Coastal Carolina Riverwatch

Water Quality for Fisheries

An Assessment of Water Quality Concerns

Introduction

The purpose of the Water Quality for Fisheries (WQ4F) Project is to identify and address the impacts of water quality on the North Carolina fisheries.

Part of this process includes researching and assessing what is currently being done to address water quality issues that impact fisheries. The assessment part of this project will include what is being done to address sources of pollution from all areas of NC (including those outside of the coastal area).

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Table of Contents:

Priorities Identified by Coastal North Carolina Fishermen:

Agriculture and Factory Farm Runoff
Stormwater Runoff from Roads, Highways, and Parking Lots
Industrial Pollutants

Coastal Carolina Riverwatch. 2021. “Commercial and Recreational Fishermen Survey.” ECU Center for Survey Research, Thomas Harriot College of Arts and Sciences, East Carolina University, Greenville, NC. March 4-21.

Industrial Pollutants

Introduction

Industrial pollutants have contaminated North Carolina waters for decades as a result of different manufacturing processes and industrial activities. For example, facilities such as Dupont and Chemours release chemicals into local bodies of water, coal-based operations’ discharge contaminants into coastal rivers, and Superfund sites leak hazardous waste into the environment. In several instances, industries are responsible for discharging toxic chemicals into drinking water without the knowledge of the public and governmental agencies.

Common contaminants found in the southeast include 1,4 dioxane, bromides, and PFAS (Southern Environmental Law Center, 2021). There is still a significant amount of uncertainty associated with these “emerging compounds” and a need for additional research, regulatory, and outreach efforts. Fish can take in these pollutants through absorption in their food, contaminated sediments or when polluted water passes through their gills. Studies have indicated that the toxins are concentrated in fish’s skin, organs, and other tissues. Bottom-dwelling fish tend to contain higher concentrations of pollutants due to a large amount of contaminated sediments settling on the bottom due to runoff (Environmental Defense Fund, 2013). Also, top predators have greater toxin levels in their tissue due to biomagnification or the process of a contaminant increasing its concentration in tissues of organisms as it moves up the food chain (Environmental Defense Fund, 2013).

One common class of industrial chemicals includes perfluoroalkyl and polyfluoroalkyl substances, termed PFAS. PFAS have been used in products for decades, but their utilization in manufacturing processes has continued to increase in recent years. Due to these compounds' effective resistance to physical, chemical, and biological degradation, they are used in products with nonstick coating, nonconducting materials for electronics, firefighting foam, and waterproof materials (Kluck, et al., 2021).

PFAS are composed of strong carbon-fluorine bonds which contribute to their fire and water resistance capabilities. Their composition makes it difficult for the chemicals to break down naturally through biodegradation, hence their alternative name, “forever chemicals.” Due to their chemical nature, they remain in the environment for long durations of time. Also, they are highly water soluble which means they can be easily transported after entering water. PFAS chemicals generally bioaccumulate in organisms and attach to dust and air particles which allows for easy transfer from food packaging into food products (Kluck, et al., 2021).

The presence of PFAS in North Carolina waters can be dated back to the early 1980s. Researchers have determined that these chemicals have been identified in every body of water in North Carolina that has been sampled as of 2021 (Kluck, et al., 2021). Crops, livestock, fish, and shellfish have all been found to contain PFAS (Kwiatkowski, 2020). PFAS enters water from manufacturing emissions, land application of contaminated biosolids, and facilities’ wastewater, firefighting foam, products, and chemicals leaching from products located in landfills.

When PFAS were first discovered and studied, some companies transitioned from the traditional long-chain PFAS to short-chain PFAS. The replacements were advertised as safer alternatives, but research has proven short-chain PFAS produce similar health risks (Kwiatkowski, 2020).

In 2009, DuPont Chemours Company, located in Fayetteville, North Carolina, began commercial production of the PFAS chemical, GenX. This event led to the discovery of the

contaminant in bodies of water in the Cape Fear River basin (NC PFAS Testing Network, 2021). In 2013, Dr. Detlef Knappe from NC State University along with other researchers found high levels of industrial pollutants in the Cape Fear River.

