INTRODUCTION

We designed a device to establish a more cost efficient way of testing the turbidity(cloudiness) of a water sample. Using an Adafruit Metro Mini board, a color sensor, an LCD screen, and a red LED, we built a device which measured the cloudiness of a sample by measuring the amount of light emitted perpendicular to a monochromatic light source by the process of Mie Scattering. Once the device was properly built, we used milk as a test sample, as the turbidity of milk has been well studied and is less toxic than the standard, formalin. The amount of light scattered by the sample was measured by the color sensor, allowing for turbidity to be measured. Cloudier samples, with higher concentrations of milk, have a higher turbidity, measured in NTU (Nephelometric Turbidity Units). Our device has a much lower cost (about $50) than comparable commercial units (about $1000).

BACKGROUND

Turbidity is the measure of a liquid's cloudiness. Turbidity is an important test of water purity because it describes the amount of insoluble matter, such as silt, algae or insoluble minerals such as iron rust suspended in the water. Our goal in measuring turbidity is to test drinking water and well water for contaminants (Ref. 3). Turbidity is typically quantified in terms of Nephelometric Turbidity Units (NTU), an empirical comparison standard based on the amount of scattered light from various concentrations of a particular polymer (formalin) suspended in water (Ref. 2). Because formalin is toxic, for safety we instead use another well-characterized system as our comparison standard: pasteurized homogenized whole cow’s milk (Figure 3, Ref. 4).

METHODS

We used an Adafruit Metro Mini board, an Adafruit AS7262 6-Channel Visible Light / Color Sensor, an LCD screen, a red LED (650 nm output), and a 3-D printed base to construct the device. We expanded the capability of the sensor to turbidity in addition to its previous use as a 6-color colorimeter. A cuvette filled with a fluid sample is inserted in the middle of the device, where the LED then flashes, allowing for the color sensor to measure the amount of light that was emitted through the sample. We started with whole milk purchased from a convenience store and bottled drinking water. From there, we diluted the sample down for ranges from 100% milk to 0.01% milk (see figure 8).

THEORY

Optically, milk can be described as spheres of fat suspended in water. The size of the fat globules in homogenized milk have a median diameter of 0.46 µm and have a log-normal size distribution (Fig. 4, Ref. 6). Turbidity is caused by the optical process of Mie scattering (Ref. 1), which predicts the direction and intensity of light as it is scattered off of particles of similar size to the wavelength of the light. Using the known distribution of globules sizes we did a Monte Carlo simulation to predict the light intensity scattered in each direction (Fig. 5). Our device measures the output at an angle of 90°.

DATA AND ANALYSIS

As the concentration of milk increases, we can see that more light is scattered up to some maximal point. Beyond this the majority of light is absorbed. The fitting equation used is an adaption of the Beer-Lambert law to include both scattering and absorption effects. At low concentrations (NTU<650), a linear Taylor series approximation using the same fitting constants works well.

FUTURE WORK

The first of our future goals are to update the sensor and LED used to infrared light, in order to reduce the absorption percentage. Additionally, we aim to change to using a circular sample cell for user convenience, and finally we aim to build a flow-through submersible version of the device which can be used in rivers and lakes for real time sensing.

REFERENCES

4. S. Prabl "miepython library" https://github.com/scottprahl/miepython

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