A Summary of the Negative Effects caused by Pulp and Paper Mill Effluents in Estuarine Systems
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ABSTRACT:
The pulp and paper mill industry is important to the global economy because it generates thousands of jobs and billions of dollars. The United States in particular is a key player in the production of pulp and paper. As with any major industry, there are problems that arise during production. For the P&P mills this can be mainly seen in air and water pollution. This paper will focus on the types of P&P production commonly seen in the United States as well as the pollutants that they produce and possible treatments for the contaminated effluences. Harmful chemicals that are frequently released into wastewater include PCBs, dioxins, and furans. The effects that these toxins have on biota normally seen in estuarine environments were also reviewed using international studies. Studies on bony fish, bivalves, and marine mammals were assessed and all showed that these toxins have the ability to cause some type of biological disturbance to the organism’s normal body function. Overall, the data reviewed in this study showed that at the current level of regulation worldwide, P&P mills have the potential to release toxins that can affect ecosystems in a bottom-up fashion.
INTRODUCTION:

In the United States, the pulp and paper industry represents an important economic and practical resource. As of 2008, there were 597 P&P mills operating in the United States alone who are known to produce over 9 million tons of pulp annually (US census bureau, 2012). On the global scale, the US accounts for 35% of all pulp produced and 16% of the total number of P&P mills (EPA, 1997). Like any large industry, it has its fair share of problems. One continuous problem is the release of toxic chemicals into the environment. P&P mills have a long history of dumping toxic chemicals, such as dioxins, polychlorinated biphenyl (PCBs), furans, and Absorbable Organic Halide (AOX), into estuarine environments. Data collected from past practices, experiments, and reports from international paper mills show these pollutants diminish water quality and disrupt the aquatic ecosystem.

This paper will focus on the effects of the wastewater that is released during the different steps in the pulping process. It is estimated that P&P manufacturing activities can generate between 10-250 cubic meters per metric ton of wastewater discharge at one time (IFC, 2007). Before treatment, these effluents are high in total suspended solids, biochemical oxygen demand, chemical oxygen demand, and dissolved organic compounds. Bleaching processes can also put chlorinated dioxins and furans into the wastewater. The types of toxins released depend mainly on the type of mill in operation and pulping process it uses. This paper will focus on two specific types of P&P mills: virgin fiber mills and recovered fiber mills. Pulping processes can be classified as: chemical, mechanical, or semi-chemical. A variety of methods are used to treat this
wastewater, including both physio-chemical and biological techniques. The best results are often seen with a mixture of the two techniques (Kamali and Khodaparast, 2014). A recent call to arms against the release of toxic substances into the environment has been pushing new technologies into the field, but paper mills are still limited to what their budget can support.

The aforementioned effluents have the ability to affect an ecosystem on every level, with toxins migrating down the food web and immersing themselves into the sediments and water column. Dioxins and furans also have been seen to accumulate in fish species through bioaccumulation and even made it out to larger species in the open ocean. These can have ill effects, especially on the biology of fish. They have also been seen to accumulate in filter feeders, who draw out these toxins from the water column. Virgin Fiber Paper and Pulp mills are an example of how these effluents that harm the estuarine environment created.

**TYPES OF PAPER MILL**

*Virgin Fiber Paper and Pulp Mills*

The operation of a virgin fiber P&P mill can be broken down into three main components: pulp making, pulp processing, and paper making.

*Pulp Making:*

Pulp making begins with the conversion of timber into usable wood chips. This is done by cleaning the raw materials of bark and soil and then chipping it into smaller pieces.

*Pulp Processing:*
These smaller pieces can then undergo either chemical pulping or mechanical pulping. In chemical pulping, the wood is cooked in high pressure with a solution of chemicals that help to separate organic components by removing lignin and leaving behind the cellulose (EPA, 1997). An example of this is Kraft pulping, in which alkaline processes are used to produce the pulp. Generally, the chips are cooked in NaOH and NaS₂, a solution named white liquor. The resulting waste is called black liquor and is high in pollutants (Kamali and Khodaparast, 2014). In mechanical pulping, the chips are pressed against a grinder that physically separates the fibers (EPA, 1997). While it has a relatively high yield as compared to chemical pulping, the quality is diminished (Kamali and Khodaparast, 2014).

