

# Agua Clara Turbidimeter Team

Julia Morris, Andrew Gorodetsky, Heidi Rausch

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## **Abstract**

This report will cover all the work that has been done at Cornell's AguaClara Lab on Turbidimeters. Research first started on creating a new low cost turbidimeter Cornell in the Spring of 2011. Since then several different prototypes have been created and 10 turbidimeters have been sent to Honduras for use by communities who are considering getting an AguaClara plant built. The first part of this report will cover why research needs to be done on turbidimeter design and how turbidimeters work. Then past research on turbidimeter designs will be summarized, including details on the latest prototype which was sent to the field in Honduras this past summer. The current research being done will then be described, including new ideas such as the use of mirrors to lengthen the light path of the LED light and the use of colored cellophane to change the color of the light that reaches the user's eye. Finally, all conclusions that have been made this semester will be discussed and possible ideas on future research will be noted.

## Introduction

The turbidimeter is a vital part of the AguaClara design. The turbidimeter helps AguaClara decide if communities need a plant to be built or not. The final goal of the Turbidimeter team is to build a device that can accurately measure turbidities down to  $<5\text{NTU}$ . The device would then be distributed to any community that is looking into having an AguaClara plant built for them. Next, the community would use the device for approximately a month until it can be accurately determined whether or not a plant should be built for them. Some communities may have water that is already clean enough to drink and some may unfortunately have water that is too dirty for AguaClara plants to be able to handle. The turbidimeter should also be user friendly.

There are many different turbidimeters on the market for use by labs and scientific experimentation, however there is no such device available at a low cost for “home” use. It would be impossible to give all the communities in Honduras that are considering building an AguaClara plant a turbidimeter that costs hundreds of dollars. The community would not be willing or able to pay for it. One of the most important design parameters of the turbidimeter we are trying to create is that it can not cost more than \$20. The latest prototype that was built and is currently be used in Honduras is under \$5, it is the hope of the AguaClara that all future designs will remain this affordable. It is possible that in the future one of the turbidimeters we design here at Cornell will make it on to the market so that others can take advantage of this technology as well.

## Background

### How Traditional Turbidimeters Work

Turbidity is defined as an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a sample. If light were to travel through “pure” water, the light beam should travel relatively undisturbed, but if there are other particles, such as suspended solids, present then the light will be scattered and absorbed as it interacts with these molecules. Traditional turbidimeters contain a light source, sample container or cell, and photodetectors to sense the scattered light. The most basic turbidimeter design, seen in Figure 1, consists of a light source that is projected through a sample. The detector is located at a ninety degree angle to the light source. Therefore, the light that is scattered at a ninety degree angle is detected. The amount of light detected is then related to the turbidity of the water.

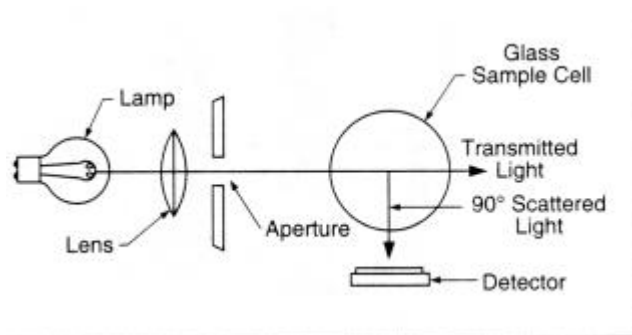


Figure 1: Single Beam Design Turbidimeter

### Past Research

Research on the turbidimeter began in the Spring semester of 2011 and was continued during the summer. During the Spring 2011 semester a relationship between depth and turbidity was confirmed and a first prototype with a turbidity scale was designed. During Summer 2011 the turbidimeter design was improved and a more accurate relationship between depth and turbidity was found. A number of different LED designs was tested (See Figure 2 and 3 )

