Creating a Phone Based Turbidimeter

Saleena Dawadi, Dr. Amanda Northcross, Dr. Mike Fisher, Ekin Aygen, Tia Goswami, Aidan Cushman
UNC Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC

GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH

Background

Turbidity is the cloudiness or haziness of a liquid caused by countless microscopic particles that are normally invisible to the human eye, similar to smoke in the air. About 45 million Americans utilize private wells, and 2.4 of these Americans are from North Carolina. Despite the state's large number of private well water systems, less than 200,000 private wells in North Carolina had their water tested for contaminants from 2000-2010. While it is important to regularly test water for potential water borne diseases, an average Turbidimeter costs around $1500, which is not affordable for individuals in low-income communities utilizing private wells. An accessible measuring device that calculates the concentration of turbidity is crucial to the goals of the ECUIPP lab and community. The potential for the app to support educational processes and raise awareness of water quality makes it another key component of the ECUIPP lab's goals.

Research Question

How do we develop an accurate calibration for turbidity concentration using the ImageJ analysis software: would the calibration curve be impacted due to cell phone camera quality?

Material and Methods

Creating Serial Dilutions
- In order to create serial dilution solution, a 4000 NTU of 100 mL calibration standard of Formazin was utilized.
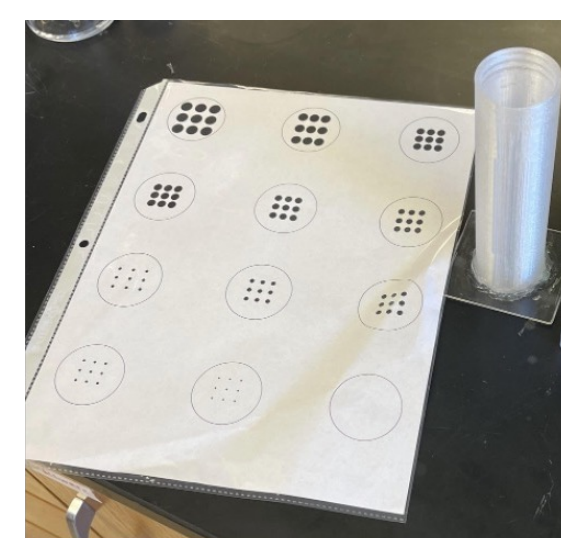
Utilizing the Turbidimeter
- The Hanna Instruments Turbidity Calibration Standard Cuvette was used to measure the NTU concentration of the serial dilutions. The instrument was calibrated at three points of <1 NTU, 15 NTU, and 100 NTU.
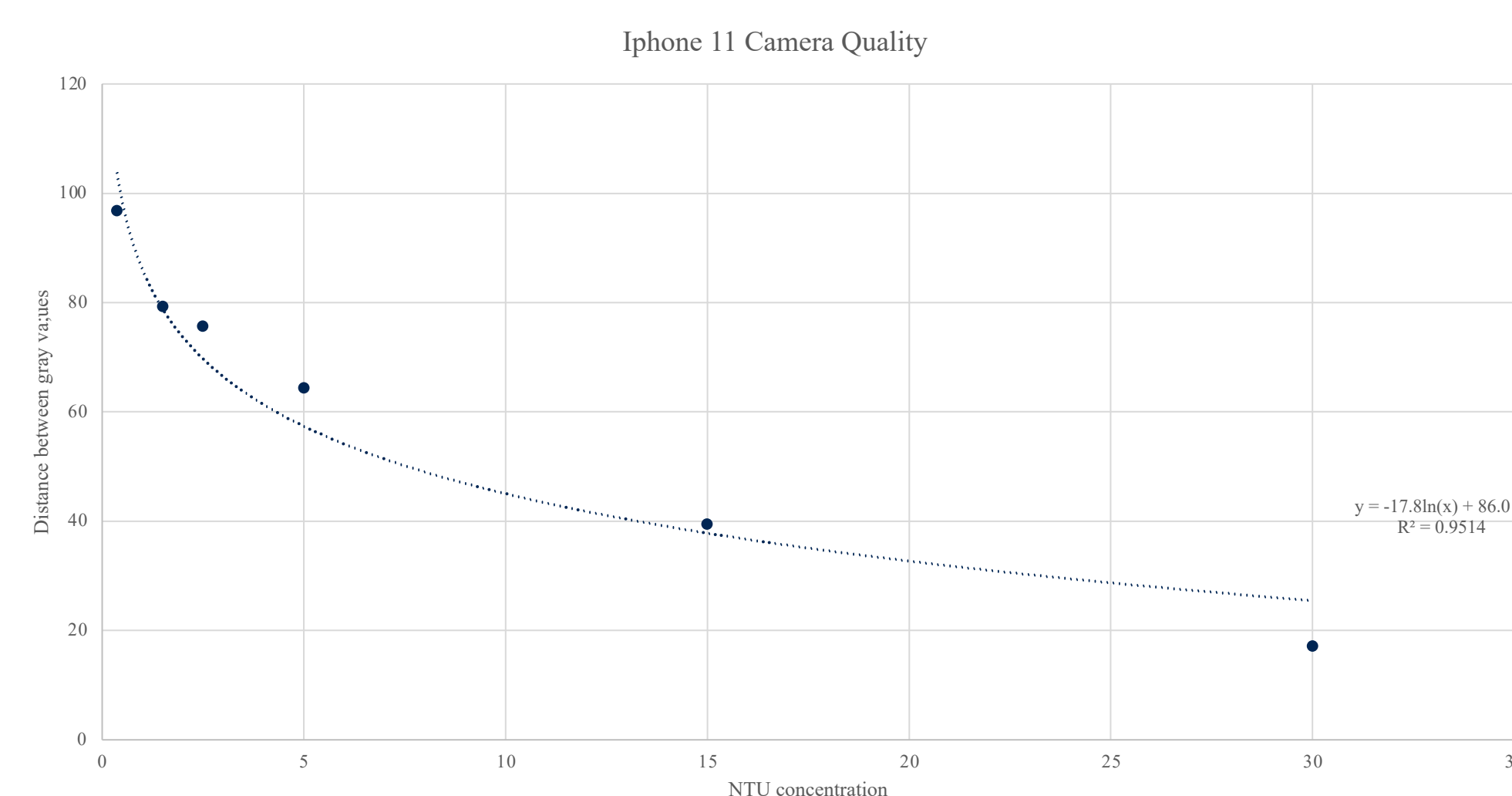
Taking lab photos
- 100 mL of the NTU solution was placed into the 150 mL 3-D printed cylinder.
- The acrylic base of the 3D printed cylinder was placed on top of the circular images and photos were taken from 7 inches above the base of the table. Pictures were taken without flash.
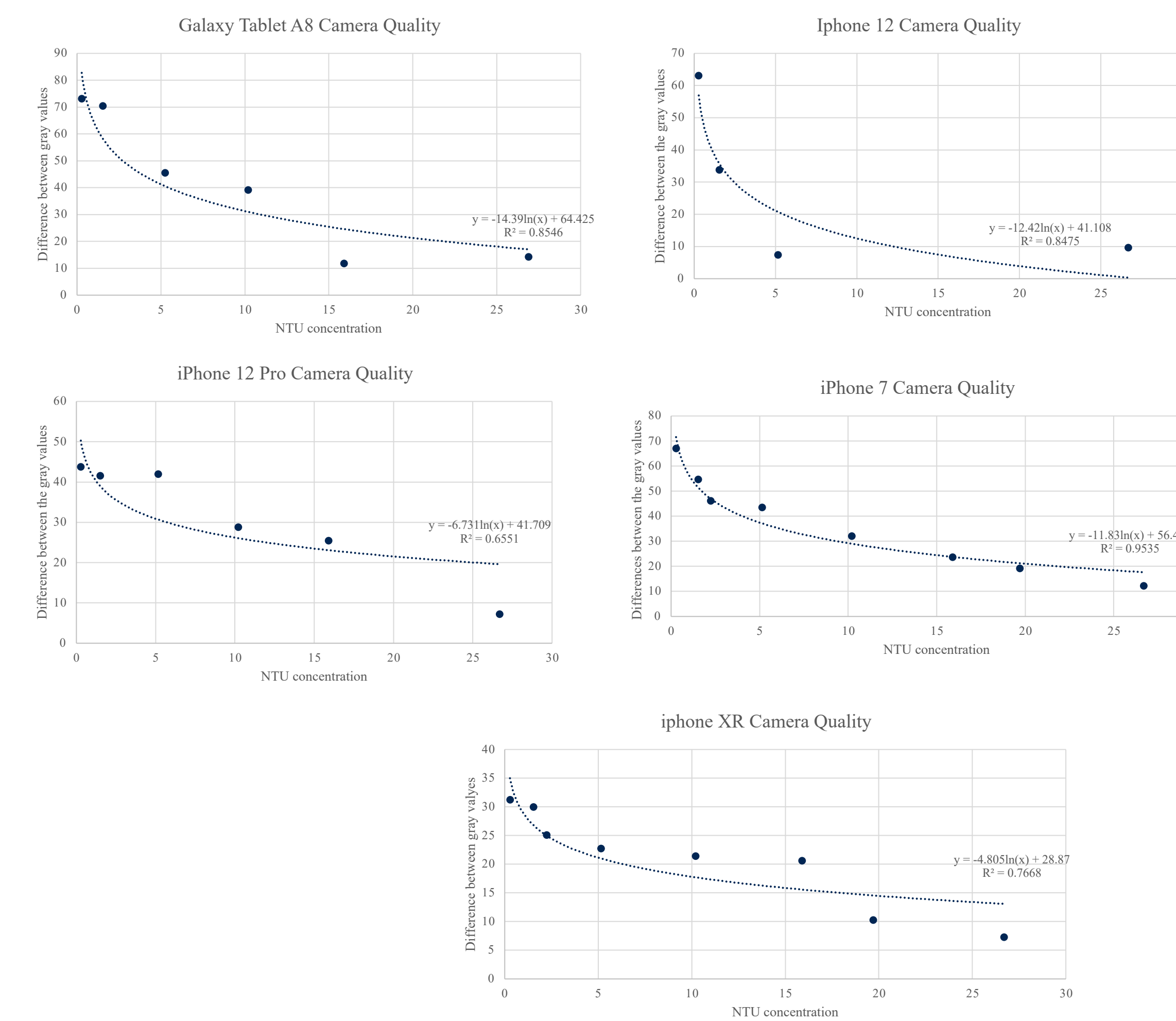
Image J analysis
- 1) In Image J, a rectangle was drawn across the circles/rectangles of the images.
- 2) The Analyze> Plot Profile tool was used to obtain a graph of the grey values for each column of pixels across the image. The plot profile and list function was used.
- 3) The average maximum and minimum gray values were calculated through excel with the data driven from Image J.
- 4) A scatter plot was created in Excel to create natural log graphs and equations for each NTU solution and phones.
- 0= completely black; 256=completely white

