WATER QUALITY ANALYSIS OF EFFLUENT DISCHARGE EFFECTS ON THE SAMPIT RIVER FROM INTERNATIONAL PAPER MILL IN GEORGETOWN, SOUTH CAROLINA

Photo By: Amanda Macek, depiction of Sampit River at the Arcelor Mittal Georgetown Steel Mill

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Abstract

Pulp and paper mills are hypothesized to be leading contributors to environmental pollution through the dumping of effluents into local waterways. While in the past, this assumption was more or less correct, modern treatments and procedures have effectively reduced the impact mills have. Expanding on a study conducted by the National Council for Air and Stream Improvement (NCASI) that evaluated four US paper mills to determine the exact environmental impact, students from Coastal Carolina University took samples from a local International Paper mill in Georgetown South Carolina on September of 2014 to determine the water quality at the mill dumping site and below it. Testing parameters included dissolved oxygen, phosphorous, nitrogen, chlorophyll, conductivity, chlorophyll and pheophytin. While samples were only taken only once, results were inconclusive as to whether the mill effluent discharge had caused any increase to the parameters, which would result in environment damage. These inconclusive results matched results from the study conducted by NCASI, who concluded paper mills were not the greatest anthropogenic contributor to water way pollution.

Introduction

The Sampit River runs through Georgetown County coming in contact with several big industries, including the Arcelor Mittal Georgetown Steel mill and the International Paper mill. The river has several concerning factors of effluent discharge in the water column. International Paper was questioned to be one of these effluent discharges. Students collected samples from the Sampit River, located in Georgetown, SC on September 27, 2014. Students focused on International Paper and the water quality of its surrounding waters by comparing instantaneous data to previous studies. Environmental parameters evaluated included phosphorous, nitrogen, pheophytin, chlorophyll, temperature, salinity, dissolved oxygen, following modified EPA

methods to account for the length of time between samples and lab analysis. Water quality is important for several reasons. One being the importance of determining specific water quality problems that are due to human impact to better correct the problems and prevent further issues. Two, to understand and correct any possible negative impacts caused to the environment which is turn also affects humans as water ways provide an important local food source. Both of these are issues of extreme importance for International Paper.

Background

Paper and pulp mills use a variety of manufacturing techniques, depending on the type of wood or recycled product used, and if there is a bleaching process or not. Kraft mills are the dominate mill type making up 70% of the world's paper making process. Kraft mills use chemicals to break down wood and recycled materials (Männikkö, 2014). The process starts by taking raw wood or recycled matter through a cleaning process. Waste water from cleaning contains solids, dirts, and fibers all of which have very high biological oxygen demands (BODs), chemical oxygen demands (COD's), absorbable organic halogens (AOX). Second, the clean matter is taken to a digester where a "black liquor" is generated, a byproduct from the breakdown of ligin fibers. This waste contains some ligin, acids, BOD, COD, acetones, alcohols, and dioxins. Dioxins are a general term for the array of chemicals used that contain hydrogen, chlorine, oxygen, and carbons. From here the matter which is now termed pulp, goes to pulp washing and bleaching to further purify the product and obtain the crisp white finish. In this step wastewater contains bleach and more BODs and CODs. The final step is the paper making product where fibers are smashed together and dried. (Männikkö, 2014).

The exact environmental impact caused by the effluent discharge depends specifically on the mill and treatment style, but common chemicals used in each include dioxins, nitrates, BODs,

CODs and AOXs. Dioxins are linked to causing cancer by building up in the fatty tissues of exposed organism that can be transferred and accumulate up trophic levels all the way to humans (United States Environmental Protection Agency, 1999). Besides cancer dioxins can cause birth defects, and cause hormonal deficiencies as found in fish (Rosa, 2010). Excess BODs, CODs, and AOXs deplete surrounding water of the available oxygen making the environment uninhabitable. Freshwater and coastal marine ecosystems are harmed primarily by eutrophication which is a result of an increase in nutrients. Extra nutrients and phosphorus fuel accelerated algae and plant growth which lead to blooms and eventually fish kills. One other cause of eutrophication is from the nitrogen cycle introduced in the paper and pulp making process (Chislock, 2013).

The nitrogen fixation completed in the Nitrogen cycle is done in two different ways, including biological fixation, which occurs naturally, and industrial fixation. Industrial fixation occurs in pulp and paper mills. Some mills use the Haber-Bosch process to complete this cycle for successful papermaking. This process uses iron catalyst to make ammonia and other nitrogen containing compounds from nitrogen and hydrogen (Gauthier, 2000).

