University of Illinois at Urbana Champaign
Department of Physics
PHYS 398 DLP

Surface and Drinking Water Quality at UIUC

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Abstract

The water quality of drinking water was observed and analyzed for locations on the University of Illinois at Urbana-Champaign.The properties measured were: temperature, electrical conductivity, pH, turbidity, and total dissolved solids. The measurements were conducted with a data acquisition system (DAQ) that was built using a microcontroller and sensors. In general, it was determined that the water on campus was on par with the drinking water standards for the properties that were measured. Outdoor runoff water, due to its conditions, was expected to be unsafe for drinking. However, when comparing the data to the standards of drinkable water, it was found that outdoor runoff water was within the drinkable water standards. This is likely due to the limit of properties that were able to be measured. Measuring more properties such as the amount of lead in water could provide a better indication on the quality of water. The drinking water on campus was expected to be safe for consumption. All properties of drinking water on campus measured were withing the drinking water standards. In general, the properties that were observed were not enough to determine whether a sample is safe for consumption; rather, they can only determine whether it is unsafe.

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1. Background and Introduction

1.1 Introduction

In 2014 it became public that the water supply to Flint, Michigan had been contaminated by lead due to the use of old, corrosive pipes. In general, we take the quality of our tap water for granted, but the Flint Water Crisis shows us that we should always be aware of possible dangers. This project is meant to discover whether the water on campus of the University of Illinois at Urbana-Champaign is safe to drink.

Water samples are taken from various buildings to cover as much of the campus as possible; faucets, regular drinking fountains, and drinking fountains with electric filters are present all over campus. Furthermore, the surface water from Bone Creek is tested along its course. This creek flows from east to west on the northern side of the campus. Many sewage and drain pipes spill water into this creek, creating the possibility of dangerous contamination. Bone Creek water is not drinking water, but it is soaked up by the soil, creating a possibly dangerous environment for the plant life on campus.

The water quality is analyzed by measuring: pH, Conductivity, TDS (Total Dissolved Solids), and Turbidity (amount of suspended particles). The temperature of each sample is also measured in order to correctly calibrate the four main sensors.

Water quality requirements from different sources are compared in order to find the most reliable standards and judge whether the water samples are safe.

1.2 Water Requirements

pH

pH variations in tap water are most often due to corrosion of metal pipes. In general pH should be between the values $6.5 - 9.5$ for drinking water. If tap water exceeds these bounds it is very likely that there is something wrong with the distribution system. This information is from the World Health Organization.

Healthy surface water systems generally have a pH of $6.5 - 8.5$ while ground water generally has a pH of $6.0 - 8.5$. Exceeding this range can be dangerous for aquatic life and surrounding plants. [1]

Conductivity

Conductivity is measured in Conductance (Siemens) over distance (m). World Health Organization does not have requirements for conductivity as it is a very general measure; it does have requirements for distinct ions, like lead and copper. However, conductivity outside of the $0.05 - 0.50$ mS/cm range is seen as unhealthy so in this paper it will be used as the standard for drinking water.

If surface water approaches sea water levels of conductivity (50 mS/cm) there is a risk of salinization, which is the phenomenon where the ground becomes too salty for regular inland plants to survive. [2]

TDS

TDS is very closely related to conductivity as it indicates the total dissolved [ionic] solids in the water. Those ions are the charge carriers that determine the conductivity. TDS is measured in ppm by mass, or in other words in mg/L. Similar to conductivity, there are no specific WHO standards for TDS values. The EPA does have a recommended maximum level TDS of 500 ppm, so this will be the acceptability measure we will use. [Official EPA Report]

Turbidity

High levels of turbidity can protect microorganisms from disinfection, which raises the chance of getting sick from contact with the water. For water that is disinfected the maximum turbidity should be 5000 ntu and the median should not exceed 1000 ntu, otherwise disinfection can not be guaranteed. Note that when turbidity is over 5000 ntu the amount of particles is generally large enough to be visible with the naked eye.

There are no requirements for turbidity of surface water, as is expected. All large particles should be sieved out before disinfection for drinking. [Official EPA Report]

1.3 Locations

Five samples were taken from locations along Boneyard Creek, which runs along the north side of campus from west to east. Another three were taken from different water fountains in Loomis Laboratory of Physics. More details on these locations can be found in Appendices A.1 and A.2 respectively.

2. Methods and Procedure

2.1 Equipment

Our data acquisition was done through peripheral sensors feeding data into an Arduino microcontroller. For our project, we used the Arduino Mega 2560 board. The peripheral sensors we used were: Digital Thermometer, Analog EC Meter, Analog pH Meter, Analog Turbidity Sensor, TDS Sensor. The Arduino was also set up with an LCD and a 4x3 keypad to allow user interaction with the data acquisition system (DAQ). Each sensor feeds data into the Arduino which writes it onto a microSD card. The microSD was mounted on an Adafruit MicroSD Card Breakout Board+. All the hardware was installed on a printed circuit board (PCB).