After pulping, the product then usually undergoes some type of bleaching to brighten it. The bleaching process creates many effluents that impact water quality. There are two major types of bleaching processes, elemental chlorine free (ECF) and total chlorine free bleaching (TCF). In ECF, ClO₂, H₂SO₄, and other chemicals are used in an acidic environment to help enhance the stage of lignin oxidation (Kamali and Khodaparast, 2014). This method can create chlorinated pollutants such as chloroform, dioxins, and furans (EPA, 1997). TCF, on the other hand, uses a combination of methods including a bleaching acid (again H₂SO₄) along with ozone, O, chelating agents, and hydrogen peroxide steps (Kamali and Khodaparast, 2014). Normally, the mixture is injected several times into the pulp, which results in large amounts of wastewater. Dioxins, furans, and chlorinated organics are also found in the effluent (EPA, 1997). Despite this, ECF methods are still seen as superior and are defined as a core component of Best Available
Technology by both the EPA and the European Community in P&P regulations (AET, 2005). Wastewater reduction is possible with ECF with the use of closed loop strategies (AET).

\textit{Paper making:}

In this step the processed pulp is combined with dyes, resins, fillers (clay, titanium dioxide, and calcium carbonate), and sizing agents (rosin and starch) to form paper (Kamali and Khodaparast, 2014). This is the most energy dependent step. Kamali and Khodaparast (2014) found that it consumes 47.2% of electricity and 94% of thermal energy. Recovered Fibers pulp and paper mills also produce pollutants that are detrimental to the estuarine ecosystem.

\textit{Recovered Fibers Pulp and Paper Mills:}

Recovered Fiber (RCF) mills have seen growth in the last few decades with the increase of recycling. Mixed office waste, old newsprint, and old corrugated containers are being repurposed using RCF pulping techniques. These mills are more common near urbanized areas where greater waste paper is produced. This technique produces a relatively low amount of wastewater as compared to virgin fiber techniques. Also, much of the waste produced can be repurposed as it contains Si and Ca, which can be used to make lightweight bricks or cement. The techniques are also divided into three major stages, pulping, high-density screening, and de-inking (Kamali and Khodaparast, 2014).

\textit{Pulping:}

Pulping is much simpler in RCF methods, requiring only that the waste paper be converted into RCF dispersed in water. This process helps to prepare it to be de-inked.

\textit{Screening:}
Likewise, screening is relatively simple. This includes removing large particles with higher densities such as paperclips and staples.

_De-inking:_

This is the most important stage in RCF mills. De-inking refers to the process in which the ink particles are removed from the cellulose fibers of the pulp, including the removal of detached ink fibers less than 25 μm in diameter and of the larger particles such as toner inks and laser printed papers. De-inking involves injecting many types of toxic chemicals into the pulp. These chemicals can include H$_2$O$_2$, NaOH, Na$_2$SiO$_3$, Na$_2$CO$_3$, and other compounds such as surfactants. Even though Recovered Fiber mills produce less waste water than Virgin Fiber mills, the RCFs still add hazardous chemicals that affect the biota in the aquatic environment.

_Pollutants:_

Interestingly, the types of chemicals that arise from RCF mills are directly related to the type of paper being repurposed. For instance, lightweight coated paper releases more organics because of the binding on it than newsprint does. In laser printed paper, thermoplastic resins are more commonly released into the wastewater as they are present due to when toner was originally melted and adhered to the paper. Paper and pulp mill pollution degrades the water quality and harms the biota in the environment.

**WATER QUALITY:**

_PC Bs:_

As described above, P&P mills are a large contributor to pollution of the marine environment. Many of the major chemicals that are emitted are toxic, including
polychlorinated biphenyls (PCBs). Polychlorinated biphenyls are defined as biphenyl molecules that substitute chlorine molecules in place of two or more hydrogen ions. These toxins are classified as Persistent Organic Pollutants (POPs) and are known carcinogens. PCBs were first created in the late 1880’s, but they were not readily available for usage until the 1930’s (Coyne 2013). PCBs were, and still are, used in many manufacturing techniques and trades. Examples of these industries include wood, pulp and paper, metal/steel, concretes, and plastics. It is estimated that 1.4 billion pounds of 209 PCB variations were produced between the peak production range of 1929 to 1977 (Marks 2014). The residual effects of these toxic compounds have detrimental effects on organic life. As stated by Coyne (2013), “Polychlorinated biphenyls are among the most insidious of environmental pollutants…and are resistant to biodegradation and have a tendency to bioaccumulate.” Despite many countries banning the manufacturing of PCBs, these enduring chemicals are still present in many global environments due to their tenacity to be broken down.

