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Presence of Freshwater Septic Tracers in North and Central New Jersey Water Bodies

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AUTHOR BIOGRAPHY

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ABSTRACT

This study investigates the presence of septic tracers and fecal bacteria in the waterways of North and Central New Jersey. Checking water quality has become very important with the increase in world population and the subsequent need for clean water. This study focuses on 4 tracers: Boron, Fluoride, Sulfate, and Escherichia coli (E. coli), which are indicators of septic contamination. Utilizing data from the Water Quality Portal, the analysis covers 4 years (January 1, 2020, to January 1, 2024), and 3 NJ counties (Hunterdon, Morris, and Somerset). The approach involves quantitative and correlational analysis to understand trends and correlation between the tracers over time.The study indicates that Boron and Fluoride concentrations generally fall within acceptable safety thresholds; however, periodic increases in Sulfate and E. coli levels suggest potential contamination incidents. A remarkable correlation between Boron and Sulfate concentrations points to a shared contamination source. However, the analysis is restricted by incomplete E. coli data for the entire study period, limiting the ability to conduct a thorough correlation assessment. This research is important for protecting the environment and keeping people healthy. By finding out where the pollution is coming from, it helps improve how we manage and keep our water clean. It also gives useful information for making better policies about water safety. In the future, more research should be done to fill in missing information and look at other ways to track pollution in New Jersey.

Keywords: *septic tracer, fecal bacteria, water quality, boron, fluoride, sulfate, escherichia coli, water contamination, New Jersey*

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INTRODUCTION

As the world's population continues to increase rapidly, sufficient and safe resources are required to maintain sustainable living conditions worldwide. Among these resources is water, which is vital for the survival of all organisms on Earth. Water quality has become a more prevalent issue as the demand for fresh drinking water increases, and there have been historical instances of the dangers that come with unmaintained water quality. One such example is the Flint, Michigan water crisis, where a switch in the town's water supply resulted in a national emergency due to lead poisoning from the water (Mohai, 2011). Incidents must be prevented in the future as they affect everyone around the world, which is why water quality standards should be closely monitored and maintained. While traditional monitoring aims to detect the contamination itself, it is also important to track the source of the contamination to mitigate its adverse effects. One way to detect and track the source of contamination in water bodies is through chemical tracers. If there are large concentrations of a certain septic tracer, then waste from septic systems is a source of contamination. Examples of common tracers include chemicals such as Boron, Fluoride, Sulfate, and Escherichia coli (*E. coli*), all of which enter water bodies in varying ways and degrees. This research paper intends to address the question, "To what extent are septic tracers and fecal bacteria prevalent in North and Central Jersey waterways?" by utilizing data about the concentrations of these tracers and draw associations between different variables.

LITERATURE REVIEW

What are Tracers?

Tracers, in a hydrological context, are defined as substances that are present in waterbodies or a water property that can be measured to hypothesize environmental occurrences. There are two subtypes of tracers: artificial, which are put into water for this purpose, and environmental, which are present either naturally or due to human activity (Cook, 2015). This study will focus on environmental tracers, specifically Boron, Fluoride, Sulfate, and Escherichia coli (*E. coli*). These tracers are typically utilized in isotope or ion form and usually enter the environment through septic waste systems as a result of human waste disposal.

Boron's Effectiveness as a Tracer

According to research done in 2002 by James Hogan and Joel Blum, Boron isotopes are usually present in water bodies near which anthropogenic waste is being produced, such as agricultural and landfill leachate. This means that this isotope can determine the source of water contamination, strengthening its use as a tracer. In the study, the Boron isotope values allowed the researchers to conclude that the contamination came from industrial sources and the leachate (Hogan & Blum, 2002).

Additionally, it has been accepted that Boron is a valid tracer that can source water contamination and other anthropogenic releases into the environment (Guinoiseau et al., 2018). This assertion was further established in a study where it was found that anthropogenic Boron in wastewater can be utilized to identify contamination due to its differing isotopic structure (Vengosh et al., 1994). An additional example of the effectiveness of Boron came from a study that concluded that there was a significant correlation between Boron levels and wastewater levels (Schreiber & Mitch, 2006).

Fluoride's Effectiveness as a Tracer

Fluoride ions are found in water bodies mainly because of human-made products such as toothpaste, which goes into water sources through waste disposal. Despite its use as a tracer, it isn't quite as effective as Boron since it is mainly advised to utilize in regions where fluoridated drinking water is present (Lockmiller et al., 2019). Despite its limited versatility, it can still be used, alongside other tracers, which can yield better results on the source of the contaminants in waterbodies. In the aforementioned study, Lockmiller and the other authors used Fluoride along with tracers such as Boron and Optical Brighteners so that the results would be more precise and accurate.

E. coli's Effectiveness as a Tracer

E. coli is another tracer that typically indicates the presence of contaminants such as fecal coliform and waste. However, it is usually neither present in high concentrations nor detected at all in waterbodies due to naturally occurring processes where the soil removes these sorts of microorganisms from the surface and stormwater (Atherholt et al., 2015). Despite the low presence of *E. coli* in waterbodies, it can still be utilized as a tracer since increased levels of its standard amounts may prove to be indicative of the presence of wastewater and fecal bacteria. In another study, caffeine and *E. coli* tracers were utilized together, and the results displayed that both *E. coli* and caffeine were suitable tracers, which were also positively correlated with fecal coliform (Richards et al., 2017). A different study reported similar results to this; in their study, they utilized Optical Brighteners and *E. coli* fecal bacteria indicators and found that the two were moderately associated with each other, which could aid in tracking the source of contamination (Billian et al., 2017).

Sulfate's Effectiveness as a Tracer

Similar to Boron, Sulfate is used as a tracer in its isotope form to determine the origin and amounts of contaminants entering waterbodies. An example of its utilization as a tracer was in a study in which the researchers used Sulfate to determine the source and amount of clear water entering the septic systems, as well as what processes occurred in septic systems (HouHou et al., 2010). Sulfate is comparable to Boron in the way that both are quite versatile in terms of what information these tracers are capable of revealing about that water body.