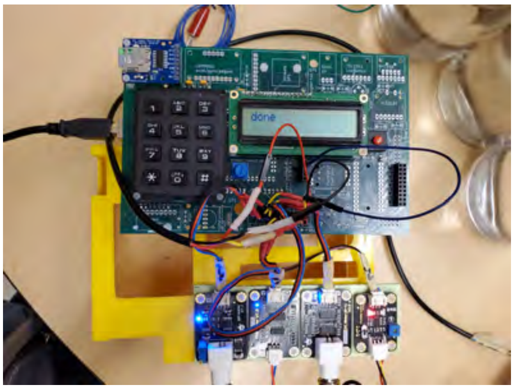

Figure 2.1: Group 3 device

Figure 2.2: Sample testing in progress

2.2 Data Acquisition System

The Arduino Mega 2560 board is ideal for our project because it provides plenty of digital and analog pins for the our sensors and enough memory to run all the code. The specifications for the board are in Table 2.1. The Arduino is programmed to read from all our sensors simultaneously and write to a microSD card. The LCD indicates this process and updates to reflect what the program is doing. The keypad allows for interactions with the Arduino. The DAQ is able to reset and overwrite the microSD card if prompted by the keypad. It can take all measurements simultaneously or individually. It is also able to set the frequency and the number of measurements. The data is stored into text files which are labeled by the measured property. The text files are then stored by the sample it was taken from for analysis.

All water samples were measured 250 times for each parameter, with a frequency of 10 measurements per second (for each parameter). Some extra time is needed between measurements for writing to the SD card. This means the samples were taken over around one minute. The length of taking samples should not influence the results, as the samples are allowed to rest for multiple hours; a minute difference between measurements does not make a difference.

Table 2.1: Arduino Mega 2560 specifications.

Operating Voltage	5.00 V
Digital I/O Pins	54
Analog Input Pins	16
Flash Memory	256 KB
Clock Speed	16 MHz

2.3 Measurement Locations

A total of 12 measurements were taken across the campus:

- 3 samples were taken inside Loomis Laboratory. Two of these were from an electronic-filter water dispenser. One of these dispensers had a green indicator light, the other had an orange indicator light. According to the manufacturer, the lights indicate the lifespan of the filter. The filter should be replaced once its lifespan is fulfilled, which is indicated by a red light. The orange indicator means that the filter has reached ¿66% of its lifespan, the green indicator means less than 66% has been reached [3]. The third Loomis sample was from a standard type water fountain, in this case produced by the company Elkay.
- 1 sample was taken from a regular, old-fashioned water fountain in the Activities and Recreation Center (ARC).
- 1 sample was taken from an electronic-filter water dispenser in the Student Dining and Residential Programs Building (SDRP) with a green indicator light.
- 1 sample was taken from an electronic-filter water dispenser in the Illini Union with a green indicator light.
- 1 sample was taken from the indoor pool at the Activities and Recreation Center (ARC).
- 4 samples were taken from along the course of Bone Creek (B.C.). These were taken, going from up to downstream, at Scott Park, the Bardeen Pavilion, in front of the Mechanical Engineering Lab (M.E.), and finally in front of Daniels Hall. Scott Park is on the edge of campus in the West; Daniels Hall is the first place where Bone Creek is accessible coming from the east. The water in front of the Bardeen Pavilion is relatively still-standing while the rest of Bone Creek is in constant visible motion.
- 1 sample was taken from one of the accessible drain pipes that flow into Bone Creek.

2.4 Cross-Calibration

To make sure that the sensors yield reasonable measurements, two sets of all sensor types are used, called set A and set B. The data for these two sets can be compared for each parameter. If the results vary significantly, this probably means the sensors are not very well-calibrated. If they are very similar we can conclude with reasonable certainty that their results are an accurate representation of reality.

2.5 pH Sensor

The pH sensor kit consists of a breakout board and an attachable electrode. The electrode is made of pH glass and a silver silver chloride reference electrode. A glass electrode is a type of ion-selective electrode, made of a doped glass membrane that is only permeable to a certain ion. In the case of the pH glass this ion is hydrogen: H^+. The glass electrode works as follows.

In Figure 2.3 we see a glass membrane (a thin layer of pure glass) separating the test solution on the left from the buffer solution, with a known pH value, on the right. On both sides of the glass a sort of hydrated gel forms, which is simply a layer of glass that has absorbed water similar to a sponge. It is essential to keep this layer intact by keeping the electrode hydrated at all times. Both hydrated gel layers absorb the amount of H^+ ions needed to create a balance with their respective solutions. If the concentration of ions differs between the layers, there will be a charge between the two layers. The reference electrode (in this case the silver silver chloride electrode) is used to measure this potential difference.

Important to note is that the glass absorbs and ejects hydrogen ions, which influences the conductivity of the water. Therefore it is important to not measure the same samples with both the pH sensor and the conductivity sensor.