In 2017, Dr. Knappe and his team's discoveries were added to a scientific journal which led to several released media reports that brought attention to the issue in North Carolina (NC PFAS Testing Network, 2021).

The company was mandated to cease discharge of its wastewater, but PFAS still contaminates Wilmington's water through runoff, groundwater leakage, and river sediments (Barnes, 2021). Adding to water pollution, the emission of PFAS into the air causes the chemical's deposition in rainwater (Kluck, et al., 2021).

A safe level of consumption for PFAS and GenX is still uncertain. However, laboratory studies on animals indicate these chemicals are endocrine disruptors associated with thyroid problems, cancer, and pregnancy complications (GenX and Emerging Industrial Contaminants, 2018). Increased research in recent years links PFAS exposure to different cancers, lymphoma, thyroid problems, and immunotoxin symptoms.

The chemicals are transferred from mother to fetus and can cause development issues in the baby's respiratory, endocrine, and cardiovascular systems (GenX and Emerging Industrial Contaminants, 2018).

Similarly, to PFAS, heavy metals are pollutants resulting from industrial activities and they can be toxic to marine life. High levels of heavy metals concentrate in marine organisms in their liver and muscle. The result has been lung pathology and immuno-suppression. These pollutants also bioaccumulate in aquatic species (Tanaka, et al., 2004).

Currently, coal ash can be identified in water supplies in southeastern North Carolina. Even though Duke Energy was forced to relocate their coal ash waste to dry, lined storage, some coal ash spills remain unmonitored and utilized as a soil fill (Duke Today, 2020).

One chemical still found in North Carolina waters resulting from the residue includes the carcinogen, hexavalent chromium. Another chemical product from coal-powered manufacturing processes is 1,4-dioxane which is commonly found in the Cape Fear River.

Finally, endocrine disruptors are chemicals entering bodies of water through disinfection processes and industrial facilities' chemical releases. They are found in disinfecting products, bisphenols, pesticides, and natural and synthetic estrogens.

The effects of endocrine disrupting chemicals on humans and aquatic life include decreased development, fertility, and reproductive function (Gonsioroski, et al., 2020). PFOAs and PFOS, the two most common PFAS chemicals, are considered endocrine disruptors.

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization
Implementation of Filtration Systems	• Decreases PFAS, heavy metals, and endocrine disrupting chemicals' concentrations in water • Protects aquatic life from harmful health effects	Environmental Protection Agency (Southeast Regional Office) 800.241.1754 PFAST Network ncpfastnetwork@unc.edu

City-Wide Filtration Systems for Wastewater Treatment	• Reduces PFAS and other industrial pollutants levels • Promotes safe drinking water sources	Local Municipalities
Use of Public Water Lines as an Alternative for Wells	• Reduces consumption of contaminated water	Local Municipalities

With industrial pollutant management being relatively new to public knowledge, there is a lack of certainty in the effectiveness of the few infrastructures utilized to filter chemicals from water. The EPA has identified effective ways to treat PFAS from drinking water using four different technologies. First, granular activated carbon (GAC) causes chemicals to stick to small pieces of carbon as the water passes through the filter. GAC has been used for almost 15 years and is successful in absorbing PFAS in water (Kluck, et al., 2021).

Powdered activated carbon (PAC) adds powdered carbon to water and then chemicals like PFAS will stick to the particles (Environmental Protection Agency, 2018). Ion exchange resins are small beads made of hydrocarbons that function like magnets and cause chemicals to stick to the beads as the water runs through them. Finally, nanofiltration and reverse osmosis is a process that occurs when water is pushed through a membrane with small pores (Environmental Protection Agency, 2018). This membrane behaves like a wall that stops chemicals and particles from entering drinking water.

Similarly, reverse osmosis, membrane filtration, ion exchange, and absorption are techniques utilized to remove heavy metals from water sources. Additionally, methods

such as advanced wastewater treatment processes, UV irradiation, ozonation, and ultrasound have been effective in removing endocrine disruptors according to the Water Quality Association (Scavetta, 2021). Different innovative companies such as Aquasana have led the way in developing these technologies.