Pulp and paper mills depend on the bioavailable "fixed" nitrogen in the system. This is for the reduction of dinitrogen gas to ammonia. Nitrogen fixation requires key nutrients, including available carbohydrates for energy, low fixed-nitrogen concentration, and absence or low concentration of DO. Due to the wood material of the mills there is a high carbon to nitrogen (C/N) ratio. To prevent any excess, precise dosing of nitrogen and phosphate is a crucial part in the pulp and paper making process. If there is excess nitrogen it may result in fish toxic free ammonia, and subsequently, gill damage. However, if there is not enough nitrogen it can cause microorganisms to die. A surplus will cause the nitrogen cycle to be in excess, including the

processes of nitrification and denitrification. This will lead to an excess of nitrogen, resulting in a decrease of biosolids in the reception waters.

Nitrogen fixation has been accounted for in aerated lagoons in previous studies (Gauthier, 2000). With this knowledge, testing can be accomplished by detecting N_2 in primary clarifiers and bioreactor ecosystems in pulp and paper mills. However, there are several setbacks making it difficult to study the nitrogen in these tanks. One setback is due to the high DO level in aeration tanks and secondary clarifiers. Another setback is due to the methodically addition of NH_3, ammonia. Last, there has been found low levels of free sugar due to the carbon and energy resource from the activated-sludge. This sludge can is found in the primary clarifier, which is an unmixed tank that removes suspended fibers and particles from the wood in the process. Each of these setbacks makes detecting the nitrogen fixation more difficult because of the lack of essentials the mill has incorporated.

There has been previous studies on the nitrogen fixation process being performed in pulp and paper mills. A study was conducted in eastern Canada on several paper and pulp mills. There were a total of seven mills that were tested on that contracting effluents through different processes. The types of mills had two types of furnish, including hardwood and softwood. These furnishes can undergo several different biotreatment processes. The softwood furnished mills consisted of thermomechanical processes for newsprint products, bleached kraft paper and pulp processes, and sulfite pulping processes for newsprint products. The hardwood furnished mills consisted of bleached kraft processes for fine papers and market pulp products (Gauthier, 2000).

By taking indirect measurements of nitrogenase activity, or acetylene reduction (AR) and functional gene probing, researchers were able to collect datum represented in the primary-clarifier. The nifH probes signal intensity and average insitu nitrogen fixation activity. The data

was then compared to the results of the rates from the aerated lagoon systems. This research concluded that nitrogen fixation correlates with depth, and nitrogen is captured in activated sludge (Gauthier, 2000).

A second comparable study was conducted between 1998 and 2006 by the National Council for Air and Stream Improvement (NCASI). The goal was to understand, establish and report paper mill and pulp relations in regards to effluents, biological, and ecological effects in a range of stream types, with a variety of paper mill types and water treatment processes. The wide variety of environments allowed for variables to be taken into consideration, such as weather, seasonal changes, water type (fresh, cold vs. warm, river shape, and anthropogenic point sources), and biological (fish, invertebrates), which provided a baseline for "normal" conditions unique to each area. The length of the study allowed for understandings between annual cycles, isolated events, solving temporal and spatial scale issues not addressed by short term studies. Four points of interest were highlighted that served as the framework for the study, 1) determining the environmental compatibility of mill effluents and corresponding margins of safety against adverse impacts, 2) documenting improvements in environmental quality as contaminate waste loads are reduced, 3) providing as early indication of any important adverse impacts related to mill effluents, 4) extending the framework for interpreting new and subtle measures of aquatic organism and ecosystem health (Hall, 2009). This study took into consideration pH, conductivity, chlorophyll, nutrients, nitrate, phosphorus, and dissolved oxygen which were similar parameters used in taking samples of the Sampit River.

International Paper is the world's leading and largest paper and pulp producer and built the Georgetown paper mill in 1937 followed by updates and modifications in the 1980s-1990s. Annually the mill payrolls $60 million to employees and retirees, making it the backbone for the

Georgetown community and neighboring counties with an overall positive economic impact of $200 million statewide. The mill is a bleach kraft paper and pulp mill responsible for producing file folders, pulp, ReelCote, and wallboard tape and specialty envelopes (International Paper). Pulp, the main export is used in the production of diapers, packaging, and is one of the most recycled products.

International Paper continues to face challenges dealing with their environmental impact through the discharge of effluents into local water sources. After being faced by fines and acquisitions of contamination, International Paper has worked to become a more environmentally friendly company. In 2009, International Paper Mill in Georgetown, SC faced lawsuits from 135 local community members claiming alleged pollutants from International Paper were having negative impacts to their health and properties. The cases, Anderson vs. International Paper, and Winley vs. International Paper, were later dismissed by the South Carolina federal court for failure to provide adequate data and specificity to the health and property damage that was occurring due to International Paper.