**Effects on Biota**

A study was conducted on PCB levels in fish that lived close to P&P mills in the Peace-Athabasca-Slave river basins within several provinces in Canada between 1991 and 1997. Different fish species, including the Long-Nosed Sucker, were tested for PCBs near and away from pulp mills. The fish near the pulp mills exhibited greatly elevated levels of PCBs in their liver tissue while those farther away from the mill did not (Alaee 2006). PCBs are known to be endocrine disruptors. The fish in the study displayed several further distinguishing abnormalities. Two hotspots were found downstream of pulp plants that showed hormonal steroid depression, tissue abnormalities including enhanced liver
and overall growth, and contaminant concentrations. Some of the fish sampled displayed disruptions in metabolic processes, such as the circulation and production of certain sex hormones necessary for reproduction. Also, males downstream showed an increased gonadal growth, leading to further potential fertility and reproductive issues (Alaee 2006).

The bioaccumulation of PCBs in organisms is one of the main concerns to come out of their introduction into an aquatic environment. While they may first be introduced into small organisms such as copepods, in estuarine or river environments, they have the potential to make it all the way to the open ocean with devastating effects as consumption occurs through the food chain. One article, published in the *New York Times*, describes how computer models were used to track PCBs in Killer Whales (Fountain, 2007). They explain that PCBs entered the whales’ system by the consumption of salmon. Varanasi et al. (1993) proposed a possible explanation as to how salmon could originally become contaminated. In their study, juvenile Chinook Salmon were tested from the Duwamish Waterway and the Puyallup River Estuary, Nisqually Estuary, Snohomish Estuary, and Stillaguamish River. There were higher concentrations of hepatic PCBs and FACs in the salmon of the Duwamish Waterway and the Puyallup River Estuary. PCBs remained in the fish for at least three months after exposure. The researchers checked the salmon’s stomachs for chemicals. The salmon in the Duwamish Waterway consumed copepods, amphipods, insects, annelids, and small fish. In the Puyallup River Estuary, the salmon did not consume annelids and small fish, but they did consume the rest of the prey items previously listed. The salmon from the Snohomish River Estuary consumed crustaceans
and small fish. Finally, the salmon from the Nisqually Estuary consumed insects and annelids. The small prey items hold the potential to be the cause of contamination in the juvenile Chinook Salmon, and eventually whales.

Similar contaminating effects can be observed in North Atlantic Right Whales. Klanjscek et al. (2007) showed the effects of PCBs and bioaccumulation on these whales, using adults and calves as examples. Right whales have evolved so that they can go long periods of time without eating by utilizing lipid cells stored in their fat. When the lipid cells are used to provide nutrients to the whales, they run the risk of exposing them to toxins. When maternal whales nurse their young, the calves could potentially be exposed to any present toxins. Due to bioaccumulation, the toxicity level would increase with every calf the mother produces.

Before a whale fasts they tend to consume a lot of food. For example, the right whale will eat large amounts of zooplankton that have the potential to contain toxins, such as PCBs. After the toxins are in their system, they accumulate in their blubber. Furthermore, when the toxins are released it could cause a decrease in fertility and even death.

The information provided about the compared bioaccumulation levels in the male and female right whales. Data shows that the male right whales have more PCB bioaccumulation than the female right whales because they are larger. Klanjscek claimed, “Even though the accumulation of toxicants in both males and females is greater in seasonally variable environments, there are significant differences between male and
female patterns of accumulation” (Klanjscek et al. 2007). For example, a 30-year-old male is larger than a female of the same age and has more than double the concentration of toxicants. Furthermore, when energy is high the right whales can dilute the toxicants. When right whales absorbed lipids the toxins are accumulated directly into their blood.

The authors believe that “Reduction in energy intake increases bioaccumulation and the amount of toxicant transferred from mother to each offspring. With high energy availability, the toxicant load of offspring decreases with birth order. Contrary to expectations, this ordering may be reversed with lower energy availability” (Klanjscek et al. 2007). The hypothesis was correct because they found this information to be true because they proved it in experiments and their calculations. However, the scientist could have used other methods to figure out the bioaccumulation in right whales. For example, Klanjscek mentioned that they did not use urine as a bioaccumulation indicator, but they explain why. In addition, the scientists assumed the whales were in a stable environment and the mother whales were healthy before they bio-accumulated toxins.