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When combined with the other tracers, this can expand the body of knowledge regarding a certain site, which increases the tracer's overall effectiveness.

Other Tracers

While these four tracers are the main focus of this study, numerous other tracers vary in versatility and ease of use. The two that will be discussed here are artificial tracers, unlike the tracers that are involved in this study. Their presence alone shows waste is present, unlike elevated levels of the 4 main focus tracers being the primary indicator.
One of these are surfactants, which are defined as surface-active compounds that have a variety of uses in household and industrial products such as cleaning products and metallurgy (Knepper & Berna, 2003). This type of tracer is relatively new to the scientific community, which means that its capabilities and uses as a tracer haven't been looked into as much as the others. However, it is emerging as a potentially useful tracer that may be beneficial in the future.

Another type of tracer is Optical Brighteners, which are found in laundry detergents and can detect the presence of bacteria as well as discover the source of bacterial contamination (Glickstein, 2006). Optical Brighteners, unlike surfactants, have been studied more for their utilization as a tracer. It was found that Optical Brightener concentrations and the amount of fecal coliform present in the water body had a strong correlation, which demonstrates its acceptance to be a valid and effective tracer (Tavares et al., 2008). Additionally, another study's results showed that Optical Brightener tracers can be used as a fast-surveying method to test water quality and are even more effective compared to other tracers such as Boron, Fluoride, and *E. coli*. However, one hindrance is that the technology used to analyze the concentration is often expensive and can generate erroneous results (Finegan & Hasenmueller, 2023).

While the tracers mentioned above are rising in usage, there are still a variety of less commonly used chemicals that yield good results. One such example is in a study conducted in the Hudson River Estuary, where two compounds, sucralose and caffeine, were utilized as tracers to identify the source of the wastewater (Cantwell et al., 2017). Another instance of less-used tracers is Contaminants of Emerging Concern (CECs), which consist of caffeine and illicit drugs, among other substances. The researchers using this tracer analyzed the effectiveness of the use of CEC as a tracer and found that they may be useful as a source tracer for bacterial contamination (James et al., 2015). While there are a variety of tracers that are studied in varying degrees, this research project aims to use the more prominent environmental tracers, which are easily accessible in terms of the presence of current data.

ADDRESSING THE GAP

As mentioned in the previous subsection, there are more effective tracers, namely Optical Brighteners, which can produce more accurate results. Additionally, in the aforementioned studies, looking at each of the tracers individually shows that without other tracers being involved in the analysis of the water body, the results may not demonstrate the entire picture of the source and what are the major contributing factors of contamination in a certain water body. Moreover, there is no guarantee that there will be a 100% success rate in the accuracy of determining the presence and other details regarding the pollutants and contamination of the water body. Some of the studies above use words such as 'may' when making conclusions to show how the nature of this process isn't guaranteed to be accurate (James et al., 2015). Despite this uncertainty, there is still truth in the statements being made, considering the number of sources that have time and time again proven that certain septic tracers are effective. This leads back to the question, "To what extent are septic tracers and fecal bacteria prevalent in North and Central New Jersey waterways?"

METHODS

Ethical Compliance and Safety of the Project

This project does not pose any concerns with the researcher's safety as the procedures do not impose any physical or psychological harm at any point. Additionally, this project was approved by an IRB committee, certifying that this research method doesn't violate any ethical or moral standards. This project only involves online sources that provide public data, and this does not pose harm to the researcher or other individuals in any way.

Structure of the Research Study

This study can be classified as both quantitative and correlational, as it involves the collection of numerical data and the analysis of relationships between variables. In correlational studies, there is an examination of the extent to which differences in one data point are related to variations in another (Leedy & Ormrod, 2019). This data would then be used to draw conclusions and correlations, helping to answer the research question regarding the extent to which septic tracers and fecal bacteria are prevalent in North and Central New Jersey waterways. The variables that are being correlated include the four tracers and the dates they were recorded, in order to investigate various trends. The period being studied starts on January 1st, 2020, and ends on January 1st, 2024, maintaining the consistency of start and end dates. Additionally, this study draws data from three counties in North and Central New Jersey: Hunterdon, Morris and Somerset County. Since these counties are in proximity to each other, the results can be generalized to the three counties as a whole.

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The Validity of the Method

Various pieces of literature in the scholarly conversation surrounding the topic of sourcing septic waste utilize a similar methodology. One notable example is a study done in 2017 by Krometis H. Billian and other researchers, where they drew correlations between *E. coli* and Optical Brighteners. They were able to find an association between the two, which aided in identifying the source of contamination. This technique of utilizing associations to conclude that the waste is from the same source is precisely the methodology that I will use in this research project.

Instruments involved in the study

The only instrument being used in this project will be the Water Quality Portal, utilizing the search and narrow function, which will be explained in more detail later. Other data sites primarily used for analysis purposes were the EPA's reports and the New Jersey Water Quality Standards (NJ SQWS) report, which outlines the recommended standards for different chemicals. These data sites were chosen for this experiment because they comply with ethical standards and eliminate the need for the researcher to collect their samples to send over to the lab, which is costly.

Procedure for Collecting the Data

This study uses publicly-available data collected by the US government and posted on waterqualitydata.us. The process of narrowing down the data is as follows: "United States of America (NWIS, STEWARD, STORET)" and then "New Jersey" for the location. From there, narrow the data to the three counties of focus: Hunterdon, Morris, and Somerset. Finally, for the type of site "Lakes, Reservoir, Impoundment (NWIS, STORET)" and the "Stream (NWIS, STEWARD, STORET)" options are chosen. As for the data sources from which the Water Quality Portal will draw its data, the NWIS and WQX data sources checked. Below, a data range will show up; for the start date, enter 01-01-2020, and for the end date, enter 01-01-2024. To narrow down the specific parameters that will be studied within these waterbodies, the "Water (NWIS, STEWARD, STORET)" and "Biological (STORET)" options are selected. However, this isn't narrowed down enough for analysis, so the "Inorganics, major, nonmetals," "Inorganics, minor, nonmetals," and "Biological, Counts" options are chosen. For the necessary further specificity, the advanced function is utilized, and the options "Biological Parameters Assemblage" and "Bacteria/virus" are selected. The data is ready to be downloaded and can be imported into Google Sheets to be analyzed.