Methods and Materials

Field Procedures

Sampit River samples were taken at varying locations to include samples at the dump site and downstream (Figure 1). At each site samples were taken from water collected by a bucket thrown over the boat in clean plastic bottles and stored over ice to slow biological activity until each was analyzed in lab. Each site was measured for salinity, chlorophyll, nutrients, dissolved oxygen, temperature, nitrogen, conductivity, and phosphate and each bottle was marked accordingly. The parameters measured had their own set of pre-cleaning, sampling, and sample

storage criteria. Other parameters, such as temperature and salinity, were measured immediately after the samples was collected.

September 27, 2014, was cloudy with light rain, no wind, and a temperature of 71 degrees Fahrenheit. The tide schedule showed flood (rising) tide was at its peak at noon. This is important because the International Paper Mill in Georgetown releases its water discharge in accordance with the falling and rising of the tide. Paper plants tend to release at the beginning of ebb (falling) tide. The theory behind this release is so all discharge can travel out with the tide instead of lingering in freshwater sites or travel upstream. One main goal of the research trip was to be on site when the plant released so the best water samples possible could be gathered.

The research team arrived on the East Campus of Coastal Carolina University at 10:40 AM. All members were accounted for as the proper gear for water sampling was gathered. Gear included: gloves, eighteen water sample bottles, five-gallon bucket, Hanna Meter, data charts, notebook, and ice cooler.

For each site, the location, date and time of sampling, tide stage, water temperature, dissolved oxygen, salinity, pH, and depth was recorded in a data table. Also included is a description of the sampling site, weather conditions at the time of sampling, potential pollution sources, and times of low and high tides. At each site, six water samples were collected in clean plastic bottles.

At 13:10, the team was en route to Site 1. This site was located on the Sampit River directly in front of International Paper's waste water release canal. The river is a black water river system. It has a dark tone due to the decaying of organic material. By 13:25, the team arrived to Site 1, located 33º 21´ 29.9 N- 79º 18´ 52.4 W. The depth of the water was eight to ten

feet. According to the captain, the water at this site often turns yellow and has a strong unpleasant odor. The five gallon bucket was rinsed with water from that site and brought aboard. Six samples were gathered and stored properly in the respective containers, then packaged on ice. The use of the Hanna Meter collected all data including salinity and dissolved oxygen. All data was compiled on the data chart by 13:29.

Site 2, traveling out the mouth of the Sampit and entering Winyah Bay, a mile downstream from Site 1, the same techniques were used. At 13:45, water samples were collected into six bottles. It was apparent there was a change in the water color. The color was much clearer. Reasons for the change included leaving the black water river system upstream and entering an open bay. The location of 33º 21´ 28.6 N- 79º 17´ 29.5 W was not directly in front of the discharge site. This site's water depth was fifteen feet and a usual tide range of four feet. Salinity, temperature, dissolved oxygen were processed using the Hanna Meter. By 14:15 PM, samples were taken at Site 3. This site was .75 miles from Site 2 and the water was less turbid. The depth was twenty feet and the location was 33º 21´ 00.5 N- 79º 16´ 47.2 W. All six samples were taken.

Lab Procedures

-Chlorophyll and Pheophytin

The health of phytoplankton population can be determined by finding the relative concentrations of chlorophyll and pheophytin in the sample. A 25 mm glass fiber filter was placed onto a filtration apparatus. 100 milliliters of the sample was poured into the filtration apparatus and filtered under a .5 atmospheric pressure vacuum until no water seemed to be dripping through the filter. The filters were then placed into a centrifuge tube with 10 mL of 90%

acetone. They were shaken for five minutes before allowing sitting in a dark refrigerator for one hour.

After sitting, the tubes were centrifuged for five minutes at room temperature. Five milliliters of the solution was transferred into a fluorometer cuvette. The fluorometer was zeroed and the cuvette was inserted to find the fluorescence reading for the chlorophyll. Two drops of 5% hydrochloric acid were added to find the new reading, which was the pheophytin, or dead phytoplankton reading.

-Phosphorous Concentrations

Using 100 mL of the sample in a flask, a mixed reagent, ammonium molybdate and antimony potassium tartrate, was added and mixed immediately. The reagents combined created antimony-phospho-molybdate complex. After seven minutes, the absorbance wavelength was recorded. Using Excel, the absorbance values were graphed and using the slope equation, the concentrations of the phosphorous were calculated into parts per million.

-Nitrate Concentrations

Using 15mL of sample in a Falcon tube, a packet of NitraVer6 Nitrate Reagent Powder was added to the sample. The tube was shaken vigorously for three minutes and left to sit to allow the solid deposits to settle to the bottom. Then, 10mL of that solution was transferred to another Falcon tube without disturbing or transferring the cadmium particles. The contents of a packet of NitriVer3 Nitrate Reagent powder was added and shaken gently for three minutes. After 20 minutes, the absorbance of the solution was recorded.

-Chlorine Testing

Multiple samples from each site were tested using chlorine strips from Hach that tested for total chlorine and free chlorine. 10 ml of each sample was tested with a different strip each time.

