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Polychlorinated Biphenyl (PCB) Pollution of the Hudson River: Social Policy and Health Considerations

Laura Schad
Union College - Schenectady, NY

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By

Laura Schad

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Abstract

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The purpose of this paper is to examine pollution in the Hudson River and the role General Electric has had in creating this problem. The focus will be on social issues and problems that have emerged as a result of the environmental damage from pollution. Until recently, there was little research done on the health and environmental justice issues that impact the New York communities where GE's factories were located. This paper examines the material collected and studies that were done which document Hudson River pollution and the contributions as well as clean up efforts of General Electric. The overall problems associated with PCBs and human and health conditions are discussed first, followed by a presentation of the relevant environmental policies and input of grass roots organizations. A discussion of the role of General Electric and the pollution and cleanup of the Hudson River is presented next. Concluding remarks suggest future research and policy to help prevent pollution and protect human and environmental health.

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Preface

There are many different social problems that impact modern society. How these issues are viewed and handled is dependent upon the social hierarchy and economic standing of those who are affected. Often, those of lower socioeconomic classes are taken advantage of by those with higher status and power, leading to issues of environmental justice. Environmental justice, sometimes referred to as environmental racism, is defined by the EPA as, “the fair treatment and meaningful involvement of all people, particularly, minority, low-income, and indigenous populations, in the environmental decision-making process,” (EPA, “Environmental Justice”, 4/3/16). It tends to be poor, uneducated, minority communities that house sites that are dangerous to human health such as hazardous waste facilities. This is a problem that is often handled not by lawmakers and governing bodies, but instead by NGO’s and grassroots organizations.

One of the most famous environmental justice cases took place in the town of Hinkley, California. Hinkley was a small, uneducated farming community located near Pacific Gas & Electric’s (PG&E) natural gas compression station. In the 1990s, residents learned that groundwater was polluted with chromium 6, a cancer-causing metal. It had seeped into the water after being dumped into unlined ponds at PG&E’s compressor station in the 1950s and ‘60s (Esquivel, 4/20/15). PG&E tested the groundwater for chromium 6, and when they notified the state that some of their wells had levels above the legal limit, the EPA raised the allowable parts per billion. Soon after, PG&E began to buyout the homes of many of the residents in the areas close to

their factory (Esquivel, 4/20/15). When PG&E tried to buy the home of Hinkley resident Roberta Walker, she became suspicious and started digging into why this was happening. To her shock, she uncovered the toxic pollution problem that was silently plaguing the residents of Hinkley and being kept secret by the area's water control board (Steinberg, 7/12/13).

In 1993, a legal clerk by the name of Erin Brockovich began investigating clusters of illnesses in the community linked to the toxic chromium. Her investigation revealed PG&E was using chromium 6, not the safe chromium they had claimed to be (Steinberg, 7/12/13). These toxins had been infiltrating the town's water supplying and causing countless health problems for the residents. Brockovich partnered with attorney Edward Masry, who brought in another law firm. Due to Brockovich's unrelenting persistence, almost 650 plaintiffs in the Hinkley community won $333 million in an out-of-court lawsuit settlement with PG&E in June 1996 (Esquivel, 4/20/15). It was not a large law firm or a governmental organization that came to the aid of the small town of Hinkley, but instead the determination of one woman who was able to build a grassroots network and give a voice to the poor, uneducated residents.

One more example of an environmental health and justice case centers on environmental pollution that occurred in Massachusetts in the 1980's. Environmental toxins, specifically a known carcinogen named trichloroethylene, leaked into the city's aquifer and contaminated the drinking water; these toxins were linked to the rise in the number of leukemia diagnoses and deaths of several children in the local neighborhood (Kennedy, 12/17/98). After an investigation of local well water was

conducted and high levels of toxins were found, a concerned mother by the name of Ann Anderson started her own investigation. Her son had leukemia, and she was adamant that the high number of cancer cases in her neighborhood was not random, and that there was a link between the nearby industries and children's health. She called those who had children with leukemia together in a meeting where they mapped out where each family lived (Heneghan, 2000). Once this had been completed, it was glaringly obvious that there was something causing children in the area to develop leukemia.

A lawyer named Jan Schlichtmann entered the scene and discovered a few large companies in the area owned land that the pollution was occurring on. He argued Beatrice Foods and W.R. Grace & Company collectively could be held responsible for the high levels of toxins found in the water (Heneghan, 2000). Schlichtmann decided to fight for the residents of Woburn after hearing the pain and suffering of the citizens, even though he had been advised not to due to the size of his firm. After a long and arduous case, Schlichtmann was financially bankrupt. He had been run dry emotionally, and ended up settling with Grace for $8,000,000 but without any admission of guilt, apology, or cleanup (Kennedy, 12/17/98). Even though Schlichtmann was unsuccessful in achieving these things, his work left a legacy that was picked up by the EPA. After an investigation, they identified both Beatrice and Grace to be at fault for the pollution, and forced them to pay for the largest and most expensive toxic cleanup in the history of the United States.

The dominant social issue facing Woburn was one of environmental justice. The town where these companies were located was rural, small, and poor. The

residents lacked the resources to keep factories out of their backyards, as well as the education to understand that the companies' business practices could be killing their children without their knowledge. It was due to the relentlessness of a small law firm who knew they were overmatched that the EPA caught onto the case and got involved.

Another case study dealing with environmental justice occurred in Norco, Louisiana. African American residents in Diamond, Louisiana, a small town located with Norco, housed a massive Shell petrochemical complex in the backyards of those who lived there. Residents did not live in this town by choice; instead, they had nowhere to go as they lacked money as well as the ability to sell their homes due to their location. No one wanted to move to the area, as the damage Shell was doing was obvious (Skolnick and Currie, 2011, 214). When residents vocalized concerns regarding their personal health and safety, Shell reassured them nothing dangerous was occurring at the plant. Many of the residents in the area became very ill and confronted Shell about this; Shell reassured them that their practices were ethical and it was impossible to link their illnesses to the factory's processes. After a few incidents that resulted in the deaths of some residents, there was a major explosion at the plant that spewed millions of pounds of toxic chemicals into the air (Skolnick and Currie, 2011, 215). Those who lived there hired a lawyer, desperate to be relocated; however, the lawyer went after monetary compensation because he would receive a larger part of the settlement if they won (Rosen, 2/20/2005).

Frustrated with the lack of response or help by professional, citizens joined together to form a grassroots campaign called Concerned Citizens of Norco. Instead

of asking for money or compensation for those who had become seriously ill or died, they asked Shell to buy their homes (Rosen, 2/20/2005). All they wanted was to move somewhere their families could breath clean air and avoid dangerous chemicals. The group lost several battles against Shell, but remained resilient. Marjorie Richard, who would eventually be awarded the prestigious Goldman Environmental Award for her relentless determination throughout this struggle, led the way. Her home was directly across from the plant, and many family members had suffered severe illnesses and early deaths from respiratory problems (Rosen, 2/20/2005). The white community, many of whom worked for Shell, located on the other side of forest behind the plant, had no issues to complain about. This continued to fuel the fight for justice, causing other environmental activists to take an interest in Diamond. Eventually, the campaign caught attention of huge national grassroots organizations, such as Greenpeace and the Sierra Club. With this many people involved in the fight, Shell could no longer ignore Diamond. They paid to relocate all of the families to new homes, away from their toxic factory.

This is an important example showing issues linked to environment justice. The Shell plant was located in the back yards of poor, uneducated, minority citizens; Shell was aware of the demographics in the area, and realized they could easily fool residents and take advantage of them. Those living in the neighborhood could not afford to put up a fight against such a large and powerful company. Many of them said they would "prefer to leave town rather than fight Shell…as long as Shell paid

enough to relocate in a safe area," (Skolnick and Currie 2011, 217). The events that occurred in Diamond reflect yet another example of a large corporation exerting their power over a marginal group that was defenseless in fighting back.

All of these exampled illustrate a sad reality that we are still faced with today. While there has been a lot of media attention given to big high profile cases, there are undoubtedly smaller communities that live and work in the presence of harmful pollution but lack the voice or power to attract attention or bring about change. Through this thesis, I hope to shed light on a problem that is often ignored, examining the pollution of the Hudson River and the role General Electric had in it up through the 1970's. Little research has been done looking at the health and environmental justice issues that impact the New York communities where GE's factories were located. This paper examines the material collected and studies that were done which document Hudson River pollution and the contributions as well as clean up efforts of General Electric. Before problems associated with PCBs and human and health conditions can be fully comprehended, we must learn the science behind these toxic substances. Once we have this basic understanding, we will be able to discuss how they impact those who are exposed to them on a daily basis, and what has been done on their behalf by laws and grassroots organizations. A discussion of the role of General Electric and the pollution and cleanup of the Hudson River is presented next. Concluding remarks suggest future research and policy to help prevent pollution and protect human and environmental health.

Chapter 1: An Introduction to Polychlorinated Biphenyls

Polychlorinated Biphenyls, more commonly known as PCBs, are ubiquitous pollutants. They are found at low but measurable levels in nearly all marine plants and animals, fish, mammals, birds, bird eggs, and humans, and levels increase up the food chain. PBCs belong to a broad family of man-made organic chemicals called hydrocarbons (EPA, "Health Effects of PCBs", 2/12/16c). They were domestically manufactured in the United States from 1929 until 1979, when their manufacture was banned. PCBs range in toxicity and consistency; some are thin, light-colored liquids, while others are yellow or black waxy solids (ATSDR, "Polychlorinated Biphenyls (PCBs) Toxicity", 2/27/16). They are chemically stable, non-flammable, have high boiling points, and good electrical insulating properties. These characteristics make PCBs ideal for use in hundreds of industrial and commercial applications, including electrical, heat transfer, and hydraulic equipment, plasticizers in paints, plastics, and rubber products, in pigments, dyes, and carbonless copy paper, and many other applications (EPA, "Polychlorinated Biphenyls (PCBs)", 2/12/16a). Their toxicity and potential human health effects made them a controversial chemical, and eventually lead to a ban nation-wide.

Although they are no longer commercially produced in the United States, PCBs may be present in products and materials produced prior to the 1979 ban. Prior to the ban, PCBs entered the environment during their manufacture, use, and disposal. Today, they can still be released into the environment from poorly maintained waste

sites that contain PCBs, illegal or improper dumping of waste or products that contain PCBs, and disposal in landfills that are not designed to handle the hazardous wastes; they can also be released into the environment by the burning of waste (EPA, "Polychlorinated Biphenyls (PCBs)", 2/12/16a). Once they are released into the environment, PCBs do not readily break down due to their stable chemical structure and therefore may remain for long times, cycling between air, water, and soil.

Once in the environment, PCBs can be carried long distances; some have been found in areas far away from where they originated. As a result, PCBs are found all over the world. As a general rule of thumb, the lighter the form of PCB, the further it can be transported from the source of contamination. PCBs can accumulate in the leaves of plants and food crops; they are also taken up by small organisms and fish and store in their fat. As a result, humans who ingest fish with high PCB concentrations may be exposed to those chemicals and can store them in their bodies. PCBs have been shown to cause cancer and other adverse health effects on the immune, reproductive, nervous, and endocrine systems (EPA, "Health Effects of PCBs*",* 2/12/16c). Studies conducted in humans provide support for classifying PCBs as a potential carcinogen, although this is highly debated.

Human exposure to PCBs is primarily through low-level food contamination. However, occupations, environmental surroundings, and other factors may lead to the ingestion of PCBs, and can cause a variance in the amount humans are exposed to the harmful chemical. The rate at which PCBs are eliminated from the body is dependent on several complex metabolic factors such as weight (amount and variability), diet, and activity level; other factors such as sex and race may or may not be significant to

this process (Erickson, 2001). It is thought that the health effects of PCBs are dependent upon their concentration and that they are interrelated. If one system is impacted by PCBs, this could have significant implications on other systems of the body. While there is debate as to how much of an adverse effect PCBs have on human health, it is agreed that the higher the concentration in the human body, the higher the potential for serious negative impacts.

There are 209 discrete chemical compounds of PCBs called congeners, where between one and ten Chlorines are attached to biphenyl (Erickson, 2001; Figure 1). However, only 130 of those are likely to be found in commercial products or mixtures. Most of the congeners are clear, odorless crystals; they are viscous mixtures, and the more highly chlorinated the mix, the more viscous it is. In general, all congeners have low water solubility, low vapor pressure, and are soluble in most organic solvents, oils, and fats. All of these characteristics make PCBs very stable and unable to easily degrade. However, under certain conditions, various chemical, thermal, and biochemical processes can destroy them (Erickson, 2001). Due to their high thermodynamic stability, all degradation mechanisms are difficult, and internal degradation of unwanted PCBs requires high heat or the addition of a catalyst. This makes destroying PCBs and removing them from the environment difficult.

Chemical Composition of PCBs

PCBs are commercially produced as a complex mixture of multiple isomers at different degrees of chlorination. PCBs are synthetic chlorinated hydrocarbon compounds that consist of two benzene rings linked by a single carbon bond, with

from one to ten of the hydrogen atoms replaced with chlorines. They are semi volatile organic compounds, and their commercial utility is based on their chemical stability and desirable physical properties, such as low flammability and electrical insulation (Erickson, 2001). However, it is this stability that is responsible for their environmental persistence. The chemical properties of PCBs are important in understanding their analytical, physiological, and environmental properties.

All 209 variations of PBCs form a set of congeners; when subdivided by degree of chlorination, the term homolog is used. PCBs of a homolog with different chlorine sub-positions are called isomers (Bedard, 2001). When analyzing a PCB mixture, it is not “what” is in it, but “how much” is that is important. PCB analyses are generally similar to other trace environmental analyses. Samples are collected and stored until extraction, and the PCB composition is detected using a gas chromatograph with an electron capture detector. The results are compared qualitatively and quantitatively with a standard result in order to determine the mixture. These PCB mixtures are not known to occur naturally, although they can inadvertently be created as byproducts of other chemical manufacture.

The most common mixture of PCBs that were sold and manufactured was the Aroclor series, produced from around 1930 to 1979. There are many different types of Aroclors, and each has a unique suffix number that indicated the degree of chlorination (Bedard, 2001). The first two digits in the Aroclor number refer to the number of Carbon atoms in the phenyl, which, for PCBs, is 12. The second number indicates the percentage of Chlorine by mass in the mixture. For example, Arcolor 1254 means that the PCB is 54% Chlorine by weight. The higher the second number,

the more viscous the mixture (EPA, “Aroclor and Other PCB Mixtures”, 2/12/16a). PCBs, Aroclor 1260, and Aroclor 1254 occupy three of the top 20 spots on the Hazardous Substances list published by the EPA and the Agency for Toxic Substances and Disease (ASTDR) Registry; there are a total of ten different types of Aroclors on the list (ASTDR, “Priority List of Hazardous Substances”, 2/12/16; Figure 2). There are three main criteria that have to be met for a chemical to be included on the list, including frequency at sites listed on the National Priorities List of hazardous waste sites, toxicity, and potential human exposure. Using these criteria, the hazard potential of each substance is generated and ranked using the following algorithm:

TOTAL SCORE	=	*NPL FREQUENCY*	+	*TOXICITY*	+	*POTENTIAL FOR HUMAN EXPOSURE*
(1,800 *max. points*)		(600 *points*)		(600 *points*)		(300 *concentration* + 300 *exposure points*)

This generates a list of substances ranked based on their total score; the top 275 scoring chemicals become the Priority List of Hazardous Substances. Currently, there are 848 candidate substances found at a minimum of three sites each for the list (ASTDR, “Priority List of Hazardous Substances”, 2/12/16). There are thousands of other harmful chemicals found at waste sites, but they do not meet all the criteria to be scored.

Not all transport and degradation mechanisms, including biodegradation, vaporization, partitioning among phases, and dissolution, do not occur equally on all congeners. As a result, original chemical patterns can change over time; this phenomenon is commonly referred to as “weathering” and distorts the analysis. A weathered PCB pattern may have an increase in higher congeners are the more volatile components evaporate from the surface. Weathering does not convert one

congener into another, as the processes are much more complex. Measurement of stable isotopic ratios by mass spectrometry is a common tool used to determine PCB transport and end fate after weathering (Erickson, 2001). Current research on PCB analysis is focused on decreasing the amount of time it takes to obtain a chromatogram, making identification faster and more reliable while still remaining detailed.