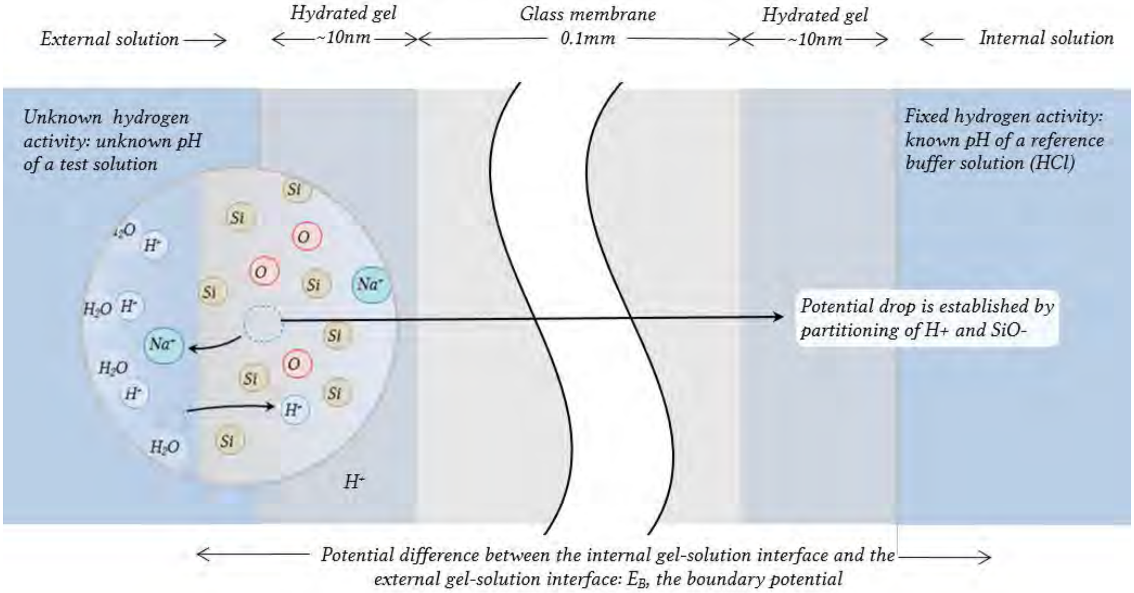

Figure 2.3: Schematic showing the Hydrated Layers of the glass membrane [4]

The electrode will output a certain voltage, which is fed into the breakout board. The analog output of the board can then be fed into an analog pin of the Arduino.

The Table 2.2 shows the specifications as given by the manufacturer. It states that the operating range is from 0 to $14pH$. However, generally this type of sensor only works (approximately) linearly between 0 and $12pH$. Lower and higher pH results in unpredictable behavior, so the voltage cannot easily be converted into pH. Between 0 and 12 pH we can approximate the relationship as linear.

Table 2.2: Table showing the pH sensor specifications.

Power supply	5.00 V
Measurement range	0 – 14 pH
Temperature range	0 – 60 °C
Accuracy	±0.1 pH (25 ° C)
Response time	≤ 1 min

The sensor is calibrated by testing in 4.01, 7.00 and 10.01 pH solutions. Figure 2.4 shows the results. The theoretical linearity is confirmed, at least for these three points. Using this linear relationship, a simple formula could be extracted to determine the pH from the voltage read by the Arduino:

$$pH = 0.0103 \cdot V + 2.8776 \tag{2.1}$$

Where V is read in mV.

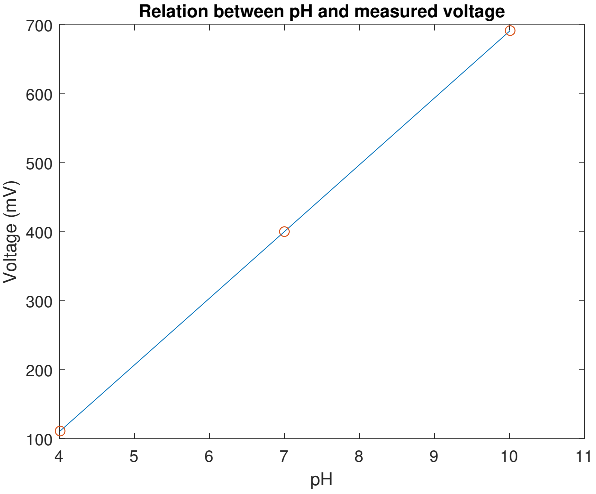

Figure 2.4: Graph showing the approximately linear relationship between pH and output voltage. Red circles show measured data points, blue lines connect the data points.

2.6 Conductivity Sensor

The Electrical Conductivity Meter was used for measuring the electrical conductivity of liquid samples. Electrical conductivity is the ratio of the current density and the electric field. Electrical conductivity is the reciprocal of electrical resistivity. Essentially, the electrical conductivity of a material is its ability to carry current. It is denoted in SI units as Siemens per meter (S/m). Pure H_2O does not carry current well. The conductivity of water is dependent on the number of ions present. In its purest form, water molecules spontaneously split to produce some H^+ and OH^- ions, which give it a conductivity of $5.5 \bullet 10^{-6}$ S/m. The conductivity increases as ionic materials are dissolved. This makes electrical conductivity useful for calculating the salinity. Salinity is the amount of salt that is dissolved in water.

Electrical conductivity is dependent on the temperature of the material, so the sensor works in conjugation with the DS18B20 Digital Thermometer. The sensor was calibrated by testing in solutions with known conductivity. The EC meter outputs a voltage that the Arduino reads and converts. The voltage is converted into EC with a temperature compensation. The conductivity is recorded in mS/cm onto a microSD card. The specifications for the EC meter are in Table 2.3.

Table 2.3: EC meter specifications

Power Supply	3.0 – 5.0 V
Measurement Range	0 – 20 mS/cm
Temperature Range	0 – 40 °C
Accuracy	±5%
Output Voltage	0 – 3.0 V

2.7 TDS Sensor

The TDS sensor measures Total Dissolved Solids, using the conductivity of a solution. It is expressed as microSiemens per cm. The TDS sensor has two contact probes that are inserted into the solution. An AC waveform is sent through one probe, through the solution, and is received by the other probe. An AC waveform is used to prevent polarization and prolong the life of the probe. The relationship between the sent and received waveforms determines the TDS value in ppm (parts per million). The sensor is used in conjunction with the temperature. The acceptable ranges can be found in Figure 2.5. The specifications for the sensor can be found in Table 2.4.

