Colby-Sawyer College Community-Based Research Project 2017-2018:

Phosphorus Load Assessment of Municipal Sewerage Systems & Public Outreach Proposals for the Town of New London, NH

Colby-Sawyer College Community-Based Research Course

Brooke Vigliotta, Jordan O'Brien, Grace Ledgard, Nicole Semeraro, Michelle Lopes, Justin Enright, Will Astle, Shayna Levesque, Ashleigh Wilson, & Cody Wickline.

Introduction

The Town of New London, New Hampshire, is interested in decreasing their phosphorus loads within the municipal sewerage system. Phosphorus can be detrimental to aquatic ecosystems in high concentrations and needs to be treated in order to protect nearby waterways. Reducing phosphorus loads in the system would lower the percentage of taxes put toward its treatment and reduce the strain on the Sunapee Wastewater Treatment facility when treating water before releasing it into the Sugar River. The Community Based Research course at Colby-Sawyer College worked with the Town of New London Public Works Department to sample and analyze various sites along the town sewerage system. Data was collected over the 2017-2018 academic year, with the purpose of quantifying the total phosphorus loads in specific areas within the sewerage system. In addition to the results of this study and suggested alternatives from supplemental research contained in this report, relevant information was presented to the public twice during the study. The results of this study present a clearer picture of the phosphorus dynamics throughout the town, but also bring more questions to investigate in the future. This research gives the town a foundation to build upon when determining how to move forward with public outreach to help residents and businesses reduce their phosphorus inputs.

Literature Review

Phosphorus is an essential nutrient for establishing and maintaining life within ecosystems (Natural Resources Conservation Service, 2007; Turner & Raboy, 2003; Kroiss, Rechberger, & Egle, 2011; Miller, 2012). It is considered a limiting nutrient, meaning that is available in short supply relative to other nutrients (National Research Council, 2000; Turner & Raboy, 2003; Stoddard, Van Sickle, Herlihy, Bahney, Paulsen, Peck, Mitchell, & Pallard, 2016). Phosphorus cycles through terrestrial and aquatic ecosystems, originating from rocks, which break down into soil through weathering, allowing plants to access the nutrient. From plants, it circulates up to higher trophic levels, and is returned to the soil when plants, animals, and animal wastes decay. It is only when phosphorus is present in excess that it becomes a threat to the balance of ecosystems. Eutrophication is a natural process where excess nutrients such as phosphorus can create harmful algal blooms and excessive plant growth that drastically alter the health and structure of aquatic ecosystems (Sunapee Area Watershed Coalition, 2008; Turner & Raboy, 2003). Humans accelerate this process by using cleaning and hygiene products that contain phosphorus, and phosphorus-based fertilizers, which eventually leach into water bodies from septic systems or end up in the sewerage system. Wastewater must be treated to remove excess phosphorus before it is discharged into natural systems.

Wastewater Systems-Treatment for phosphorus consists of precipitating the nutrient out of the water and creating a sludge, which is then filtered and turned into a biosolid to be spread on agricultural fields as a fertilizer. A total ban on phosphorus would lead to a reduced amount of sludge in these facilities and reduced treatment costs (Green Seal, n.d.). The Sunapee Wastewater Treatment Plant in the past used Polyaluminum Chloride, or “PAC” for phosphorus removal. When the PAC comes in contact with the phosphorus, binds to it and precipitates out as sludge. It is important to explore alternatives to PAC to avoid the addition of excess aluminum into natural water bodies because it is also toxic to aquatic ecosystems. Alternatives to using PAC include converting phosphorus to aluminum phosphate in solid form, which is more easily extracted from wastewater (Weaver, n.d.), removing the chemical phosphorus with membrane treatments, or incorporating the phosphorus into biomass (Sathasivan, n.d.). Reverse osmosis or nano-filtrations are also methods of removing all pollutants from wastewater, including phosphorus (Ratanatamskul, Yamamoto, Urase, & Ohgaki, 1996). The downsides to these methods are the high costs and lack of extensive research to support implementation. There are also volume limitations, as it is difficult to use these methods with high volumes.

Common Sources-One of the main contributors of phosphorus in a sewerage system are surfactants. Surfactants are substances that are commonly used in cleaning products to break down dirt and remove oils. In surfactants, phosphorus is most commonly used in the form of sodium triphosphate (Essential Industries, n.d.), which can soften the water and increase the potency of soap products. One commonly used replacement for sodium triphosphate is the compound EDTA, or Ethylenediaminetetraacetic acid, which also acts to soften the water. EDTA however, is slightly less effective than sodium triphosphate, which is why it is less commonly found in cleaning products (Kaluza, Klingelhofer, & Taeger, 2015), but has seen increased usage in recent years as companies strive toward being "phosphorus-free."