Results

Upon arrival in Georgetown it was noted the parking lot was flooded from the swelling tide and eventually receded back out. In transit to the first site, floating derbis of logs and trash were observed. At Site 1, there was large amounts of organic debris floating in the water, and the banks were lined with decaying trees and plants. The water had a deep brown to yellow color. This also resulted in a higher turbidity. There was also a very pungent smell associated with the paper plant. Site 2 had much "better" looking water than the previous site, the water still had a brown tint but was more transparent. The phosphorous odor was also gone at Site 2, and there were still decaying trees along the bank but where more sparse compared to Site 1. At the third site, there were little to no trees, but there was more grasses like *Spartina altrniflora*. The banks also widened considerably as it the water mixed with the Black River and Waccamaw River. The water was the most transparent and had a slightly bluer tint to it.

At each of the three sites along the Sampit River in Georgetown, South Carolina, several parameters of water quality were taken. These included temperature, dissolved oxygen, pH, conductivity, turbidity, and salinity. These readings were collected using a Hanna meter. Also, Nitrogen levels, Phosphorus levels, Chlorophyll, Phaeophytin, and Chlorophyll to Pheophytin ratios were found after lab work and calculations.

For Site 1 the temperature was 24.12ºC, DO was 43.69 percent saturation, pH was 7.75, conductivity was 5500, turbidity was 30.1 FNU, and salinity was 2.9psu. The Nitrogen levels

resulted in a mean of 0.446666667ppm. The Phosphorus levels retained a mean of 0.081666667 ppm. The Chlorophyll measurements resulted in a mean of 1.952666667 mg/m3. The Phaeophytin measurements resulted in an average of 0.398266667mg/m3. The C/P ratio was 4.9029. This site tested negative for chlorine.

At Site 2 the temperature was 24.93ºC, DO was 65.5 percent saturation, pH was 7.38, conductivity was 1178, turbidity was 11 FNU, and salinity was 6.7psu. The Nitrogen levels resulted in a mean of 0.259333333 ppm. The Phosphorus levels had a mean of 0.008666667 ppm. The Chlorophyll measurements resulted in a mean of 0.363366667 mg/m3. The Phaeophytin measurements resulted in an average of 0.319333333 mg/m3. The C/P ratio was 1.1378. There was no chlorine at this site.

At Site 3 the temperature was 24.21ºC, DO was 61.6 percent saturation, pH was 7.28, conductivity was 8370, turbidity was 9.8 FNU, and salinity was 4.69 psu. The Nitrogen levels resulted in a mean of 0.099666667 ppm. The Phosphorus levels retained a mean of 0.008333333 ppm. The Chlorophyll measurements resulted in a mean of 0.80516667 mg/m3. The Phaeophytin measurements resulted in an average of 0.38493333 mg/m3. The C/P ratio was 2.0917. This site had no chlorine present.

The averages of the data collected can be found in Tables 1 and 2 and represented in Figures 2, 3, and 4. Site 1 showed high nutrients and a low dissolved oxygen percent saturation. Site 2 had the lowest nutrients of the sites as well as the highest dissolved oxygen percent saturation. Site 2 had a lower dissolved oxygen percent saturation and a lower salinity than Site 3 but both were higher at this site than at Site 1.

Discussion

Through the sampling on the Sampit and lab analysis, results were determined to be inconclusive. Part of this is due to the inability to preform further tests on specific chemicals present in the water. A second issue is that samples were single, instantaneous results, meaning other factors such as the weather, location, and other anthropogenic sources could not be properly accounted for.

There were two different water masses mixing, the river and the waste water, so getting a true reading for any of the parameters using the Hanna meter was difficult. The Sampit River also mixes with two other water ways, The Waccamaw, The Black River. The level and type of pollutants in each of these rivers was not studied or known thus there possible impact on the Sampit is also unknown. As there were only three sample locations the changes in regard to location were only lightly studied. As the sites got further away from the dump site multiple changes were observed, leading to general increase in water quality.

The higher nutrient and lower DO percent saturation at Site 1 could be explained by the fact the waste water was flowing through a canal that was lined with trees. The leaves falling into the canal when there is no water flowing through it can cause an accumulation of organic matter which is then blown out with the waste water resulting in higher concentrations of nutrients. This may also have been a contributing factor to the yellow discoloration of the water in the area as well. The higher salinity at Site 2 is most likely a result of being so close to the Steel Mill. Excess Nitrogen from effluent runoff was not found from possible misdosing the Nitrogen in the industrial process.

