Coastal Carolina Riverwatch

Water Quality for Fisheries

An Assessment of Water Quality Concerns

Acknowledgements

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https://coastalcarolinariverwatch.org/water-quality-for-fisheries/

Introduction

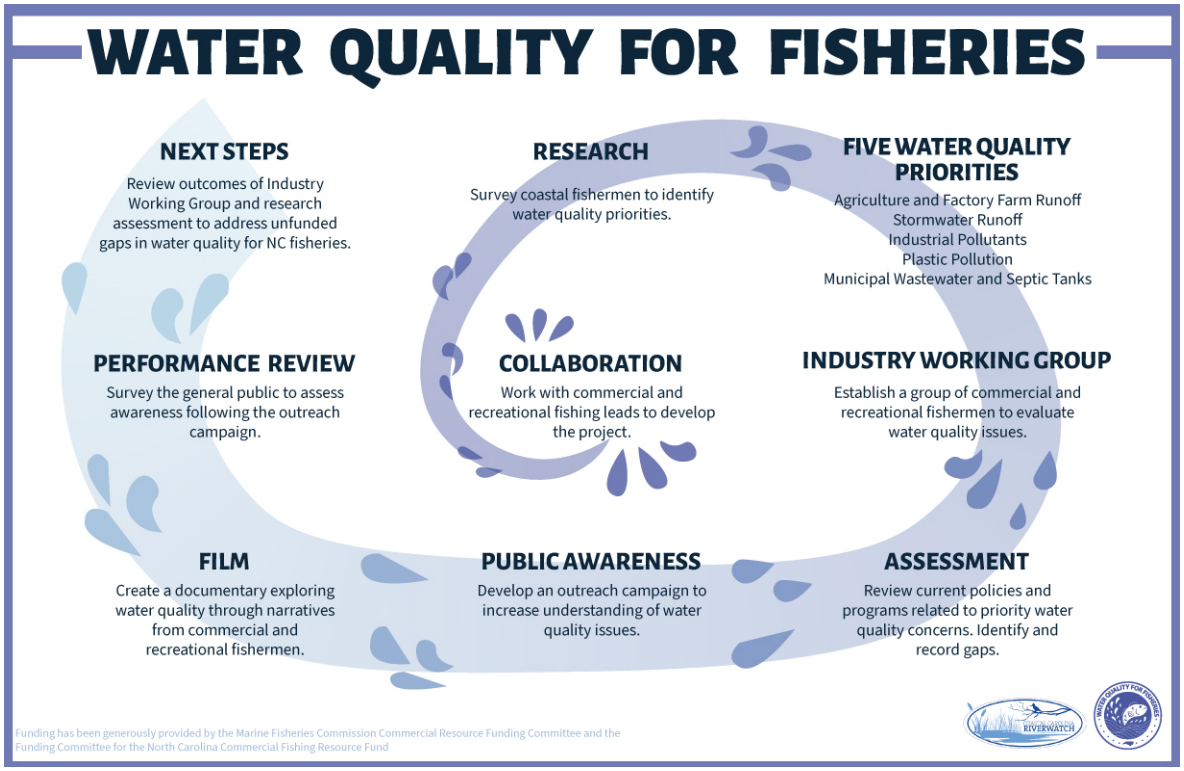
The purpose of the Water Quality for Fisheries (WQ4F) Program is to identify and address the impacts of water quality on North Carolina fisheries. This assessment is a living document that serves to address impacts on water quality that are identified by the coastal fishing community. Updates to the assessment can be found here: https://coastalcarolinariverwatch.org/water-quality-for-fisheries/

This assessment is categorized by the following methodologies for addressing each water quality concern: Infrastructure, Policy and Enforcement, Research, and Outreach.

Water Quality Priorities Identified by Coastal North Carolina Fisheries Representatives:

Agriculture and Factory Farm Runoff
Stormwater Runoff from Roads, Highways, and Parking Lots
Industrial Pollutants
Plastic Pollution
Municipal Wastewater Treatment Plants and Septic Tanks

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. https://surveyresearch.ecu.edu/wp-content/pv-uploads/sites/315/2018/06/Carolina_Riverwatch_Summary_Report1.pdf