PCBs favor a nonpolar phase, and therefore will move away from water towards most solids; once in the solid, they prefer the organic portion. 99% of the environmental mass of PCBs is found in the soil (Erickson, 2001). Due to their large molecular size and low solubility, transport is incredibly slow and is measured in years-to-millennia. For PCBs of lower chlorination, it takes anywhere from six years to several years to be released back into the environment. For 80-90% of the PCBs absorbed by soil, they typically desorb within 48 hours after contact with water (Erickson, 2001). The movement of PCBs through soil is not consistent due to the heterogeneity of soils, and various other factors that can impact travel time such as root transport and worms.

PCB Production and Use

PCBs were commercially produced as complex mixtures for a variety of applications beginning in 1929, with most producers throughout the world reducing or stopping production in the 1970s. Since 1929, approximately 2 x 10^9 kg of PCBs has been produced commercially of which 2 x 10^8 kg remain in mobile environmental reservoirs (Faroon, 4, 2003). Total worldwide production of PCBs is generally

unknown, but has been cited by the World Health Organization (WHO) at an estimated one million metric tons; this figure includes only five western European counties, Japan, and the United States, and is from 1993 (Holoubek, 2001). Production of PBCs in Eastern Europe, Russia, and China is known to exist, but exact values are not available.

PCBs were used in hundreds of industrial and commercial applications, including but not limited to electrical, heat transfer, and hydraulic equipment, plasticizers in paints, plastics, and rubber products, and in pigments, dyes, and carbonless copy paper (EPA, "Polychlorinated Biphenyls (PCBs)", 2/12/16d). While they are no longer commercially produced in the United States, PCBs can be present in products and material produced before the implementation of the 1979 ban. Figure 3 shows the top applications of PCBs in the US from 1930-1975, with a large majority of them being used in capacitors and transformers. WHO divides PCB use into three main categories: completely closed systems such as electrical equipment, nominally closed systems such as hydraulic and heat transfer systems and vacuum pumps, and open-ended applications like plasticizer in PVC and other chlorinated rubbers (Faroon 2003). Those produced for "open" usages had the highest potential for direct release into the environment if not properly managed. Once concern about the toxicity of PCBs started to grow, companies began to voluntarily curb their "open" end production.

One of the largest American producers of PCBs was the Monsanto Corporation, which produced Aroclor mixtures from 1930-1977. In the 1993 estimation of world production of PCBs completed by WHO, 60% of the total was

accounted for by Monsanto's Aroclor production. Monsanto Chemical Company had two production plants in the US: Anniston, Alabama, which closed in 1970, and Sauget, Illinois, which closed in 1977 (EPA, "Aroclor and Other PCB Mixtures", 2/12/16a). They also had several plants in Europe. The EPA has estimated that US production was around 635,000 tons, with the world total for Monsanto much higher (Holoubek, 2, 2001). The most commercial mixtures of PCBs produced in the US were under the trade name Aroclor, with the majority of them produced by Monsanto. In the 1960s and 1970s, Monsanto voluntarily curtailed open uses that could directly impact the environment, and by 1972, they restricted PCB sales to capacitor and transformer applications in completely closed systems (Erickson, 2001). This was mainly due to pressure from consumers due to increasing concerns about the potential environmental hazards of PCBs.

While PCB production and usage has been banned in the United States, this is not the case worldwide. Several countries have taken steps to limit or prohibit the use of PCBs, but they are still spread around the globe. Their widespread use and chemical persistence has led them to remain in the ecosystems in which they were produced or disposed of, as well as spreading to further rural and pristine areas of the globe (Faroon 2003). Chemicals emitted in warmer climates volatize and are transported by air currents to colder areas where they are deposited in soil and water. This results in high concentrations of PCBs in temperate or Polar Regions, and low concentrations in tropical areas (Holoubek, 2001). This means that PCBs can be found in areas far away from a point source, meaning the whole globe has the potential to be contaminated.

PCB Disposal

Since the placement of bans and restraints on PCBs across the world, the current focus has shifted from production to managing PCBs in existing equipment that is either still in use or that has been disposed improperly of. It is important to prevent the loss of PCBs into the environment in order to avoid contaminating areas that were remediated. With significant restrictions on use and controls of disposal, there has been a significant decline in environmental and human PCB concentrations since the 1970s (Farroon, 2003). A significant portion of all of the PCBs ever produced remains in service, in storage, or in landfills; few have been disposed of. As current uses become phased out, they will become waste and add to the large stockpiles of existing PCB waste (Holoubek, 2011). In order to destruct PCBs so they no longer pose a toxic threat to humans or the environment, destroying or degrading the molecules are the only acceptable procedures.

Destruction of the PCB molecule is the best way to ensure the complete disposal of PCBs. Chemical, thermal, and biochemical processes may accomplish this, but due to their high thermodynamic stability, all destruction mechanisms are complicated and highly regulated in the United States and in other countries. Incinerators in the United States are strictly regulated in order to assure that PCBs are effectively destroyed; for a non-liquid PCB, less than 0.001 g/kg of the PCB may be emitted into the atmosphere. This 99.9999% destruction efficiency is the overall incineration target in the United States for all PCB emissions. For ash, it can contain no more than 2 ppm PCBs (Erickson, 2001). Almost all incinerators have some sort

of pollution control systems such as filters or scrubbers in order to ensure that excess PCBs are not being released.

PCB mixed waste poses a serious disposal problem for the United States. Mixed waste is a combination of radioactive waste and a hazardous waste such as PCBs. The US Department of Energy controls large sites that have been used in the past for nuclear weapon production or nuclear reactors, and that also used PCBs in various forms. The cross-contamination of the two wastes creates a product so toxic that there is one facility in the United States capable of treating it; it is an incinerator in Tennessee run by the Department of Energy. The only other option for treating mixed waste is to separate the two products and treat each of them separately (Erickson, 2001). Treating PCBs alone is an incredibly difficult process. When they are contaminated with radioactive waste that is even more harmful and toxic, it presents new problems that must be addressed. If this mix were able to get into the environment, it would have detrimental effects, and would be incredibly costly and time consuming to try and mitigate.

In the environment, photolysis and biodegradation are the two natural disposal processes; rate of photodegradation is dependent upon the degree of chlorination of each individual PCB molecule. Depending on the mixture, this process can take three years or forty years until the microbial degradation is complete. Under anaerobic, reducing conditions such as aquatic sediments, microorganisms partially dechlorinate the more highly chlorinated congeners. Under aerobic, oxidizing conditions, microorganisms break down the congeners of lower chlorination levels, opening the phenyl rings and releasing carbon dioxide, water, and chloride ions (Erickson, 2001).

When PCB degradation occurs naturally in the environment, the process is not only slow but also incomplete. As a result, when PCBs are released into the surrounding ecosystems, remediation is necessary in order to fully clean the site.

Although destruction of PCB molecules is the most successful solution to the remediation of waste, it is not always feasible. This is especially true when the PCBs are dispersed at a low concentration within large volumes. In this case, the focus switches to limiting the mobility of the PCB contaminate in the subsurface, thereby reducing but not eliminating the exposure risk. In order to accomplish encapsulation, a porous surface such as concrete is coated to seal in the PCBs; solidification hardens the soil to prevent leaching, and stabilization chemically bonds additives to prevent leaching (Erickson, 2001). While this is not an ideal solution or a permanent fix, it is the preferred option to doing nothing and letting the PCBs spread and cause further contamination.

When material such as paint or electrical equipment that contains PCBs catches fire, the chemicals are subjected to degradation, transformation, and dispersal. There are several instances of such occurrences, none of which resulted in human health effects but cost millions to clean up. The first PCB fire in the United States was in 1981 in Binghamton, New York in an 18-story office building. Leakage from a transformer that was made of PCBs was spread throughout the building, requiring extensive cleanup and testing that cost three times the amount it took to construct it. It took 14 years for the building to reopen. Fires that occurred after this were just as expensive, costing an average of $20 million to clean, but were remediated in under a year. Cleanup after these fires is expensive, protracted, and complex due to

regulations implemented by the EPA for planning and execution of mitigation, as well as the need for extensive risk assessment (Erickson, 2001). Fire cleanup is complicated in every situation, but when hazardous and toxic wastes are added, it becomes a very serious and detailed process that encompasses all aspects of the environment.

When a PCB fire occurs, the resulting product is a highly complex mixture. Products from the original PCBs are present, and these products can mix to form new compounds under extreme heat; there are also thermal chemicals from all of the other plastics, adhesives, and other materials from the building. The cleanup must be continuously monitored until after it is completed and very specific standards must be met before anyone is allowed back in the building. Even after the site is cleared, PCBs that were spread from smoke during the burning can still exist in the surrounding environment. It is almost impossible to locate the end location of all molecules that were dispersed in the air, making mitigation difficult.

PCBs and the Environment

PCBs have entered the environment during both use and disposal. The list of potential environmental sources is length and includes past open, uncontrolled uses, past disposal practices, illegal disposal, and accidental releases. Environmental levels increase near the source of the chemicals, which means urban and industrial areas have higher levels than pristine environments. Similarly, indoor levels are about one order of magnitude higher than outdoor levels, a trend that is in line with other air pollutants (Erickson, 2001). Since PCBs do not regularly degrade, they are persistent

and tend to bioaccumulate (Figure 4) . The EPA defines bioaccumulation as a, "general term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical," (EPA, "Ecological Risk Assessment – Glossary of Terms", 2/12/16b). It is this process that is partially to blame for the fact that PCBs have been found in all marine plants and animals, fish, mammals, birds, and humans at low but detectable levels.

PCBs are transported through the environment by air, water, fish, birds and other similar methods. They are deposited from the air by rain, snow, dry fallout, and vapor-phase deposition. PCBs enter the environment during both use and disposal; since they do not readily degrade and are lipophilic meaning that they dissolve in fats and lipids instead of water (Bedard, 2001). Open-ended applications such as inks result in widespread, low-level releases over decades of use, where closed and controlled uses such as parts of electrical equipment typically result in distinct, localized releases due to spills, improper handling, or improper disposal. When the latter occurs, the PCBs are found near the site and in high concentrations. Transport of PCBs from initial contamination sites leads to the widespread contamination at low concentrations; as a consequence, 99% of the environmental PCB mass is found in soil (Erickson, 2001). The transport of PCBs through the environment is complex and global. Spills, landfills, road oils, and various other sources of PCB molecules volatize and result in measurable atmospheric emissions.

PCBs tend to migrate from low latitudes where evaporation predominates to Polar Regions where deposition dominates. Although this is common, the large

majority of PCBs are retained in a sink such as oceanic sediments or degraded during transportation. Bidleman et al. (1990) studied PCBs in the Arctic air and commented that, while it is tempting to think of cold air as a sink or trap for chemicals, low precipitation, poor vertical mixing, and an aerodynamically poor surface do not favor deposition. Therefore, there is a possibility that PCBs created on one side of the world may reach sub-Arctic latitudes on the other side by transit "over the top" of the globe. Environmental transport has resulted in a fairly uniform global concentration of PCBs with little difference between hemispheres. Murphy et al. (1985) estimated that 9×10^8 g of PCBs cycle through the atmosphere annually in the United States alone (less than 1% of total PCBs in the environment). While most of these molecules originate in landfills and incinerators, there are still unknown sources of PCBs in the cycle.

Although much of the focus of deposition of PCBs into water bodies, the reverse process can occur via evaporation and aerosolization from bursting water bubbles. The overall persistence of PCBs in water is five years with the reaction persistence being around eight years. Since most PCBs are found in soils and sediments in water, this is believed to be the generally accepted fate of most of the molecules. The long residence time in sediment can be linked to the slow equilibrium process which ranges from six weeks for PCBs of low chlorination up to years for higher chlorinated PCBs (Erickson, 2001). It is important to note that these and other transport mechanisms do not act on all congeners equally, resulting in distorted chemical patterns.

PCB concentrations in the environment have fluctuated throughout history, peaking in the late 1950s/early 1960s, and generally declining since. Worldwide

control of sources, regulation of disposal, virtual elimination of production, and natural reduction have combined to reduced overall contamination levels; however, reduction rates in terrestrial environment and costal areas are slow, riverine clearances is dependent upon the rate at which the system naturally flushes, and the ocean continues to serve as a sink for PCBs (Faroon, 2003). Bioaccumulation in plant biota such as leaves is a direct indication of the concentration of atmospheric PCBS; other indicator organisms include earthworms and mayflies. Earthworms are a very sensitive indicator, and exhibit levels five to eight times the soil concentration (Bedard, 2001). Understanding how PCBs are transported through ecosystems is important in order to fully eliminate these chemicals from the environment.

There are four major PCB contamination incidents that have happened throughout world history, stimulating research and policies. These are the Yusho incident in Japan, the Hudson River in New York State, New Bedford Harbor in Massachusetts, and the Great Lakes in Central North America (Erickson, 2001). The Yusho case was one of mass food poisoning, when a commercial brand of rice oil became contaminated by PCBs and was ingested by thousands. PCB discharges from two General Electric capacitor plants lead to contamination of significant portions of the Hudson River, and PCBs from electrical equipment manufacturing plants contaminated the New Bedford Harbor. Whether these two systems are able to clean themselves through flushing and biodegradation of PCBs, or if active cleanup is required is a source of debate. The PCB contamination of the Great Lakes did not come from an identifiable source; the active cleanup of this area is not feasible

(Erickson, 14, 2001). PCB contamination is a problem that impacts all kinds of ecosystems across the globe, and that does not have a simple mitigation solution.

Chapter 2: Social Factors: Human Exposure, Health, and Environmental Justice

The concerns surrounding PCBs arose from findings that they were potentially toxic, and therefore undesirable to be used in commercial products or to be released as environmental contaminates. PCBs have been linked to cancer and other serious health effects in animals on the immune, reproductive, nervous, and endocrine systems. They have been shown to cause cancer in animals, and studies of PCB exposure in humans provide support evidence for potential carcinogenic effects (EPA, "Health Effects of PCBs"*,* 2/12/16c). The different health effects of PCBs may be interrelated, as alterations in one system may have significant implications for the other systems of the body.

Human exposure to PCBs occurs primarily via low-level food contamination. Due to the availability of PCBs to biomagnify through the food chain and the relative position of humans in the food chain, the occurrence of PCBs in food has been a great concern and one that has been widely studied. As a general rule, PCB concentrations are directly correlated with the fat content of the food and the potential for exposure. Fish, milk, and other fat-containing products have been of concern, and those that come from contaminated sources are more likely to have higher levels. The PCB distribution in the human body is highest in adipose tissue, followed by the skin, the liver, muscle, and the blood (Erickson, 2001). Due to these concerns, governments around the globe have regulated the permissible levels of PCBs found in foods produced for consumption.

As is the case with other species, PCBs accumulate in fatty tissues in humans because of their non-polar, lipophilic physical properties, and their resistance to biochemical degradation. In the past, all mixtures have been measured as PCBs; however, there is now an emphasis on determining the distribution of different congeners. PCB levels in humans have been studied for over 30 years. According to Erickson (13, 2001), “General conclusions can now be made that PCBs are ubiquitous, with average levels in adipose somewhere around 1 ppm and in blood, 10 ppb.” In the United States, general levels found in humans have declined since their peak in the 1980s, but are still high enough to be a cause of concern. It is also important to realize that not all bodies have the same PCB levels. Exposure from food, occupation, environment, and other sources can lead to variation among people. Total body burden should increase with age if there is steady exposure.

PCBs and Cancer

The EPA’s first assessment of PCB carcinogenicity was completed in 1987, and in 1996, at the direction of Congress, they completed a reassessment of PCB carcinogenicity, titled "PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures”. This report used information on toxicity, deposition, and environmental processes to evaluate PCB risks in the environment. While the main focus of the report was on cancers, it also mentioned several other diseases that could result from PCB exposure (Cogliano et al., 1996). The report and the EPA both concluded that PCBs are probable human carcinogens; the 15 peer reviewers agreed with this statement. The EPA came to this conclusion based on clear evidence that

PCBs cause cancer in animals, from epidemiological studies of workers that were exposed to higher levels of PCBs that found increased cases of rare and fatal cancers, and several other studies.