The data present in the Nitrogen profile for each station defines the conclusion found in the Eastern Canadian mill study. The conclusion of nitrogen fixation from this study correlates with our data found. Nitrogen has been found through nifH gene detection in the activated sludge, a byproduct of pulping process (Gauthier, 2000). This allowed students to conclude the activated sludge is not increasing the nitrogen levels in the Sampit River and canal. The decreasing rate of nitrogen is a vital data set, concluding the environment is not being affected by the effluents of activated-sludge being released. If the environment was impacted, there would be an increase of nitrogen with the increase of depth. There would also be an effect on the biological activity, such as a decrease of fish population within the environment. Future research can be conducted focusing more on the biological impact in the environment that is relative to the nitrogen values.

Conclusion reached by the NCASI study were the same conclusions reached by analysis of the water samples from the Sampit River. While there were elevated concentrations of nutrients, low dissolved oxygen, increased organic matter, limited visibility and photosynthesis the source of pollutants was found to not be limited to only paper mills. General environment conditions had a large impact on overall water quality, including turbidity, mixing, sediment type, river shape, and biological processes. In two of four sites other anthropogenic sources such as storm water runoff, agriculture, and construction had significant impact on pollution levels. Relations were also found between the amount of pollutants and the mixing patterns unique to the environment. The two rivers with the highest pollution level mixed with other major water ways that carried other pollutants. Overall NCASI stated there was not significant evidence to blame paper mills for the pollution in the water waters (Hall, 2010).

Besides the lack of chemical evidence of water pollution from the mills there is a historical lack of pollution evidence specific to the Georgetown mill. The cases in which International Paper was being sued failed to prosecute the mill on any charges. As federal Judge C. Weston Houck stated,

> The court finds that the plaintiffs' complaints are lacking in specific facts to support required elements of each of their causes of action. Moreover, although the plaintiffs allege injuries to themselves and to their property, the complaints are devoid of details regarding physical ailments or property damage; cancer, birth defects or serious, disabling and life-threatening diseases and health conditions…. Does not answer the most fundamental questions in this type of tort suit: 'When did the purported releases from the mill occur?' 'What was the source of the alleged emissions?' 'Through what pathway — air, water, or otherwise — did emissions travel to impact plaintiffs?

In further agreement to the case dismissal even the lawyer representing the 135 community members, Ed Bell stated the judge's ruling was a "really good order" (Chiem, 2012).

In a short interview with Nancy Cave of the Coastal Conservation League further support of International Paper was expressed. When asked what the relationship and standings were between International Paper and the Coastal Conservation League she replied with "During court cases in 2009, CCL monitored the situation and was preparing to take part in supporting the community members, but, the cases were not pursued. Since 2009, IP has worked towards making better changes and today there is neither a positive or negative relationship between IP and CCL." When asked where she and the League felt their presence was more important she expressed their concerns with Santee Cooper Coal plants and the corresponding coal ash and air pollution taking place in their power plants.

In a yearly progress report for International Paper the company expresses their goals set for year 2020. These goals include reduction of energy use, clean air discharge, clean water discharge, and to set up more sustainable resources. Since 2010 the company reports a worldwide drop in effluent discharge from 25.97 million Kg to 19.09 million Kg in 2012. This is due to their secondary treatment processes that use anaerobic processes to reduce BODs, CODs. In order to reach their 2020 reduction goals the company began mapping water ways where mills were located in 2013. In 2015 the company will release plans unique to each mill and site for new water treatment systems. In recent years the company has also started using left over solid matter as fuel to burn, which turns their turbines and generates their own electricity. Overall the company works with several large world environmental conservation agencies, including World Wildlife Fund, The Nature Conservancy, The National Fish and Wildlife Foundation to name a few. Besides their cooperation with conservationists international Paper has several awards and recognitions, one from Fortune Worlds Most Admired Companies in 2013, ranking them first in Forest and Paper Product Industry. Besides having to legally abide by National Emission Standards, and limit discharge as set by the Central pollution Control Board, International Paper continues to work, by their own will, to become more environmentally friendly (International Paper, 2012).

Conclusion

Water quality analysis of the Sampit River at the International Paper dump site, and away from site lent results that were inconclusive as to whether the water pollutants came solely from the mill, and if those possible effluents were in such high concentrations that they were a reasonable environmental threat. These conclusions were like those of the NCASI study which found other anthropogenic pollutants. Results are also backed by the history of the mill which

has failed to be persecuted for any pollution harm, and their current good standing with the local Coastal Conservation League. In Georgetown there is a variety of other possible pollutants including but not limited to the Steel Mill, Santee Cooper Power Plants, storm water runoff, and boat pollution. To gain a better understanding of the unique area further studies can be done to look at the water quality around other anthropogenic sources, and in mixing zones across the Sampit. It would also be important to relate biological processes to nitrogen results.

Tables and Figures

Figure 1: Yellow pins mark sampling sites, site 1 is the dump location for International Paper marked in the red. Site 2 is in close proximity to the Steel Mill marked by the red. Blue markers indicate the other water masses and where the meet with the Sampit, close to site 3.