A frequently used product containing high concentrations of phosphorus relative to natural levels is lawn fertilizer. Phosphorus-containing fertilizers can leach into the sewerage system through infiltration, increasing the threat of eutrophication and algal blooms in aquatic systems. Unfortunately, there is essentially no replacing phosphorus in fertilizer without sacrificing effectiveness (Withgott & Laposata, 2011). Normally, fertilizers would only enter into waterways through runoff. However, most sewerage systems are not entirely free of infiltration, as cracks in the system can form over time and allow groundwater to enter the system. Another contributor of high phosphorus concentrations is human waste, where phosphorus is excreted as a by-product of the human diet. A study from the United Kingdom revealed that the sewerage contribution of urine was quantified at 0.9g-phosphorus/person/day (Kroiss, Rechberger, & Egle, 2011). New London has a far smaller population by comparison to the group this study surveyed. This could still mean that urine as well as feces are relevant contributors to phosphorus loads in the system, however it is one of the sources that cannot be regulated to mitigate loads in the future.

Legal Parameters-Even though New Hampshire has passed regulations prohibiting the sale of cleaning products containing more than 0.5% elemental phosphorus by weight (NH. Rev. Stat. § 485-A:56, 2016), there are still concerns that stricter regulations from the EPA on wastewater treatment of phosphorus will outpace how much phosphorus companies use in their products. By lowering the levels of phosphorus leaving the town, not only will the environment benefit, but the town will be prepared for any future regulations that may be placed on phosphorus output.

Green Seal & Ecolabelling-As defined by the Global Ecolabelling Network, ecolabelling is a voluntary method of certifying products and practices for having good environmental performance within a specific product or service category (Global Ecolabelling Network, n.d.). These certifications are awarded by independent third-party organizations, each representing a different type of ecolabel. There are three types of ecolabels: Type 1, a voluntary, third party program that authorizes the use of environmental labels on products indicating overall environmental preferability of a product, Type 2, which is for informative environmental self-declaration claims, and Type 3, which is for voluntary programs that provide quantified environmental data of a product, under pre-set categories of parameters set and verified by at least two qualified third parties (Global Ecolabelling Network, n.d.).

Green Seal is an independent, non-profit organization and a national Type 1 Ecolabel (Green Seal, 2010) that has approved several commercial cleaning products and creates standard limits for several different environmental factors, including phosphorus. Currently there is a proposed revision to drop the concentration of allowed elemental phosphorus in undiluted soaps, cleansers, and shower products from 0.5% by weight to 0.2% by weight (Green Seal, 2010), which is far less than the current legal standard in New Hampshire. The work and research that organizations like Green Seal do requires an immense amount of collaboration with several other organizations, colleges and universities, as well as businesses in order to create stricter regulations. Green Seal is also more open to sharing their information than product manufacturers.

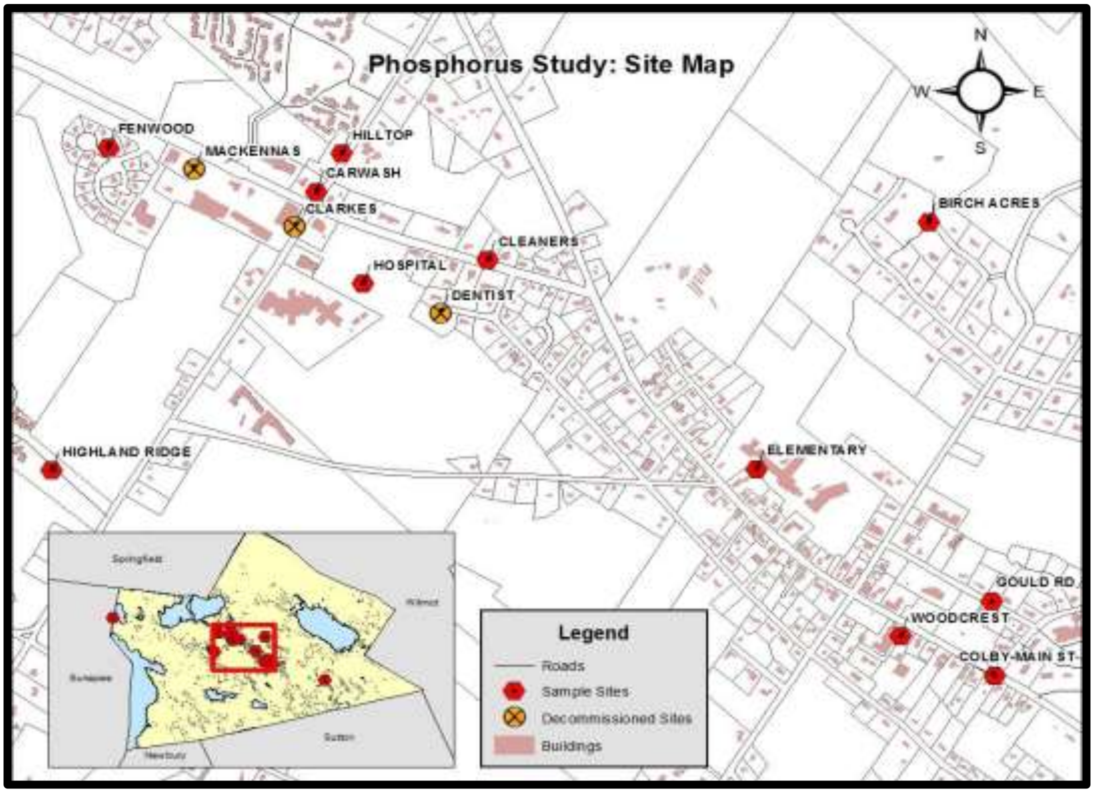
Overall, the presence of excess phosphorus continues to create problems for the environment as well as policy makers who want to be proactive in protecting their natural resources. The current problem with this body of knowledge is when high concentrations of phosphorus are found, the responsibility is almost always put on the wastewater treatment facilities that have to remove it, and not the people who are adding it to the system in the first place. This study will look into specific areas within an existing sewerage system and determine where the highest sites of input are coming from. The purpose of this is to spread awareness of phosphorus pollution to the general public, and to lessen inputs before the wastewater treatment facilities have to.