Often, human studies have not demonstrated an associated between PCB exposure and disease; however, this can be explained by small sample size, methodological limitations, and factors such as smoking rates that can taint statistics (EPA, “Health Effects of PCBs”, 2/12/16d). Even though these studies do not produce a correlation, they should be seen as inclusive, not negative. Their results do not by any means suggest that PCBs are safe. The EPA is not alone in its conclusions regarding PCBs; The International Agency for Research on Cancer has declared PCBs to be probably carcinogenic to humans, and The National Toxicology Program has stated that it is reasonable to conclude that PCBs are carcinogenic in humans. The National Institute for Occupational Safety and Health has also determined that PCBs are a potential occupational carcinogen. It is also important to mention the weathering of PCBs. Upon entrance into the environment, their composition changes (EPA, “Health Effects of PCBs”, 2/12/16d). Those that tend to bioaccumulate are the most carcinogenic, and those who ingest or come into contact with these products may be exposed to more toxic mixtures that what is originally released into the environment.

Studies of those who work in close proximity to or with PCBs found increases in rare liver cancers and malignant melanomas, with possible correlation between exposure and breast cancer rates (EPA, “Health Effects of PCBs”, 2/12/16d). Studies conducted on occupational exposure have focused on biliary/liver and lung cancers. Those who are exposed to PCBs through occupational sources often come into

contact with a mix of PCB congeners and/or a mix of PCBs and chemicals. Therefore, determining specific health effects due to occupational exposure of isolated PCBs presents a challenge (Persky, 2001). Studies have shown increased deaths from biliary/liver, melanoma, thyroid, pancreas, gastrointestinal, and brain cancers among those who face occupational exposure. Brown (1987) studied cancer mortality among 2,588 workers at two capacitor-manufacturing plants. He noted increased risk of liver, gallbladder, and biliary cancer among those exposed to PCBs. Sinks (1992) conducted a similar study, looking at 3,588 workers exposed to PCBs on a daily basis; he found they were at an increased risk for melanoma, with a suggested increased risk for brain cancer. He did not find an increased risk for liver or biliary cancer. The largest cohort study looked at 138,905 electric utility workers. It was conducted by Loomis (1997), and concluded that there was a statistically significant association of PCB exposure with melanoma. These and other similar studies have helped lead to the conclusion that PCBs have adverse, cancerous health effects on humans who experience prolonged exposure.

Other Health Impacts

PCBs also have harmful non-carcinogenic effects that have been supported through results found from studies on animals. The immune effects of PCBs have been studied in Rhesus monkeys, which have immune systems very similar to those of humans. A significant decrease in the size of the thymus gland, which is critical to fighting off disease, a drop in the response of the system, and a decrease in resistance to viruses and other infections were observed through these studies (EPA, “Health

Effects of PCBs", 2/12/16d). These experiments were not able to detect levels of PCB exposure that did not cause effects on the immune system. Effects on the reproductive system were also studied in Rhesus monkeys; it was concluded that PCB exposure reduced birth weight, conception rates, and live birth rates of the monkeys. A decreased sperm count was seen in rats. In studies done on human populations with exposure to PCBs, it was observed that children born to women who had exposure to PCBs from employment in factories had deceased birth weights and significant drop in the gestational age; these were directly correlated with PCB exposure (EPA, "Health Effects of PCBs", 2/12/16d).

Newborn Rhesus monkeys exposed to PCBs showed persistent and significant deficits in neurological development, including but not limited to visual recognition, short-term memory, and learning ability. Some of these studies were conducted using the PCB mixtures most commonly found in human breast milk; studies in humans have suggested effects similar to those observed in monkeys exposed to PCBs, including learning deficits and changes in activity associated with exposures to PCBs. The similarity in effects observed in humans and animals provide additional support for the potential neurobehavioral effects of PCBs (EPA, "Health Effects of PCBs", 2/12/16d). Proper development of the nervous system is critical for early learning, and if underdeveloped, can lead to significant impacts on future health.

Much of the focus on non-carcinogenic health effects of PCBs in humans has focused on the endocrine system and endocrine disruption. PCBs have been shown to impact thyroid levels in humans and animals, which are critical for normal growth and development. While the important of this disruption is the subject of present

study, changes in thyroid levels can have detrimental implications. Studies have shown that PCBs decrease thyroid hormone levels in rodents, and that they have resulted in developmental problems including hearing loss. In the Netherlands and Japan, PCB exposure has been associated with changes in thyroid levels in human infants (EPA, "Health Effects of PCBs", 2/12/16d). While there is a link between exposure and impacts on the human endocrine system, additional research is needed to determine how substantial these effects can be on humans. The same is true for cardiovascular diseases and diabetes (EPA, "Health Effects of PCBs", 2/12/16d). While there is reason to believe there is a link between PCB exposure and cardiovascular disease and diabetes, there is debate as to how strong of a correlation exists. More research is needed to determine this.

Environmental Justice

Environmental justice is an important part of the struggle to improve and maintain a clean and healthful environment, especially for those who live and work closest to the source of the pollution. Environmental justice, sometimes referred to as environmental racism, is defined by the EPA as, "the fair treatment and meaningful involvement of all people, particularly, minority, low-income, and indigenous populations, in the environmental decision-making process," (EPA, "Environmental Justice", 4/3/16). According to the EPA, "fair treatment" means there should not be one group of people that bear a disproportionate amount of negative environmental consequences as a result of various operations and policies. In order to eliminate issues related to environmental justice in the United States, the EPA believes

everyone must have the same degree of protection from environmental and health hazards, and must have equal access to the decision-making process that involves potentially harmful processes (EPA, "Environmental Justice", 4/3/16). Once both of these goals are met, environmental justice will no longer be an issue of concern in America.

Those who are often impacted the most by facilities that have adverse environmental impacts are primarily African-Americas, Latinos, Pacific Islanders, and Native Americans; generally, they are poor people of color (Figure 5; NRDC, "The Environmental Justice Movement", 4/3/16). According to Robert Bullard, "Race seems to be the most significant predictor of disparities that are tied to an existing system of privilege for some and discrimination against others," (Bullard and Wright, 2009, xix). While minority communities are not always poor and vice versa, a community experiencing both of these factors tends to be at a higher risk for issues regarding environmental justice for several reasons.

Historically, corporate decision makers, regulatory agencies, and local planning and zoning boards quickly learned it was easier to put facilities in minority, low-income communities than in primarily white, middle to upper-income communities. Poor communities often lack connections to decision makers on boards and councils that could protect their interests. More so, they cannot afford to hire technical and legal experts that can provide information to be used in fighting these facilities. People in these underserved communities also lack the knowledge and access to information about how the particular pollution produced by the source could affect their health and the livelihoods of those who come into contact with it on a

regular basis. Additionally, the important documents outlining the proposed construction and potential adverse human effects are written in English. For communities that are predominately Spanish speaking, they cannot read any of the papers, even if they have access to them (NRDC, "The Environmental Justice Movement", 4/3/16). All of these factors keep low income and/or minority communities at risk of being taken advantage of by larger, wealthier, and more powerful individuals and companies.

Sociologists Robert Bullard and Beverly Wright argue that, "minorities and the poor are more likely than all other groups to be underprepared and underserved, and to be living in unsafe, substandard housing," (2009, xx). They believe that this impact is cumulative, and that agencies critical in helping these communities are slow to respond. Often, it is those living in these areas that form Grassroots organizations and lead the fight for equality. Bullard is known as the "father" of the environmental justice movement, and is credited with sparking its beginnings. In the 1970's, Bullard discovered that landfills and incinerators in Houston, Texas, were far more likely to be located in communities of color than in white neighborhoods, even though blacks made up just one-fourth of the city's population (Dicum, 3/15/16). He has since dedicated his life to the fight for environmental justice.

The environmental justice movement began in 1982 in Warren County, North Carolina where a PCB landfill ignited protests and hundreds of arrests. This forced a 1983 study by the US General Accounting Office, which discovered that three out of four off-site hazardous waste sites in EPA Region 4, compromising eight southern states, were located in predominately African American communities even though

they only made up 20% of the population (NRDC, “The Environmental Justice Movement”, 4/3/16). These protestors and the study results placed environmental racism on the map. 15 years after the fight against the landfill began, North Carolina was forced to spend over $25 million to clean and detoxify the landfill (NRDC, “The Environmental Justice Movement”, 4/3/16). This was both the first environmental justice case to gain national attention, as well as the first case to be successful in remediating the problem.

In 1987, under the direction of Charles Lee, the United Church of Christ published a report titled, “Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites,” (1987). It was written as part of the church’s Commission for Racial Justice, which aimed at providing justice for all races both within the church and society in general. The report was the first national publication that comprehensively documented the presence of hazardous wastes in racial and ethnic communities throughout the country. In January 1986, two cross-sectional studies were done analyzing the extent to which African Americans, Hispanic Americans, Asian Americans, Pacific Islanders, and Native Americans were exposed to hazardous wastes in their residential communities. The studies showed race as the single most important factor in determining where toxic waste facilities were placed in the US, and gained national support for environmental justice action (Lee, 1987). The report concluded that the strong statistical correlation found between race and location was not an accident, but instead was the result of intentional local, state, and federal land use policies (Table 4; Lee 1987). This report sparked interest with

environmental activists and forged the way for the start of an environmental justice movement in the United States; it was the first study that was able to correlate waste facility sites and demographic characteristics.

In October 1991, the first National People of Color Environmental Leadership Summit was held in Washington, D.C. It lasted three days, and brought together several hundred environmental justice leaders and advocates from around the world. Bullard was one of the main planners. The goal of the summit was to redefine environmental racism and push for change (NRDC, "The Environmental Justice Movement", 4/3/16). People gave testimony of their personal experiences with issues of environmental justice in their communities and shared ways in which they had tried fighting back. They developed 17 principals of environmental justice in order to develop a worldwide movement to fight the destruction of communities of lower socio-economic status, as well as to celebrate the cultures, languages, and beliefs that made the minority groups gathered there unique (NRDC, "The Environmental Justice Movement", 4/3/16). These principals served as the first defining document for the growing grassroots movement for environmental justice.

The summit was a successful attempt at gathering together groups harmed by issues of environmental racism, as well as groups that could offer help in the fight. Those who were most impacted by the injustices spearheaded the fight for equality. Part of the summit's success can be attributed to the environmental movement in the United States, which took off in the late 1970s and 1980s. This started increasing awareness and a willingness to fight environmental problems in the country, and the ideals and beliefs instated during these decades transferred into the 1990s. In 1992,

President Bill Clinton appointed two leaders of environmental justice to help create a federal government policy. Following this, the EPA Office of Environmental Equity was established in November 1992, and a federal advisory committee to the EPA named the National Environmental Justice Advisory Council (NEJAC), was established in September 1993 *(*EPA, “Environmental Justice”, 4/3/16). These new resources provided advice and recommendations about issues related to environmental justice, and established a forum where problems could be heard and discussed.

Up to this point in history, there was still not a federal order directly addressing problems of environmental justice. On February 11, 1994, with the help of Bullard, President Clinton signed executive order 12898, entitled, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” (EPA, “Environmental Justice and National Environmental Policy Act”, 4/5/16). This order directed Federal Agencies to make achieving environmental justice part of its mission, stating:

> To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environ- mental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories… (Executive Order 12898, 1994).

This order also stated it was mandatory for Federal agencies to look for ways to prevent discrimination by race, color, or nationality in any federally funded program specifically dealing with health and/or the environment. It also directed Federal agencies to analyze the environment, human health, economic, and social effects of proposed actions on minority and low-income communities (EPA, "Environmental Justice and National Environmental Policy Act", 4/5/16). This order was significant in that it was the first nationally mandated call for offices to address significant adverse effects on underserved communities.

Despite significant improvements in environment protection for minorities over the past several decades, many Americans still live in areas that are unsafe and could have harmful health implications for themselves and their families. Today, much of the fight for environmental justice is headed by grassroots organizations, which act as strong and permanent forces both for environmental protection and social change in communities (NRDC, "The Environmental Justice Movement", 4/3/16). These groups typically form when members of the affected community have decided enough is enough, and it is time for change. Their actions usually start with educating themselves and others to provide empowerment and improve governmental regulations concerning issues of environmental racism.

Since the turn of the century, grassroots organizations have had increased success in changing the way the government views and treats minority communities and those of low socio-economic status. However, this has not been enough to eliminate issues tied to environmental justice in their completion. As more and more cases of environment justice and environmental racism are brought to the media and

made public, it is the hope that citizens will fight harder for the equal treatment of those who may be of a lower socio-economic status or belong to a minority group. This is the only way to eliminate problems related to environmental justice.

Chapter 3: PCB Policy and Regulation

PCBs have been strongly regulated in America since the mid-1970s. There are strict disposal requirements companies now have to adhere to in order to avoid seepage into the environment. The US government has developed standards and regulations for PCBs that are designed not only to protect the environment, but also to keep the general public and workers that may be exposed to PCBs safe from potential adverse health effects (Faroon, 2003). PCBs have long been recognized as posing a threat to the environment due to their toxicity, persistence, and tendency to bioaccumulate and build up in the bodies of animals, particularly those that are at the top of the food chain. Although their use has been on the decline greatly since the 1970s, those that remain in existence pose a continuing threat to the environment and humans that come into contact with them.

In the United States, Congress initiated formal regulation of PCB management in 1976 under the Toxic Substances Control Act (TSCA). The EPA was put in charge of rule promulgation and enforcement and was also given the ability to grant exemptions to the ban if the manufacture, processing, distribution in commerce, or use is totally enclosed or does not present risk of injury to humans or the environment (EPA, "TSCA"). In the US, only asbestos and PCBs are singled out for mention in the TSCA with their own class of rules and regulations. This reflects how important the government feels the regulation of PCBs is and resulted in differences that force special considerations and separate actions from other harmful substances that can make their way into the environment.

Aside from the TSCA, there are a number of other federal legislative actions related to environmental protection aimed at specifically preventing the pollution of American waters. A number of intermediate acts dealt with public health, water quality, and air pollution up until the formation of the EPA in 1970. After the EPA was established, subsequent legislation was administered, including the Clean Water Act (CWA, 1972), the Resource and Conservation Recovery Act (RCRA, 1976), and the TSCA just to name a few. One of the main guiding principles of PCB regulation is based on the likelihood of exposure, regardless of concentration.

There are several ways to legally dispose of PCBs in the United States. The can be incinerated in designated areas, placed in specialized landfills, be placed in high efficiency boilers, be burned in scrap metal recover ovens and smelters, or be decontaminated. No matter the method, PCB disposal is a very complex and highly regulated process. There are a handful of toxic waste facilities in the US that can accept waste contaminated with PCBs; this means toxic wastes must be transported long distances before they can start to be disposed of, which increases the potential for spills or leaks into the environment, and puts those in charge of transporting them at risk of exposure (EPA, "Laws and Regulations: PCBs", 2/27/16a).

The Toxic Substances Control Act (TSCA) Regulations

In the United States, the significance of the TSCA regulations of PCBs cannot be overemphasized. There are only two substances singled out in the act, and PCBs are one of them. Passed on October 11, 1976, this law gave the EPA broad authority to regulate virtually all aspects of the manufacture, distribution, use, and disposal of

chemicals in the US. The Act authorized the EPA the ability to secure information on all new and existing chemical substances, as well as to control any of the substances that were determined to cause unreasonable risk to public health or the environment (EPA, "TSCA"). When Congress was considering passing this law, the general public became aware of an incident in Yusho, Japan, where people became ill from consuming rice oil that became contaminated with PCBs during its processing. This increased public concern surrounding the safety of PCBs, and under new pressure, Congress directed the EPA to promulgate regulation concerning PCBs (Erickson, 13, 2001). PCBs are defined in the TSCA in 40 CFR 761 as:

> *PCB* and *PCBs* mean any chemical substance that is limited to the biphenyl molecule that has been chlorinated to varying degrees or any combination of substances that contains such substance… (TSCA, 1976).

The specific legislative provisions regarding PCBs appear in Section 6(e) of TSCA, 15 USC 2605(e) (1). Here, the focus is on regulatory action on PCBs by the EPA in order to limit their impact.