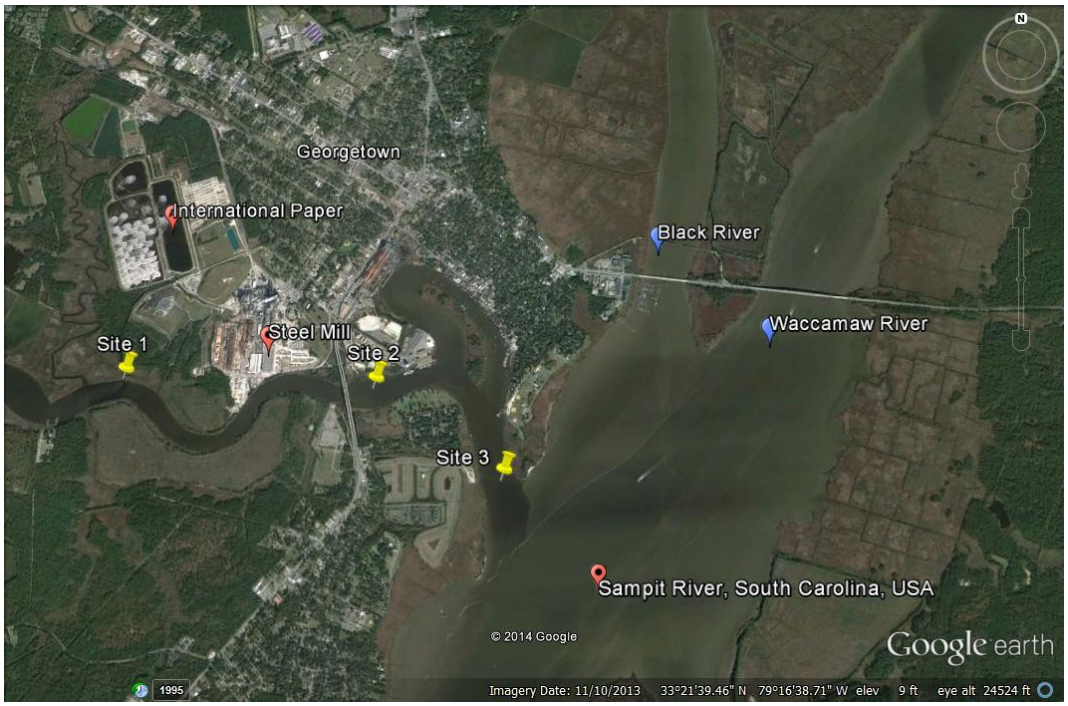


Figure 2. Averages of chlorophyll and pheophytin concentrations in mg/m3. Results indicate decreasing trends as the sites got further away from the dump location.

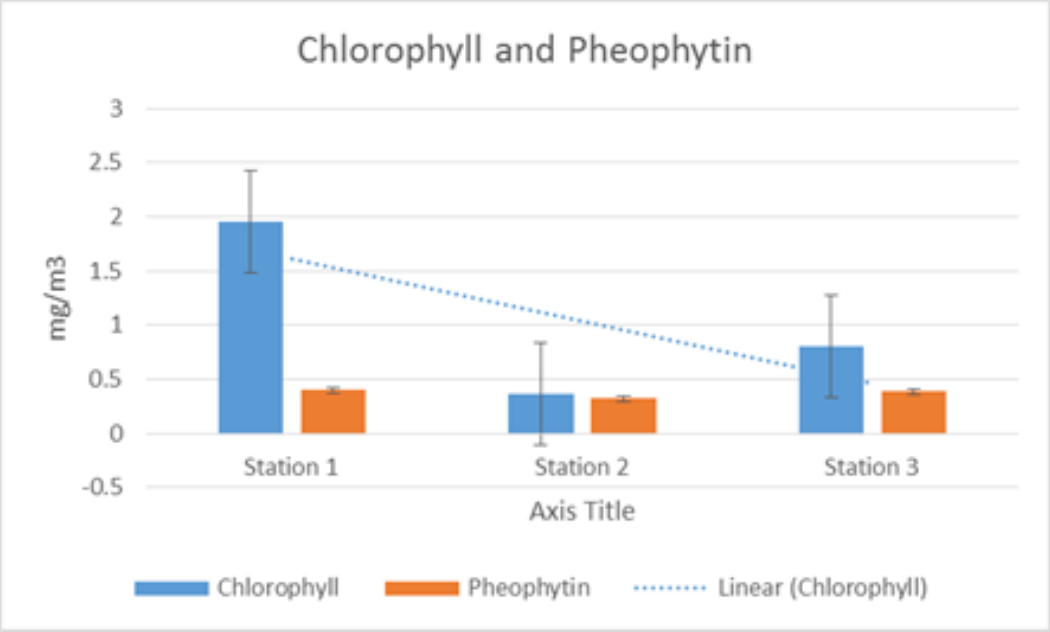


Figure 3. Average phosphorous concentrations in parts per million. Results show a decrease as the sites get further away from the dump location.