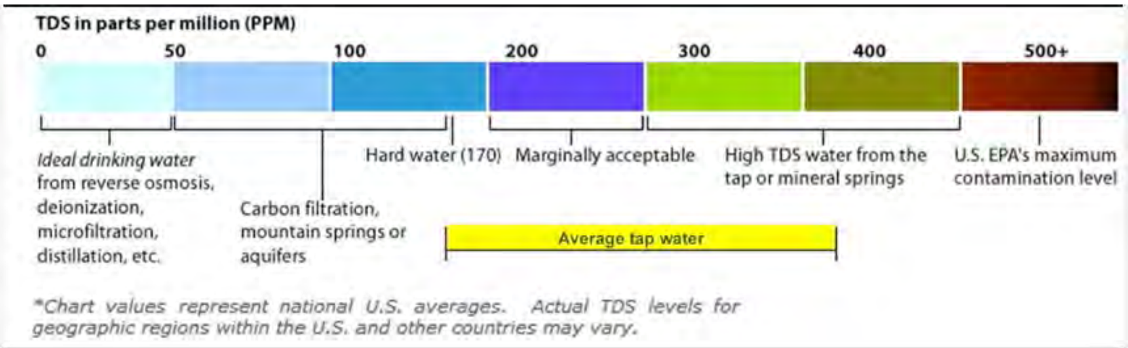

Figure 2.5: Acceptable TDS values as determined by the US EPA [5]

Table 2.4: TDS meter specifications

Power Supply	3.0 – 5.0 V
Measurement Range	0 – 1000 ppm
Working Current	3 – 6 mA
Accuracy	±10%
Output Voltage	0 – 2.3 V

2.8 Turbidity Sensor

The Analog Turbidity Sensor is a DFRobot product which can be used to scan transparency in water. The sensor is supposed to rely on the property of Rayleigh Scattering and light transmittance as mentioned by the manufacturer. Rayleigh Scattering is when light bounces off molecules differently, which allows the sensor to realize when a new medium has been introduced. Light transmittance is the translucence or opaqueness of a material, with the atmosphere having 100% transmittance and many solids, such as metals or concrete, having 0% transmittance. This transmittance and scattering should be read by the device as long as there are granules larger than 2 microns which have remained as a suspended solid. The device sends an output voltage between $0-4.5V$ depending on both factors within the medium. Voltage is then translated to ntu (Nephelometric Turbidity Units). ntu is specifically for measuring incident light which is scattered between the device and the medium, with the device and incident light set at 90°. The equation to change from V to ntu is given by the manufacturer as: $ntu = -1120.4V^2 + 5742.3V - 4352.9$. When output voltage from the sensor comes back as $4.2V$, the ntu should be equal to 0. This is water which is completely clear of suspended solids. At $3000ntu$, the medium has become opaque and there is no light transmittance and thus no light scattering detected by the sensor. Refer to Figure 2.6.

Figure 2.6: Representation of change in NTU and light transmittance

In the end, the device could not give accurate readings out of three separate devices. The manufacturer said that light transmittance and Rayleigh Scattering change the voltage sent via the sensor. Testing out the device in separate samples that ranged from clear to slightly muddied showed no change in readings. This may be an error from the device as no proper explanation on the device is mentioned from the manufacturer. This could be on the end of the experiment team from an error in code structure, unknown problems arising from usage of multiple devices in one sample, or improper adjustments made to device.

Table 2.5: Gravity: Analog Turbidity Sensor for Arduino

Power Supply	5.00 V
Measurement Range	$> 2\mu$m
Operating Temperature	$5 - 90$℃
Analog Output	$0 - 4.5$ V

2.9 Liquid Temperature Sensor

The Digital Thermometer is a simple digital thermometer that operates on a one wire-bus.The thermometer sends nine data bytes which are converted by the Arduino into the temperature in $^{\circ}C$. The thermometer is used in conjunction with the EC meter and TDS meter which both need temperature compensations. The specifications for the sensor are in Table 2.6. The sensor requires a $4.7k\Omega$ resistor between the voltage and the data line input. This powers up the one-wire bus that the thermometer utilizes. The samples were all allowed to settle to the same temperature, so the temperature on its own isn't valuable to analyze.

Table 2.6: DS18B20 Digital Thermometer specifications

Power Supply	$0 - 5.5$ V
Measurement Range	$-55 - 125\ ^{\circ}$ C
Accuracy	$\pm.5$ °C

3. Results

3.1 pH

Table 3.1: pH data for all measurement locations.

	min		**max**		**mean**		**std dev**	
Sensor set	A	B	A	B	A	B	A	B
Loomis Filter Orange	8.54	8.72	8.60	8.73	8.577	8.722	0.0194	0.0040
Loomis Filter Green	8.55	8.71	8.65	8.73	8.611	8.719	0.0263	0.0041
Loomis Elkay Fountain	8.74	8.87	8.83	8.94	8.793	8.924	0.0273	0.0082
ARC Fountain	8.74	8.78	8.80	8.83	8.773	8.814	0.0137	0.0111
Ikenberry Fountain	8.90	8.94	8.98	8.97	8.950	8.952	0.0244	0.0063
Illini Union Fountain	8.65	8.85	8.71	8.87	8.684	8.864	0.0149	0.0049
ARC Pool	7.68	7.89	7.76	7.93	7.720	7.909	0.0199	0.0070
B.C. Scott Park	7.54	7.66	7.67	7.67	7.617	7.666	0.0393	0.0049
B.C. Bardeen Pavilion	7.48	7.83	7.60	7.84	7.551	7.834	0.0344	0.0048
B.C. M.E.	7.48	7.78	7.60	7.84	7.542	7.814	0.0329	0.0081
B.C. Daniels Hall	7.38	7.77	7.53	7.78	7.744	7.772	0.0414	0.0037
B.C. Drain Pipe	7.66	8.03	7.71	8.05	7.694	8.040	0.0173	0.0058

Table 3.1 shows the minimum, maximum, mean and standard deviation for all of the measurement locations.