Recently, local North Carolina governments have begun to invest funds in improving infrastructure that filters emerging compounds like GenX. For example, Wilmington and New Hanover County will allocate approximately 46 million dollars to filter out "forever chemicals" from drinking water that is distributed to about 200,000 people (Barnes, 2021). Similarly, Brunswick County approved a bid for 137 million dollars to develop a similar filtration system that will remove PFAS within the next two years (Barnes, 2021).

Also, using alternative water sources is important in halting industrial pollutants consumption from drinking water as fast as possible. Cumberland county will spend approximately $10 million to run public water lines to schools and homes whose wells are contaminated with industrial pollutants (Barnes, 2021).

Recommended Future Actions:

Type of Infrastructure	**Water Quality Impacts**
Reducing Industrial Activities that Utilize Industrial Chemicals in their Processes	• Reduces industrial pollutant contamination in local waters • Protects the natural habitat and aquatic life
Improved Wastewater Treatment at the Local Level	• Reduces industrial pollutant contamination at a larger-scale, city-wide • Reinforces healthy fish populations and aquatic ecosystems

Development of New Filtration Technologies	• Decreases PFAS, heavy metals, and endocrine disrupting chemicals' concentrations in water • Protects aquatic life from harmful health effects
Creation of Coal Ash Treatment Technologies	• Treats coal ash ponds and reduces risk of contamination in nearby rivers • Reduced health risks for fish populations and people

Reducing industrial activities utilizing pollutants such as PFAS should be a priority in future infrastructure development. Ceasing these activities and finding alternatives would decrease the level of contaminated wastewater from entering local waters.

Though a few cities have begun to invest in new infrastructure, the need for improved wastewater treatment in municipalities is urgent. Current water treatment plants' filtration systems lack the ability to remove all PFAS. However, scientists at UNC have developed a resin that will filter PFAS molecules.

Some newer methods that may assist in breaking down PFAS compounds include advanced reduction processes (ARPs), plasma-based water treatment, and using β- cyclodextrin polymers (Kluck, et al., 2021). There are still unknowns about the efficiency of using ARPs to break down PFAS and reduce toxicity levels in water. Therefore, investigating the effectiveness of these processes could greatly assist in accelerating their implementation.

Technologies are currently being developed to assist in treating coal ash found in water sources. One company, Saltworks Technologies, partakes in coal ash pond water treatment through biological treatment, reverse osmosis, and filtering membranes (Saltworks Technologies, 2019).

Policy and Enforcement Assessment

Current Actions:

Type of Policy	Water Quality Impacts	Lead Organization
Health Advisory (70 ppt) for PFOS and PFOA	• Limits concentrations of PFOS and PFOA in drinking water • Protects public health from negative effects of PFOS and PFOA	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
NPDES for Industrial Activities	• Limits industrial pollutants entering bodies of water through stormwater discharges • Regulates industrial activities exposure to the environment	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
National Defense Appropriations Act	• Reduces contamination due to the decrease in use of PFAS-firefighting foam • Manages and monitors contamination levels in bodies of water	Department of Defense

NC Legislation Providing Funding for the NC PFAST Network	• Increases understanding of effects of PFAS on aquatic ecosystems • Identifies areas of concern within coastal watersheds	NC PFAST Network ncpfastnetwork@unc.edu NC General Assembly 919.733.4111
Public Utilities are State-Mandated to Have Discharge Permits	• Decreases levels of emerging compounds in wastewater • Encourages monitoring of industrial pollutant concentrations in bodies of water • Implements city-wide contaminant reduction efforts	NC Division of Water Resources 919.707.9023
Safe Drinking Water Act (SDWA) Third Unregulated Contaminant Monitoring Rule	• Monitors concentrations of emerging compounds and identifies areas of concern	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Superfund Legislation)	• Proposes adding PFOA and PFOS to the legislation, defining the chemicals as hazardous waste • Increases management efforts for PFOA and PFOS	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

Hazardous and Solid Waste Amendments	• Minimizes the production of hazardous waste • Reduces water contamination of hazardous waste	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Toxic Substances Control Act (TSCA)	• Reduces water contamination from PCBs • Reduces PFOS and PFAS use in US commerce, decreasing their impacts on water quality	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Toxics Release Inventory	• Monitors concentration levels of industrial pollutants in bodies of water • Identifies areas of concern	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

Legislation regulating emerging compounds and other industrial pollutants is severely lacking. North Carolina follows the 70 parts per trillion (ppt) advisory level for PFOS and PFOA that was established by the EPA, but the state made another objective to have less than 140 ppt of GenX chemicals in all drinking water (Kluck, 2021). The EPA has not created health advisory levels for any additional PFAS chemicals.