Results

Galaxy Tablet A8 Camera Quality

Iphone 12 Camera Quality

iPhone 12 Pro Camera Quality

iPhone 7 Camera Quality

iphone XR Camera Quality

Results

Iphone 11 Camera Quality

$y = -17.86x + 86.018$
$R^2 = 0.9514$

Images were bar like images and average values between max and min bar points were taken.
NTU concentrations for the iPhone 11- 0 NTU, 1.4 NTU, 2.43 NTU, 4.50 NTU, 9.45 NTU, 15.2 NTU, 29.5 NTU

Discussion

- The overall general trend of the data suggests that as turbidity increases, the differences between the maximum and minimum gray values decreases. This is because as water gets more turbid, it is harder to see the difference between white and black options.
- Eventually, the turbidity becomes extremely concentrated, and it is difficult to differentiate between the black foreground and the white background.
- The iPhone 11 data depicts an accurate R^2 value compared to the graphs with other concentrations. This may be due to the bar-like lines used to take the images. Additionally, iPhone 7 also shows a R^2 value of .9535.
- For the other mobile devices, the R^2 values are fairly accurate for the iPhone 12 and Galaxy Table a8. However, for iPhone 12 Pro, the R^2 value of 0.6551 is inaccurate. This may be because the distance between the circles are too far apart to differentiate between the values.
- There are some outlier values within the graphs, such as for 5 NTU on the iPhone 12 graph, which could be due to the scattering of light and imaging taking procedure.
- Additionally, Image J differentiates data between extremely low NTU values. This is important for detecting accurate NTU concentration of water. The NTU concentration of turbidity should be based on its actual concentration, not dependent on the camera quality.