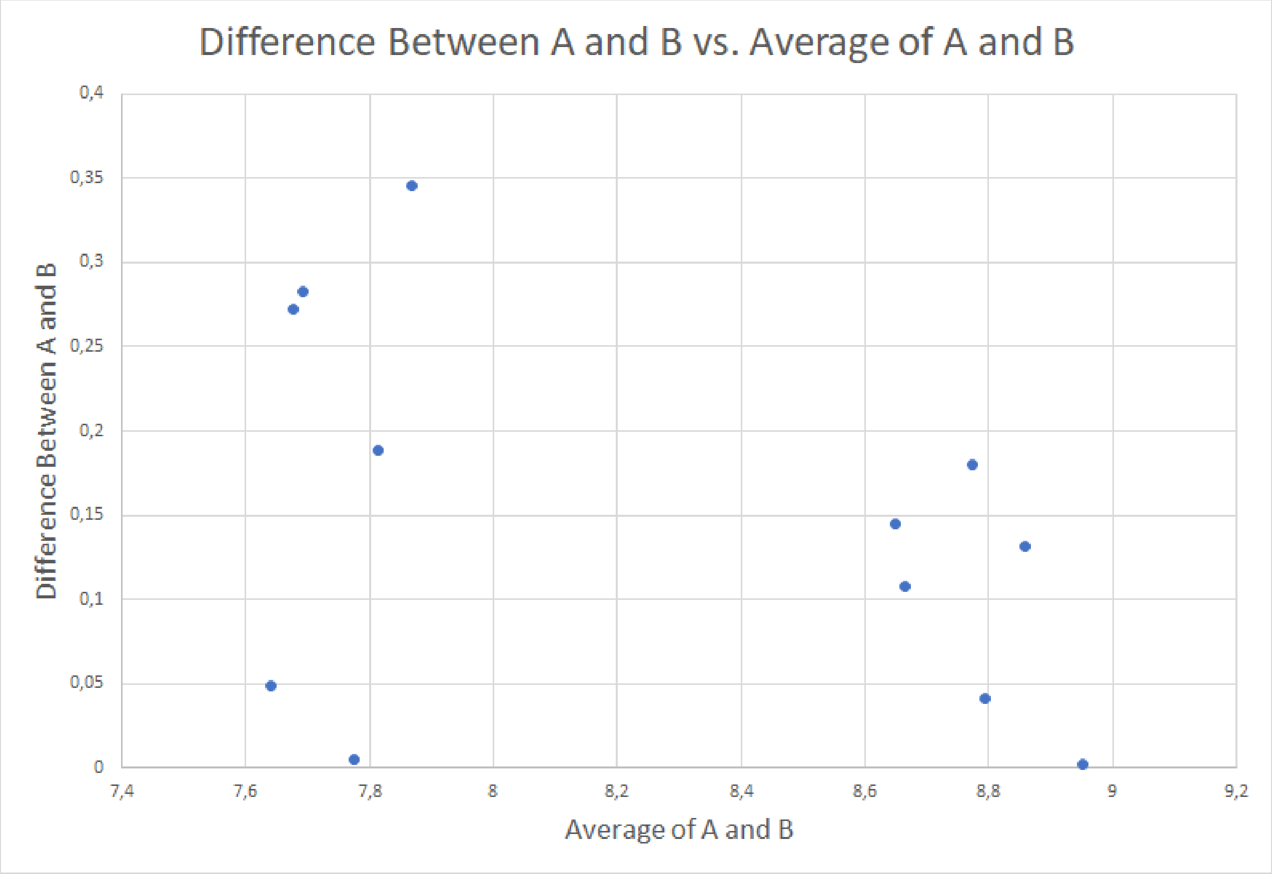

Figure 3.1: Scatter Plot of Difference in pH between the means of sensor A and sensor B plotted against their average.

Figure 3.1 shows the relationship between the difference in mean between A and B and their average value for the different locations. A pH value further from 7 generally means a smaller difference between the two sensors. B is almost always higher than A. The maximum difference in mean is 0.346. The standard deviation of B is always lower than that of A. A third sensor is needed for definitive conclusions regarding the exact values of the pH. However, the following observations hold for the sample sets of both sensors.

All six drinking fountains fall within the healthy range prescribed by the WHO $(6.5 - 9.5)$. The four B.C. Locations fall within the usual surface water range $(6.5 - 8.5)$. The pH at the Bardeen Pavilion is higher than at the other locations, but not significantly. The pH of the pool falls within the recommended range for both drinking and surface water.