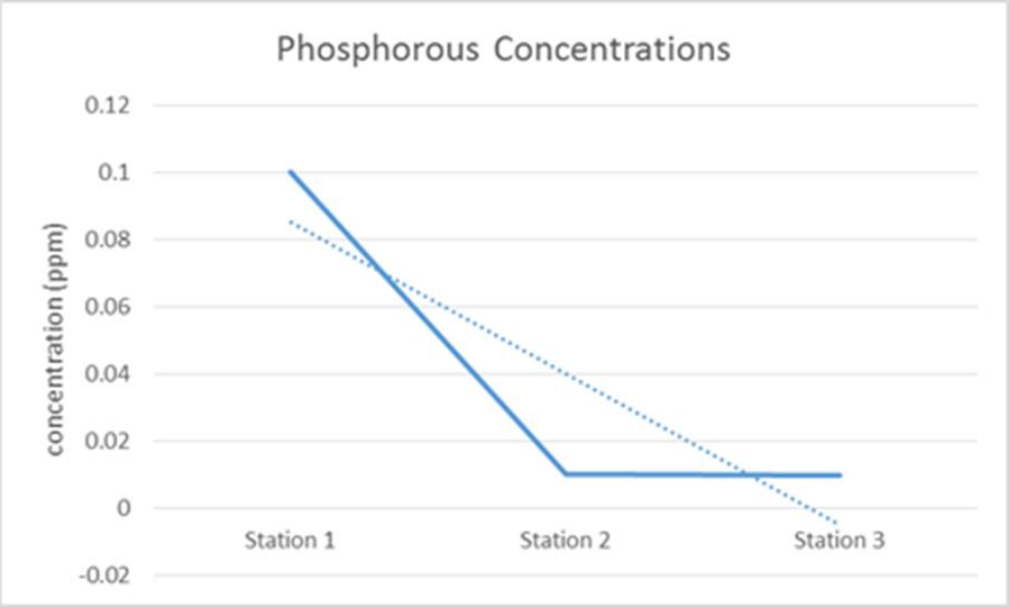
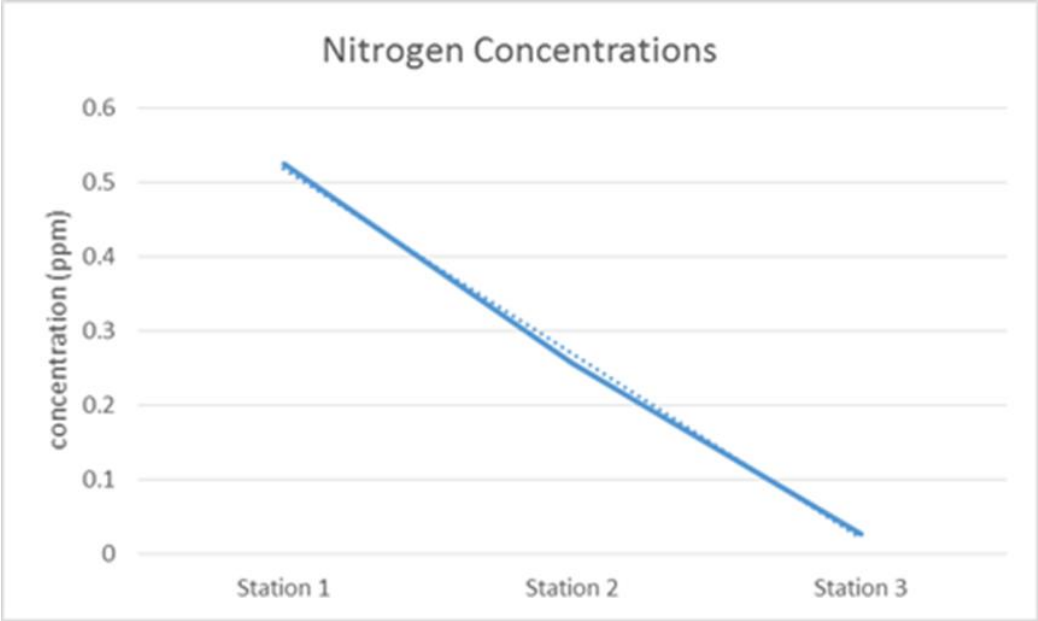


Figure 4. Average nitrogen concentrations in parts per million. Results also show a decreasing trend in nitrogen as the sites moved away from the dump location.



	Temperature (degrees Celsius)	D.O. (percent saturation)	pH	Conductivity	Turbidity (FNU)	Salinity (psu)
Station 1	24.93	43.69	7.75	5500	30.1	2.9
Station 2	24.12	65.5	7.38	1178	11	6.7
Station 3	24.21	61.6	7.28	8370	9.8	4.69

Table 1. Average values collected from Hanna meter.