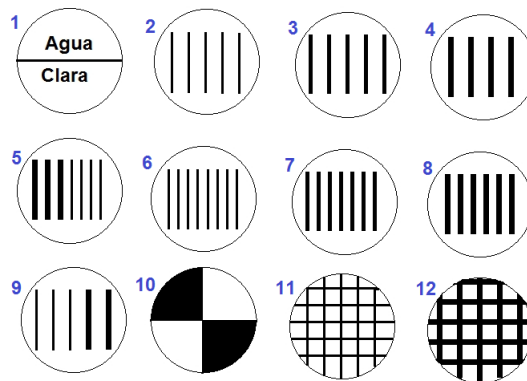


Figure 2: First 12 Designs

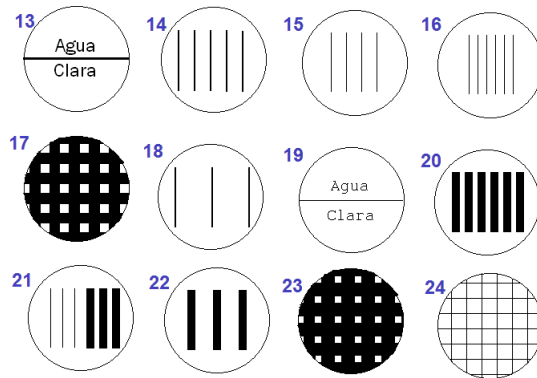


Figure 3: Last 12 Designs

Design #14 did not have the best total percent error but it did have the best fit to a power function, therefore, it was chosen to be the final design. Figure 4 is a Log Log plot of Depth vs Turbidity for the final design. As can be seen a very good fit for the data was achieved. The power law function for this set of data was as follows:

$$1463.7 * Turbidity^{-1.29}$$

Using this formula the scale for the final turbidimeter stick was developed by inputting desired Turbidities such as 15, 16, 50, 100, 400 NTU etc. and marking the given depth that many cm above the light on the stick.

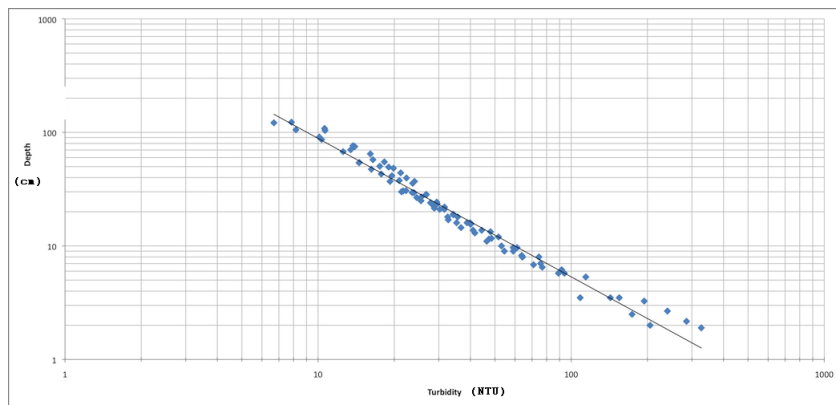


Figure 4: Log-log plot for Design 14

The latest design for the turbidimeter can be seen below in Figure 5. Ten of these turbidimeters were sent to Honduras to be used as seen in Figure 6.



Figure 5: Latest Turbidimeter Design



Figure 6: Turbidimeter being used in Honduras

## Methods

### Mirror Component Design

The team wants the turbidimeter to be able to measure turbidity as low as 5 NTU. One idea to achieve this was to extend the range of the turbidimeter by placing the light source at the top of the water column (facing down) and then attaching a mirror to the end of the lowering rod. The team's first design task was to figure out how to attach the LED (light source) at the top of the PVC pipe (water column)

facing down. The team screwed the LED light (including light diffuser and pattern) to the inside of a PVC coupling, as seen in Figure 7. There is a slit in the coupling so that the operator can attach and remove it as needed. The mirror is glued to a L-shaped piece of metal (see Figure 7). The L-shaped piece of metal is then attached to the end of a lowering rod.



Figure 7: Mirror Component Design

### Colored LED Design

The team does not currently have any colored LED lights but wanted to start testing to see if color will help to measure lower turbidities. Therefore the team bought colored cellophane at a local craft store (blue, green, red). A small piece of cellophane was cut and placed between the LED light and the light diffuser as seen in Figure 8. To get the cellophane to the right size we simply placed a large piece of cellophane inbetween the light and the HDPE block and then cut around the edges of the block.