3.2 Conductivity

Table 3.2: Conductivity data for all measurement locations (mS/cm).

	min		**max**		**mean**		**std dev**	
Sensor set	A	B	A	B	A	B	A	B
Loomis Filter Orange	0.16	0.22	0.19	0.26	0.175	0.229	0.0150	0.0154
Loomis Filter Green	0.19	0.19	0.26	0.22	0.213	0.203	0.0200	0.0207
Loomis Elkay Fountain	0.19	0.16	0.23	0.19	0.213	0.178	0.0197	0.0148
ARC Fountain	0.22	0.22	0.26	0.25	0.238	0.235	0.020	0.0150
Ikenberry Fountain	0.22	0.22	0.29	0.29	0.240	0.240	0.0174	0.0183
Illini Union Fountain	0.16	0.16	0.19	0.22	0.172	0.177	0.0147	0.0153
ARC Pool	1.44	1.50	1.50	1.58	1.452	1.523	0.0149	0.0202
B.C. Scott Park	0.58	0.57	0.65	0.61	0.606	0.589	0.0145	0.0140
B.C. Bardeen Pavilion	0.32	0.32	0.35	0.38	0.326	0.336	0.0121	0.0154
B.C. M.E.	0.29	0.29	0.35	0.35	0.314	0.315	0.0125	0.0123
B.C. Daniels Hall	0.32	0.32	0.39	0.39	0.356	0.350	0.0140	0.0113
B.C. Drain Pipe	0.93	0.93	1.00	0.96	0.965	0.941	0.0132	0.0144

Table 3.2 shows the minimum, maximum, mean and standard deviation for all of the measurement locations.

The means and standard deviations of sensor A and sensor B are quite similar. Some measurements show slightly larger differences between the two sensors, so no definite answer can be given as to which sensor is right. A third sensor would be needed for exact results. However, the following observations can be made for both sensor sets.

The seller DFRobot mentions that the measurement accuracy falls within ±5% Full Scale (F.S.)[6]. Each individual measurement may be ±5% off what is given.

The typical drinking water range for conductivity is $0.05 - 0.5mS/cm$. All samples of the Loomis drinking fountain measurements fall in this interval as can be seen by the **min** and **max** columns. The Scott Park B.C. measurements exceed this range, meaning it is slightly too salty for normal drinking water. However, along the course the conductivity drops to within the normal range for drinking water. The B.C. Drain Pipe water falls significantly outside the normal range, but it is not yet close to sea water levels $(50mS/cm)$. It therefore does not create the risk of salinization.

ARC and Ikenberry Fountain have greater minimum and maximum conductivity than the Loomis fountain samples. The mean value still falls within safety levels for drinking water conductivity. Illini Union Fountain has tested the best among all samples in conductivity. Mean with both group A and B devices have measured at or below the Loomis Filter Orange conductivity.

ARC Pool falls outside the safety levels of drinking water, falling in at a minimum of $144mS/cm$ and $150mS/cm$ for device group A and B, respectively. However, ARC Pool falls within the safety limit of $< 1,500ppm$[7], at $921ppm$ using the Lenntech conductivity converter[8].

3.3 TDS

Table 3.3: TDS data for all measurement locations (ppm).

	min		**max**		**mean**		**std dev**	
Sensor set	A	B	A	B	A	B	A	B
Loomis Filter Orange	154.78	198.12	157.07	201.80	156.258	199.920	0.886	0.628
Loomis Filter Green	152.68	187.52	167.84	189.37	160.927	188.776	4.578	0.864
Loomis Elkay Fountain	156.48	167.21	168.05	171.61	162.153	169.971	3.866	0.644
ARC Fountain	172.84	206.80	180.53	217.77	174.166	209.878	1.945	1.098
Ikenberry Fountain	173.41	202.89	178.44	208.12	175.545	204.639	0.808	1.288
Illini Union Fountain	143.23	174.62	150.77	184.06	148.797	177.204	0.754	2.089
ARC Pool	579.93	762.02	597.40	791.60	589.040	785.840	4.051	3.648
B.C. Scott Park	289.76	392.72	295.74	400.91	293.308	397.041	1.235	1.286
B.C. Bardeen Pavilion	207.02	228.31	209.39	234.10	207.896	230.122	0.927	1.304
B.C. M.E.	199.61	224.92	201.97	239.91	200.787	231.231	0.955	5.771
B.C. Daniels Hall	212.57	233.81	223.36	250.95	214.060	235.754	1.091	1.591
B.C. Drain Pipe	392.17	519.14	400.91	527.95	395.389	525.806	1.496	1.693

Table 3.3 shows the minimum, maximum, mean and standard deviation for all of the measurement locations.

Figure 3.2 shows the relationship between the average TDS of sensor A and B and the difference between A and B. A lower TDS value gives a lower difference between the sensors, indicating either a decrease in precision or a mistake in calibration. As higher TDS values are typically more dangerous, the values of B (which are consistently higher) will be used to judge the samples. Some samples show a large standard deviation (more than the typical $0.5 - 1.5$. These are always due to the first couple of samples (at most 10 samples) being very different from the others (a difference varying from 6 to 100 ppm). Removing the first 10 samples results in only standard deviations between 0.5 and 1.5. The sensors were always allowed to rest in the fluid for several seconds and are powered before measurements are made. It is therefore unclear why the first couple of samples are so different from the rest. As these first couple of samples do not significantly influence the mean, and it being unscientific to arbitrarily disregard certain samples, the samples are kept in the dataset.

The TDS for drinking water should typically not exceed 500 ppm. The only samples that exceed this range are from the ARC Pool and the B.C. Drain Pipe. This indicates that both the pool and the Drain Pipe are not fit for drinking with regard to salinity.