A well-known example of the destruction of these particular toxins is exposed in *Silent Spring* by Rachel Carson. DDT and PCBs both have the ability to cause the eggs of birds, including marine species, to become too thin to sustain the weight of the mother. The way that PCBs cause this to happen is by inhibiting enzymes that control calcium movements. Due to the persistent nature of these compounds they tend to bio-accumulate within organic tissue over time and increase up trophic levels.

Dioxins:
More sinister effluents that are emitted from the pulp industry into the marine environment are dioxins. These compounds are produced through many processes, largely through burning of organic material and bleaching techniques, and are among the most toxic chemicals known to exist. Dioxins, unlike PCBs, can be quickly destroyed, by being broken down with sunlight. However, they are known endocrine disruptors and are cancer-causing in even minuscule trace amounts. Dioxins enter an organism`s system by the inhalation of contaminated air, drinking of polluted water, or by consuming other organisms that have been exposed to the toxic chemicals. However, the consumption of contaminated food is the primary source of exposure to these chemicals (ATSDR, 1999).

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in emissions from the pulp-bleaching process were characterized by EPA as the nation’s third largest dioxin source” (Feng 2000). A 1989 study conducted by the EPA concluded six paper mills had dumped dioxins and other harmful chemicals into the Colombia River in Portland, Oregon (Crum, June 4, 1990). Many species of bottom fish, such as carp and sturgeon, acquired high levels of dioxin in their tissue. Mary O’Brien, a marine biologist, claims, "Dioxin is the most toxic compound known to humans (Crum, June 4, 1990)."

Research on dioxins was also conducted through an observational study surveying five pulp and paper mills in Northern China. Three stages of the paper making process were sampled to see how much dioxin was produced within each process, including chlorine bleaching (c), alkaline extraction (e), and white liquor. Chlorine bleaching had the highest levels of dioxin produced, followed by the alkaline extraction, then the white liquor. Alae (2006) also studied information on the amounts of dioxin that were present
downstream of pulp locations. It was found that levels as high as 3.48 ng/kg. This is well above the Canadian guideline of .85 ng/kg (Alaee 2006). While these levels don’t appear to be enough to be considered lethal, they certainly can still result in adverse effects to the organisms that call the river home.

Evaluating organisms can also be a significant method for measuring dioxin levels in a selected environment. In fact, a research team from the University of the Basque Country (UPV/EHU) was involved in a project that measures the contamination levels along the Spanish coast by using chemical, biochemical and ecotoxicological tools (Fudazaioa, 2008). The UPV/EHU team studied the toxicity levels in the mussels near the port. "We place 20 or 30 mussels mounted on plastic supports and inside gauzes, and submerge them at a depth of two meters", Dr Etxebarria, director of the project, explained (Fudazaioa, 2008). "After a selected time, the team collected the mussels for analysis of level and type of contamination accumulated in the mussels (Fudazaioa, 2008). In fact, bivalves are excellent specimens to assess the dioxins levels in an aquatic ecosystem because they accumulate chemicals in their tissue and are able to handle high levels of toxicity.

Favotta (2007) gives another example of a paper mill, located on the northern section of the Venice Lagoon, who released chemical pollutants including absorbable organic halides (AOXs), furans, dioxins, and polychlorinated biphenyl (PBCs) into the water (Favotto, 2007). The sediments near the paper mill became contaminated with the toxins and exposed the residential Manila clams to POPs. Consistent exposure to the pollutants weakens the clam`s immune system and damages their reproductive organs. The Venice
clamming industry is heavily dependent on the Manila clam (Tapes philippinarum). Fishermen often illegally harvest the clams near the paper mill and introduce the contaminated clams to the seafood market (Favotto, 2007). People who consume tainted clams can experience skin disorders, reproduction issues, or acquire cancer (Pulp and Paper Industry, 1997). The Manila clam in the lagoon had accumulated high concentrations of POPs in its tissue and was unfit for human consumption. However, in this study it was claimed that natural detoxification could improve clam health and make them safe for human consumption. They sought to prove this by relocating the clams to the southern section of the lagoon or detoxification zones, which have lower levels of POP contamination in the sediment (Favotto, 2007).

The sediment data collected proved the southern section or detoxification sites had lower levels of paper mill pollutants than the industrial zone where the clams were initially collected (Favotto, 2007). The dioxin fingerprint was also larger in the industrial zone than in the detoxification zone. The toxicity levels in the clams in the industrial zone were significantly high and were the same level as the sediments in the industrial area. Yet, the clams in the southern portion of the lagoon demonstrated a considerable decrease in all persistent organic pollutant levels. The results from the experiment showed that clams can naturally detoxify if placed in an area with decreased amounts of POPs.