The implementing regulatory framework took into consideration what form the PCBS take, such as liquid, non-liquid, or a combination of both, and the amount of PCBs in each form. The degree of risk presented by PCBs in any form is dependent upon the concentration in the object used or the material to be cleaned, disposed or, or remediated. As concentration increases, regulations become more restrictive and tend to have greater reporting and marking requirements. In general, PCBs in concentrations less than 50ppm are not considered to pose unreasonable risk

to human health or the environment, meaning such PCBs are excluded from regulation (Chary and Neuberger, *PCB Policy in the US*). As a result, only highly concentrated PCBs are considered worth remediating, leaving smaller concentrations to be exposed to humans and the surrounding environment.

Congress banned the manufacture, processing, distribution in commerce, or use of PCBs after January 1, 1978, unless such activities were done in a completely enclosed manner. The EPA was given full authority in determining which actions were totally enclosed, as well as authorizing non-totally enclosed uses if it was concluded that these did not present a risk of injury to health of the environment. Finally, Congress stated that after January 1, 1979, no one could process or distribute any PCBs regardless of the practice, unless the EPA granted an exception. Exemptions could only be granted if the EPA found that the activity did not present any risk, and that the company had tried to find a suitable substitute; no exemption could be granted for more than a single year (Erickson, 14, 2001). In order to control the amount of exceptions that were granted, Congress imposed strict limitations on the manufacture, processing, distribution and use of PCBs, leaving the EPA with more responsibility to regulate the disposal and marking of PCBs instead of allowing exemptions.

The EPA's regulations have changed and expanded over time as developments have been made regarding PCBs. The EPA's initial response to the 1978 ban was the promulgation of regulations that addressed disposal by incineration or in specially permitted landfills. Since then, they have published over 30 major regulatory publications that address labeling, inspection, record keeping, disposal,

restrictions on use and burning of used oil containing PCBs, storage for disposal, spill prevention, spill cleanup policy, food and feed restrictions, PCB transformer fire regulations, substitute dielectric fluids, storage container specifications, notification and manifesting rule, policy on the physical separation of PCBs, reclassification of transformers, PCB fluorescent light ballast disposal, and PCBs in laboratories (EPA, "Laws and Regulations", 2/27/16a). The most recent discussions surrounding PCB rules and regulations in the EPA occurred in 2010, and focused on authorizing use.

One of the biggest changes to PCB regulations under the TSCA came on June 29, 1998. Officially called the PCB Disposal Amendments, but more commonly called the "Mega-Rule", it largely focused on waste management issues and had over 80 changes in its 200 pages of text. It was originally proposed in 1991, but underwent a tortuous process of public and internal comment and discussion (EPA, "Laws and Regulations", 2/27/16a). The amendments added provisions authorizing certain uses of PCBs, authorized the manufacture, distribution and use of PCBs for research and development activities, and added additional options for PCB cleanup and disposal; large volume waste types were reclassified to permit a broader range of low risk disposal options. The amendments also established standards and procedures for dealing with PCB remediation waste largely from spill cleanup, and bulk product waste from manufactured products, established methods for determining PCB concentration, specified management controls for PCBs being reused, and established a mechanism for coordination PCB management approvals among federal programs (Erickson, 14, 2001). These amendments contained numerous other changes and

clarifications regarding PCB analysis, marking, recordkeeping, reporting, and exemption requests.

Under the "Mega-Rule", the EPA stated that PCB concentrations had to be reported on a dry-weight basis. While this was not a new regulation, wording in the TSCA left confusion as to whether PCBs had to be dried before their concentrations were determined. This rule also contains an unprecedented appendix with eight subparts that detailed procedures for many of the concepts presented generally in the rule such as "Determining a PCB Concentration for Purposes of Abandonment or Disposal of Natural Gas Pipe" (EPA, "Laws and Regulations", 2/27/16a). This rule did not contain any information regarding non-liquid PCBs; while the EPA acknowledged that regulation of these substances was needed, it determined more research needed to be done to fully understand their human and environmental impacts. It did, however, contain several provisions that greatly facilitated the storage and disposal of radioactive PCB wastes.

Effective October 1, 2007, a revision to the TSCA shifted management of the PCB cleanup and disposal program to the EPA's Office of Solid Waste and Emergency Response (OSWER). This was done in order to increase overall efficiency in EPA cleanup and disposal activities and to result in a more effective use of resources. OSWER provides policy, direction, and guidance for safely managing PCB waste, preparing for and preventing spills, responding to accidents, and cleaning up and reusing contaminated property (EPA, "Polychlorinated Biphenyls (PCBs) Transfer", 2/27/16b). This transfer used existing PCB policies and regulations under the TSCA and restricted future changes from occurring until 2008. The Office of

Chemical Safety and Pollution Prevention continue to manage current authorized uses of PCBs.

Other Federal Laws

Although the primary vehicle for PCB regulation in the US has been the TSCA, there are other federal laws that address PCBs. Under guidance from the Occupational Safety and Health Administration (OSHA), The Occupational Safety and Health Act (1970) has a section aimed at regulating employee contact with PCBs. The Hazardous Materials Transportation Act deals with the transportation of hazardous materials; PCBs are classified as hazardous when present in quantities greater than ten pounds. In general, all PCBs transported by rail, aircraft, vessels and motor vehicles are regulated under this act. The Food, Drug, and Cosmetic Act (1938, 1968) lists PCBs as poisonous and deleterious substances, and the Food and Drug Administration (FDA) warns against their presence in the food supply under this act (Erickson 15, 2001). While these laws were not passed specifically for the regulation of PCBs, they have several important key features that are applicable to PCBs and aim to protect human health and the environment.

While the EPA's main federal law aimed at PCB management is the TSCA, they also have several others that deal with similar issues. The Clean Water Act (CWA, 1972) has discharge limits for PCBs; anything over ten pounds of PCBs within a 24-hour period must be reported. CWA has been significant in establishing zero discharge and elimination of toxic chemicals, including PCBs, into the nation's waterways. It also required a new standard of water quality, requiring all surface

waters to be fishable and swimmable, which has increased the need for mitigation in a lot of areas polluted by PCBs as a result. While CWA includes the Great Lakes, the main legislation restricting and mitigating pollution in this area is The Great Lakes Water Quality Agreement (GLWQA, 1972). GLWQA is a non-binding treaty between the US and Canada reemphasized these principals, calling for a policy that implements actions to improve water quality by both parties (Chary and Neuberger, *PCB Policy in the US*). While this agreement does not explicitly address PCBs, it authorizes funding to remediate concentrations in sediments found in the Great Lakes Basin areas of concern.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980) and The Superfund Amendments and Reauthorization Act (SARA, 1986), sites infected with high PCB concentrations can be deemed Superfund sites, and there are specialized cleanup processes that are site-specific. Remedial investigation and feasibility studies determine the mitigation process based on the amount of cleanup needed. The Resource Conservation and Recovery Act (RCRA, 1976) handles the storage and disposal of hazardous wastes; PCBs and materials that contain PCBs are classified as hazardous wastes according to the EPA. RCRA also requires immediate response to imminent hazards created by the handling, storage, or disposal. The Safe Drinking Water Act outlines the maximum contaminant levels maximum contaminant level goals for the future. Finally, the Clean Air Act (1970) monitors emissions from both mobile and stationary sources, as PCBs are listed as a hazardous air pollutant (Erickson 15, 2001). The EPA is the main source of rules and regulation for PCBs at the federal level.

PCB regulations and disposal requirements differ from country to country, but share a common analytical interest in determining presence in the environment. Regardless of laws, in order to determine this, needs are similar: reliable, practical, sensitive methods that can determine PCBs, their commercial mixtures, by-products, and destruction residues, in a variety of mediums. As a result of their toxicity, many countries have developed regulations for PCBs. The European disposal rules and status for PCBs were passed in 1996. The Canadian Environmental Protection Act, passed in 1999, governs PCBS with four regulations that restrict manufacturing, use, disposal, and export (Erickson, 15, 2001). While the majority of countries that have legislation restricting PCBs use passed such laws much later than the US, it is important that they have them in order to decrease the worldwide demand for products that use PCB in their function or manufacturing processes.

Acceptable PCB Concentrations

The EPA has strict environmental standards that must be followed regarding concentrations in food, water, soil, the environment, and other areas that have the potential to adversely effect human health (Figure 6). OSHA's permissible exposure limit for air in the workplace is a time-weighted average airborne concentration dependent upon the percentage of chlorine in the PCB. On average, for PCBs containing 42% chlorine, the limit is 1.0 milligram per cubic meter (mg/m^3); for PCBs with 54% chlorine, the limit is 0.5 mg/m^3. These limits are based on an 8 hour/ 5 days work week. The higher the chlorine content, the less concentrated the limit. These standards are for aerosols, vapors, mists, sprays, and PCB-laden dust particles.

The National Institute for Occupational Safety and Health (NIOSH) FDA recommends a 10-hour average exposure of 1.0 micrograms per cubic meter (µg/m3) based on the minimum reliable detectable concentration and the potential carcinogenicity of PCBs (ATSDR, "Polychlorinated Biphenyls (PCBs) Toxicity", 2/27/16). While these are the highest acceptable concentrations, the goal is to have zero or the lowest possible exposure to airborne PCBs in the workplace.

Under CWA guidelines, the EPA prohibits industrial discharges of water containing PCBs. The EPA's goal for dinking water's maximum contaminant level, and the enforceable level for PCB's in public water systems is 0.0005ppm (parts per million). The limit for chronic exposure through drinking water or fish ingestion is 0.00008 ppb (parts per billion). The FDA mandates tolerances of 0.2-3.0 ppm PCBs for all foods to protect from non-cancer adverse health effects; the tolerance level in fish is 2 ppm. The FDA also limits PCBs in paper food packaging materials to 10 ppm. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) allow a daily PCB intake of 6 µg/kg (microgram per kilogram) per day (ATSDR, "Polychlorinated Biphenyls (PCBs) Toxicity", 2/27/16). Again, while these are the maximum concentrations deemed tolerable under federal law and regulation, it is important to understand that concentrations lower than the maximum are preferred in order to reduce potential for adverse health and environmental impacts.

Disposal Options for PCBs and PCB Items Based on Concentration

While there are other federal laws concerning PCB regulation and disposal as discussed, this section will focus mainly on those methods that fall under the TSCA. The TSCA PCB disposal regulations are for PCBs and PCB Items with a PCB concentration of ≥ 50 ppm are no longer in use and are declared to be waste. In certain circumstances, wastes with a PCB concentration of < 50 ppm must also meet the disposal requirements outlined by the TSCA. Once determined to be no longer "in service," PCB wastes with a PCB concentration ≥ 50 ppm must be disposed of in a TSCA approved incinerator, TSCA chemical waste landfill, or by an EPA approved alternative method within one year. Wastes with PCB concentrations < 50 ppm must be disposed of in a municipal waste landfill or equivalent (US Department of Energy, "Disposal Requirements for PCB Waste", 1994). Items containing PCBs are not subject to TSCA disposal regulations until declared a waste; there are no regulations pertaining to a maximum amount of time PCB Items may be stored for use or reuse as long as the items are in useful condition and a future use has been identified. However, PCB Items that are no longer fit for use must be taken out of service and declared a waste.

In general, the TSCA regulations identify three main disposal methods for PCBs: incineration in a TSCA approved facility, disposal in a TSCA approved chemical waste landfill, and disposal by an EPA approved alternative method. Soil, debris, or any non-liquid waste contaminated by PCBs at a concentration ≥ 50 may be disposed of in an incineration, chemical waste landfill, or approved alternative method. Liquid PCBs at concentrations ≥ 500 ppm must be incinerated or be destroyed using an

approved alternative method. Liquid PCBs <500 ppm may be disposed of in a chemical waste landfill, provided that the waste is non ignitable and is stabilized to a consistency where it cannot flow. PCBs of these concentrations may also be destroyed in an EPA approved boiler or incinerator US Department of Energy, "Disposal Requirements for PCB Waste", 1994).

The disposal of industrial sludge and slurries containing PCBs at concentrations ≥ 50 ppm is not specifically regulated under the TSCA. However, EPA has two policy statements that established requirements for disposal of industrial sludge and slurries according to PCB concentration. Industrial sludge and slurries ≥ 500 ppm should be disposed of in a TSCA incinerator or by an approved alternative method, and industrial sludge and slurries < 500 ppm should be disposed of in a TSCA incinerator or TSCA chemical waste landfill, or by alternate method. Alternatively, solid and liquid phases of industrial sludge with a PCB concentration < 500 ppm may be separated and each phase may be disposed of according to the TSCA disposal regulations for liquid and non-liquid PCBs (US Department of Energy, "Disposal Requirements for PCB Waste", 1994). In this case, TSCA would require that the liquid and non-liquid phases of the sludge be disposed of according to the original PCB concentration of the material.

PCB Transformers that contain ≥ 500 ppm PCB may be disposed of in a TSCA chemical waste landfill if they are first drained of dielectric fluid and then flushed with an appropriate solvent. Other PCB-contaminated electrical equipment with a concentration ≥ 50 ppm but < 500 ppm must be drained of all free-flowing liquid before disposal. The drained electrical equipment may then be disposed of in a

municipal landfill. The resulting PCB contaminated liquid must follow liquid disposal rules based on concentration (US Department of Energy, "Disposal Requirements for PCB Waste", 1994). The most basic summaries of the regulations regarding different forms of PCBs and their destruction reflects how complex and hazardous PCB handling can be, and how important it is to have strict rules to mandate disposal.

Problems with PCB Regulation

Even with increased legislation, there are still four critical gaps in US policy that hinder progress towards reaching the goals of virtual elimination and zero discharge of PCBs. They include: failure to address the historical deposition of PCBs, including their persistence and recycling through the environment, and the lack of political will and dedicated resources to achieve permanent destruction; conflicting laws and policies and a fragmented regulatory structure where several offices and agencies are charges with overseeing PCB policy, often with conflicting agendas; the failure of the TSCA regulatory structure to reflect current scientific data and a shrinking risk assessment paradigm leading to an absence of policy addressing PCB concentrations less than 50ppm; the reliance on voluntary rather than legally mandated reductions in PCB concentrations combined with inadequate reporting and requirements (Chary and Neuberger, *PCB Policy in the U.S.*). Even after a federal ban and strict regulations, there are still several ways PCBs are released into the environment, making their complete elimination almost impossible.

Acts such as CWA and GLWQA are after zero discharge and virtual elimination of pollutants such as PCBs. However, the EPA can still grant exemptions

to TSCA, and PCB use can be authorized. In order to ensure that PCBs cannot contaminate the environment, their production must be stopped. While there is still a way to gain permission for the use of PCBs, there is no way to ensure their total elimination. This fragments PCB policy, and creates a structure that is ineffective (EPA, “Laws and Regulations: PCBs”, 2/27/16a). There are also several offices and agencies tasked with overseeing PCB policy, which increases the likelihood that something will be missed or overlooked due to the assumption that it is under the control of a different agency. While the TSCA “Mega-Rule” tried to relieve some of this discourse, there are still several different offices involved with regulating and mitigating PCBs.

Another issue with current PCB regulation is that it essentially ignores all concentrations less than 50ppm. The EPA has determined that there is little to no risk to human or environmental health at these low concentrations, and therefore does not require any sort or cleanup or regulation of areas where these are found. However, there is little scientific data or research that has been conducted to support these assumptions. Since it is assumed that lower concentrations are not harmful, studies are not conducted on these areas (EPA, “Laws and Regulations: PCBs”, 2/27/16a). As a result, there is no data that suggests even small concentrations are harmful, and there is no data that correlates with resulting health risks. It is assumed that PCBs under 50ppm are safe, however, this may not be the case and still leaves parts of the environment contaminated.

Another problem with PCB regulation is its failure to address the historical deposition of PCBs that continue to persist in and recycle through the environment.

When TSCA was passed, it was designed to be prospective and, as a result, did not address major contamination that existed due to past practices. Additionally, some of the PCB uses that were permitted before the total ban was implemented have created a reoccurring PCB cycling through the environment. There was a severe underestimate of the magnitude of PCB contamination in waters and other man-made and natural reservoirs when the ban was put in place, which also allowed PCBs to cycle through the environment (EPA, "Laws and Regulations: PCBs", 2/27/16a). PCB legislation was not put in place at the time to address past PCBs, as it was not understood how severe concentrations were and how they cycled through the environment. As technology has improved and there is a greater understanding of PCBs and how they interact in various environments, knowledge as to the extent and scope of their contamination has grown. As a result, policy, regulations, and remediation are far behind where they should be, and a lot of PCB cleanup has relied on voluntary programs or lawsuits that have resulted in forcing companies responsible for contamination to clean up the areas.