The National Pollutant Discharge Elimination System (NPDES) included permitting for stormwater discharges from industrial activities beginning in January of 2021 (National Pollutant Discharge Elimination System, 2021). This program enforces federal regulations for stormwater discharge resulting from material handling and storage, equipment

maintenance, and additional industrial activities. Some of the facilities regulated under the legislation include heavy manufacturing sites such as mills, coal and mineral mining facilities, hazardous waste treatment plants, landfills, transportation facilities, and construction sites (National Pollutant Discharge Elimination System, 2021). The EPA gives the state the authority to administer and enforce the permitting system.

The National Defense Appropriations Act passed in 2020 included sections that addressed the application of PFAS in government activities. The policy phases out the use of firefighting foam with more than 1 ppb PFAS contents and prohibits the purchase of PFAS firefighting foam by 2022 (Cook, 2019). The act also provides funding for the creation of a replacement for non-fluorinated firefighting foams. The legislation requires collaboration between state governments and the Department of Defense (DoD), mandating cooperation with testing, monitoring, removing, and remedial actions relating to contamination from DoD facilities.

The NC Division of Water Resources has begun implementing programs focused on addressing concerns with emerging contaminants. In 2018, the NC General Assembly passed the first piece of legislation regarding PFAS that funded the NC Policy Collaboratory with over 5 million dollars to create the PFAS Testing Network. However, the General Assembly has rejected initiatives to reduce firefighter foam usage and limited the DEQ's technological capabilities to test water for PFAS.

Some positive progress for legislation development in North Carolina includes the DWR's mandating of publicly owned utilities with pretreatment programs (POTWs) and industrial dischargers to acquire state permits located within the Cape Fear River Basin. Their goal is to monitor a group of emerging compounds in this area's wastewater. All participants in the permitting program sampled their wastewater for 1,4-dioxane and PFAS for three months (NC DEQ, 2021).

After completing the monitoring project, they found that 1,4 dioxane levels were elevated in Greensboro's, Reidsville, and Asheboro's POTWs while the rest of the samples were

lower (NC DEQ, 2021). The cities were mandated to implement reduction efforts to address the issue. In comparison, only one sampling site for PFAS located in Sanford indicated concentrations exceeding the health advisory for PFOS and PFOA (NC DEQ, 2021). The DEQ has begun monthly sampling and assisting the city with locating the source of contamination.

The EPA also completed research under the Safe Drinking Water Act's (SDWA) Third Unregulated Contaminant Monitoring Rule and found that there are high concentrations of 1,4 dioxane and PFAS in the Cape Fear River Basin (NC DEQ, 2021). The DWR's monitoring programs supported the EPA's results.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as the Superfund Legislation, permits the federal government to address any contaminant's environmental release. Currently, PFAS are not listed under CERCLA, but the EPA has proposed defining PFOA and PFOS as "hazardous substances under CERCLA (Environmental Protection Agency, 2021).

The federal regulation for hazardous waste, specifically Superfund Sites, in North Carolina dates back a few decades. Some important pieces of legislation include the Clean Air Act (CAA), the Clean Water Act (CWA), and the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) (Patterson, 1989).

The goal of the HSWA is to minimize the production of hazardous waste and support regulatory action by governmental agencies, industries, and the public. Also, the Superfund Amendments and Reauthorization Act (SARA) forces the public release of information regarding toxic waste discharges into the environment (Patterson, 1989). The Emergency Planning and Community Right-to-Know Act (EPCRA) was added to the legislation to increase public awareness. There are about 1700 Superfund sites prioritized for cleanup by the EPA on the National Priority List (Roth, 2014). However, only a small number of hazardous waste sites are addressed through the Superfund program.