Figure 8: LED light with colored cellophane

## Experimental Design

Just like in previous semesters a pump (with a flow rate of 1.4 L/min) was used to continuously stir the water sample. A PVC pipe with holes drilled at the top and bottom was used to hold the water. Using tubing the bottom hole connects to an electronic turbidimeter, from there to a pump and finally to the top of the PVC (See Figure 9). The electronic turbidimeter is connected to a computer in the lab room and using a Process Controller program the NTU at every second was recorded into an excel file. This program proved extremely useful in that it was possible to write notes directly into the excel file at any given point in time.

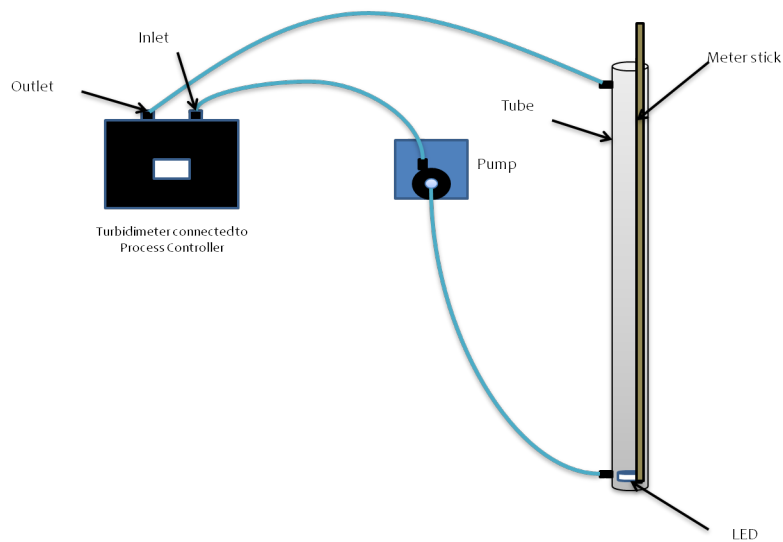


Figure 9: Continuous-mix experimental schematic

1. Turn on data log i.e. the process controller on the computer
2. Add initial amount of clay
3. Run pump system for four minutes
4. Unplug pump, make a mark in data log as to show when pump was first unplugged
5. First team member takes depth reading
6. Plug pump in
7. Wait 60 seconds
8. Unplug pump
9. Second team member takes depth reading
10. Repeat steps 6-8
11. Third team member takes depth reading
12. Wait 60 seconds
13. Add the next amount of clay, make mark in data log as to show what the new total amount of clay in the system is
14. Repeat steps 3-13 until you reach the final amount of clay/NTU desired



# Analysis, Results and Conclusions

## Results and Conclusions

### Mirror Component Design

After first testing out the mirror design the team found that aligning the mirror so the operator could see the reflection of the LED light pattern was very difficult. Even after brainstorming a few ideas to improve the design, the team decided that it would be best to reject the mirror concept and focus solely on improving the LED design. The team then decided to try using different colored LED lights.

### Colored LED Tests

The team ran its first colored LED light test, using the color blue. As can be seen in Figure 10 the relationship found resulted in a R-squared value of .6419. This value is too low. The team hopes to achieve an R-squared value in the .9 range. This low R-squared value could be due to the fact that the our range of turbidity was not large enough (13-30 NTU) and that only a few measurements have been taken (see Table 1). As the team continues to test the colored lights, more samples over a large range of turbidities will be taken. Therefore, the R-squared value should increase and the relationship found between turbidity and depth should be more accurate. Once an accurate relationship is determined, the team will be able to analyze if there is a difference between using colored light and white light and if it will be able to measure lower turbidities.