PCB regulations have been done using a fragmented approach to management, disposal, and elimination. Decades after the passage of strict rules and regulations, PCBs still circulate throughout ecosystems and waterways, resulting in continuous human and environmental exposure. As a result, there is a necessity for fish consumption advisories and/or bans in many of the nation's great bodies of water, including the Great Lakes and the Hudson River (EPA, "Hudson River Fish Advisories", 3/7/16). This leads to a debate over how PCBs should be treated and removed from the areas in which they are found, and what concentrations should be

considered as a concern due to the determination that they pose an unreasonable risk if exposure occurs.

While there is an existing debate as to the effectiveness and success of PCB policies and regulations that have been implemented, having flawed restrictions are better than a total absence of rules. In order to completely remove PCBs from the environment, acceptable uses of PCBs must be restricted to cases where there is no other possible alternative and the technology is necessary to protect or save human life. This would virtually eliminate any use of PCBs, as technology has led to the development of many acceptable alternative substitutes. There also must be a greater emphasis on cleaning past contamination. Now that the extent and risk of PCBs existing in the environment is more widely known, more needs to be done to remove them so they no longer cycle through the environment. In order to have successful PCB policies and regulations, several changes need to be made to those in existence. However, it is still important to remember that we are better off with flawed legislation than we were before the ban of PCBs when they were widely produced and almost always improperly disposed of.

Chapter 4: Case Study: General Electric and the Hudson River

From its start in the Adirondack Mountains 315 miles south to its entrance into the New York Harbor, the Hudson River is abundant with a diverse array of species and natural resources. The lower part of the river, from Albany to New York City, is known as an estuary- a long arm of the sea subject to tides and the upriver press of salty ocean water. The estuary is high in biodiversity; the plants and animals found there depend on its productive waters in order to live and reproduce (DEC, "Cleaner Water for the Hudson River Estuary", 3/7/16). In the days following the Industrial Revolution, industry depended on waterpower and many factories were located along the Hudson River. The fast flowing river provided both power to operate machinery and a convenient means of waste disposal. Toxic wastes entered into the precious ecosystem, destroying natural resources and habitats. General Electric (GE) is a prime example of a corporation that took advantage of the power producing capabilities of the Hudson River and chose to use it as a dumping ground, leaving behind a trail of toxins in its wake.

General Electric and PCBs

GE used PCBs in its capacitor manufacturing plants in Fort Edward and Hudson Falls, New York, about 50 miles north of Albany. It is approximately 8 feet deep by the shoreline, 18 feet deep in the channel, and has a maximum depth around 45 feet. It is estimated that GE dumped around 1.3 million pounds of PCBs into the Hudson during its production and use of these substances until their federal ban in 1977 (EPA

Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). While GE applied for permits to dump PCBs into the river in 1973 and obtained their first permit in 1975, they had released PCBs for years. GE began releasing these toxins at the Fort Edward plant in 1947, and at Hudson Falls in 1951, meaning they dumped PCBs from 1947 to 1975 illegally (Ferro, 2014). PCBs also seeped into the river illegally after permits were obtained from contaminated soil and groundwater. Further evidence that GE dumped PCBs illegally before it obtained permits in 1975 came from a 1969 study that found detectable levels of PCB in Hudson River fish for the first time (EPA, "Actions Prior to EPA's February 2002 Record of Decision (ROD)", 4/13/16). Once these PCBs entered into the river, they were either deposited or mixed with sediments along the river bottom as well as along the shoreline in the floodplain.

The NYSDEC decided to bring legal action against GE in 1975, which settled with a $7 million program for the investigation of PCBs in the Hudson, as well as for remediation and their removal. In the same year, the NYSDOH issued the first health advisories warning people to limit their consumption of fish from the river, still in effect today (Figure 7). In 1976, the DEC issued a ban on all fishing in the Upper Hudson River from Hudson Falls to Troy due to the potential for consuming PCB contaminated fish. The DEC reopened this part of the river to catch and release in 1995 (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). From Hudson Falls in the north, south to Troy, fish caught in this area are strictly forbidden from consumption; they must be caught and released. From Troy to Catskill, near the middle of the river, women of childbearing

years and children under the ages of 15 are not allowed to eat fish caught here. For everyone else, there are certain species that can be eaten once a month; everything else is not edible. In the lower Hudson, from Catskill to NYC, women of childbearing years and children under the ages of 15 are not allowed to eat fish caught here. Others can eat certain species once a week or once a month; there are still species that are inedible in this area (EPA, "Hudson River Fish Advisories", 4/16/16). Waters and PCB levels in fish are continuingly monitored along the Hudson, and regulations are updated accordingly.

In 1973, the dam at Fort Edward was removed due to its deteriorating condition. This removal and subsequent flooding released all the PCB-ridden sediments that had accumulated behind it downstream. This revealed five major "Remnant Deposits" where PCB-contaminated sediments were exposed due to lower water levels, and started to raise concern about the safety of the Hudson River (EPA, "Actions Prior to EPA's February 2002 Record of Decision (ROD)", 4/13/16). The NYSDEC surveyed the Upper Hudson River sediments from 1976-1978, and again in 1984. Areas with total PCB concentrations of 50ppm or greater were identified and listed as hot spots; 40 sites were labeled as such during this time.

In 1984, 200 miles of the Hudson River between the Hudson Falls plant and NYC were placed on EPA's National Priority List of the country's most contaminated hazardous waste sties, designating it as a Superfund site in need of remediation. At this time, a no action remedy solution was selected, as the effectiveness and reliability of mitigation solutions was questionable (EPA, "Hudson River PCBs Superfund Site", 3/7/16). In 1989, the EPA decided to initiate a detailed reassessment remedial

investigation study of the no action decision for the Upper Hudson River, prompted by the five-year review requirement of CERCLA (EPA, "Actions Prior to EPA's February 2002 Record of Decision (ROD)", 4/13/16). This reassessment found that once introduced into the river, PCBs stuck to the water column, where they would make their way along the food chain until removed or remediated. Therefore, the EPA determined the removal of PCB-contaminated sediments would result in reduced concentrations in fish, thereby accelerating the decrease in potential human health and ecological risks (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). Ongoing evaluations of water quality, sediments, air quality, fish, and wildlife by the Federal Government and NYS showed that the Hudson was not cleaning itself and PCBs in the sediment posed a serious risk to both human health and the environment.

The Human Health Risk Assessment completed by the EPA under the 1989 reassessment showed that the cancer and non-cancer health risks from consuming fish from the Upper Hudson River were above EPA's acceptable levels for 40-year exposure duration beginning in 1990. The total cancer risk for a "reasonably exposed" human based on age were 1,000 times higher than the goal for protection, and 10 times higher than the highest risk level allowed under the Superfund law. Non-cancer risks for young children, adolescents, and adults respectively, were 104, 71, and 65 times higher than the level considered as protecting public health (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). The report also determined the cancer and non-cancer health hazards from ingestion of fish from the Mid-Hudson were about half as high as those in the

Upper Hudson due to lower concentrations of PCBs (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). While levels in the Mid-Hudson were lower, they will still cause for concern.

In 1991, GE detected an increase in PCB concentrations from Upper Hudson sampling sites that they attributed to the collapse of a tunnel near an abandoned mill located near the Hudson Falls plant. PCBs that had been released from the plant originally collected in the tunnel; its collapse flushed them into the river. Between 1993 and 1995, GE removed approximately 45 tons of PCBs from the tunnel under the jurisdiction of the DEC (EPA, "Actions Prior to EPA's February 2002 Record of Decision (ROD)", 4/13/16). In 1998, GE ran into more problems with PCBs, this time at an area known as Rogers Island. This location had been a dump for PCBs in the 1970s, and concern was being raised as to whether or not it posed human health concerns. Surface soils on the floodplains were found to be contaminated, and it was determined that they presented an imamate health threat. 4,440 tons of soil contaminated with lead and PCBs were removed and disposed of off site (EPA, "Actions Prior to EPA's February 2002 Record of Decision (ROD)", 4/13/16).

In February 2002, the EPA issued a Record of Decision for the Hudson PCB Superfund site that called for targeted environmental dredging of approximately 2.65 million cubic yards of PCB-contaminated sediment from a 40-mile section of the Upper Hudson from Fort Edward to Troy, New York, totaling around 150,000 pounds of PCBs. Dredge areas were identified using the results of a multi-year sediment sampling program conducted by GE that began in 2002; it generated over 60,000 samples from the bottom of the Upper Hudson River, and led to the conclusion that

most of the contaminated sediments were in localized spots along this stretch of the river. (EPA, “Hudson River PCBs Superfund Site”, 3/7/16). The dredging was aimed at removing 65 percent of the total PCB mass present within the Upper Hudson. Generally, this remedial plan had several goals, including: reducing the cancer and non-cancerous health risks for people eating fish from the Hudson, reducing PCB concentrations in fish, reducing PCB levels in sediments to reduce overall river concentrations, and minimizing the long term transport of PCBs downriver (EPA Region 2, “First Five-Year Review Report for the Hudson River PCBs Superfund Site”, 6/1/12).

Hudson River Dredging

The dredging of river bottom sediment began in 2009 and was completed in fall 2015. The dredging was divided into two phases, both of which were completed by GE with EPA oversight. Dredging ended up removing over 300,000 total pounds of PCBs from the upper Hudson and cost around $1.6 billion dollars (The Hudson River Dredging Project, “A Historic Achievement”, 3/7/16). Throughout this process, drinking water was continuously monitored in order to ensure PCB concentrations did not exceed 500 ppt, the limit deemed acceptable by the EPA. On May 15, 2009, Phase 1 dredging began with the removal of sediments from the Hudson, using mechanical dredges with enclosed clamshell buckets (Figure 8). Sediments were then transported by barge to the processing facility at Fort Edward where they were put through a multi-stage dewatering process before being loaded into railcars for transportation to a permitted disposal landfill, Waste Control Specialists in Andrews,

Texas. In a letter dated May 7, 2010, GE terminated their relationship with this landfill, siting failure to meet contractual agreements. Remaining Phase 1 sediments were shipped to Clean Harbors Grassy Mountain in Grassy Mountain, Utah, US Ecology Idaho in Grand View, Idaho, and Wayne Disposal in Bellville, Michigan (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). Water produced during the dewatering processes at these facilities was treated before being discharged into the Champlain Canal. After sediment removal, areas of the Hudson that had been dredged were capped according to EPA design. Total removal during this phase equated 286,000 cubic yards, with an additional 1,500 cubic yards removed from the Champlain Canal to allow for continuing passage of barges going to the unloading wharf (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12).

After completion of Phase 1, both GE and EPA conducted evaluation reports listing successes and challenges of the dredging, as well as the plan for the second phase. These reports came to three main conclusions; the first was that sediment volume and PCB mass removed met of exceeded initial estimates. The second conclusion stated fish tissue impacts were limited within 2 to 3 miles downstream of the most contaminated area, and no measurable impacts to fish or water quality occurred in the Lower Hudson. The report also discussed the success of completing and capping in compliance with all standards (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). Overall, it was determined that Phase 1 of the project had been successful, and that all problems that had been encountered were manageable and could be avoided in Phase 2. GE

conduced habitat replacement and reconstruction in areas that experienced dredging between 2010-2011, with completion in July 2011. On August 15, 2011, EPA approved GE's Certification of Completion of Phase 1 activities (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). While EPA concluded dredging had been in full compliance, peer reviews of Phase 1 concluded that there were several changes that had to be made before commencing Phase 2; GE altered parts of the methodology and sampling of sediments.

GE conducted Phase 2 of dredging from June 6 to November 8, 2011. Dredging was initially scheduled to being in May, but was delayed due to a historic 100-year flood. Once flows subsided, GE began dredging 24 hours a day 6 days a week. During this phase, three dredge platforms with 5-cubic yard buckets were on the Upper Hudson at a given time. The 19 barges and 17 tugboats on the river were a decrease from the amount used in Phase 1, but still managed to meet all standards (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). 670 barges were unloaded at the processing facility, representing a total of 362,332 cubic yards of sediment and approximately 6,000 pounds of PCBs. Processed sediments were sent to facilities in Grand View, Idaho, and Bellville, Michigan for disposal, some of the same from Phase 1. In 2011, GE conducted a deposition study and concluded that PCB deposition was not having a measurable impact on sediment PCB concentrations (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12).

In June 2012, EPA released the first Five-Year Review Report for the Superfund site. This was done in an effort to ensure that the implemented remedy

remained protective of public health and the environment, and that it was functioning as designed. The report was originally supposed to be published earlier, but due to requests from the public for additional time to submit comments and therefore more time needed to review these comments, the EPA extended the completion date.

Now that dredging has finished, GE's environmental cleanup work on and along the Hudson will switch its focus to restoring under-water vegetation to areas that were disturbed during cleanup as well as monitoring environmental conditions in the river for the foreseeable future. They will also continue to evaluate the floodplains along the river to determine if mitigation is needed there.

Groundwater Contamination

It is has been reported that the Hudson River was not the only body of water polluted by GE. A report written by two federal agencies and the NYSDEC in 2015 revealed groundwater was contaminated in three towns- Hudson Falls, Fort Edward, and Stillwater (Nearing, 9/3/15). The report also warned underground contamination around the plant in Fort Edward appears to be spreading, creating a threat to new areas of groundwater. Twelve test wells drilled in the 1980's near the plant did not detect PCBs through the 1990's, but by 2011, showed unsafe levels of PCBs higher than the state standard for groundwater; in some cases, the water had levels thousands of times higher than safe levels (Nearing, 9/3/15). Stillwater, located in Saratoga County southwest of Washington County, used wells near the Hudson as a public drinking water supply until 2011. They would draw up PCB tainted river water into and through the ground, causing PCBs to accumulate. The tainted aquifer,

not the river itself, is the cause of the majority of PCBs in the groundwater. Stillwater now buys its drinking water from the county (Nearing, 9/3/15).

The town of Waterford, also located in Saratoga County, shut down its water treatment plant in 2009 when dredging of the Hudson River began. Halfmoon, another town in Saratoga County, opened a $12 million water plant along the river in 2003. The town kept pumping water from the river but had to turn its plant off repeatedly the first year of dredging. In March 2010, when there was no dredging, PCB levels in the upper Hudson River spiked to 2,000 part per trillion, prompting Halfmoon to shut down its plant (Lyons, 3/8/14). It has not used water from the Hudson River since then.

Environmental Justice Issues

Fort Edward and Hudson Falls are both located within Washington County, a rural county in eastern NYS approximately 50 miles north of Albany. It lies between the Hudson River on the west and the Vermont border on the east. The 2010 Census lists the county population at 63,216 people and 94.6% white non-Hispanic. (Washington County Quick Facts, United States Census Bureau, 4/25/16). Fort Edward had 6,371 residents during the 2010 census, while Hudson Falls had 7,281 (United States Census Bureau, "Washington County Quick Facts", 4/25/16a). First, we will look at socioeconomic data for Fort Edward, zip code 12828. Then, we will analyze the same data for Hudson Falls, zip code 12839, and compare all the data to Washington County and NYS in order to look for evidence of environmental justice issues. Even though GE's pollution reaches beyond Washington County, only data for this county

will be analyzed, as this is where the capacitor plants were located.

The 2010 Census states that 12.5% of the total population aged 25 years or older has a Bachelor's degree or higher in Fort Edward. The median value of owner-occupied housing units is $101,100, and 8.6% of housing units in the town are vacant. The mean household income is $49,742, and the percent of persons in poverty is 14.2 (United States Census Bureau, "Fort Edward Quick Facts", 4/25/16b).

According to the 2010 Census, in Hudson Falls, 13.3% of the population aged 25 years or older has a Bachelor's degree or higher. The median value of owner-occupied housing unites is $135,000, and 6.2% of housing units are vacant. The mean household income is $41,122, and 25.3% of the population is below the poverty line. (United States Census Bureau , "Hudson Falls Quick Facts", 4/25/16c).

As a county, only 18.5% of persons 25 years or older in Washington have a Bachelor's degree or higher, compared with a NYS percentage of 33.7%. In Washington County, the mean value of owner-occupied housing units is $144,100, and the percent of vacant housing units is 16.3; in NYS, the mean value of owner-occupied housing units is $283,700, and 9.7% of houses are vacant. The mean household income in Washington County is $51,494, and 13.0% of people are below the poverty line. In NYS, the average household income is $58,687, and 15.6% of persons live below the poverty line (United States Census Bureau, "Washington County Quick Facts", 4/25/16a; United States Census Bureau, "New York State Quick Facts", 4/25/16d).