Methodology

In order to assess the phosphorus loads from different sources within the New London municipal sewerage system, water samples were collected by the student field crews along with the New London Public Works Department. Field sampling included collecting water depth, velocity, discharge measurements, and a sample of sewage water. Data collection occurred at sixteen sites, which was carried out once a week from September 15th, 2017 to March 9th, 2018, over a period of 2-4 hours. A flow-meter measured discharge, velocity, and water depth in the field using a probe that relayed data to a field computer (see Appendix B). A second discharge value was also calculated to ensure data accuracy. Samples were preserved using acid to allow for a 28 day hold-time until our wet-chemistry analysis was completed. Before preserving the samples with acid, a small amount of sample was extracted and preserved to be analyzed with the soluble reactive phosphorus procedure.

Lab analysis followed a modified version of the NHDES Total Phosphorus Method (see Appendix A), which uses dilution, digestion and color-metric testing stages to measure both organically-bound phosphorus and available inorganic phosphorus. In addition, a soluble reactive phosphorus method was used alongside the total phosphorus method during the second half of the study to analyze only inorganic phosphorus, coming from fertilizers and surfactants. The color-metric test developed color in samples that corresponded to the concentration of phosphorus. Darker-colored samples contained a higher concentration of phosphorus, whereas lighter-colored samples contained less. To determine exact values, the colored samples were run through a spectrophotometer to record absorbance. All laboratory protocols followed a Quality Assurance & Quality Control Manual developed by the students (see Appendix B).

Study Area - The New London Sewerage System is located in the center of New London, New Hampshire, and caters to some of the town's businesses and residential communities.



Through collaboration with New London Public Works, parts of the system were divided up into *sewage sheds*, or areas of the system that all traveled through one manhole before reaching the main pipeline. This allowed us to sample a percentage of the system with as few sites as possible to save time and resources in the field. Our sample site naming convention is based on what businesses or landmarks may be near the site, so it is important to note that not all of the sites exclusively capture the businesses or area they are named after. For example, the "Carwash" site captures the carwash, Jake's Market & Deli, as well as Hilltop and the Ledyard Bank.

Survey Development-Data collection involved using two surveys to acquire product usage data on the residencies and businesses in New London using the system Qualtrics. The first survey was directed to the residents of New London, and asked about the products they use that might contribute to phosphorus loads. A second survey collected data from local businesses, and asked similar questions aimed at commercial products. Students took this survey directly to businesses that either did not receive the email containing the link to the survey or did not respond. Businesses were asked to fill out the survey in person and still were able to decline if they chose. The data collected was compiled into a final list of what products were contributing to the phosphorus loads leaving New London. This allowed us to target our product research in order to create a list of "phosphorus-free" alternatives for residents and businesses to use.

Data Analysis-To determine load calculations for each site, discharge measurements were taken and calculated to ensure accuracy, and concentration was determined from samples analyzed in the lab; multiplying these values together gave us our phosphorus load data. After pulling the data from each of the surveys, it had to be organized and modeled in order to attain any usable information from it.

Geographic Information Systems-All maps appearing in all reports and presentations were created using ArcGIS mapping software. In addition to the completed maps, GIS was also used to update the Town of New London's sewerage maps, which had not been updated since 1996. These updates included adding and naming new buildings, renaming main and residential roads, and updating sewer pipeline data. This was attempted through acquiring newer maps for different areas of the town, and splicing them together using a rubber-sheeting technique. The plots for each manhole were found through various older maps and by using a GPS out in the field to create an updated map. Despite our efforts, there are still areas in which we do not have accurate information and do not have the means to obtain that information for ourselves.

Results & Discussion

Phosphorus Load Data-The students analyzed a total of 16 sites over the course of two semesters, collecting samples on 19 days from September 2017 to March 2018. Site selection was based on residential areas and businesses that were suspected to have high contributions to the town phosphorus load. Selecting these sites was based on analysis of sewerage maps and consultation with the New London Public Works Department. The purpose of each sample site was to identify, isolate, and measure densely populated residential areas and businesses that may contribute higher phosphorus loads from items such as the surfactants in cleaning products. It is important to note that the technique used to name sample sites is based on businesses or landmarks near the site. This means that not all of the sites exclusively capture the businesses or area they are named after.