They concluded that the POP levels were lower in clams that undergone detoxification in the southern lagoon than clams in the Marghera Industrial Zone. Furthermore, the research conducted in the scientific study was helpful to scientists that want to understand the detoxification process in bivalves that are exposed to paper mill toxins. It also
promoted natural detoxification as a reliable solution to the high toxicity levels in the clam flesh in the Marghera Industrial Zone of the Venice Lagoon. However, more research was recommended to help better improve the health and safety of the seafood industry.

**WASTEWATER TREATMENT:**

There are many waste water treatments available to help treat the paper mill pollution. Due to advancements in wastewater treatment, the toxicity of the final effluent is relatively low. However, as mentioned throughout this paper, toxins are still commonly seen in the aquatic environments near P&P mills. Kamali and Khodaparast (2014) attribute this to technical problems within individual mills and economic limitations in regards to effective wastewater treatment. Treatments can be divided into two major types, physiochemical and biological. Overall, physiochemical methods were found have a higher operating cost then biological techniques, mostly due to necessary plant designs. However, for many of the biological options, chemical processes must still be performed first for them to be successful.

**Physio-chemical Treatments:**

There are four types of physio-chemical process that are used in waste water treatment. The processes consist of Sedimentation and Flotation, Coagulation and Precipitation, Membrane Technologies, Adsorbents, and Oxidation. The effectiveness of sedimentation and flotation treatment is dependent on the production effluents as well as secondary treatment methods (Kamali and Khodaparast, 2014). The Coagulation and Precipitation process consist of metal salts being released into the environment to generate larger flocs from small particles. This method showed a reduction of COD (chemical oxygen
demand) greater then 90 percent. The effectiveness seemed to be driven by the flocculent agent, which can cause variation in COD reduction and turbidity (Kamali and Khodaparast, 2014). The Membrane Technology method includes reverse osmosis, which has the ability of pathogen destruction and is especially useful with use of a flocculent agent as a pre-treatment. Membrane electrochemical reactors were also shown to be economical and removed pollutants as well as produced a smaller quantity of low-density sludge (Kamali and Khodaparast, 2014). Adsorbents, on the other hand, include such substances as activated carbon, silica, fuller’s earth, and coal ash and have shown to remove colorization as well as refractory pollutants (Kamali and Khodaparast, 2014). Oxidation has been used to deal with a large number of refractory organics pollutants. Ozone treatment of nanofiltered effluents after activated sludge processes showed a reduction in turbidity, color, and lignin as well as COD removal (Kamali and Khodaparast, 2014).

**Biological Treatments:**

Biological treatments are seen to be more cost effective, eco-friendly, and suitable for the removal of BOD (biochemical oxygen demand) and COD. However, they’re not adequate for the removal of color and recalcitrant compounds. Biological treatments include, fungal treatment, aerobic treatment, Anaerobic Digestion. Fungal treatment was seen to be fairly common in P&P mill wastewater treatment. The fungi is able to withstand higher effluent loads and, in optimized conditions, reduced methyl tertiary butyl ether extracts, as well as COD, turbidity, and color without a preflocculation step. It was seen however, that it does not do well in environments with high PH levels or oxygen limitations (Kamali and Khodaparast, 2014). Aerobic treatments have high
environmental adaptability. These treatments use bacteria in aerated lagoons and activated sludge. While it was seen to be effective in the removal of BOD and chlorinated phenolic, it only moderately took care of COD and AOX levels, and was unable to remove lignin and other recalcitrant pollutants (Kamali and Khodaparast, 2014). Anaerobic digestion has seen growth in the recent years due to its benefits. These include a reduction of sludge volume, methane production as an energy carrier, design simplicity and cost effectiveness. The efficiency was also seen to be driven by the makeup of effluent released, such as consisting mainly of hardwood or softwood debris. Additionally, AOX was seen to be highly reduced and COD moderately reduced (Kamali and Khodaparast, 2014).