Under (CERCLA) and (SARA), PCBs are classified as a hazardous substance and if an operation has a greater quantity than the specified reporting threshold of PCBs, they are required to report annual releases of PCBs (EPA, 2014). The Toxic Substances Control Act (TSCA) prohibits the manufacturing, processing, and distribution of PCBs in US commerce. Some PCB substances that are regulated include dielectric fluids, solvents, oil, hydraulic fluids, paints, sludges, sediments, and soils (EPA, 2014). Also, the TSCA phased out PFOA and PFOS use in United States commerce.

The EPA manages the Toxics Release Inventory which is a report developed based on the collection of information from industrial operations using 770 chemicals. PFAS were added in 2019. However, not all toxic chemicals are evaluated with the inventory and the data is self-reported by the polluters (Sorg, 2021).

Recommended Future Actions:

Type of Policy	Water Quality Impacts
PFAS Action Act of 2021	• Reduces PFAS use and pollution across the country • Encourages public release of information regarding PFAS
Groundwater Quality Standards for PFOS and PFOA	• Reduces PFAS contamination throughout the state • Limits discharge from industrial activities
Enforceable Maximum Contaminant Levels for Municipal Water Treatment Facilities	• Reduces industrial pollution from entering bodies of water • Decreases negative health effects for fish populations

Adding PFAS to the Contaminant Candidate List under the Safe Drinking Water Act	• Provides additional information and data regarding the pollutants • Encourages regulatory action to limit industrial pollutant discharges based on their findings
Banning or Mandating Reduced-Use of PFAS in US Products	• Reduces risk of industrial pollutants contaminating water sources • Eliminates discharge from industrial facilities
Legislation Providing Funding for Research and Treatment of Industrial Pollutants	• Reduces water contamination from industrial activities • Allows monitoring and managing of water resources • Protects aquatic ecosystem health

Recently, the House of Representatives passed the PFAS Action Act of 2021 and the bill has entered the Senate. This policy would require that the EPA lists PFAS as hazardous substances under CERCLA (PFAS Action Act of 2021, 2021). As a result of this act, the EPA must test for PFAS, companies disclose use of PFAS, and national drinking water regulations would be enforced.

The DWR has proposed developing a regulated Groundwater Quality Standard in place of a health advisory for PFOA and PFOS of 70 ppt. Also, they have created in-stream target values of 0.35 ug/L for 1,4-dioxane and a target of 80 ug/L for all other surface waters (NC DEQ, 2021). However, we need enforceable statewide PFAS drinking water standards that establish maximum contaminant levels (MCL) for municipal water facilities to follow.

EPA Administrator Regan announced in April of 2021 that the agency will establish a new "EPA Council on PFAS." The goal of the council is to address the risks associated with PFAS

using scientific information that will provide the basis to create regulations (Environmental Protection Agency, 2021). Additionally, the agency has suggested adding PFAS to the Contaminant Candidate List (CCL) under the SDWA. The CCL is composed to assist in determining whether those specific contaminants should be regulated with a National Primary Drinking Water Regulation (NPDWR). This preliminary determination to regulate PFOA and PFOS may be useful in developing regulatory policies for PFAS in the future.

One suggested way to prioritize the regulating of specific chemical classes includes using their persistence levels in the natural environment as a determining characteristic. Also, banning products that use PFAS or reduce the use of hazardous chemicals to instances when it is completely essential to public health (Kwiatkowski, 2020). Meanwhile, encouraging the use of replacements could greatly reduce their impacts on fisheries. Though, we would need to establish a policy-making standard that defines the term, "essential."

One way the government could become more involved in regulatory actions for industrial pollutants includes implementing and enforcing strict standards for emerging compounds such as PFAS rather than solely health advisories. Ten bills have been introduced with the goal of addressing the water quality implications associated with industrial pollution (Barnes, 2021). Some bills aim to hold the industries responsible for the pollution while others hope to ban the manufacturing, sale, and distribution of PFAS in North Carolina. Creating political and public support for these laws will assist in the management of industrial pollution.