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Procedure for Gathering the Results

After following the above steps, a chart will show an overwhelming amount of numbers and parameters. In this case, only certain parameters will be studied, so all the parameters except for the site, date, Boron, *E. coli*, Fluoride, and Sulfate are removed. Since the various characteristics are all jumbled into one column at this time, the data must be sorted through for easier readability. Click on the upper left-hand corner of Google Sheets to select everything, then go to the Data tab and select "Sort." At this point, the data can be sorted into characteristic names and from A to Z. Now, the data is in neater rows and columns based on the previously mentioned parameters.

After this, the next step is to determine whether the concentration of each tracer in the data sheet exceeded the recommended standards assigned. Using data collected from the EPA's reports and the NJ SQWS's reports, the standards can be found, and the drawing of comparisons can begin. To determine how many times a value in a data set exceeds a certain data point, use the "COUNTIF" function. The first step is to copy the desired row of the tracer and paste it into another day in the sheet to reorganize it. Then, hover over the first column of the tracer to filter out the row so that there are no gaps in any of the columns. To use the COUNTIF function, move to a random cell where data is not inputted and type "=COUNTIF(Range of cells,">= Recommended level")" (please note that the Range of cells and the recommended level area will be replaced when inputting and that there are no quotes when inputting the full equation) Repeat this COUNTIF process for the other three tracers and to figure out how many data values are exceeding the recommended limit.

After this comes dot plot graphs for the visual analysis aspect. This will first be done with the date range and the various tracers. After generating the graphs, a trendline can be added so that linear relationships can be drawn. Although the Trendline shows the r^2 (R-squared) value, delete the legend and remove the r^2 because the r^2 should be depicted independently due to its importance in the analysis.

The second set of graphs to be generated will be the correlation graphs, which are used to determine the relationship between two tracers. Do the same steps mentioned in the previous graph, but this time, include only two tracers per graph. This analysis created the graphs for Fluoride and Sulfate, Sulfate and Boron, and Fluoride and Boron. For all three of these graphs, select the option to display a trendline.

The final step in data analysis is to calculate the significance of the data. To do this, both the R-value and the R-squared value should be calculated. Since the R-squared value is automatically calculated with the trendline, no manual calculations are necessary. However, for the R-value, also known as the Pearson correlation coefficient, a formula should be used for the calculation on Google Sheets. The formula used will be "PEARSON (Data set 1: Data set 2)," and a numeric value will immediately appear in the cell. For the r value, if the value is positive, that indicates a positive correlation, while a negative value indicates a negative correlation.

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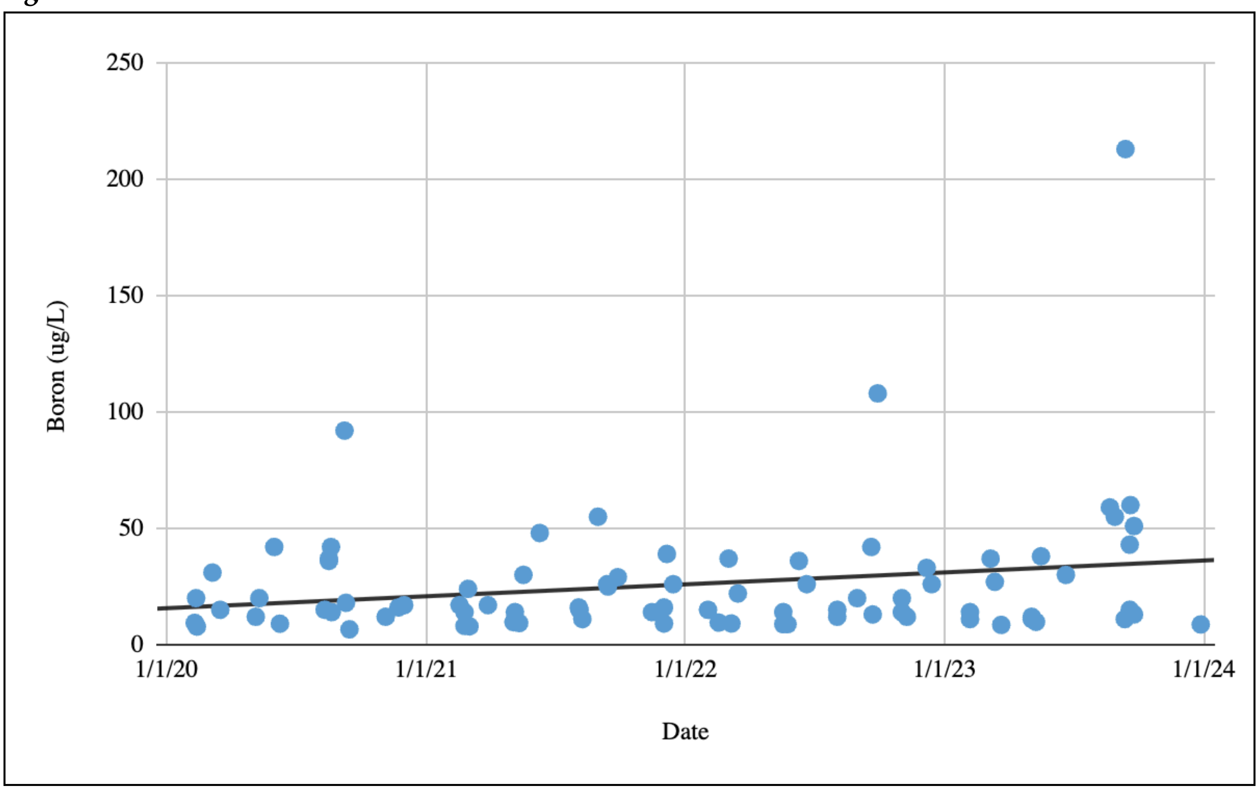
The r^2 values range between 0 and 1, and the closer the value is to 1, the stronger the relationship is between the data points (Barrett, 2000).