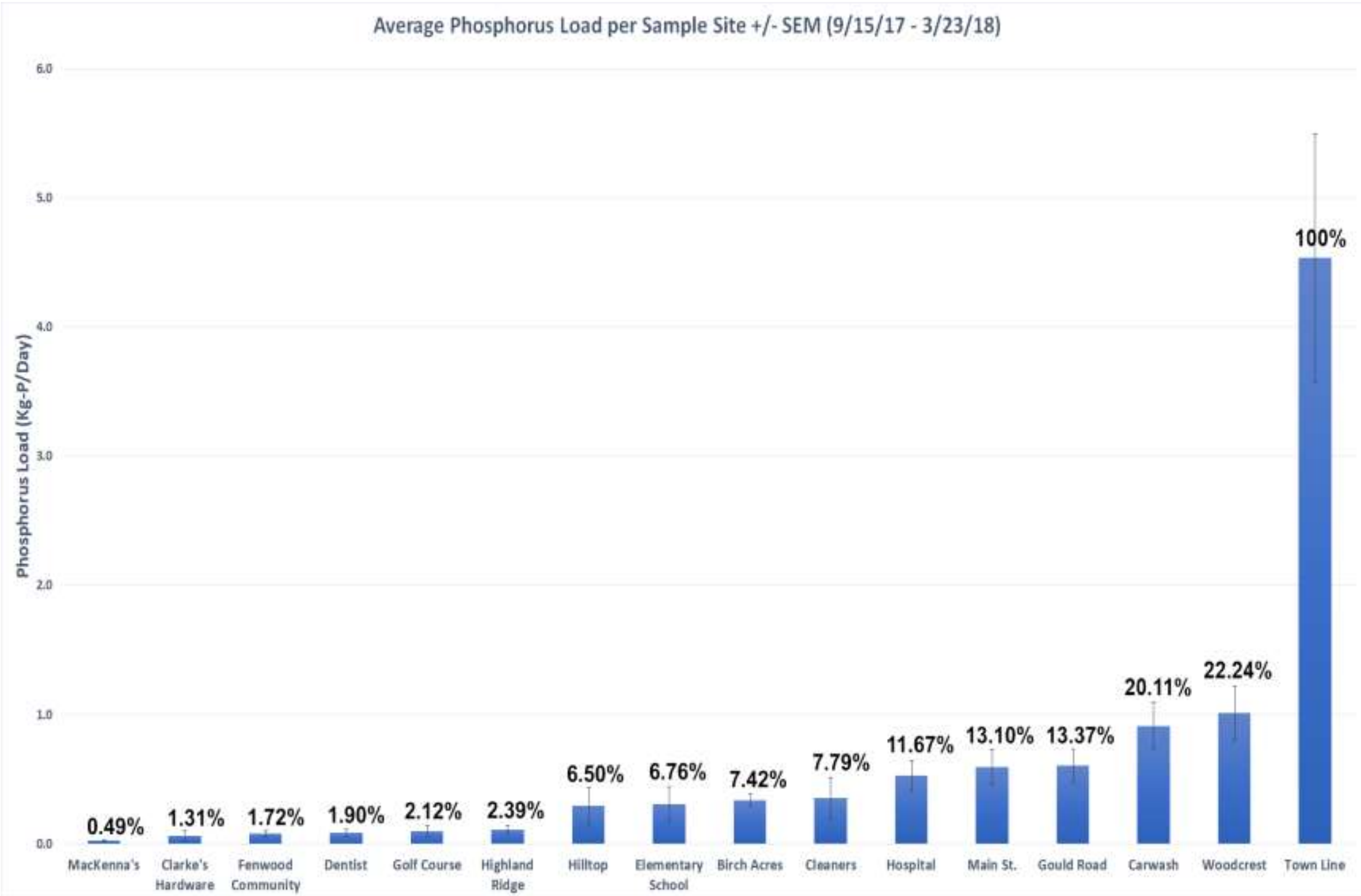


Figure 1: Average phosphorus load per sample site. Percentages show individual site contributions in relation to the total (Townline).

Since the beginning of the project three sample sites have been omitted, including "Dentist," "MacKenna's," and "Clarke's" due to consistently low phosphorus loads. These three sites only make up an average of 1.9%, 0.49%, and 1.31% of the town's total phosphorus output respectively (Figure 1). These percentages can be calculated by comparing the average phosphorus load of each site in question to the average phosphorus load of the "Townline" sample site, which captures all wastewater leaving New London and gives an estimate of New London's total phosphorus load contributions. To give these percentages some context, the average percentage of total phosphorus output for each of the 19 sampling sites is 7.93%, therefore any site substantially lower than that average is of low relevance to the study.