The percentage of minority races that reside in both Fort Edward and Hudson Falls are almost immeasurable; there is no sense in comparing them with Washington

County or NYS, as they are less than 1% (United States Census Bureau, "Fort Edward Quick Facts", 4/25/16b; United States Census Bureau, "Hudson Falls Quick Facts", 4/25/16c). While race may not be a large factor, it is the other socioeconomic facts mentioned above that tell a more interesting story (Figure 9).

One of the largest differences between the geographic areas is the percent of persons 25 years or older who hold at least a Bachelor's degree. The NYS rate is almost double the rate for Washington County, and it almost triple the rates in Fort Edward and Hudson Falls. The average value of owner-occupied houses is also quite different between NYS and Washington County, as well as between the county and Fort Edward and Hudson Falls. The NYS median value is more than double the value of a home in Fort Edward and Hudson Falls. In Washington County, the average home is worth $10,000-$40,000 more than a home in either town. While the percent below the poverty line is not as stark for Fort Edward when compared to the county and state average, the percent in Hudson Falls is very high; it is more than 10% higher than both the state average and the county average.

The median household income is also noticeably lower in Fort Edward and Hudson Falls than in Washington County or NYS. Figure 10 shows the average household income in the area, with the GE factories marked with a star. The closer to the factory someone resides, the lower the average household income.

While the absolute numbers may not be incredibly compelling, the fact remains that the data for several different socioeconomic factors is consistent with other areas that have been the focus of environmental justice cases. Those who live near the GE plants in Fort Edward or Hudson Falls are less educated, have homes that

are worth less, have lower incomes, and are poorer than not only other areas of NYS but also different areas within Washington County.

Health Impact: Cancer Rates

As discussed, PCB molecules have several human health concerns associated with them. Prolonged exposure can lead to diseases including cancers and other serious illnesses. With the all of the PCB contamination in Fort Edward and Hudson Falls, human health in Washington County is analyzed in an attempt to identify correlation between exposure to PCBs and serious health problems among all ages and genders. Saratoga County health data will also be analyzed, due to the known groundwater contamination. Since PCBs are a probable human carcinogen, we will look at cancer rates in Washington County and the areas surrounding the GE plants where the pollution occurred in neighboring Saratoga County.

In July 2012, the American Cancer Society published a detailed report on cancers in NYS, entitled *The Cancer Burden of New York State.* The report starts by stating general cancer statistics for NYS that we can use for comparison against Washington County. One in two mean and one in three women in New York will get diagnosed with cancer at some point during their lives, with more than half of these diagnoses occurring after the age of 65. Cancer is the second most common cause of death in the state after heart disease. In 2011, more than 107,000 New York residents were diagnosed with cancer and over 34,000 of them died from the disease (The American Cancer Society, *The Cancer Burden in New York State,* July 2012). Overall, NYS has a higher cancer incidence rate that the nation as a whole, but a

lower death rate.

Using data from 2010-2012, NYS has a crude incidence rate per 100,000 of 550.9; Washington County has a rate of 659.0, and Saratoga County has a rate of 593.0. These are statistically significant differences. Cancers are also the leading cause of death and premature death in Washington and Saratoga Counties (Figure 11; NYSDOH, "Cancer Indicators-Washington County", 5/1/16). Recall that studies of PCBs in humans have found increased rates of melanomas, liver/biliary cancer, gall bladder cancer, gastrointestinal/stomach cancer, thyroid cancer, and brain cancer, with a possible link to breast cancer. Since there is speculation as to whether PCBs can be linked to breast cancer, we will remove these rates from the analysis.

In looking at the CDC's state cancer profile for both sexes and all ages for Age-Adjusted Incidence Rate cases per 100,000 (95% confidence interval) from 2008-2012, we see rates in Washington and Saratoga counties that should raise questions and be investigated. For melanomas, NYS has an age adjusted incidence rate of 17.5, while Washington and Saratoga counties have higher rates at 22.0, and 24.0, respectively. For brain cancers, the NYS rate is 6.6 per 100,000; the Washington County rate is 9.1 per 100,000, and the Saratoga County rate is 8.7 per 100,000. NYS has an age adjusted incidence rate for thyroid cancers of 18.2; Washington County has a much higher rate at 27.2, as does Saratoga County at 20.2 (CDC, "State Cancer Profiles, New York Incidence Rates Table", 4/30/16). NYS has an age adjusted incidence rate for liver cancer of 8.3, while Washington County has a lower rate at 5.9; Saratoga County also has a lower rate of 5.4. For stomach cancer, the NYS rate is 8.6 per 100,000, where the Washington County rate is 5.9 and the

Saratoga County rate is 6.1 (CDC, “State Cancer Profiles, New York Incidence Rates Table”, 4/30/16). Gallbladder cancer rates could not be obtained.

For three of the five cancers linked to PCBs that NYS age adjusted rates per 100,000 could be obtained for, rates were significantly higher in Washington and Saratoga counties than the NYS average. The thyroid cancer rate for Washington County is the second highest rate for any county in NYS (CDC, “State Cancer Profiles, New York Incidence Rates Table”, 4/30/16). Aside from liver cancer, these statistics are consistent with the findings of studies on prolonged PCB exposure and resulting cancers. Since PCBs are a probable human carcinogen, and cancer rates for those commonly associated with PCBs in Washington County and Saratoga County where residents were subjected to prolonged exposure are much higher than the state average, this raises concern about a potential correlation between PCBs and risk of cancer (Figure 12).

Health Impact: Non-cancerous Conditions

While cancers are one adverse health implication associated with PCB exposure, they are certainly not the only one. Pregnant woman who experience prolonged exposure to these toxins have children with lower birth weights; PCBs can also be transmitted to infants through breast milk, so those who are at higher risk may choose not to breast-feed. In 2011-2013, in NYS, the percentage of low birth weights (<2.5 kg) was 8; in Washington County, the percentage was 7.6, and in Saratoga County, the percentage was 6.6 for the same time period. The percentage of very low birth weights (<1.5kg) in NYS for 2011-2013 was 1.4; in Washington, it was 1.7, and was

Saratoga, 1.1 (NYSDOH, “Maternal and Infant Health Indicators- Washington County”, 5/1/15a; NYSDOH, “Maternal and Infant Health Indicators- Saratoga County”, 5/1/15b). The percentage of infants enrolled in WIC who were breast-feeding at 6 months in NYS between 2011-2013 was 38.2; the rates in Washington and Saratoga counties were much lower, at 16.2 and 21.2 percent, respectively (Figure 13; NYSDOH, “Maternal and Infant Health Indicators- Washington County”, 5/1/15a; NYSDOH, “Maternal and Infant Health Indicators- Saratoga County”, 5/1/15b). The rates of breast-feeding for infants in counties where pregnant women likely consumed PCBs between 2011-2013 were significantly lower than the NYS rate. Concerned mothers worried about passing the toxins on to their newborns could potentially explain this discrepancy.

The link between cardiovascular diseases, diabetes, and PCBs is heavily debated. Comparison between NYS average incidence rates and Washington and Saratoga counties reveal no distinct correlation. Some rates are higher, while others are lower than the state average. This supports claims that cardiovascular diseases and diabetes incidence rates are not directly correlated with PCB exposure.

Another health impact of PCB exposure is developmental disabilities. While rates for specific conditions could be obtained, the 2007 ACS listed the percentage of both sexes aged 16-64 years old who had a mental disability but were non-institutionalized. For NYS, this was 4.17%; for Washington County, it was 5.75%, and for Saratoga County, it was 3.37% (US Census American Fact Finder, 5/2/16). While these percentages do not entirely reflect the proper disabilities associated with PCBs, they do provide numbers that suggest more data should be compiled and

analyzed regarding developmental disabilities and PCB exposure.

GE's Stance Regarding PCBs and Human Health

GE has stood by its belief that there was nothing dangerous released at its plants, and PCBs do not have harmful human health implications. Jack Welch, CEO of the company from 1981-2001, always insisted that PCBs are safe — a position he and GE hold to this day, despite scientific evidence to the contrary (Lyons, 3/8/14). However, documents have been uncovered, revealing GE was warned of the potential serious health threats as early as the 1960's. In 2004, four years before she became GE's vice president of corporate environmental programs, Ann R. Klee sat before a U.S. Senate environmental committee to make her pitch for confirmation as the EPA's general counsel. In February 2008, after Klee left the EPA, GE hired her as its vice president of corporate environmental programs (Lyons, 3/8/14). Part of her job included overseeing management and remediation of GE's polluted sites around the country, including the Hudson River.

During a 2012 deposition, Klee repeatedly said it's her "understanding" there are "no adverse health effects associated with PCBs," (Lyons, 3/8/14). That view conflicts with the stance of her former employer, EPA, which considered PCBs a possible human carcinogen in the 1970's before amending is position in the 1990's, declaring PCBs as a "probable" human carcinogen. When asked if she'd read reports on PCBs other than those commissioned by GE, she said, "It's not part of my responsibility to be a PCB scientist," (Lyons, 3/8/14). Those who have been employed at these plants are concerned over the carcinogenic and health risks

associated with their exposure to PCBs. GE closed its Fort Edward plant in spring, 2016. The union representing those who work there is citing concerns over exposure to toxic PCBs, and is pressing the company to pay for health testing after the closure. GE is refusing the request, saying a heavily criticized company funded study in 1999 found around 7,000 current and former workers at the Fort Edward and Hudson Falls plants did not have cancers or illnesses beyond the rate of the general population. However, this study included a large percentage of workers such as secretaries, who had never been exposed to PBCs, and only looked at their carcinogenic potential; it also only followed people for five years (Nearing, 1/22/16).

Gene Elk, an official with the United Electrical, Radio and Machine Workers of America (UE), said in January 2016, that workers are concerned exposure to PCBs could put them at risk of illness later in life. The union lobbied for access to company-collected health records of workers at both Fort Edward and Hudson Falls since at least September 2014, and will receive the report with names removed (Nearing, 1/22/16). Even though GE refuses to admit PCB exposure their workers have been faced with could lead to potential health impacts, those who work there are concerned about their health.

Grassroots Organizations and the Hudson River

While the government has taken action against GE and has forced them to clean up part of the river, they have done little since dredging ended. Several residents in the area and some scientists were concerned that dredging only part of the Hudson River that was the most heavily contaminated with PCBs was not fully remediating the

problem. When they voiced their concerns, they were met with resistance from both GE and the EPA who claimed mitigation efforts were successful in meeting the goals of cleanup. Concerned citizen were left with no choice but to stand down. Eventually, their fight was picked up by grassroots organizations that made sure everyone was heard before a final decision regarding more cleanup of the Hudson was reached.

For over 45 years, Hudson River Sloop Clearwater has been at the forefront of the environmental movement surrounding the Hudson River. It has worked to pass landmark legislation, provide innovative educational programs and increase environmental advocacy. Its mission is, "to preserve and protect the Hudson River, its tributaries and related bodies of water. As an organization, Clearwater works to provide innovative environmental education programs, advocacy, and celebrations designed to expand people's experience, awareness and stewardship of this magnificent natural resource," (Hudson River Sloop Clearwater Inc.,*"Hudson River Sloop Clearwater: About"*, 3/1/16). The organization wishes to inspire, educate, and activate millions of people through its programs and outreach.

While the organization was officially founded in 1969, it had its beginnings in 1966. The raw sewage, toxic chemicals, and oil pollution that plagued the Hudson during this time began to raise concern and spurred the development of Clearwater. Musician and activist Pete Seeger had a vision to build a replica of a sloop that sailed the Hudson in the 18^{th} and 19^{th} centuries in order to bring more people to the river so that they could experience its natural beauty, form a connection with it, and be moved to clean and preserve it. The 106-foot replica named *Clearwater* was built in Beacon, New York in 1968. It was launched on May 17, 1969 from Harvey Gamage Shipyard

in South Bristol, Maine, and added to the National Register of Historic Places on May 4, 2004 (Hudson River Sloop Clearwater Inc., "Hudson River Sloop Clearwater: History and Specifications", 3/2/16). Early vessels and their crews were the main communication link between riverfront towns and outlying areas where a large percentage of the nation's population lived at the time. *Clearwater* aimed to continue that tradition as a vital link between communities while sharing the message that there is incredible beauty and wealth in the region's waterways, and an everlasting need to preserve, protect, and celebrate them.

Clearwater's Environmental Action Director, Manna Jo Green, believes that the more people know about the problems with PCBs and the river, the more likely it is that there will be more cleanup. In the last two years of GE's dredging, other organizations did legal research while Clearwater set out to get 70 municipalities to sign a call for addition voluntary cleanup of the river by GE. While this was not passed and the cleanup ended after the bare-minimum was accomplished, getting that many people to agree to this was no easy task. Manna emphasized this, saying they had to talk to several of the municipalities multiple time, had to answer countless questions, and had to present scientific facts and data in a manner that was easy for someone with minimal environmental background to understand (Jo Green, 3/7/16). In this sense, she believes their efforts were a success.

Manna also explained that the law is a large hindrance to a lot of the action Clearwater tries to pass, specifically regarding PCBs. Companies and even some governmental organizations often put profit or other monetary value above the human and environmental health; this is a frustrating problem and one that is not easily

solved. Manna explained that, “when the governor wants something, he gets it, and if he doesn’t want it to happen, it won’t”. When organizations were lobbying for GE to voluntarily cleanup more of the river, the governor was trying to get GE to move its headquarters to NY. Since he had personal and monetary interest in this, he was not as helpful as he could have been and did not push hard for this additional dredging. In the words of Manna, while Clearwater is not accomplishing everything they set out to do, they are making people talk. It is once people stop talking and caring that we need to be concerned.

In her opinion, the most frustrating part of the entire process has been that Clearwater was unable to convince EPA that there was need to dredge more than the planned area. She explained, “Of the 136 acres that remain contaminated most were within the 200 areas that were dredged. The equipment would only have had to been moved a few feet in order to get much more of the PCBs,” (Jo Green, 3/7/16). Mink can no longer reproduce along the Hudson because PCBs have interfered with their reproductive systems. According to Manna, the economic cost of this is much greater than that of additional dredging. However, without the support of the EPA, she does not believe grassroots organizations will be successful in increasing the amount of dredging completed by GE.

While Clearwater may not have been successful thus far in all of their initial goals, their success as a grassroots organization has been in increasing awareness, educating those affected by the pollution, and keeping the debate alive. Before the EPA decided GE had to clean up the Hudson, many residents in the Upper Hudson area did not trust environmental groups because they felt like they were coming in

and telling them what to do. Over time, trust has been built as citizens realized how useful Clearwater could be to them. It is thanks to Clearwater that community advisory groups now are able to meet with GE 4-5 times a year for 12 years. As Manna stated, “This build trust between the community and Clearwater, and encouraged them to use Clearwater if there is a problem instead of relying on GE or the EPA” (Jo Green, 3/7/16). Additionally, Clearwater has called for an urgent five-year review of the remedial process that the EPA has agreed to; its publication is planned for 2016. Manna said, “We are not sure what will turn up, but this gives us an opportunity to continue the debate and discussion in order to mandate additional dredging,” (Jo Green, 3/7/16). While there is no guarantee that the review will prove that more dredging needs to be completed, it is keeping the topic relevant and one that is still being closely watched.

While Clearwater has not yet been able to achieve more mandated dredging, they have helped those who live in these areas voice their concerns, and have not let their case be forgotten. Without this organization and others similar to it, it is likely that those who live in the area of the pollutants would have been ignored, and the five-year review would not have occurred as quickly as it is planned for. The role of grassroots organizations in achieving environmental justice is a very important one, as it keeps citizens from being overshadowed from bigger, more powerful companies and agencies.

Conclusion

While there has been a lot of scientific research on PCBs, the results of these studies are not necessarily widely known by the general public. One of the biggest challenges facing issues regarding environmental justice and public health problems is lack of education. As discussed, those impacted by these problems are often poor, uneducated people who lack resources. Even if information regarding potential health impacts is released, those who need access to the publications may not always have it. Grassroots organizations and some governmental agencies are aware of this problem, and are continuously trying to develop innovative ways to curtail it.