RESULTS

Tracer Concentration vs Water Quality Standard

In the Boron set of data, there were 83 data points collected between January 1st, 2020, and January 1st, 2024, at varying sites in New Jersey. Of the 83, none of the data points had exceeded the recommended standard of 1 mg/L or 1000 μg/L, as depicted in Figure 1. While the concentration didn't exceed the standard, the trendline shows an increase in concentration over time.

Figure 1: *Boron levels in relation to the date*



Note: This figure depicts the data points about boron concentration collected between the beginning of 2020 and the end of 2024. There is also a trendline showing the line of best fit for these data points and a rough trend in the data points.

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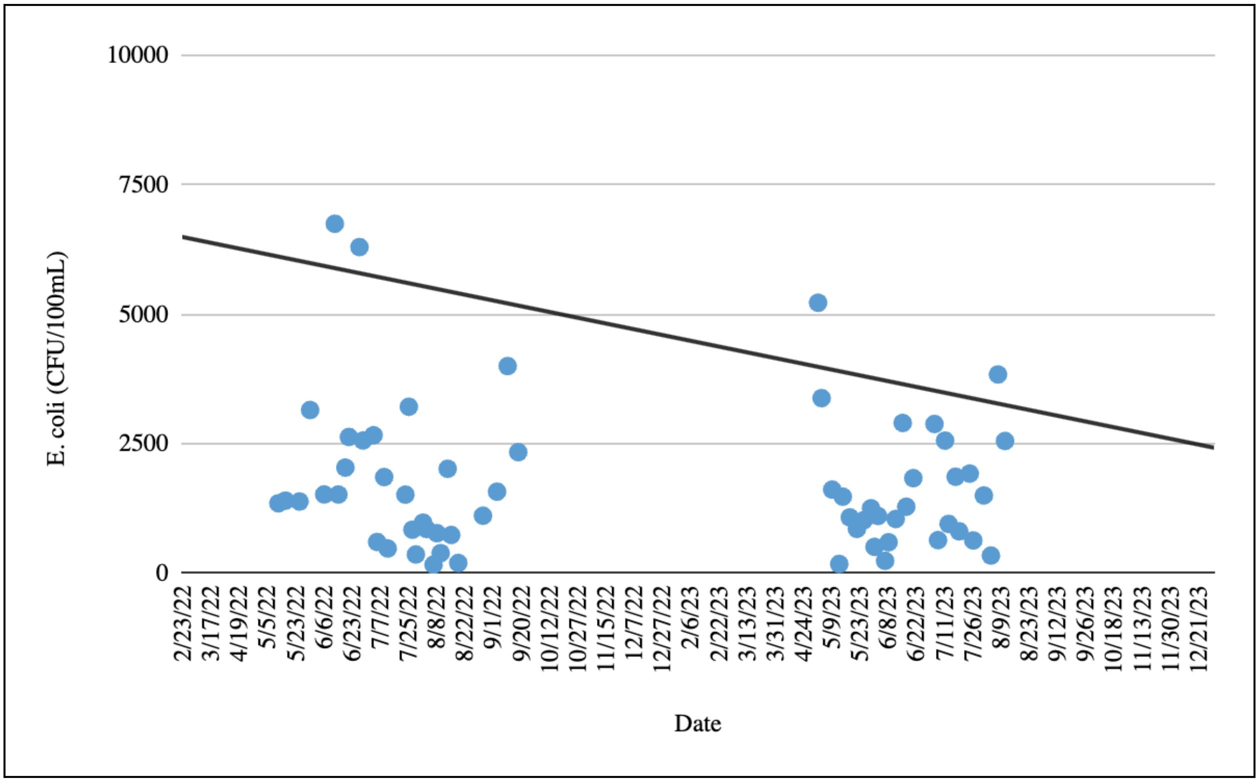
As for E. coli, there were 159 out of the 419 data points collected in the same year span exceeded the recommended standard of 235 colony-forming units (CFU) per 100 mL.

Figure 2: *E. coli levels in relation to the date*



Note: This Figure depicts the data collected on the concentration of E. coli between Mid-2020 and Mid-2023.

In the Fluoride set of data, none of the 341 collected data points exceeded the recommended standard of 2 mg/L, and this is consistent with Figure 3, which depicts all of the concentrations within the range of 0.0 mg/L and 0.25 mg/L, which is well below the standard. However, as seen in Figure 3, the concentrations are slightly increasing with various outliers now and then, such as the evident one between 2022 and 2023 (which has a concentration of approximately 0.21 mg/L).