In November, the sampling sites "Golf Course" and "Highland Ridge" were added to the study. The "Golf Course" site was added because in the summer it encompasses a densely populated development including housing and a restaurant. There are also several buildings on the golf course, and their use of surfactants and output of waste are also contributing to the total phosphorus load. The "Golf Course" site has shown the second lowest phosphorus loads of any active site and only accounts for 2.12% of the total New London phosphorus load. This site encompasses the Lake Sunapee Country Club, which has a restaurant and year-round residents. Future studies could expect a significant spike in phosphorus loads when activity increases in the summer, but also because there may be significant contributions from infiltration. The "Highland Ridge" site isolates a densely populated community, and so any high phosphorus loads can be attributed to household surfactants and human waste. On average "Highland Ridge" only represents 2.39% of the town's phosphorus output, indicating that it is not a site of high concern. "Fenwood" has the lowest average phosphorus load of all active sampling sites, accounting for only 1.72% of the total phosphorus leaving New London. The results indicate that the Fenwood area has minimal effects on the New London phosphorus dynamics and can potentially be omitted from future studies.

Overall, the five sites that are contributing the most phosphorus to the system, ordered from highest to lowest phosphorus load, are “Woodcrest,” “Carwash,” “Gould Road,” “Main Street,” and “Hospital.” Together, the “Gould Road” and the “Main Street” sample sites directly capture flow from all of the buildings on the Colby-Sawyer campus, and they account for 13.37% and 13.1% of the town’s total phosphorus output respectively. Using GIS maps and pipeline data acquired from Horizons Engineering, it is confirmed that these sites capture different areas of the college and do not feed into each other; this indicates that the college is potentially responsible for 26.47% of the town’s total phosphorus output. This is a substantial portion, and shows that the college may be a good target for future outreach campaigns on product alternatives. The most densely populated area of New London is Colby-Sawyer College, with a population of 1,043 students as of Fall 2017 (Colby-Sawyer College, n.d.). The high phosphorus load at Colby-Sawyer may be attributed to the population density of residential students living on campus, as well as the products used by facilities to maintain bathrooms and public areas.

The “Carwash” site accounts for 20.11% of the total phosphorus output, however “Hilltop” flows directly into this site, adding to the “Carwash” load. The data shown from deducting the “Hilltop” site’s phosphorus load from the “Carwash” site’s load accounts for 13.61% of the total New London phosphorus output. According to the most up to date pipeline map, the only other businesses flowing into this site include Jake’s Market & Deli and Ledyard Bank. The bank is likely of little relevance because it does not have any reason to use excessive surfactants. The 13.61% of total phosphorus output at "Carwash" is most likely attributed to the carwash and Jake's, which are using commercial surfactants to clean cars and food service equipment respectively. The sample site labelled "Hospital" flows out directly from the New London Hospital, and based on the map there are no other wastewater inputs flowing into the site. This means that the New London Hospital is responsible for the entirety of the "Hospital" site phosphorus load, which is the fifth highest site and makes up 11.67% of the town's total phosphorus output. This is likely a result of the commercial cleaning products that the hospital uses to keep rooms, tools, and equipment clean, as well as the waste excreted due to the hospital's dense occupancy. The cleaning products used by the New London Hospital may make it another possible location to recognize in any future outreach campaigns.

The most current map of the sewerage system was created in 1996, meaning that there was almost no information available on sites or pipelines that have been created since that year. The "Woodcrest" site and the pipe system flowing into it are more recent additions to the New London sewerage system. Therefore there was no available information on how those sites connect to the existing system. To remedy this, the sampling team, in conjunction with the New London Public Works Department, used red dye as a tool to discern that the "Main Street" site flows directly into the "Woodcrest" site. This means that any difference between the "Main Street" and "Woodcrest" phosphorus loads is directly attributed to the businesses and residences located between the two sites. On average, the "Woodcrest" phosphorus load is 69.81% higher than the "Main Street" phosphorus load, indicating that the few business plazas and residencies between these two sites are substantially impacting the net phosphorus output of the town (Figure 1).

To further elaborate, the “Main Street” site makes up for 13.1% of New London’s phosphorus output, and the “Woodcrest” site accounts for 22.24%. The difference between “Woodcrest” and “Main Street” was calculated to be 9.14%. Indicating that 9.14% of the town total phosphorus output is flowing out from the businesses and residencies between Colby-Sawyer College and Woodcrest Village. The businesses encompassed by this area include Pizza Chef, Grounds, Lady P’s Boutique, Gulf/Evans, Subway, Allioops, Blue Mountain Guitar, Cataleya’s, Village Sports, Erin’s Haircuts, Colby Real Estate, and Lemon Twist. Of these businesses, research indicates that the most likely contributors of phosphorus are the restaurants and hair salons, both of which use surfactants as a part of their service or for cleaning. There are also several houses between the two areas, which may have a small contribution to the high phosphorus load.