	Nitrogen (ppm)	Phosphorous (ppm)	Chlorophyll α (mg/m^3)	Pheophytin α (mg/m^3)	Chlorophyll/Pheophytin
Station 1	.5256	.09999	1.9527	.3983	4.9029
Station 2	.2568	.0102	.3634	.3193	1.1378
Station 3	.0276	.0098	.8052	.3849	2.0917

Table 2. Average parameter concentrations as analyzed in lab.

Annotated Bibliography

Chiem, Linda. Flanagan, Rebecca. (2012, October). *International Paper Pollution Suits Too Vague, Judge Says*. Law360. http://www.law360.com/articles/389021/international-paper-pollution-suits-too-vague-judge-says

Source provided information on the court cases against International Paper in 2009 involving the 135 community members. Specified reasons and details about the cases. Source also provided quotes directly from the judge and lawyer.

Chislock, Michael. Doster, Enrique. Zitomer, Rachel. Wilson, Alan. (2013). *Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems.* Nature Education. http://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466

Eutrophication in lakes and ponds are experiencing increasing rates of limiting nutrients, including nitrogen and phosphorus. The increasing rate will create toxic blooms of noxious, reducing the water quality. Improving and protecting the waters from cultural eutrophication is a large environmental issue.

Gauthier, Francis. Neufeld, Josh. Driscoll, Brian. Archibald, Federick. (2000). *Coliform Bacteria and Nitrogen Fixation in Pulp and Paper Mill Effluent Treatment Systems*. http://aem.asm.org/content/66/12/5155.full

Normal biomass growth is allowed in pulp and paper mills because of the large amount of ammonia being added to the aeration tanks. This is to allows activated-sludge microorganisms to fix significant nitrogen. All pulp and paper mill clarifiers tested positive for active N2 fixation.

International Paper. (2012). *Sustainability Report.* 2013 International Paper Company.

Detailed book source from International Paper releasing recent sustainability values involved in all aspects of the company. In particular values looking as discharge rates into waterways was used in the paper, millions of kg of effluents dropped in 2012 to 19 from 22 in 2010.

http://www.internationalpaper.com

The direct website for International Paper provided information on the Georgetown Mill and how the paper and pulp making process worked.

Männikkö, N. F. (2014). *Pulp and paper mills.* Salem Press Encyclopedia,

The source provided information on the Kraft mill processes while providing statistical values. Source also did a short overview on the paper making process step by step.

Rosa, R., Moreira-Santos, M., Lopes, I., Silva, L., Rebola, J., Mendonça, E., & ... Ribeiro, R. (2010). *Comparison of a test battery for assessing the toxicity of a bleached-kraft pulp mill*

effluent before and after secondary treatment implementation. Environmental Monitoring & Assessment, 161(1-4), 439-451. doi:10.1007/s10661-009-0759-2

Source provided background on the effect dioxins have on fish. Source found dioxins interrupted and inhibited sex organs causing fish to mature earlier. Conclusions suggested secondary treatments as an effective way to limit BODs, CODs in the water ways.

Timothy J Hall, Renee L Ragsdale, William J Arthurs, Joan Ikoma, Dennis L Borton,` and Diana L Cook. (2009, November). *A Long-Term, Multitrophic Level Study to Assess Pulp and Paper Mill Effluent Effects on Aquatic Communities in Four US Receiving Waters: Characteristics of the Study Streams, Sample Sites, Mills, and Mill Effluents.* Integrated Environmental Assessment and Management, 5(2), 199-218.

Source served as the comparative study in regards to methods, and results. The study took place in the US, in 4 waterways that were situated next to paper mills. Samples were taken above the dump location and at the dump location. Study concluded there was not enough evidence to blame paper mills for all water way pollutants, that there were many other anthropogenic sources providing pollutants.

The United States Environmental Protection Agency. (1999) *Polychlorinated Dibenzo-p-dioxins and Related Compounds Update: Impact on Fish Advisories*. http://water.epa.gov/scitech/swguidance/fishshellfish/outreach/upload/1999_11_02_fish_dioxin.pdf

Source was used to determine environmental and physical effects dioxins have on the environment and people. Also provided toxicity reports in affected areas.

Appendix

Friday, November 14, 2014. MSCI, Environmental Issues. Nancy Cave, Coastal Conservation League.

During an in class presentation about the Coastal Conservation League and some of their current and past projects, questions were taken. Amanda Macek was able to ask a few questions in regards to CCL relationship, and opinion of the International Paper mill in Georgetown South Carolina. While being aware of the mill and their past struggles (lawsuits) she expressed they had no current problem with the mill and that a relationship between the two companies was non-existent. Further questioning on where CCLs concerns were, revealed their focus on Santee Coopers coal power plants and some on the Steel mill.