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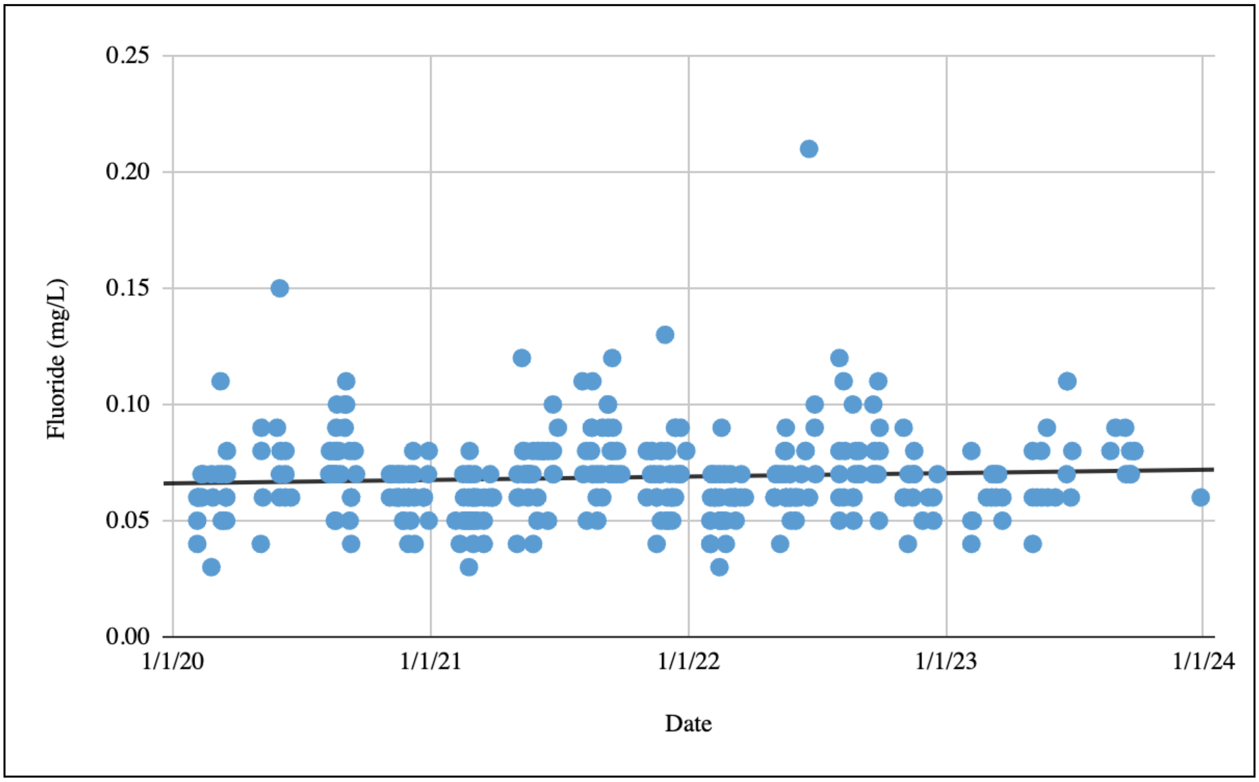
Figure 3: *Fluoride levels in relation to the date*



Note: This figure depicts the various data points for fluoride concentrations collected between the beginning of 2020 and the end of 2024. There is also a trendline showing the line of best fit for these data points and a rough trend in the data points.

Finally, for Sulfate, only 1 of the 720 collected data points exceeded the standard of 250 mg/L, and this is depicted by the spike in the Figure 4 graph between 2022 and 2023, which peaks at approximately 370 mg/L. This spike between 2022 and 2023 was present in both the Sulfate and *E. coli* graphs, which may indicate a correlation between the two concentrations.

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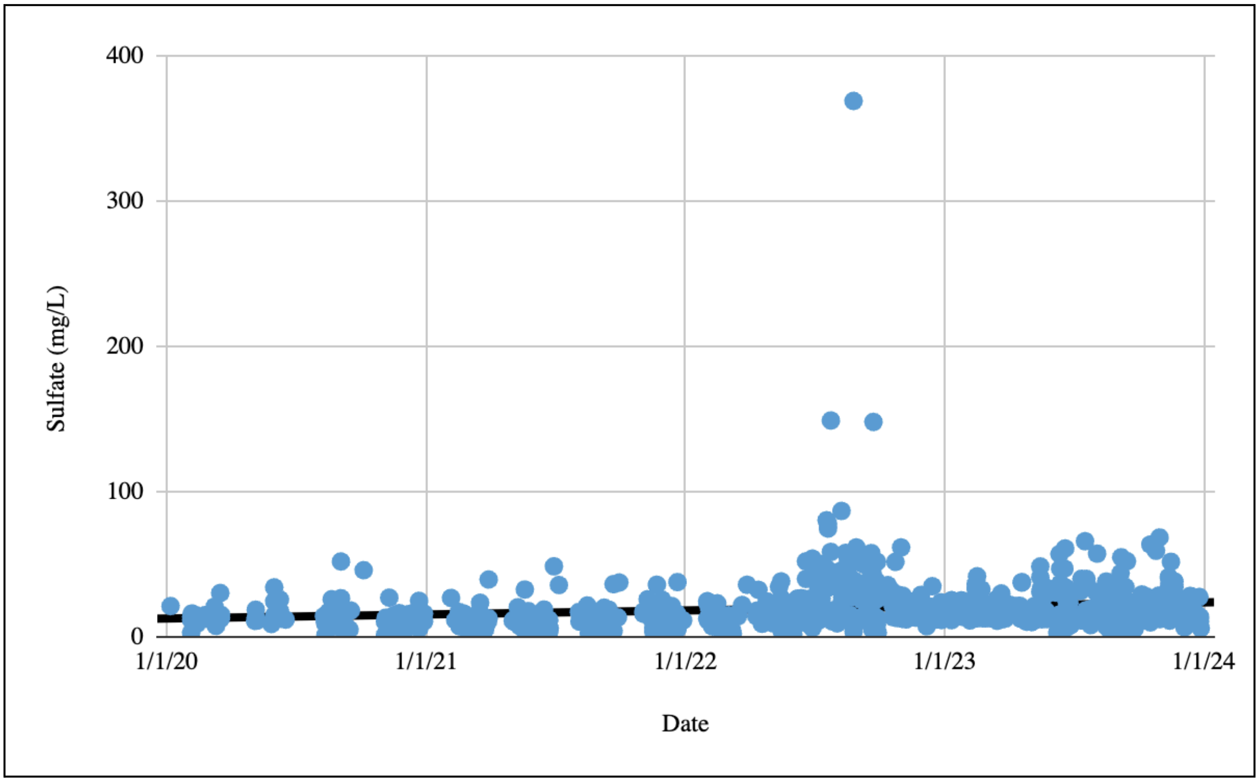
Figure 4: *Sulfate concentrations in relation to the date*



Note: This Figure depicts the data collected on the concentration of sulfate between before Mid-2020 and past Mid-2023.

Correlation between different tracers

In addition to the figures regarding the date and tracer relationship, the correlations between levels of different tracers should be investigated as well. Starting with Fluoride and Sulfate, in general, according to the trendline, there is a positive correlation between the two tracers. However, this contrasts with the graph of Boron and Fluoride, where the trendline depicts an overall negative correlation between the two tracers. Finally, Boron and Sulfate have a positive correlation, as demonstrated in Figure 7, which is also similar to Sulfate and Fluoride in Figure 5.