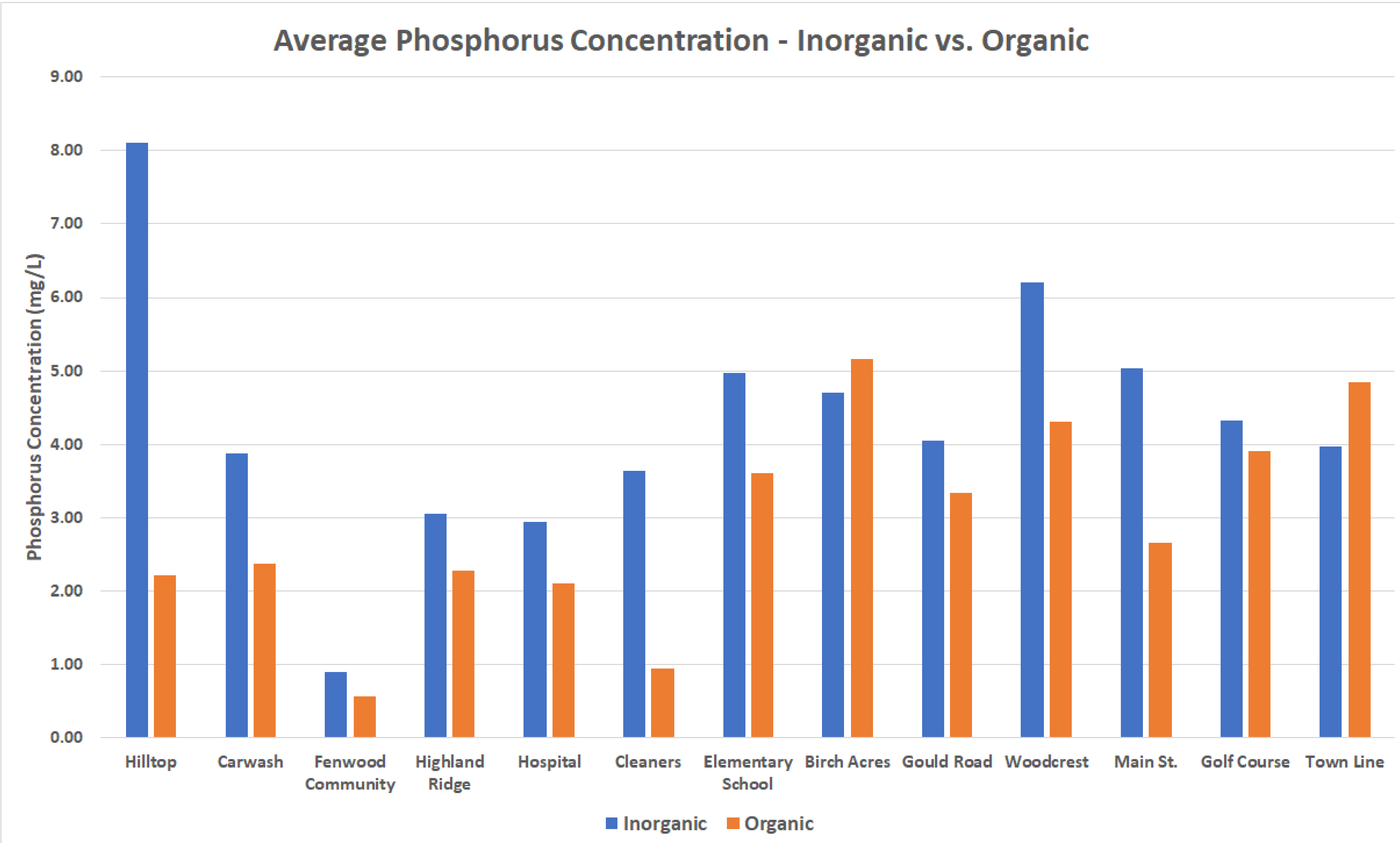


Figure 2: Inorganic versus organic average phosphorus concentrations per sample site.

Soluble Reactive Results-Testing for SRP in addition to TP made it possible to calculate the concentration of both organic and inorganic phosphorus within each sample. Inorganic phosphorus enters the sewerage system through products like surfactants and fertilizer, and could be remediated by spreading awareness about product ingredients. A majority of organic phosphorus comes from human waste entering the sewerage system, and cannot be easily regulated. An important procedural note is that the inorganic and organic calculations were only applied to the concentrations of the samples, and not the net phosphorus load. What this means is that this data is effective at determining the ratio of organic to inorganic phosphorus at each site, but it must be used in unison with the phosphorus load data to see the whole picture. Using this data in conjunction with the phosphorus load data, the most unfavorable site can be determined as one which has a high load and a high fraction of inorganic phosphorus (Figure 2). The data indicates that sites like "Birch Acres" may be a low priority target for remediation, because although they make up 7.42% of the total phosphorus output, only 47.6% of that, or 3.53% of the total phosphorus output is comprised of inorganic treatable phosphorus. Sites like "Carwash" and "Main Street" are likely the best targets for product usage outreach campaigns, because they have some of the highest phosphorus loads of any site, and are comprised of mostly inorganic phosphorus (X% and Y%, respectively).