Mass of Clay (mg)	Average Height (cm)	Average Turbidity (NTU)
0	55.7	13.6
5	46	18.1
10	40	22.1
15	37.3	22.6
20	35	21.7
30	29.7	23.2
50	26.3	25.6
100	19	29.9

Table 1: Blue LED light test data

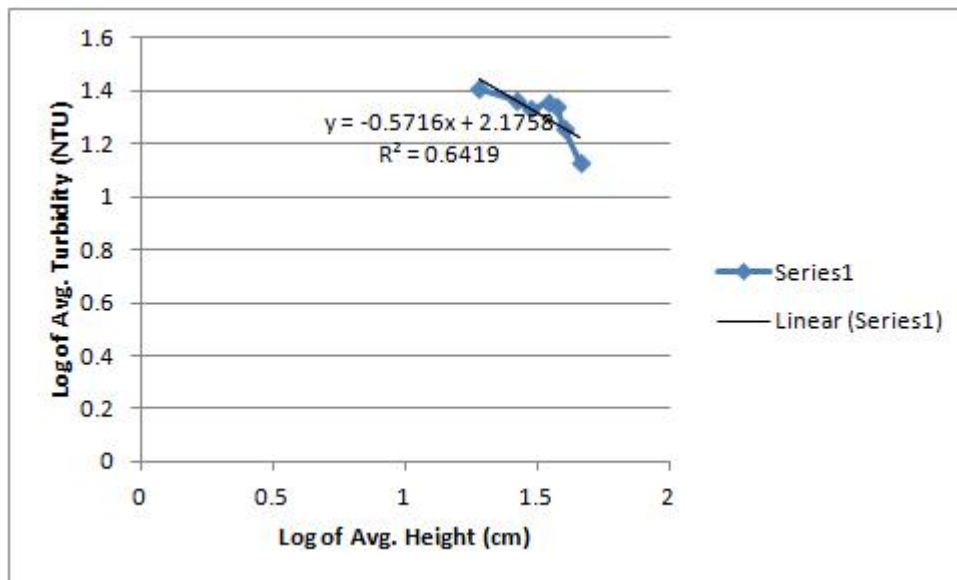


Figure 10: Log-log plot of turbidity as a function of depth for the Blue LED light

## Future work

There is still many different options that can be tried to improve the accuracy of the turbidimeter. Though we have already dismissed the idea of using mirrors for the design this semester the use of mirrors could be revisited in the future. The problem with the mirrors idea is that it does not work well with the low cost parameter. To get the mirrors to work well the design work need more components that would be more specialized and most likely more expensive than the parts we are currently using.

This semester experiments in which the color of the light has been changed have been performed. For the rest of this research period the team will continue to try more colors and more or less saturation of color. This will be done by either continuing with the colored cellophane over the light, both trying more colors and layering more of the cellophane sheets, or by acquiring LED lights that are colored themselves.

An idea that has recently come up is the idea of using lights other than LEDs. This could possibly help to solve the problem of great disparities between different users readings. The LEDs have proved to be a problem as they often turn off with the slightest movement. Sometimes a light could be on and then after setting down the light on the counter it will suddenly turn off. Another situation that has happened many times is that a user will be attempting to take a reading but the light will go dim; this could clearly influence the accuracy of readings if the user did not realize the change in the light brightness. More research needs to be done into what could

possibly be reasonable substitutes for LED tea-candle type lights.

Another suggestion that had been made by previous teams would be to try a different size of the HDPE block. This could potentially effect the amount of light which reaches the users eye and therefore the reading that the user would make. This could mean that the device could possibly read down to 5 NTU or less. Changing the size of the block could also lead to less disparity between different users readings, therefore making the turbidimeter more accurate.

In past semesters the idea of using humic acid had been brought up to the team. This would be a good idea to experiment with because it may make the water more like how it would actually appear in nature. Humic acid would change the color of the water without changing the turbidity of the water. This is something that people are often confused about, the idea of turbidity vs color. Running experiments where we could change both would help to clear up this confusion.

## References

"Basic Turbidimeter Design and Concepts." U.S. EPA. EPA Guidance Manual Turbidity Provisions, April 1999. Web. 29 Sep 2011. <<http://water.epa.gov/lawsregs/rulesregs/sdwa/mdbp/upload/20>