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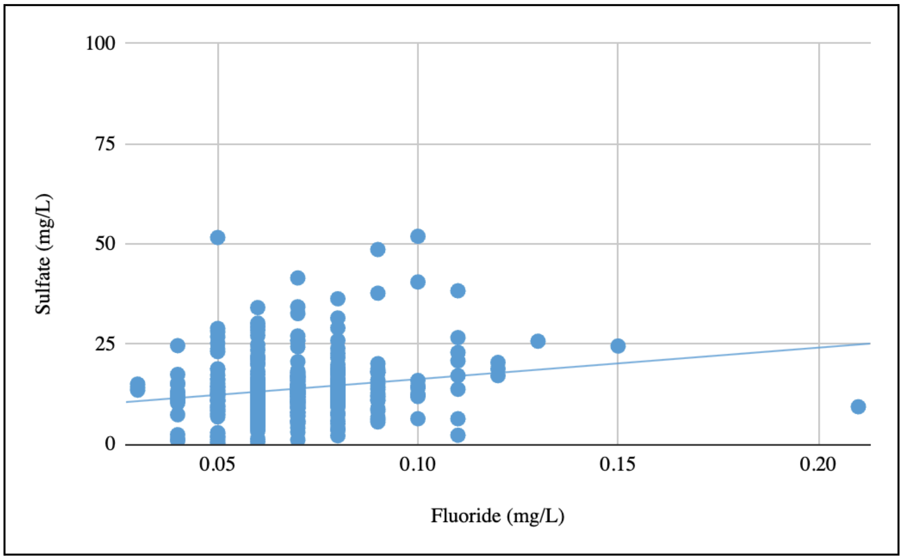
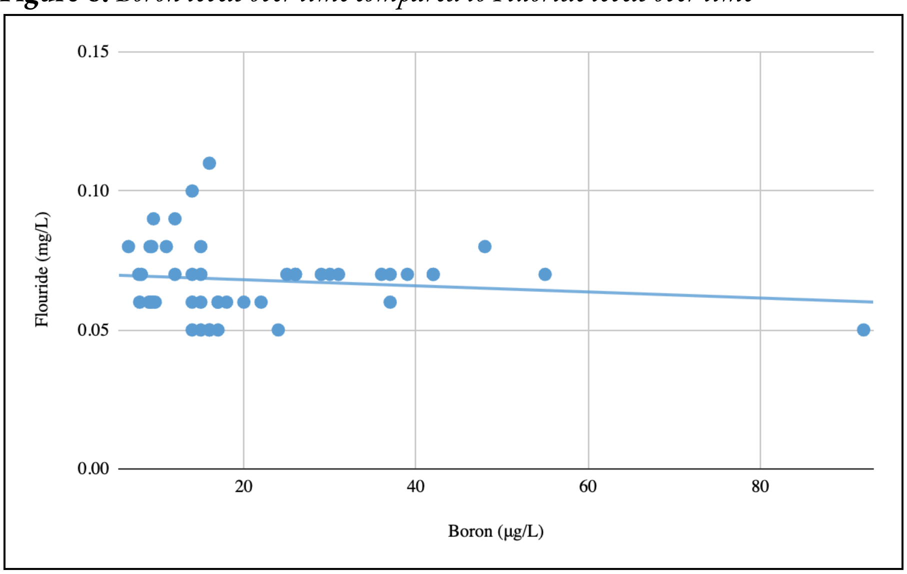
Figure 5: *Sulfate levels over time compared to Fluoride levels over time*



Note: This Figure depicts all the data collected for both Fluoride and Sulfate and an overall trend of the concentrations of each tracer.

Figure 6: *Boron levels over time compared to Fluoride levels over time*



Note: This Figure depicts all the data collected for both Fluoride and Boron, and an overall trend of the concentrations of each tracer.

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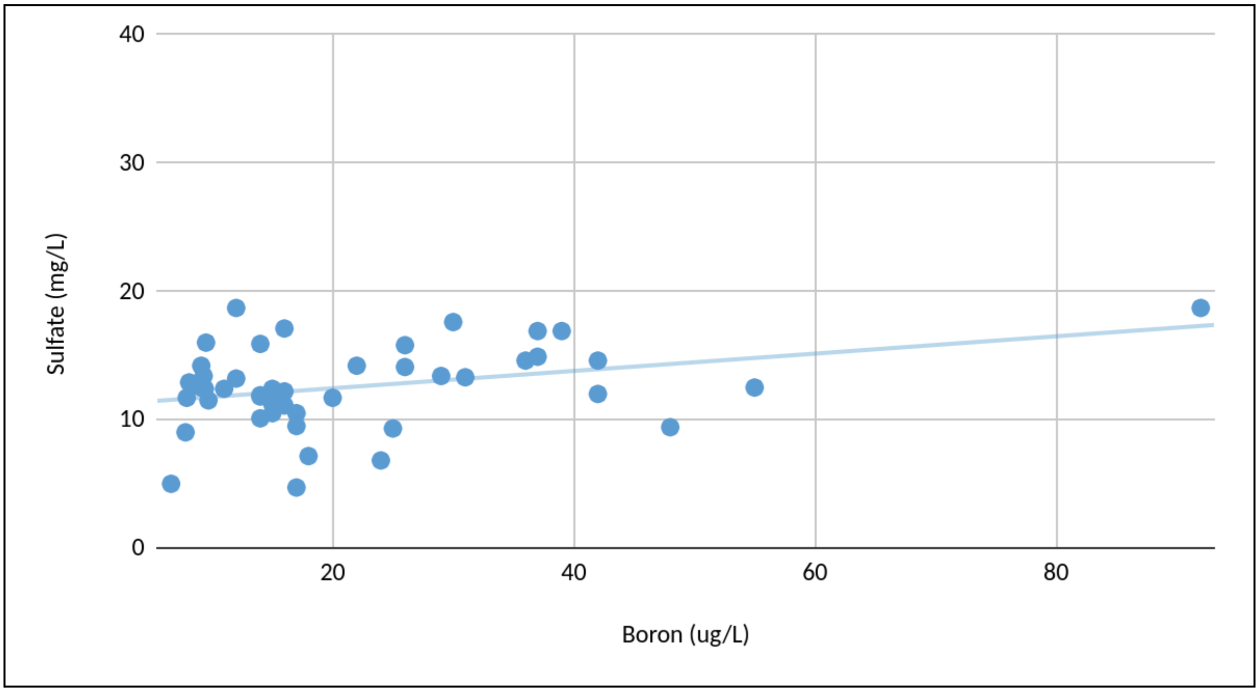
Figure 7: *Boron levels over time compared to Sulfate levels over time*



Note: This Figure depicts all the data collected for both Sulfate and Boron and an overall trend of the concentrations of each tracer.