Figure 3:

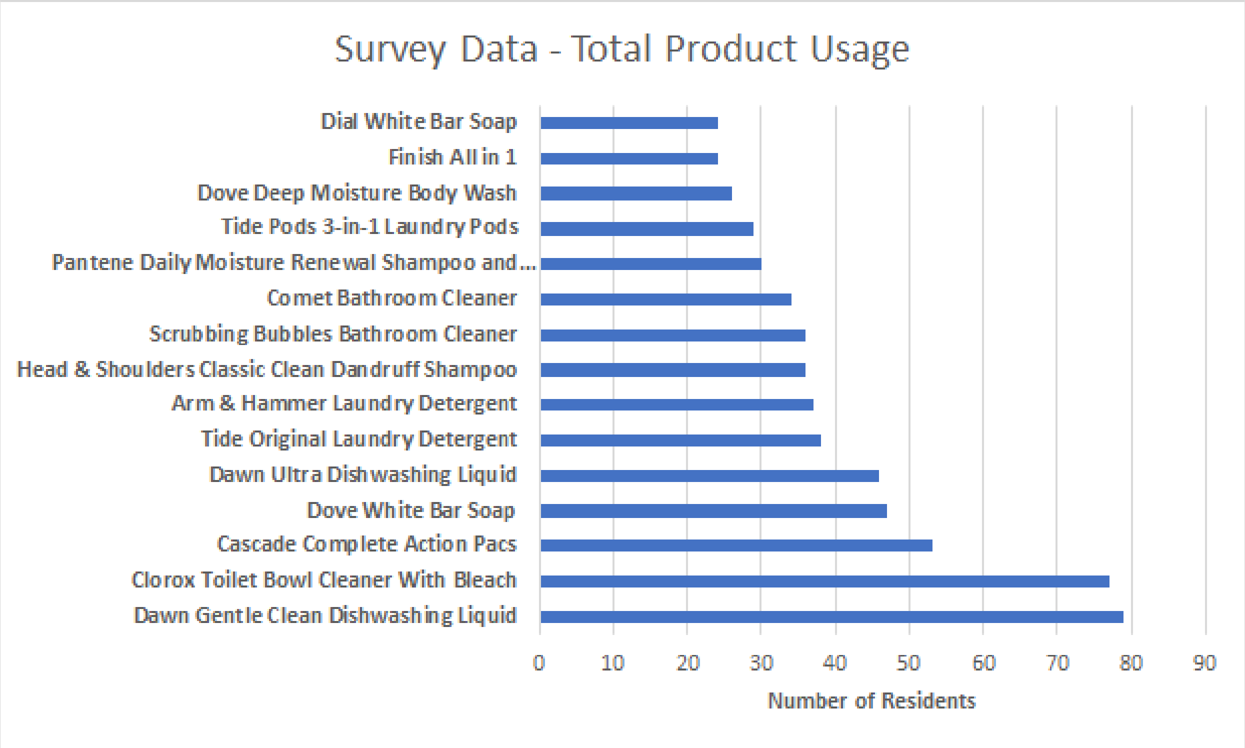


Figure 3: Residential product usage data.

Survey Data-Using the online poll software Qualtrics, the class sent out a survey to the residents of New London in order to acquire data on commonly used cleaning and hygiene products. This data can be used to determine which products should be prioritized in future phosphorus content research. Despite having a list of products to start with, the students were quickly met with one of the biggest challenges of the study, since manufacturing companies are not legally required to list phosphorus as an ingredient. However there is legislation in place limiting residential cleaning products to 0.5% elemental phosphorus by weight (NH. Rev. Stat. § 485-A:56, 2016). The same issue was encountered regarding this lack of transparency when researching the products listed in the business survey. The phosphorus contained in commercial cleaning products is not restricted in concentration by any form of legislation, or required as a listed in the ingredient on the packaging. When researching some of the commercial cleaning products used in the town and their material safety data sheets, no information about phosphorus was given. This was found to be true with many different residential cleaning and hygiene products as well, and the class decided to use the aforementioned methods to test these products. Using the survey data, the lab group took the top eleven products and tested them for their phosphorus content, but ran into many roadblocks along the way.

Detergent Analysis-To test the most commonly used products as determined by the residential survey, current methods of analysis were modified to accommodate for the color and opacity differences between soaps. Several challenges appeared when applying this method, most notably that the samples did not react as expected with the digestion process and the addition of the color reagent. Because of this, most of the results were inclusive, however both "Tide Original Laundry Detergent" and "Cascade Actionpacs" reacted to the procedure as expected. What was found from these products is that "Tide Original Laundry Detergent" contains little to no phosphorus, and that "Cascade Actionpacs" contain close to the maximum legal limit of elemental phosphorus. The survey results indicate that each of these products were used by approximately 15%-16% of respondents connected to the public sewerage system.