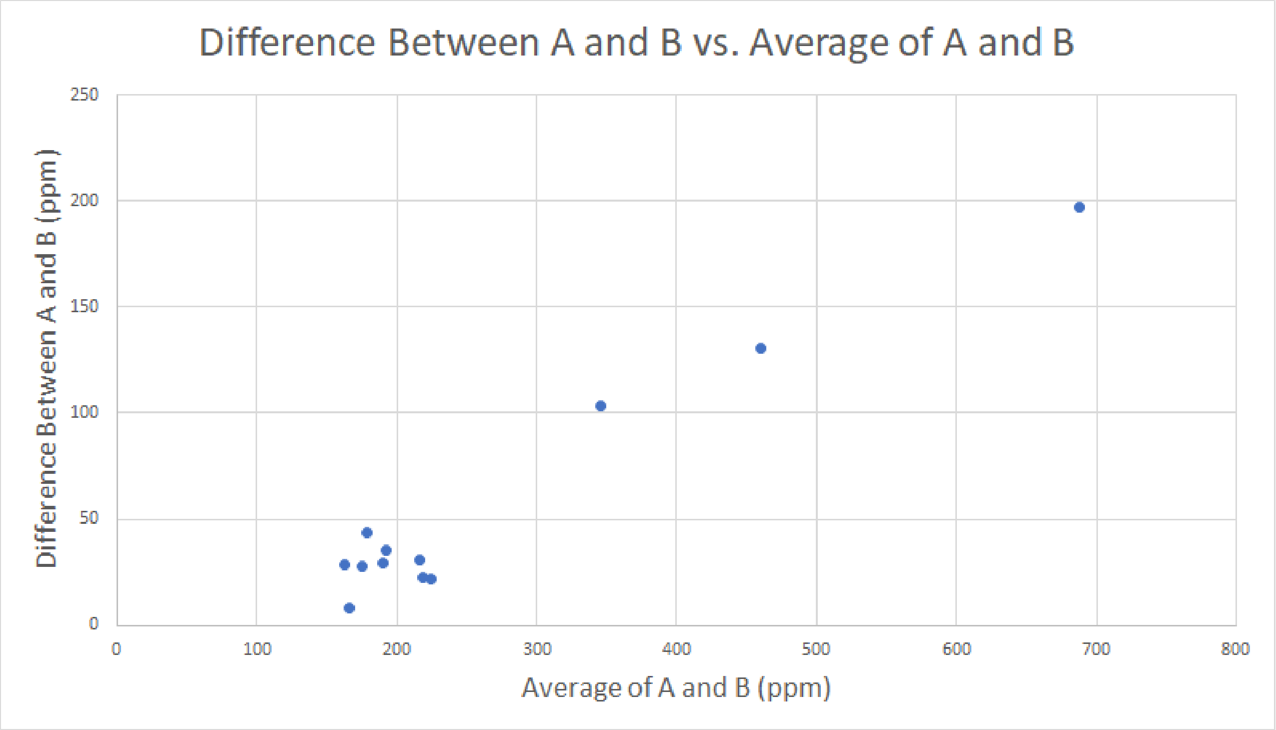

Figure 3.2: Scatter Plot of Difference in TDS between the means of sensor A and sensor B plotted against their average.

3.4 Temperature

Temperature measurements revealed no useful information, as the samples were brought to the same temperature before measurements were taken, which was approximately 20 degrees celcius. The temperature measurements were solely used to correctly determine the conductivity and TDS of the samples.

3.5 Turbidity

The sensor was broken during measurement taking. This report does not contain analysis of Turbidity data.

4. Discussion

The final device can determine conclusively that a water sample is not safe. This is done through an analysis of the base characteristics discussed above. For example, a TDS measurement out of the acceptable range would indicate that a water sample is not safe. However, the device can not determine that a sample is completely safe for human consumption. There are several water characteristics the device was unable to measure that contribute to overall water quality.

We used several sensors to ensure accurate measurements. First, the sensors were each calibrated on separate sample solutions. Then each of the sensors were used to test the collected samples. Using multiple sensors gave us more confidence in our results.

In the future, we aim to add more sensor functionality to the device to improve water analysis. The main impediment is the increased cost of refined sensors such as chlorine sensors and lead sensors. Cheaper sensors, such as those that measure Dissolved Oxygen, would provide more data, and could be used in conjunction with the current sensors to determine whether a sample is safe or not. The device could be used in the future to determine if chemicals exist in water based on readings done in test samples.

Calibrating the sensors was a requirement for accurate and precise measurements. The pH and Conductivity sensor required careful calibration in samples where values were predetermined. There were several calibrations samples for each, and the output voltages were used to determine the correlation between output voltage and the measurable characteristic. The Turbidity sensor required calibration when placed in water. If the calibration was done in other mediums, the results deviated significantly from predicted values.

5. Conclusions

The goal of this project is to measure the quality of drinking water to determine if any sources are unsafe. From the data, it was determined that the pH of drinking water from Loomis were within safety limit of drinking water. The TDS data shows that the drinking water from Loomis are within safety levels of drinking water. The results for conductivity show that drinking water from Loomis is within acceptable levels of quality. Since the parameters we measured were within the acceptable ranges, we are able to say that water from the measured Loomis fountains are safe.

Other drinking water samples taken include two samples from ARC pool and upper floor Elkay water fountain in the middle of the track, one sample from Illini Union Elkay water fountain within the Starbucks dining area, and one sample from Ikenberry dining area water faucet. The readings of drinking water are all within safety limits, but the fountains outside of Loomis have shown higher TDS and higher minimum levels in conductivity besides the Illini Union Fountain. ARC Pool, a surface water sample, has an unsafe level of contaminants within. Due to conductivity, extended time within the pool may be hazardous to swimmer's health.