CONCLUSION:
The United States has a leadership role in the P&P industry from both an economic and practical standpoint. Therefore it is important to recognize and acknowledge the problems that arise during production and find possible solutions. While there is no perfect method in producing pulp and paper, it is imperative to recognize the pollutants that come with each technique and find a viable way to treat them. Many of these pollutants are released into aquatic ecosystems through effluent and have the ability to wreak havoc on the biota living in the estuarine systems. As discussed, the effects of dioxins, furans, AOXs and PCBs have been studied around the world and caused negative effects on a variety of organisms of all sizes and species. Through bioaccumulation, the hazardous chemicals can even make it to the open ocean. It is vital that the consequences from the production of pulp and paper be recognized as a large threat. It is not a question of whether these
effluents have the ability to cause harm to the environments into which they are released, but how they are to be treated in the future.
Works Cited:


This study examined the effects of dioxins and PCBs on several fish species in a river basin in Alberta, Canada. The initiative surveyed locations up and downstream of paper mills and measured the amount of dioxin and PCBs in the water, fish tissues, and sediment. Effects on fish endocrine systems are also described.

Coyne, Mark. 2013. Polychlorinated Biphenyls: (PCB) *Salem Press Encyclopedia*

Coyne describes the history of PCBs in detail as well as other unique statistics about the amounts and industries that produce them. He begins by describing the chemical makeup of the molecule as well as when and how it was created. Included other basic information describing PCBs.


This online brochure describes both ECF bleaching as well as TCF bleaching. It mainly focuses on the benefits on ECF bleaching, providing evidence with data about reduced pollutants levels. It also describes closed water systems that can help reduce wastewater.

The article focuses on a paper mill located in Venice, Italy. The pollutant that the paper mill has discharged into the lagoon has bioaccumulated in the Manila clam. The scientist moved the clams to a section of the lagoon to see if the clams were able to naturally detoxify. After spending 120 days in the detoxification zone, the clams were no longer contaminated with paper mill pollutants.


This study starts out by describing the main processes involved in producing paper from a paper mill including the chlorine bleaching, white, liquor, etc. It also explores how much dioxin is released during each process, with the chlorine process releasing the most and the white liquor process releasing the least.


This article reference explains the difficulty of tracking killer whales for PCBs. The researchers managed to make a way to track killer whales where they are becoming endangered for several reasons. One cause is that killer whales eat salmon, which is how the whales are bio accumulating so much PCBs. The
salmon bioaccumulate PCBs, which in turn bio accumulate in the whales when they eat the salmon. This is important to include in the research paper because it shows that bioaccumulation in one aquatic organism like the salmon can cause other organisms like the killer whales to also bio accumulate PCBs, this shows that bioaccumulation can affect the food chain.


Spanish scientists used mussels to measure and analyze paper mill pollution. They collected several mussels along the Spanish coastline and tested the tissue for foreign contaminants. The results proved that heavy metals and dioxins have accumulated in the mussel flesh.


This article presents an in depth explanation of pulp and paper production in both virgin fiber mills as well as recovered fiber mills. It explains the main pollutants produced in each step of process. It also explains the current types of wastewater treatment and the pros on cons of each.

The article referenced above mentioned bioaccumulation in marine mammals specifically about the Right Whale. It expressed more emphasis on the mother whales and their calves. Like the methods the calves received toxins from their mothers, which was called Vertical Toxicant Transfer. The authors also mentioned male whale’s toxicity levels to compare to the female whales. This article is relevant to the research paper because it discusses bioaccumulation of toxins in Right Whales and it reveals the effects toxins have on the whales. North Atlantic Right Whales are also an endangered species.


The article explains how over the past 18 months restaurants in North and South Carolina have been dumping PCBs into their grease traps. It goes on to name businesses as examples, such as Food Lion and Denny’s. The contamination usually is caught at waste water facilities and requires cleanup which resulted in many employees demanding compensation for their exposure. The Carolina’s cannot come together to form a good option for the proper disposal of PCBs.

Furans and dioxins are two cacogenic paper mill effluents that negatively impact the estuarine system. They cause many health problems in marine organisms and humans. The article presents some general information on furans and dioxins.


This EPA fact sheet emphasizes what a major contributor the pulp and paper industry is in the United States with statistical evidence. It also presents the basics of pulp and paper production and what the common pollutants are, going more in depth with the effects of the bleaching process. It also touches on the effects of P&P mills in terms of air quality.


http://www.nwfsc.noaa.gov/publications/scipubs/techmemos/tm8/disc.html

Referenced above is an article about Chinook salmon. The article discussed five different estuaries where juvenile salmon were taken for the study. In the study the authors tested the stomachs for chemical analysis. It turned out that the salmon could be contaminated from their diet. This is important for the research paper because it illustrates the effects toxins have on aquatic organisms including salmon.