Sampling and Analysis Limitations-It is important to note that each grab sample represents only a single moment in time and that sites being sampled at different times could impact the accuracy of any comparisons made between them. These phosphorus load calculations are only relevant for the exact time that the samples and discharge readings were taken, so the measurements may not be an accurate representation of the site's total contribution to the sewerage system. Taking repeat samples of each site helps to compensate for this gap in the data, as an average of 19 grab samples is a more accurate indicator of a site's total phosphorus load than a single grab sample. Samples and discharge readings were only taken from 8AM until around 1PM, and because of this the data only portrays phosphorus dynamics during this time period. This has been one of the greatest challenges of this study, however in future studies it could be remedied by using an autosampler.

There is a composite autosampler at the “Townline” sample site, which gathers data on discharge and compiles a sample over a 24-hour period. The issue with this is that the “Townline” sample accounts for the total phosphorus load of the day prior to the sampling procedure. It was therefore impossible to verify that the samples collected throughout the day add up to the total depicted by the “Townline” site. To remedy this in a future study, it was recommend sampling with autosamplers one day, and collecting the townline sample the following morning.

During the second half of the project, the winter weather was often a challenge in the way of completing weekly sampling procedures. Because sampling took place in a town-owned system, a member of New London Public Works had to be present with the sample crew to open each manhole. The onset of winter presented several challenges to the sampling procedures, including school cancellations, winter break, and more urgent tasks for New London Public Works. Throughout the duration of the study, issues with equipment quality and functionality were a recurring theme. The flowmeter used to measure discharge had several malfunctions that prevented it from collecting data.

In addition to the data collection and analysis, the team was asked to update the Town of New London’s sewerage maps and create an overlay consistent with their existing tax maps. Several issues surfaced while working towards this goal, which hindered overall progress in delivery of the desired product. The most current maps that were available to work with had not been updated since 1996, leaving a large gap in pipeline and site data. To attempt to bridge the gap, both CAI Technologies and Horizon GeoSpatial were contacted, as these organizations were enlisted to supervise and create maps for several more current pipeline projects. These firms were able to provide some of the updated pipeline maps, however the class was not able to fully update the sewerage maps and are still missing several pieces needed for a fully updated map.

The purpose of this study was to find sources of high phosphorus loads within the town sewerage system, and recommend alternative products for that area. One project intention was to create a list of “phosphorus-free” products for the town and making it available to the community. However the current regulations and practices within the soap industry, as well as the previous challenges testing the soaps, resulted in an inability to create a list of products that could be confidently recommended to residents and businesses. In the future, it would be important to research the phosphorus content in products to a far greater extent.

Recommendations-Although the study was highly effective in identifying where high phosphorus loading is occurring in the sewerage system, there were numerous challenges in identifying which products contain excess phosphorus and which ones can be safely recommended. This product information would be important to have for any future outreach campaigns, and ultimately in remediating the high phosphorus loads entering the Sunapee Wastewater Treatment Plant. Because of this, the best recommendation at this point is to conduct further research on cleaning product usage and phosphorus content, in addition to studying the phosphorus dynamics within the New London sewerage system more thoroughly.

Using an autosampler would provide a composite sample from the previous 24 hours to better understand the amount of phosphorus moving through that site. Near the end of the semester the class was able to acquire an autosampler and test this process. One challenge with this method was that fitting the autosampler and the flowmeter in the manhole was difficult due to size constraints; for future studies, it would be prudent to acquire an autosampler that has a system for measuring discharge built in to avoid this. In addition, reaching out to organizations and labs that test soaps for their phosphorus content in order to determine what procedures they use to account for the color and opacity of cleaning and hygiene products would be of high priority as well. Further dye testing should also be conducted to determine the complete layout of the sewerage system, or enlisting the help of professionals to fully update the pipeline map. In terms of the survey, it would be advisable for future projects to administer a survey through the mail in addition to an electronic version. The usage of an electronic survey was an effective method to keep data analysis organized, however, using a paper survey sent through the mail would help to record responses from a larger sample size. In future studies it would also be preferable to see product research being conducted at the town transfer station or with the assistance of recycling and trash pick-up services, depending on the area. This would allow stakeholders to get an idea of what products are being used by seeing what products are being thrown away. Finally, reaching out to the community ahead of important presentation and informational release dates would be beneficial to increasing the awareness of the project. Because of this, the community missed out on two informational presentations as well as a radio interview, that would've helped to greatly increase the understanding of phosphorus dynamics in the town sewerage system.

Acknowledgements

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Appendix

Appendix A. NHDES Total Phosphorus Method

The New Hampshire Department of Environmental Services Total Phosphorus Methodology is used in laboratories around the state to monitor total phosphorus concentrations in surface waters. For the purposes of this study, samples were diluted more than this document recommends because otherwise the absorbances would be too high for the instrumentation to read.

Link to NHDES Total Phosphorus Method

Appendix B. Quality Assurance & Quality Control Manual

The Quality Assurance & Quality Control Manual used in this study was developed by the students with the help of outside materials (see Appendix A.), and professor oversight. This document contains all procedures, materials, corrective action contingencies, bench sheets, and checklists used throughout the study.

Link to Quality Assurance & Quality Control Manual