Figure 8: *r^2 values for Figures 1-7*

Boron vs date: 0.0045
E. coli vs date: 0.006
Fluoride vs date: 0.006
Sulfate vs date: 0.023
Sulfate vs Fluoride: 0.037
Boron vs Fluoride: 0.018
Boron vs Sulfate: 0.427

Figure 9: *r values for Figures 5-7*

Sulfate vs Fluoride: ~0.14
Boron vs Fluoride: ~0.002

Boron	vs	Sulfate:	~	0.65

DISCUSSION

Septic Tracer Trends Over Time

To figure out the extent to which septic tracers are prevalent in North and Central Jersey waterways, these results can be analyzed in two different sections: the Date correlations and the correlations between the tracers. In general, over time, the levels of certain tracers stayed fairly constant, which was shown in Figure 4, had an upward trend, shown in Figures 1 and 3, or had a downward trend, as seen in Figure 2. However, there was a noticeable spike in the levels of Sulfate and Fluoride around August 2022. This spike may indicate a geological or other external event that caused this sudden jump in levels. These abnormal increases suggest that there may have been a septic source that led to contamination. Likely explanations for such an event could include an environmental event, such as a drought reportedly occurring at the time. As for Boron and Fluoride, there is a positive correlation between the dates and the concentrations of the tracers in these different water bodies. While Fluoride stays consistent around the trendline, for the most part, Boron wavers to a minor extent. Figure 1 depicts a decently far outlier, which again can be a sign of septic waste contaminating the water. This event happens in a different time frame compared to the previous abnormality, which implies that a connection between the abnormalities cannot be drawn. However, this outlier may have also been the result of a drought, as it had been reported that there was significantly less rainfall near the middle to the end of 2024, matching up with the timeframe that Figure 1 displays (Theim & Borisoff, 2024). Looking at the r^2 values, none of the data points come anywhere close to one, with the closest being Sulfate at 0.023. This suggests that there is no concrete correlation between the dates and the tracers.

Correlations between Septic Tracers

In the graphs, there were upward trends in Figures 5 and 7, while there was almost a constant trend in Figure 6. Looking at Figure 8, the Boron and Sulfate relationship was the strongest with an r^2 value of 0.427. This number is considerably higher than all of the other data values while also being significantly closer to one, which suggests that there is a strong relationship between the two tracers. This, however, isn't the case with Boron and Fluoride, as well as Fluoride and Sulfate, which had r^2 values of 0.018 and 0.037, respectively. The strength of their relationship is comparable to Sulfate and Date, which, as previously stated, was the highest among the first 4 figures, yet still distant from one, showing that there aren't any strong correlations in this case. Figure 9 reinforces the idea seen in the graph; there is a positive correlation in Figures 5 and 7. In Figure 6, the r value for Boron and Fluoride is extremely close to 0, which explains why the trendline appeared to be nearly flat. While the R-values shown in Figure 9 for Boron and Fluoride, and Fluoride and Sulfate are incredibly low, there is a large contrast seen with the R-value of Boron and Sulfate, which is approximately 0.65. Since an R-value more than 0.7 indicates that there is a strong positive correlation, it can be said that there is a decently strong correlation between Boron and Sulfate, which can lead us to conclude that they potentially may stem from the same source.

Limitations

There are random spikes and outliers present in the data. While this can be interpreted as a result of an environmental event, this would mean that this event would have affected surrounding bodies, which would mean there are multiple outliers. Therefore, a conclusion cannot necessarily be made, even though a drought was proven to strike during those time ranges. Despite the evidence, conclusions cannot be drawn without further research on the relevant body of water, which can be another subject of investigation as well as a reasonable explanation for what event would have incited the spike.

Another flaw appears in the methods, which could be beneficial to consider in future research: not being able to draw correlations between *E. coli* and the other tracers. While the majority of the data starts on the 1st of January 2020, this was different for *E. coli* since no data was collected until the beginning of 2022. This means that since there was a lack of coordination between the dates, the data that would correlate the different tracers would've been inaccurate. This limitation didn't allow for an investigation into a possibly vital correlation between the tracers, and for future research, it would be beneficial to draw associations and conclusions between the three tracers and *E. coli*.

Implications

Adherence to water quality standards is crucial, especially in this day and age, when more resources are needed to support a larger population. When levels of these various tracers are abnormally high or if the water body shows other signs of septic waste contamination, something should be done to solve the issue. Considering that some of these water bodies contribute to the source of drinking water, it is imperative to observe these trends. Since the associations of tracers aid in sourcing contaminants, this will be able to provide insight as to the primary causes of contamination for various sources (Billian et al., 2017). This can then aid in determining which water bodies need more attention from a conservation standpoint. When these factors are looked into, this information can be communicated to officials, which will enable cleaner and safer water, therefore contributing to a better environment in Central and North Jersey.

CONCLUSION

The study revealed that some tracers have significant correlations with each other, while others don't. The tracers that did have significant correlations with each other demonstrate a strong relationship, which may suggest that they have detected certain pollutants from the same septic source system. One of such tracers was Boron and Sulfate, which had a drastically higher r and r^2 value compared to the other correlations, suggesting that they were derived from the same source. This, in turn, provides vital information for future research regarding the tracer association and how it enables researchers to better understand how and where local septic contamination is stemming from.