Additionally, providing additional funding to research, treatment, and disposal methods for PFAS chemicals. Also, the federal agencies should hold guilty contaminating companies accountable for their contamination to prevent recurring pollution or deter other operations to use them as well.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
PFAS Testing Network Research	• Evaluates risks of PFAS and effects on aquatic ecosystems • Monitors and reports findings, encouraging political action relative to water quality improvement	PFAST Network ncpfastnetwork@unc.edu
Emerging Contaminants in Drinking Water Sources	• Monitors PFAS levels in surface waters and groundwater • Treats water for industrial pollutants	Michael and Annie Falk Foundation's Environmental Exposomics Laboratory at Duke University https://falk.exposomics.duke.edu/contact
Coal Ash Effects on Fisheries in Lake Sutton	• Protects fish populations from coal ash contamination and selenium poisoning • Restores water quality after coal ash contamination in Lake Sutton and the Cape Fear River	Wake Forest University Research

Endocrine Disrupting Chemicals Research	• Decreases DBP contamination • Protects fish populations from development impairments and malformations	University of Illinois Research Project by Andressa Gonsioroski
Effects of Toxic Pollutants on Fish	• Improves our understanding of the effects of legacy and emerging contaminants on fish population • Assists in determining strategies to protect fisheries from these pollutants	Researchers at UC-San Diego Aquatic Pollutants Report Environmental Protection Agency (Southeast Regional Office) 800.241.1754

One of the greatest research efforts regarding PFAS and their impacts on public health and aquatic ecosystems is led by the PFAS Testing Network (PFAST Network). A group of researchers including Lee Ferguson, Heather Stapleton, Detlef Knappe, and Avner Vengosh are studying emerging contaminants in North Carolina drinking water (Duke Today, 2020). North Carolina is one of three states that has organized researchers to evaluate the risks and effects of PFAS on people and the environment. The PFAST Network's objective is to sample every public water source in North Carolina and research the following topics: modeling for well water risk, PFAS removal effectiveness testing, air emissions and atmospheric deposition, immunotoxicology effects, and exposure to North Carolina wildlife species (Cook, 2019).

The PFAST Network has noticed positive outcomes of the monitoring and reporting project. When the scientists identify high concentrations of PFAS in a water source, they contact community leaders, and the local government authorities are able to take the actions needed to change water sources or manage the problem. Also, the results from their evaluations are made public therefore community members are aware of the risks locally.

Similarly, the Michael and Annie Falk Foundation's Environmental Exposomics Laboratory at Duke University has conducted studies on emerging pollutants in every public drinking water source in North Carolina. The goal of the research is to increase their understanding of PFAS chemicals in groundwater and surface waters and assist in the creation of effective water treatment infrastructure (Duke University, 2021). The laboratory collaborates with Riverkeeper organizations to assess various watersheds.

Some studies have associated PFAS pollution with greater accumulation of chemicals in fish species. A study completed two years ago in South Carolina indicated that 83% of the research species of fish had greater levels of PFOS than the advisory levels set to protect animals (Kluck, et al., 2021).

In addition to PFAS research, scientists, including Dr. Mallin from ECU, have completed studies focused on the effects of heavy metals on fish populations. Heavy metals are a common pollutant resulting from industrial and agricultural activities. One of his studies conducted on bowfin in the Cape Fear River found that their tissue analyses identified concentrations of arsenic, cadmium, mercury, selenium, and PCBs (Mallin, et al., 2011). The concentrations of mercury, selenium, and PCBs were greater than the levels defined as safe by the EPA for fish, their predators, and people (Mallin, et al., 2011). These chemicals present health issues for fish populations such as disease, reproductive decline, and loss of prey.

Coal ash research has been conducted to assess the impacts of the residue and resulting selenium concentrations on fisheries in Lake Sutton. The body of water was managed as a public fishery just a few miles northwest of Wilmington. The lake was created as a cooling

reservoir for Duke Energy's coal-fired electric generating plant (Lemly, 2014). Water from the Cape Fear River was used to cool steam condensers in the facility and then it was discharged into Lake Sutton to cool. Finally, the water returned to the river.

The lake was contaminated with selenium which causes fish developmental abnormalities and lack of reproductive success (Lemly, 2014). The chemical enters the water through the coal ash wastewater from the plant and bioaccumulates in the aquatic ecosystem. During this study of fish in Lake Sutton, they found Lepomis spp. showed abnormalities 28.9% of the time which are biological indicators of selenium poisoning (Lemly, 2014). In 2013, the LV. Sutton Steam Plant started transitioning from their coal operations to natural gas. However, selenium continues to affect fish populations due to its prevalence in the lake sediments (Mallin, et al., 2011).