Acknowledgements

- Banks Grubbs- Grad Student
- Former ECUIPP lab students

Table 1. NTU concentration values

NTU Level of Interest	Actual NTU concentration		Mobile Devices Used
0 NTU	0 NTU		
0.25 NTU	0.28 NTU		iPhone 7
1 NTU	1.54 NTU		iPhone 11
2 NTU	2.25 NTU		iPhone XR
5 NTU	5.15 NTU		iPhone 12
10 NTU	10.2 NTU		iPhone 12 Pro Max
15 NTU	15.9 NTU		
20 NTU	20. 7 NTU		Galaxy Tablet a8
25 NTU	26.7 NTU		

Lab Images

Iphone 11 0 NTU
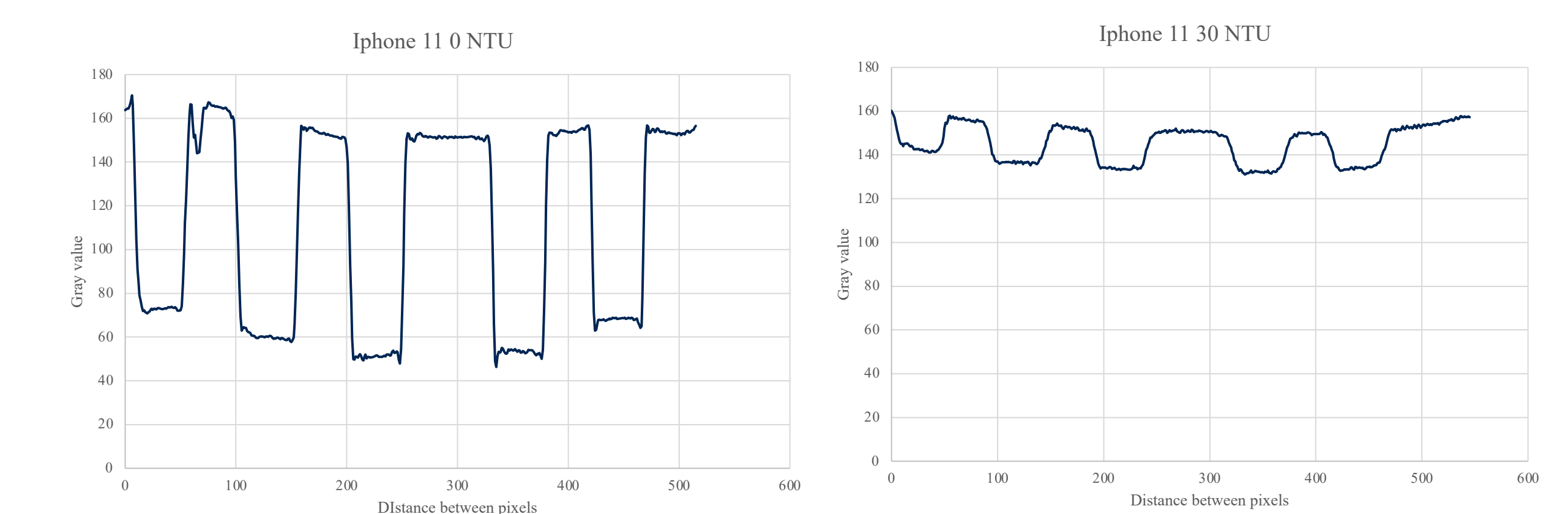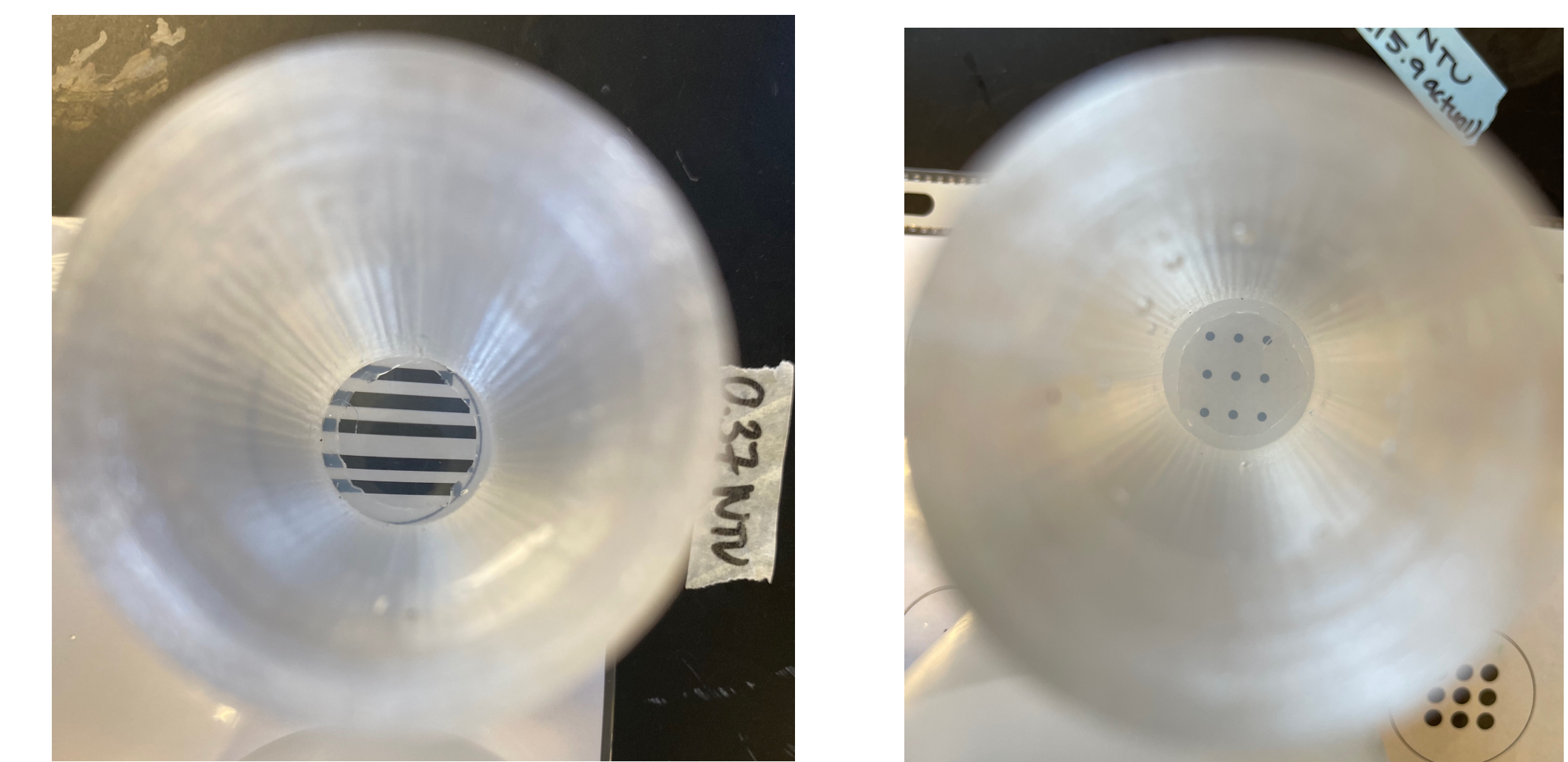
Iphone 11 30 NTU

Graph of iPhone 11 0 NTU and 30 NTU concentrations. The graphs are depicted to differentiate the maximum and minimum gray values of low and high NTU values. The graphs demonstrate that there is greater distance between the maximum and minimum gray value for low NTU values, such as 0 NTU, than high NTU values, such as 30 NTU.