REFERENCES

Atherholt, T. B., Korn, L. R., Louis, J. B., & Procopio, N. A. (2015). Repeat Sampling and Coliform Bacteria Detection Rates in New Jersey Domestic Wells. *Groundwater Monitoring & Remediation*, *35*(2), 70-80. https://doi.org/10.1111/gwmr.12094

Billian, H., Krometis, L.-A., Thompson, T., & Hagedorn, C. (2018). Movement of traditional fecal indicator bacteria and source-tracking targets through septic drainfields. *Science of the Total Environment*, *610-611*, 1467–1475. https://doi.org/10.1016/j.scitotenv.2017.08.131

Barrett, G. B. (2000). The Coefficient of Determination: Understanding r. *The Mathematics Teacher*, *93*(3), 230–234. JSTOR. https://doi.org/10.2307/27971342

C., Andrew James, Miller-Schulze, J. P., Ultican, S., Gipe, A. D., & Baker, J. A. (2016). *Evaluating Contaminants of Emerging Concern as tracers of wastewater from septic systems*. *101*, 241–251. https://doi.org/10.1016/j.watres.2016.05.046

Cantwell, M. G., Katz, D. R., Sullivan, J. C., Shapley, D., Lipscomb, J., Epstein, J., Juhl, A. R., Knudson, C., & O'Mullan, G. D. (2018). Spatial patterns of pharmaceuticals and wastewater tracers in the Hudson River Estuary. *Water Research*, *137*, 335–343. https://doi.org/10.1016/j.watres.2017.12.044

Cook, P. G. (2015). The Role of Tracers in Hydrogeology. *Groundwater*, *53*(S1), 1–2. https://doi.org/10.1111/gwat.12327

Drought expands in the East following exceptionally dry October. (2024, November 7). NOAA Climate.gov. https://www.climate.gov/news-features/event-tracker/drought-expands-east-following-exceptionally-dry-october

Finegan, C. R., & Hasenmueller, E. A. (2023). Using in situ measurements of optical brighteners for rapid reconnaissance of wastewater inputs to water resources. *Science of the Total Environment*, *881*, 163378. https://doi.org/10.1016/j.scitotenv.2023.163378

Glickstein, N. (2006). Optical Brighteners in Laundry Detergents Help Us Determine the Source of Bacterial Contamination. *The American Biology Teacher*, *68*(5), 296–298. https://doi.org/10.2307/4451992

Guinoiseau, D., Pascale Louvat, Paris, G., Chen, J., Chetelat, B., Rocher, V., Guérin, S., & Jérôme Gaillardet. (2018). Are boron isotopes a reliable tracer of anthropogenic inputs to rivers over time? *Science of the Total Environment*, *626*, 1057–1068. https://doi.org/10.1016/j.scitotenv.2018.01.159

Hogan, J. F., & Blum, J. D. (2003). Boron and lithium isotopes as groundwater tracers: a study at the Fresh Kills Landfill, Staten Island, New York, USA. *Applied Geochemistry*, *18*(4), 615–627. https://doi.org/10.1016/s0883-2927(02)00153-1

Houhou, J., Lartiges, B. S., France-Lanord, C., Guilmette, C., Poix, S., & Mustin, C. (2010). Isotopic tracing of clear water sources in an urban sewer: A combined water and dissolved sulfate stable isotope approach. *Water Research*, *44*(1), 256–266. https://doi.org/10.1016/j.watres.2009.09.024

Knepper, T. P., & Berna, J. L. (2003, January 1). *Chapter 1 Surfactants: Properties, production, and environmental Aspects*. ScienceDirect; Elsevier. https://www.sciencedirect.com/science/article/abs/pii/S0166526X03400044

Leedy, P. D., & Jeanne Ellis Ormrod. (745 C.E.). *Practical Research: Planning and Design, 12th Edition*. Pearson. One Lake Street, Upper Saddle River, New Jersey 8. Tel: 800-848-; Web Site: Http://Www.Pearsoned.com/ -00-00.

Lockmiller, K. A., Wang, K., Fike, D. A., Shaughnessy, A. R., & Hasenmueller, E. A. (2019). Using multiple tracers (F−, B, δ11B, and optical brighteners) to distinguish between municipal drinking water and wastewater inputs to urban streams. *Science of the Total Environment*, *671*, 1245–1256. https://doi.org/10.1016/j.scitotenv.2019.03.352

Mohai, P. (2018). ENVIRONMENTAL JUSTICE AND THE FLINT WATER CRISIS. *Michigan Sociological Review*, *32*(32), 1–41. https://www.jstor.org/stable/26528595

Richards, S., Withers, P. J. A., Paterson, E., McRoberts, C. W., & Stutter, M. (2017). Potential tracers for tracking septic tank effluent discharges in watercourses. *Environmental Pollution*, *228*, 245–255. https://doi.org/10.1016/j.envpol.2017.05.044

Schreiber, I. M., & Mitch, W. A. (2006). Occurrence and Fate of Nitrosamines and Nitrosamine Precursors in Wastewater-Impacted Surface Waters Using Boron As a Conservative Tracer. *Environmental Science & Technology*, *40*(10), 3203–3210. https://doi.org/10.1021/es052078r

Tavares, M. E., Mciver, M. R., Spivey, M.I.H, & Mallin, M. A. (2008). Testing for Optical Brighteners and Fecal Bacteria to Detect Sewage Leaks in Tidal Creeks. *Journal of the North Carolina Academy of Science*, *124*(3), 91–97. JSTOR. https://doi.org/10.2307/24336317

Vengosh, A., Heumann, K. G., Juraske, S., & Kasher, R. (1994). Boron Isotope Application for Tracing Sources of Contamination in Groundwater. *Environmental Science & Technology*, *28*(11), 1968–1974. https://doi.org/10.1021/es00060a030

Water Quality Data Home. (n.d.). Www.waterqualitydata.us. https://www.waterqualitydata.us/