Finally, endocrine disrupting chemicals have been researched by scientists due to our recent knowledge of their high prevalence in North Carolina bodies of water. Research on endocrine disrupting chemicals indicates that a large number of people are exposed to a specific class of chemicals, DBPs, due to the common use of disinfectant products for treating water (Gonsioroski, et al., 2020). A study focused on the effects of DBPs on zebrafish found that exposure leads to negative developmental effects, decreased tail lengths, and increased malformation rates. In humans, research shows DBPs disrupt ovarian function, reduce sperm viability, prevent healthy fetal development, and contribute to chromosomal abnormalities (Gonsioroski, et al., 2020). The researchers found similar effects on wildlife and humans resulting from PFAS exposure. Finally, BPAs used in resin coatings of canned foods, food storage containers, water bottles, and baby bottles act as endocrine disruptors as well (Gonsioroski, et al., 2020).

Persistent organic pollutants (POPs) are industrial and agricultural pollutants that have been discovered in fish populations across the globe (ScienceDaily, 2016). Studies have shown that POPs identified in fish have extremely variable concentrations, and the levels of these contaminants in individual organisms have decreased since the 1980s. A main reason

for this finding is the decreased use of legacy chemicals such as DDT and mercury (ScienceDaily, 2016). Additionally, the EPA has been completing fish tissue studies to analyze the concentration of these chemicals in fish populations.

The authors of the Aquatic Pollutants report made some similar findings, however, they discovered emerging chemicals will increase in the coming decades (Beeler, et al., 2021). They have found that chemicals persist in the environment for a long time and become more toxic. Due to bioaccumulation or the constant buildup of toxic chemicals within an organism and the food chain, fish continue to be exposed to pollutants for years. Therefore, industrial pollutants are considered to be a main source of fish populations' declines and pose risks to human health due to contaminated seafood consumption (Beeler, et al., 2021).

Recommended Future Actions:

Type of Research	Water Quality Impacts
Analysis of the Effects of All Heavy Metals on Aquatic Ecosystems	• Reduces heavy metal contamination • Develops management strategies to protect aquatic ecosystems from industrial metals
Assessment of the Effectiveness of Filtration Methods	• Reduces water contamination from emerging contaminants, coal ash, and endocrine disrupting chemicals
PFAS Research Focused on Impacts on Biota	• Assists in understanding the implications of emerging contaminants on aquatic ecosystems and wildlife • Monitors and supports fisheries conservation efforts

Researching Safe Alternatives to Industrial Pollutants	• Reduces water contamination and negative health effects on fish resulting from PFAS-containing products • Assists industries in a transition to safe alternatives from harmful chemicals

Though there has been research conducted focused on the effects of heavy metals on aquatic ecosystems, some elements have been studied more thoroughly than others. For example, there has been a significant amount of research that indicates that mercury is harmful, therefore there are more established advisories for this element (Mallin, et al., 2011). In the future, it will be beneficial to assess the impacts of other pollutants such as arsenic and cadmium on aquatic ecosystems. Then, regulatory action imposed on industrial activities may result from the scientific findings.

Additionally, analyzing the effectiveness of methods for treating water for coal ash, PFAS, and hazardous waste will greatly assist in developing support for their utilization. Currently, we do not have a significant amount of widely accepted technologies that have the capacity to filter water sources. Also, these assessments may encourage research into alternative filtration techniques.

Recently, PFAS has become a public concern leading to the allocation of financial resources to scientists studying the toxicity of these chemicals. However, experts still lack a complete understanding of how dangerous PFAS are to not only people, but aquatic ecosystems.

The majority of published research focuses on the effects of PFAS on humans, but we lack information regarding their implications on fish populations. Moving forward, prioritizing the investigation of emerging contaminants on fish species and aquatic habitat will greatly assist in protecting the fisheries of the coast.