In 2012, the NYSDOH published "Health Advice on Eating Sportfish and Game", which included new specifications for existing fish consumption guidelines. Since 2002, NYSDOH has also developed a multi-year initiative entitled the *Hudson River Fish Advisory Outreach Project* to help increase public awareness. It aims to make people aware of existing fish advisories, help them understand the advisory messages, and encourages people to comply. GE has contributed $4 million to Health Research, Inc., of Rensselaer, NY, in order to support the State's implementation of appropriate fish consumption advisories and fishing restrictions (EPA Region 2, "First Five-Year Review Report for the Hudson River PCBs Superfund Site", 6/1/12). However, many people are still unaware of the advisories and often fail to follow them. This is a frustrating problem that does not have one simple solution.

In order to widen the reach of educational materials such as fish consumption guidelines in NYS along the Hudson River, a new approach must be developed.

Those who live in poverty and may not have access to television, radio, the Internet, or other media cannot be ignored, nor can those who have limited education. Flyers can be hung up around towns, informational meetings open to the public can be held, and a variety of illustrative, easy to understand materials can be distributed in print or electronically. Those producing the resources need to be aware of the socioeconomic status of the people they are targeting, and adjust their publishing strategies to meet the needs of specific communities.

While GE has not wanted to focus on adverse human health effects from PCB exposure, scientific research supports the opposing view, listing these toxic compounds near the top of the ATSDR Substance Priority List. Those who are exposed to these toxins for copious amounts of time, either through direct contact or unintentional consumption, are at higher risk for cancers and other serious illnesses. They have been linked to developmental disorders, reproductive problems, and thyroid issues, among several other aliments. They are recognized as a probable human carcinogen and are banned in the United States, as well as several other countries.

Analyzing health data from the counties most directly impacted by GE's pollution in Hudson Falls and Fort Edward reveal some interesting trends. Rates for three of the five cancers commonly associated with PCB exposure are higher in Washington and Saratoga counties; they are the same three types of cancers, and their rates are much higher than the NYS average. While this data is a few years old, it is the data available to the general public. Although these numbers alone cannot prove that those exposed to PCBs released by GE have higher rates of cancer, they should

raise concern, and lead to further, more in-depth investigation. The same is true for the other non-cancerous health effects; the data is not conclusive by any means, but should spark a conversation as to why rates are so different in these two counties from the rest of NYS.

In looking at socioeconomic factors, only data from Washington County was looked at, as this is where GE's pollution occurred. Those who live in this area make less and are less educated than those who live elsewhere. The absolute numbers are not incredibly compelling, but they are consistent with data from other heavily investigated environmental justice cases. This data should make people think twice about GE's intentions in placing their factories in these areas, and question whether or not those who reside there were entirely informed of the processes occurring inside the plants, or if this is simply a coincidence. The location GE factories internationally and worldwide could also be examined in order to look for a pattern within the corporation.

GE's PCB pollution has a much wider reaching impact that the Hudson River. Hundreds of thousands of pounds of PCBs were disposed of in the 1970's. Once they left the GE plant, they were treated in an "out of sight, out of mind" manner. According to internal documents from GE, there is no evidence that these PCBs were disposed of correctly or safely in a way that endured they would never be able to leach into the environment (Appendix C). Few, if any, of those who disposed of the PCBs handled them as hazardous wastes. Thousands of pounds of PCBs were potentially disposed of incorrectly, in manners that could lead to soil and groundwater contamination due to leaching in the areas they were landfilled. Since the locations

where all of these PCBs were disposed of is not entirely known, GE's could be responsible for pollution in other states where the toxins were brought to landfills.

The EPA initiated its second year-review of the Hudson River dredging project in March 2016. They will use past data from fish, water, and sediment samples, as well as collect new data in the coming months (EPA, "EPA Initiates Second Review of Hudson River PCB Cleanup, Public Encouraged to Participate", 3/29/16). This review will be the first of several future five-year reviews, all aimed at understanding whether dredging was successful, or if more needs to be done. Several years of post-dredging data will be needed in order to fully understand how the removal of some of the PCBs from the Hudson is impacting the river system. This review will also include a review of the cleanup planned for the remnant deposits located upstream of the areas targeted for dredging. The EPA will hold public workshops to discuss the five-year review, in an attempt to make the process as transparent as possible (EPA, "EPA Initiates Second Review of Hudson River PCB Cleanup, Public Encouraged to Participate", 3/29/16).

The results of this new five-year review should provide some telling information. GE is expecting it to show a decrease in the amount of PCBs found in fish and in sediments in the river, thereby making it safer for those who eat fish from the river, or whose drinking supply comes from the Hudson. Grassroots organizations such as Clearwater are hoping the report shows muted success in order to force more dredging of the river, outside of the areas labeled as hotspots. If the results are inconclusive, Clearwater will continue to fight for more dredging, and GE will

continue to be adamant that they have done enough until the next five-year review is completed.

It is my hope that, through my research, I have been able to raise some questions regarding pollution and resulting social issues through a case study of GE and their practices. I believe there is enough data to suggest there is potential for environmental justice and environmental health issues related directly to GE and their release of PCBs into the Hudson River and surrounding areas. More in-depth studies must be completed in order to find causation between socioeconomic status, health problems, and proximity to GE's toxic pollution. Future research could include interviews with those who experienced long term exposure to PCBs at GE's factories as well as residents impacted by contaminated groundwater, as well as GE executives who deny any wrongdoing.

I believe grassroots organizations such as Clearwater are the driving force behind keeping cases like this alive. Without their dedication and determination to give a voice to those without one, it is unlikely that anything would be accomplished. Often, it is those living in the communities facing injustices that take charge and begin to act. However, we all must take a personal interest in fighting for environmental justice for everyone, as well as ask questions when corporations use practices that jeopardize communities if we want to see change. Human health should not be a privilege for those who have power and money to stand up for themselves. It should be a universal right.

Appendix A

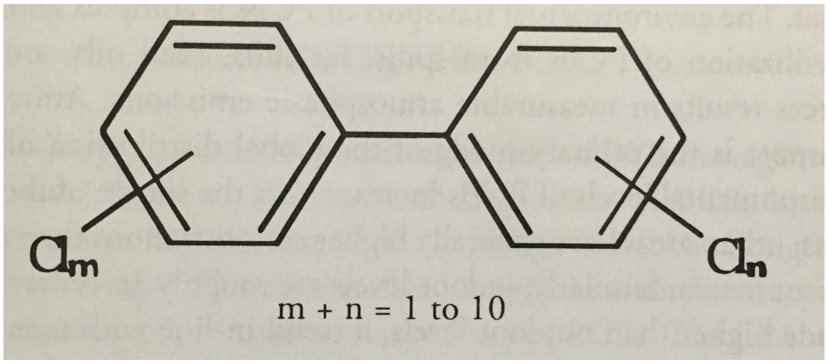


Figure 1. The most basic chemical structure of a PCB molecule, where m and n represent the number of chlorines out of a maximum of ten. (Source: Erickson, Mitchel D. *Introduction: PCB Properties, Uses, Occurrence, and Regulatory History*. PCBs: Recent Advances in Environmental and Toxicology Health Effects. The University Press of Kentucky, 2001.)

The ATSDR 2015 Substance Priority List

2015 RANK	SUBSTANCE NAME	TOTAL POINTS	2013 RANK	CAS RN
1	ARSENIC	1671.6	1	007440-38-2
2	LEAD	1529.4	2	007439-92-1
3	MERCURY	1458.6	3	007439-97-6
4	VINYL CHLORIDE	1358.9	4	000075-01-4
5	POLYCHLORINATED BIPHENYLS	1345.1	5	001336-36-3
6	BENZENE	1327.6	6	000071-43-2
7	CADMIUM	1318.8	7	007440-43-9
8	BENZO(A)PYRENE	1304.4	8	000050-32-8
9	POLYCYCLIC AROMATIC HYDROCARBONS	1279.1	9	130498-29-2
10	BENZO(B)FLUORANTHENE	1249.7	10	000205-99-2
11	CHLOROFORM	1202.4	11	000067-66-3
12	AROCLOR 1260	1190.0	12	011096-82-5
13	DDT, P,P'-	1182.0	13	000050-29-3
14	AROCLOR 1254	1171.3	14	011097-69-1
15	DIBENZO(A,H)ANTHRACENE	1155.6	15	000053-70-3
16	TRICHLOROETHYLENE	1153.4	16	000079-01-6
17	CHROMIUM, HEXAVALENT	1146.8	17	018540-29-9
18	DIELDRIN	1142.9	18	000060-57-1
19	PHOSPHORUS, WHITE	1141.3	19	007723-14-0
20	HEXACHLOROBUTADIENE	1128.2	20	000087-68-3

Figure 2. The top ten substances as listed on the ATSDR 2015 Substance Priority List. PCBs are listed as number 5, and there are two Aroclor compounds in the top twenty. (Source: ATSDR, "Priority List of Hazardous Substances". 2015. 2/12/16. http://www.atsdr.cdc.gov/spl/)

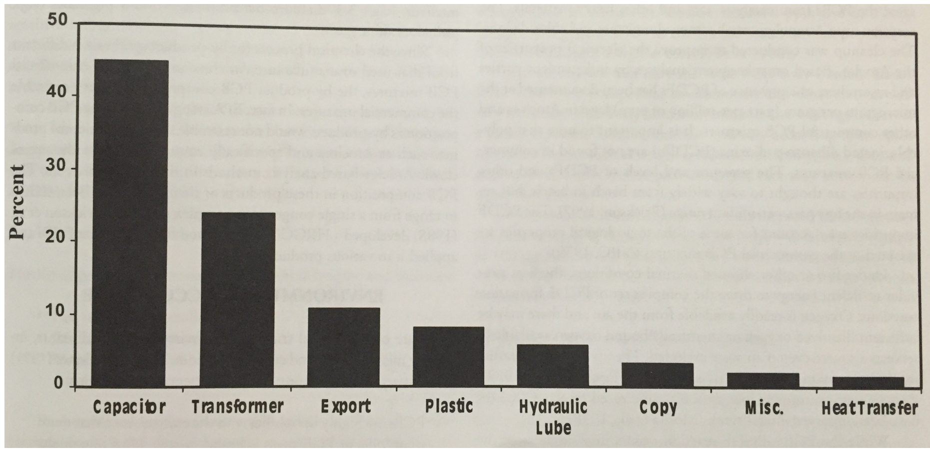


Figure 3. Applications of PCBs in the United States based on Sale Records 1930-1975. (Data from Dureff et al., 1976).

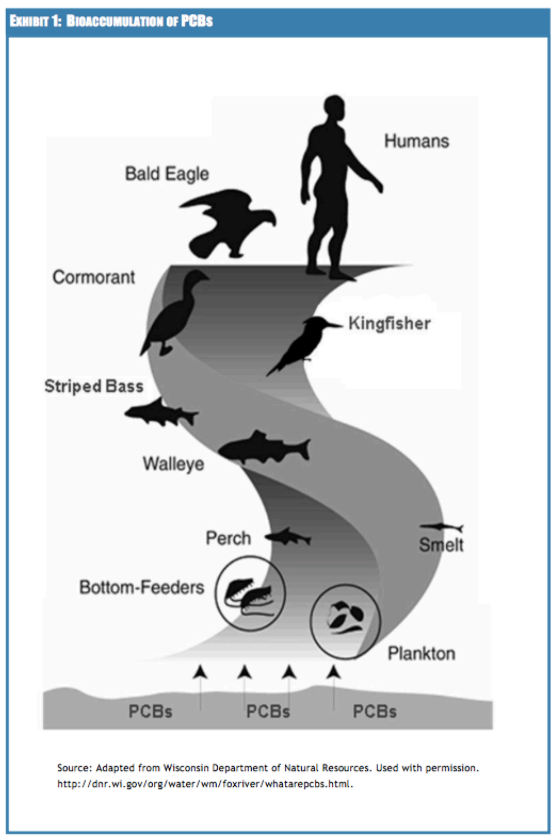


Figure 4. Diagram illustrating the bioaccumulation of PCBs along the food chain from their release into the environment through human consumption (Chart from Wisconsin Department of Natural Resources).

POPULATIONS LIVING IN COMMUNITIES WITH
UNCONTROLLED TOXIC WASTE SITES

UNITED STATES

POPULATION GROUP*	TOTAL POPULATION IN GROUP	NUMBER OF PERSONS LIVING IN WASTE SITE AREAS	PERCENTAGE OF GROUP WHICH LIVES IN WASTE SITE AREAS
TOTAL	226,523,095	122,673,020	54.15
WHITE	180,583,156	96,799,916	53.60
BLACK	26,480,783	15,123,783	57.11
HISPANIC	14,602,814	8,269,760	56.63
ASIAN/PACIFIC IS.	3,726,240	1,968,419	52.83
AMERICAN INDIAN	1,478,195	685,432	46.37
MINORITY	45,939,939	25,873,104	56.32

Number of Uncontrolled Toxic Waste Sites: 18,164
Number of Residential ZIP Code Areas: 35,749
Number of Areas with Uncontrolled Sites: 7,975

* "Minority" population is not a summation of persons in racial and ethnic groups. Hispanic population is defined by U.S. Census Bureau as a classification of Spanish origin. Since Blacks, Asians and Pacific Islanders, and American Indians of Spanish origin were double counted in the Census, they have been removed. The "White" population includes all persons who do not fall within a racial and ethnic group.

Figure 5. Populations living in communities with uncontrolled toxic waste sites in the United States, using data from the 1986 EPA Hazardous Waste Data Management System. Total percentage of populations which live in waste site areas is 54.15; the percentage of white people is lower than the total at 53.60, while the percentage of other minority groups is generally higher than the total (Table from Lee, 1987).

Agency	Focus	Level
OSHA	Air: workplace	1.0 mg/m^3 for PCBs with 42% Cl 0.5 mg/m^3 for PCBs with 54% Cl
NIOSH	Air: workplace	1.0 $\mu g/m^3$
EPA	Drinking water: environment	0.0005 ppm
FDA	Food: environment	0.2-3.0 ppm (all foods) 2.0 ppm (fish) 10 ppm (paper food-packaging materials)
WHO FAO	Food: environment	6.0 µg/kg per day

Figure 6. Standards, Regulations, and recommendations for PCBs. µg/kg: microgram per kilogram; µg/m3: microgram per cubic meter; ppm: parts per million. (Data from US Department of Energy, TSCA Information Brief).

