using the AguaClara turbidimeter.

- Determine which pattern (line thickness and line spacing) would be best for measuring low turbidities.

2 Resolution Depth Analysis

The equations describing the resolution depth as a function of turbidity are given below.

$$Turbidity\left(Depth\left(m\right)\right) = \frac{b \cdot NTU}{\left(\frac{Depth}{m}\right)^{\frac{7}{4}}} \tag{1}$$

where b is a coefficient from the curve fit equal to 2.14.

Equation 1 can be solved for the depth as a function of turbidity to create a turbidity scale.

$$Depth(Turbidity) = \left(\frac{b * NTU}{Turbidity}\right)^{\frac{4}{7}} m \tag{2}$$

The simplest model for loss of resolution is that the photons originating from the display are blocked by clay. It is possible to estimate the blocking effect of the clay particles. The density of clay is

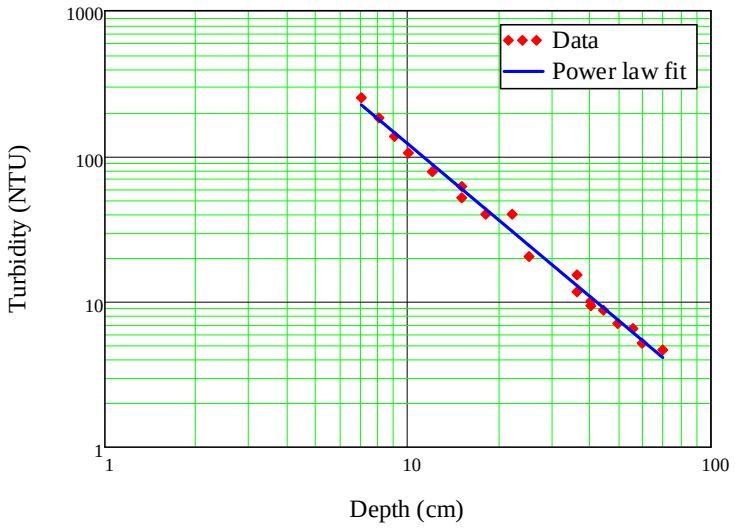

Figure 2: Turbidity as a function of the depth at which fine text can be resolved.

$$\rho_{Clay} = 2650 \frac{kg}{m^3} \tag{3}$$

The number of clay particles in an optical path is

$$N_{Clay} = \frac{C_{Clay}}{\rho_{Clay}} \frac{A_{Clay}}{V_{Clay}} L_{Path} \tag{4}$$

For a sphere the ratio of area to volume is

$$\frac{A_{Clay}}{V_{Clay}} = \frac{2}{3} d \tag{5}$$

Substituting into equation 4 we obtain

$$N_{Clay} = \frac{2}{3} d \frac{C_{Clay}}{\rho_{Clay}} L_{Path} \tag{6}$$

The number of clay particles in the optical path between the observer and the display pattern is calculated based on the turbidity model (equation 2). The number of clay particles is a function of the diameter of the particles. For an assumed diameter of 2 μm the number of clay particles in the optical path approaches 1 for low turbidity samples. It seems logical that the display pattern would be obscured when there is on average one clay particle in the optical path. It is less clear why it is necessary to have multiple particles in the optical path when the turbidity is higher. One possibility is that the clay particles aggregate at higher turbidities and thus the number of aggregates in

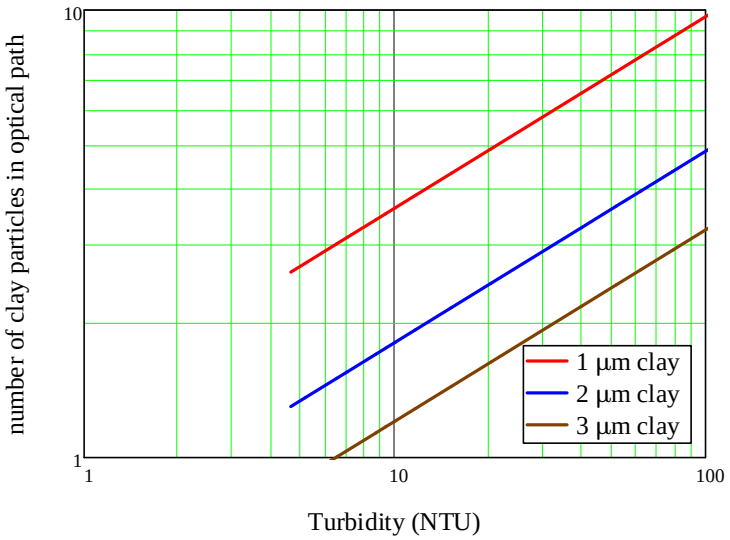

Figure 3: Number of clay particles in the optical path given a path length equal to the resolution depth.

the optical path may be approaching 1 at the measured optical resolution depth. If particle aggregation is influencing the results, then further study is warranted to assess the influence of particle size and particle aggregation on the turbidity measurements made with the AguaClara turbidimeter.

3 Fabrication

We would like to send 10 turbidimeter prototypes to Honduras for field testing on July 28. Development of these prototypes should be done simultaneously with other laboratory testing of the turbidimeter to ensure that the 10 turbidimeters are ready for deliver on July 28. Prior to use in Honduras, a waterproof scale will be need to be calibrated and labeled at regular intervals with turbidity measurements rather than depth measurements. This eliminates the need for the operator to perform a conversion from depth to turbidity each measurement, reducing this potential source of error.

The PVC pipe columns can be assembled in Honduras. The specifications for those tubes should be provided by the Turbidimeter team.