Finally, researching safe alternatives to products that contain emerging contaminants such as firefighting foams, water resistant materials, and non-stick coatings will significantly reduce industrial contamination in bodies of water internationally. Also, the findings may assist in gaining industrial support in the transition to materials that do not contain PFAS.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Outreach/Advocacy	Water Quality Impacts	Lead Organization
NGOs Advocating for Communities and the Environment	• Brings attention to industrial pollution in NC • Influences political action and regulation of industrial facilities • Encourages industrial operations to cease discharge of chemicals into water resources	Clean Aire NC 704.307.9528 Cape Fear River Watch 910.762.5606 Southern Environmental Law Center 434.977.4090 Waterkeepers Carolina heather@soundrivers.org NC Conservation Network www.ncconservationnetwork.org Toxic Free NC www.toxicfreenc.org

Litigation against Polluting Industrial Facilities	• Reduces coal ash contamination in NC • Forces industrial companies to eliminate GenX use and pollution • Protects communities and aquatic ecosystems against health implications	Southern Environmental Law Center 434.977.4090 Cape Fear River Watch 910.762.5606
The EPA's Toxics Release Inventory	• Increases public understanding of hazardous waste sites and impacts on health and the environment • Reduces habitat destruction and water contamination from Superfund sites	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

With the discovery of GenX in the Cape Fear River, public concern regarding industrial contamination in eastern North Carolina's bodies of water has increased tremendously. Due to press releases reporting on industrial pollutants, communities have been informed on current issues affecting their waterways.

Environmental non-governmental organizations (NGOs) increase awareness by using their platforms and advocating for the public and wildlife. NGOs may use litigation as a technique to address industrial pollution. The Southern Environmental Law Center (SELC)

represented Cape Fear River Watch in the case against Chemours. Similarly, the SELC advocated for the communities affected by the coal ash spill in the Dan River caused by Duke Energy. The result of the coal ash spill was the contamination of drinking water with a cancer-causing substance made of bromides. In 2020, the SELC made a legal deal with Duke that required them to remove the coal ash from the lagoon to dry, lined storage further from the river (Southern Environmental Law Center, 2021).

Collaboration and coalition-building is important in bringing about noticeable changes regarding the regulation of pollutants. For example, the DEQ, Cape Fear River Watch, and the Southern Environmental Law Center are collaborating to take action against Chemours to mandate the business to remove PFAS from groundwater at the company's plant on the Cape Fear River.

The EPA assists in providing information to the public regarding hazardous releases of industrial operations through the development of the EPA's Toxics Release Inventory. The information is released by state, city, county, or Zip code. Additionally, Duke University shared maps and resources with the public in order to increase awareness of the impacts of Superfund sites and their proximity to a given community.

Recommended Future Actions:

Type of Outreach/Advocacy	**Water Quality Impacts**
Educating Consumers on PFAS-Containing Products	• Reduces the risk of PFAS from entering bodies of water and affecting fisheries • Decreases risks to public health • Encourages companies to use alternative substances
Educational Information Regarding Filtration Systems	• Reduces contaminated discharge from entering nearby bodies of water

	• Decreases risks to human health and the environment

Educating the public on their impacts as consumers could assist in raising awareness about the health and environmental impacts of chemicals such as PFAS while protecting communities and aquatic ecosystems. Organizations can utilize the outreach techniques utilized by organizations such as Toxic Free Future, the Center for Environmental and Health Effects of PFAS, and the Superfund Center at UNC to educate consumers on the typical products that contain PFAS such as nonstick pots, water resistant clothing items, cleaning products, and stain resistant coatings.

This will greatly reduce the amount of PFAS chemicals entering bodies of water while encouraging producers to adopt alternatives to PFAS. Already, some companies such as IKEA and Crate and Barrel have vowed to phase-out PFAS use in their products. There is an increase in demand for products that do not use chemicals in the manufacturing process (Kwiatkowski, et al., 2020).

Another important outreach initiative relating to the protection of public health from industrial contaminants includes encouraging the implementation of filtration systems in home residences. Providing educational material on the advantages of these technologies could greatly increase participation. However, the cost of the systems makes them inaccessible to a large portion of people. Therefore, lobbying the government to increase funding for these treatment systems and wastewater treatment systems would greatly assist in protecting the health of communities unable to install filters in their own homes.

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