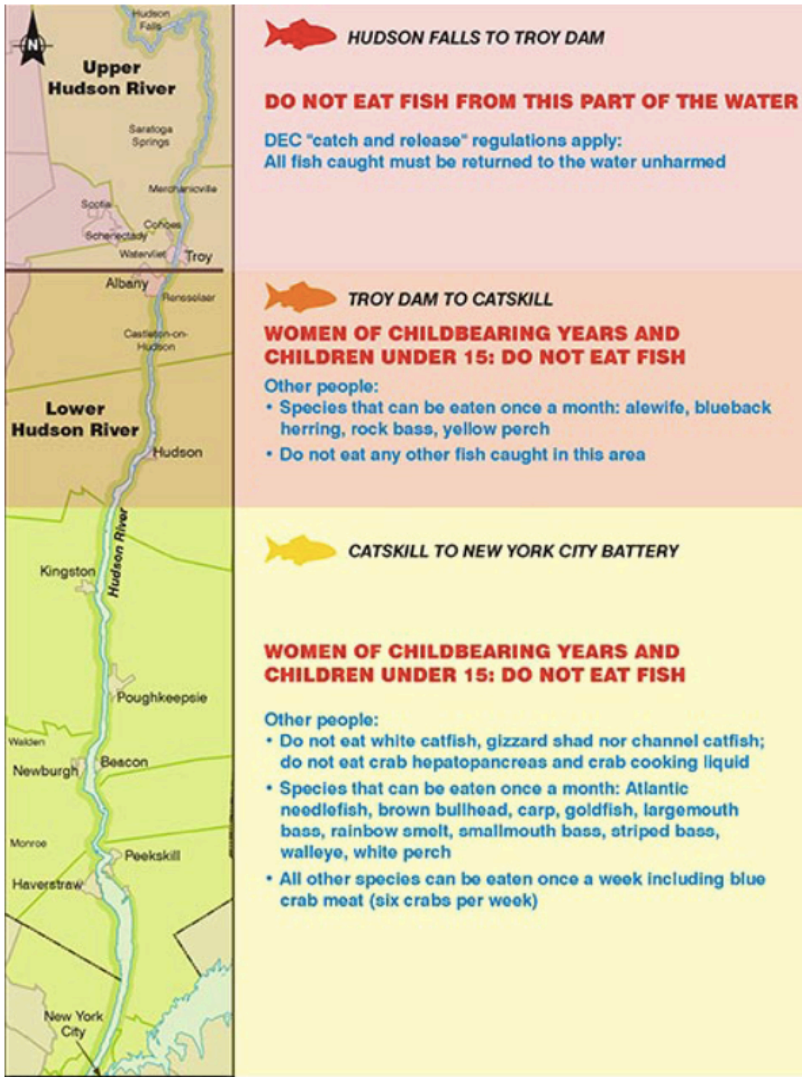
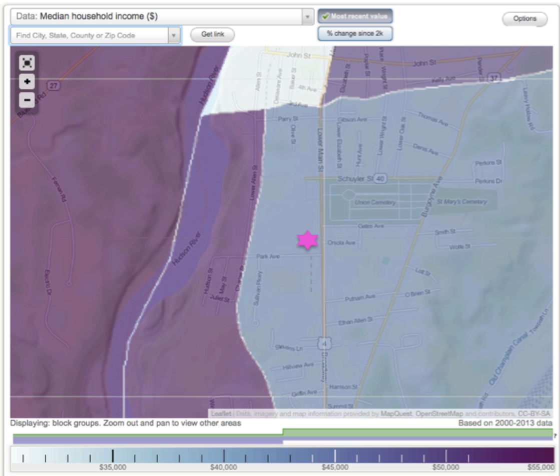


Figure 7. Restrictions on consumption of fish along the Hudson River. (Figure from EPA. "Hudson River Fish Advisories". 3/7/16).

Figure 8. Equipment used by GE during Phase 1 dredging (The Hudson River Dredging Project. "A Historic Achievement", 3/7/16).

Census (2010) Fact	Fort Edward	Hudson Falls	Washington County	NYS
Total Population	6,371	7,281	63,216	19,378,102
% 25+ with Bachelor's degree or higher	12.5	13.3	18.5	33.7
% of Vacant Housing Units	8.6	6.2	16.3	9.7
Median Value Owner-Occupied Housing Units	$101,100	$135,000	$144,100	$283,700
Median Houseold Income	$49,742	$41,122	$51,494	$58,687
% Below Poverty Line	14.2	25.3	13.0	15.6

Figure 9. A comparison of socioeconomic factors in the towns of Fort Edward and Hudson Falls to Washington County and NYS. (Data from US Census Bureau Quick Facts).



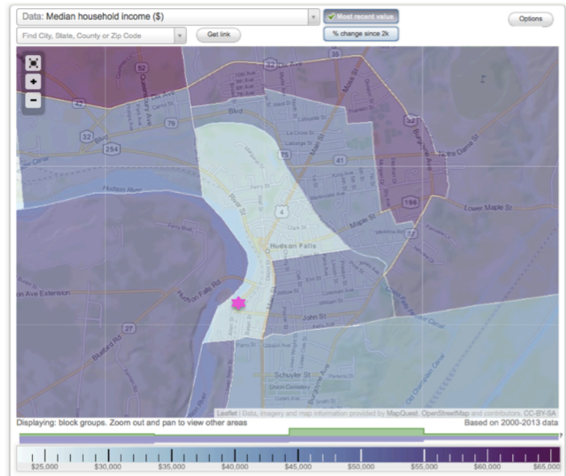


Figure 10. The map on the left shows the town of Fort Edward, NY, with the GE plant starred. The map on the right shows Hudson Falls, NY, with the GE plant there starred. The lighter the color on the map, the lower the median household income. The areas directly surrounding the plants in both towns have the lowest incomes (Maps from City Data).

County and # Deaths	**#1 Cause of Death and # of Deaths**	**#2 Cause of Death and # of Deaths**
	Age-adjusted Death Rate	**Age-adjusted Death Rate**
Saratoga	Cancer	Heart Disease
	469	448
	173 per 100,000	166 per 100,000
Washington	Cancer	Heart Disease
	149	113
	173 per 100,000	131 per 100,000

Figure 11. The leading cause of death for both Saratoga and Washington Counties is cancer. The leading cause of death in NYS is heart disease (Data from NYSDOH Leading Cause of Death by County, 2013).

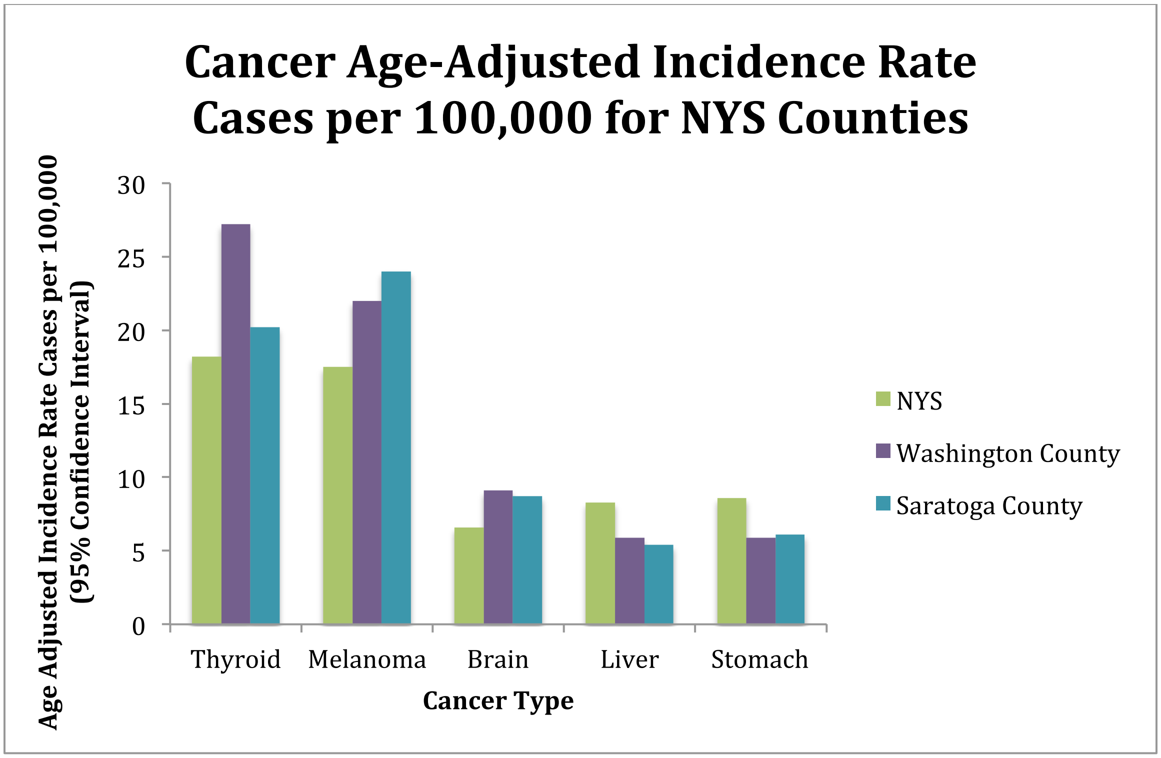


Figure 12. Cancer age-adjusted incidence rate cases per 100,000 for NYS, Washington County, and Saratoga County for five cancers commonly associated with PCB exposure. Rates are much higher in Washington and Saratoga Counties compared to NYS for three of the five cancers (Data from CDC State Cancer Profile, 2008-2012 for all ages and both sexes).

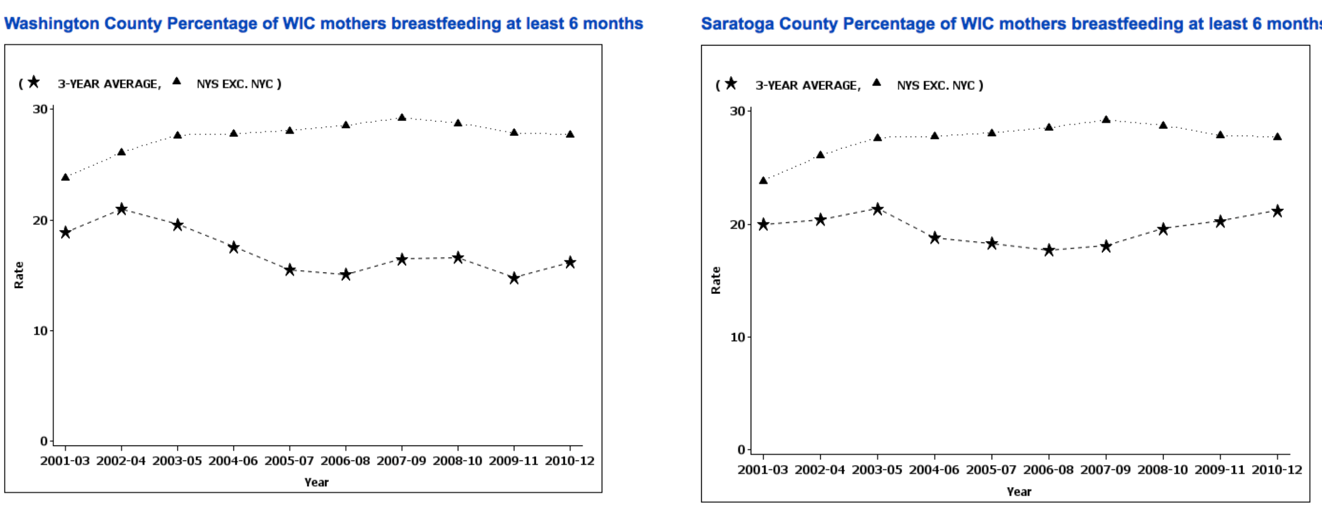


Figure 13. Percentage of WIC mothers breastfeeding at 6 months for Washington and Saratoga counties. They are compared against the NYS average. WIC is the Special Supplemental Nutrition Program for Women, Infants and Children (Figures from NYSDOH, 5/1/16).

Appendix B

Interview with Manna Jo Green, Clearwater's Environmental Action Director and Point Person on PCBs in the Hudson River conducted via phone on March 7, 2016.

Q: What do you feel is the main goal of Clearwater?

A: If I can share the message of the importance of environmental protection and restoration of the Hudson and pay it forward, then it is not just sitting on a shelf. It becomes living history. The more that people know about it, the more likely it is that we will be able to get more cleanup.

Q: What are Clearwater's strengths?

A: Clearwater addresses all issues that affect the Hudson River. There are dozens that we work on, but the two main ones have been PCBs and trying to close Indian Point before a nuclear disaster occurs. Our strong point is grassroots organizing. In last 2 years of remediation [for GE's dredging], other organizations did legal research while Clearwater helped organize teams to talk to 70 municipalities who signed call for GE to negotiate more voluntary cleanup, dozens of editorials calling for more robust cleanup. This was very effective, but it didn't happen. We organize and educate people, and rely on sister organizations that have legal staff to focus on litigation.

Q: In your opinion, what is the biggest problem that exists when it comes to the removal of PCBs from the Hudson?

A: Unfortunately, the biggest problem that is in order to get a robust cleanup, the law is not on our side. Dredging did not occur in 2010 in order to evaluate the cleanup. During this time, they found there was twice as many PCBs in the sediment at Fort Edwards than they expected. With the cleanup of PCBs, 136 acres outside the delineation area still needed dredging. However, they were not marked as hot spots and therefore were not required to be touched. There is also a debate between agencies.

Q: What has been the most frustrating part of the PCB remediation for your organization?

A: Clearwater was unable to convince EPA that there was need to do more than the basic dredge area. Therefore, dredging "finished" incompletely, which was very frustrating after working on it for 15 years. Of the 136 acres that remain contaminated most were within the 200 areas that were dredged. The equipment would only have had to been moved a few feet in order to get much more of the PCBs. Mink can no longer reproduce along the Hudson because PCBs in the areas where they live have interfered with their reproductive systems. If an economic cost were placed on this damage, it would be considerably more than the cost of doing dredging. GE could have worked out an agreement sooner that would have avoided a lot of this damage. There are also fish advisories in place all along the river. Our organization does not believe that is enough education available about them because people are still ignoring the advisories and don't know what to do about them.

Q: What controversies surround the dredging of the Hudson?

A: Core samples were supposed to be taken from the bottom of the river, but the samples were taken from woody debris that lined the bottom. At the real bottom of the riverbed, there are much more PCBs than expected. The testing of fish for PCBs also was controversial. GE was testing the fish differently than DEC's protocol, however, this has since been fixed.

Q: What would you say has been a success when it comes to PCB removal?

A: The river is much cleaner, but only around 60-70% of what we would have hoped for. The dredging gets a passing grade, but just barely. However, we are much better off than in EPA had not required GE to clean at all. Additionally, before the decision was issued by the EPA, a lot of people in the Upper Hudson River area did not like environmental groups coming in telling them what to do. Over the years, trust has been built because community advisory groups established meetings with GE 4-5 times a year for 12 years. This built trust between the community and Clearwater, and encouraged them to use Clearwater if there is a problem instead of relying on GE or the EPA.

Q: What do you think the future of PCB removal in the Hudson looks like?

A: We have called for an urgent five-year review that the EPA has agreed to. We are not sure what will turn up, but this gives us an opportunity to continue the debate and discussion in order to mandate additional dredging. Personally, I am less optimistic than I was near the end of the dredging season because EPA allowed GE to decommission the rail that was built to transport removed PCBs. In a few generations, fish could be safe to eat again. This could have been accelerated with the corporation of GE, EPA, and other state agencies.

Appendix C

An analysis of the potential environmental damage of releasing PCBs into the environment by Kenneth R. Murphy dated June 5, 1970. His report came shows GE was becoming increasingly aware of the environmental dangers of PCBs, and warned that controlling the company's PCB waste stream would be a "major undertaking".

Jit 51

GENERAL ELECTRIC COMPANY

DIAL COMM 8-235-3469

REAL ESTATE AND CONSTRUCTION OPERATION

RECO SERVING PROGRESS

EXHIBIT 41 MAP 12/4/11

June 5, 1970

TO: PYRANOL TASK FORCE

As a result of surveys at manufacturing sites and service shops, it is apparent that the effective control of waste Pyranol will be a major undertaking. The following points summarize the past status of disposal:

1. Estimates indicate that in excess of 1,500,000 lbs. of PCB per year were non-reusable scrap or waste.
2. Approximately 1,400,000 lbs/yr. of the waste PCB were in liquid form. The remaining 100,000 lbs/yr. were adsorbed on scrap parts or other solid waste. No estimates are available regarding the quantity of PCB lost to the atmosphere by evaporation, however, this is thought to be minor.
3. About 500,000 lbs/yr. of the 1,400,000 lbs/yr. of liquid PCB were discharged directly to bodies of water. The Hudson River has been the major receiving stream.
4. The remaining 900,000 lbs/yr. of liquid were principally removed by scavengers who dispose of it in an "out of sight, out of mind" manner. Few, if any, scavengers give consideration to proper disposal of hazardous wastes. A relatively minor amount has been returned to Monsanto for reprocessing.
5. The 100,000 lbs/yr. of PCB contaminated solid waste were primarily landfilled, either on or off GE property. There is no indication that any consideration was given to the handling of hazardous wastes in these landfills. Approximately 10,000 lbs/yr. were adsorbed on scrap metal sold for reprocessing.

Attached is a list of specific recommendations regarding control of Pyranol. They are presented as initial efforts; more detailed and specific controls are expected to be necessary.

Kenneth R. Murphy

Dr. K. R. Murphy, Engineer
ENVIRONMENTAL POLLUTION CONTROL

KRM:jn
Encl.

cc: (w/encl)

R.B. Ames	P.C. VanDyck	L. C. Maier, Jr.
R.W. Lewis	E.L. Raab	J. F. McAllister
C.E. Reed	V.R. Cooper	C. J. Meloun
J.F. Young	E.L. Dobbins	R. C. Osthoff

bcc: WF Reardon
HE Heddesheimer

Murphy 8 EXHIBIT 5/20/03

GEHRV00059194

CONFIDENTIAL GEWS-06819023

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