Boneyard Creek has results ranging from good to fair. These results come from October 31st, 2019, starting from Daniels Hall at 3:30PM to Scott Park 5:00PM. The day started off with a moderate rain turning into light rain towards 5:00PM. Results were affected via water draining from nearby roads and drainage pipes. Bardeen Pavilion, Mechanical Engineering, and Daniels Hall measurements returned values within the acceptable range for surface water. Past the point of Bardeen Pavilion lies Green Street and the Drain Pipe next to the Illini Pantry. The greatest change past this point comes from conductivity, where the value rises to 0.78mS/cm in Scott Park (Drain Pipe sample is not a representation of the actual surface water as it is diluted once it enters the Creek). This is within safety levels of surface water but well above Loomis samples, and is still only in the fair range of surface water. With water flowing west to east (Scott Park to Daniels Hall), Scott Park and the Drain Pipe water flow along towards Bardeen Pavilion, Mechanical Engineering, and Daniels Hall. Results show that the effect of Scott Park and the Drain Pipe result in higher levels of each measurement of Boneyard Creek.

The amount of water coming from the Drain Pipe is just a small amount compared to the entirety of Boneyard Creek, but still has an effect on the samples downstream. So far, no sample has raised a red flag. This is not disappointing. Results show contaminants do enter Boneyard Creek but have not made the creek dangerous. This does not mean that it is safe, as salt on snowy days or flooding would influence Boneyard Creek and could create a dangerous levels of conductivity or pH.

6. Acknowledgements

We would like to thank Professor Gollin for providing us the opportunity to conduct this project. Thanks to him, we had access to all the hardware and tools used in this project. We would also like to thank Justin and Christian for helping us make progress on our project. Thanks to everyone's input and help, we are able to present this project.

A. Measurement Locations

A.1 Boneyard Creek

This appendix shows the map of Boneyard Creek locations scanned.

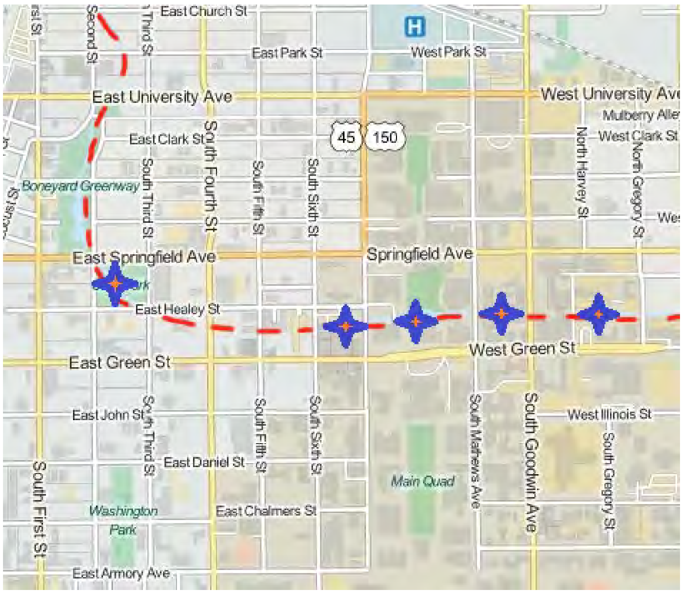

Figure A.1: Locations of Water Scans(Left to Right): Scott Park, Drain Pipe, Bardeen Pavilion, Mechanical Engineering Building, Daniels Hall [9]

Figure A.2: Scott Park

Figure A.3: Daniels Hall

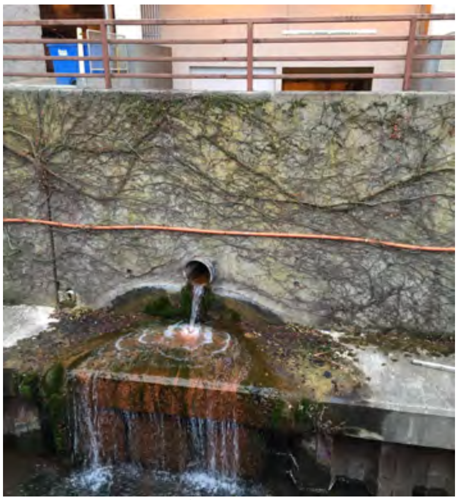

Figure A.4: Drain Pipe

Figure A.5: Bardeen Pavilion

Figure A.6: Mechanical Engineering Building

A.2 Loomis

These are pictures of the water fountains scanned within Loomis Laboratory. All are on the first level.

Figure A.7: Elkay EZH20 with green light showing filter quality

Figure A.8: Elkay EZH20 with orange light showing filter quality

Figure A.9: Unfiltered water fountain in Loomis

A.3 Campus

These pictures are from the four locations frequently used by group members.

Figure A.10: ARC Pool[10]

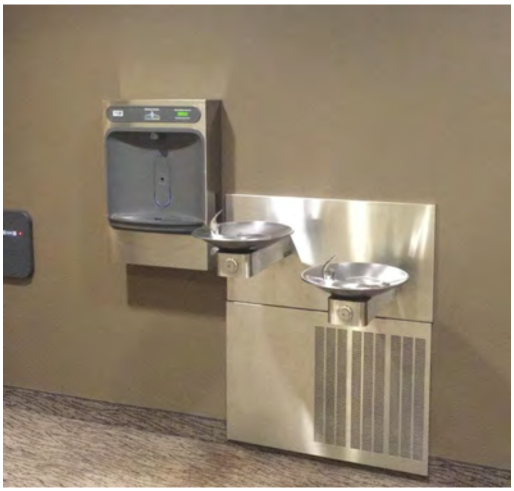

Figure A.11: Ikenberry Fountain

Figure A.12: ARC Fountain

Figure A.13: Union Fountain, green filter

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