GRAPHIC: Noah Weaver, *Water Quality for Fisheries Program Outline*, 2021

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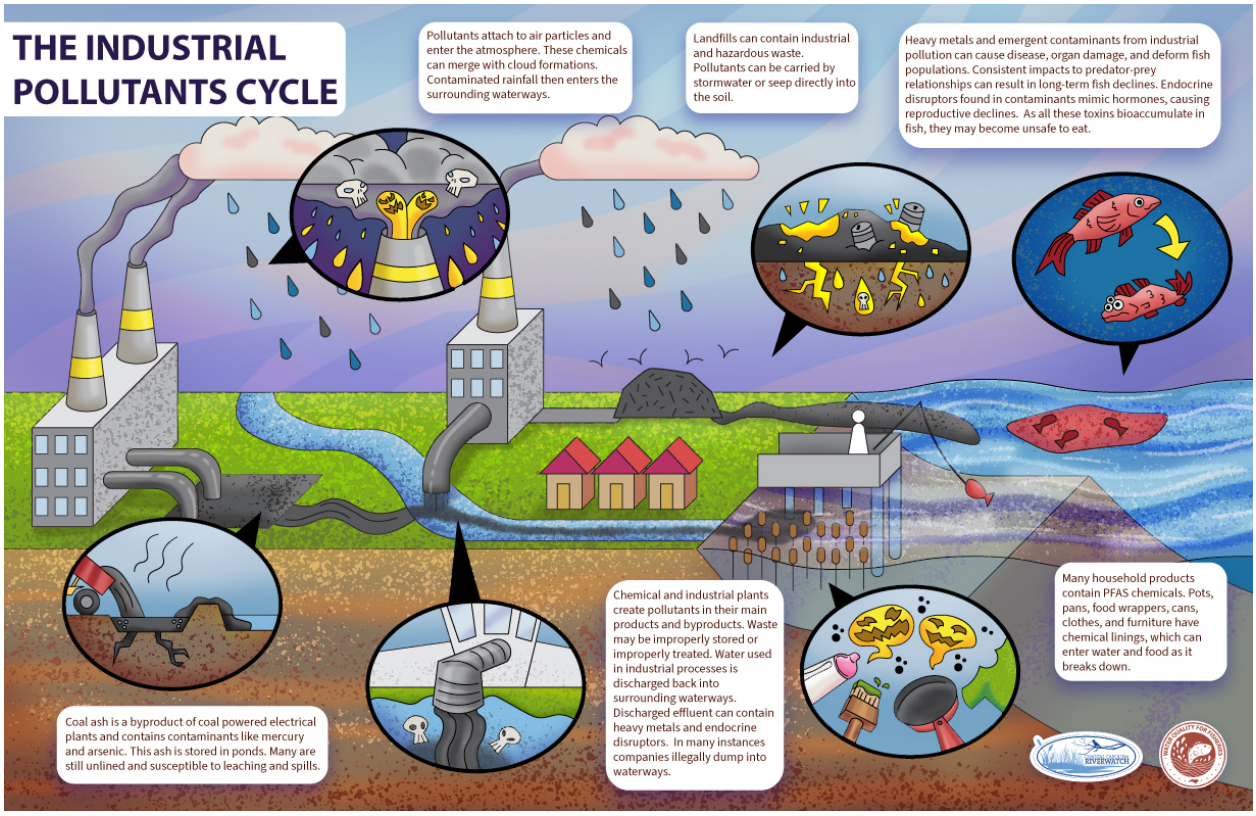

GRAPHIC: Noah Weaver, *The Industrial Pollution Cycle*, 2021

Introduction

Industrial pollutants have contaminated North Carolina waters for decades as a result of manufacturing processes and industrial activities. For example, facilities such as Dupont/Chemours release chemicals into the air as well as local bodies of water, coal-based operations discharge contaminants into coastal rivers, and Superfund (inactive) sites leak hazardous materials into the environment. It has also been found that industries may knowingly discharge toxic chemicals into the environment unbeknownst to the public or governmental agencies.

Common contaminants found in Southeastern NC include 1,4 dioxane, bromides, and PFAS (perfluoroalkyl and polyfluoroalkyl substances) (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, contact with 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, fish considered top predators have greater levels of degradation resistant toxins, such as

PCBs and mercury, present in their tissues. This is due to biomagnification or the process of a contaminant increasing its concentration in tissues of organisms as it moves up the food chain.

PFAS have been used in products for decades and their utilization has continued to increase in recent years due to these compounds' effective resistance to physical, chemical, and biological degradation. Commonly, they are found in products with nonstick coatings, nonconducting materials for electronics, firefighting foam, and waterproof materials (Kluck, et al., 2021).

PFAS contain strong carbon-fluorine bonds which contribute to their fire and water resistance capabilities and their resistance to biodegradation, hence their alternative name, "forever chemicals." 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 use of PFAS accelerated in the 1970's and 1980's. Researchers have found PFAS 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, facilities' wastewater, firefighting foam, household product use, and landfill leachate.

When environmental impacts of 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 exposure results in similar health risks (Kwiatkowski, 2020).

In the early 2000's, DuPont Chemours Company, located in Fayetteville, North Carolina, began commercial production of the PFAS chemical, GenX. Subsequent to this, PFAS contamination was found in bodies of water in the Cape Fear River basin (NC PFAS Testing Network, 2021). Specifically, in 2014 researchers found high levels of PFAS in the Cape Fear River and in the drinking water of Wilmington, NC (Sun et al., 2016).
In 2017, Dr. Knappe and his team's discoveries were published, resulting in media reports that brought attention to the PFAS issue in North Carolina (NC PFAS Testing Network, 2021).

Dupont Chemours was mandated to cease discharge of its wastewater, but PFAS still contaminates Wilmington's water through runoff, groundwater, and river sediments (Barnes, 2021). In addition, PFAS air emissions result in the chemicals' deposition by the way of regional rainwater (Kluck, et al., 2021).

Safe human exposure levels for PFAS and GenX have yet to be determined. However, laboratory studies on animals indicate these chemicals may act as endocrine disruptors associated with thyroid problems, cancer, and pregnancy complications (GenX and Emerging Industrial Contaminants, 2018).

Heavy metals resulting from industrial activities can be toxic to marine life. High levels of heavy metals concentrate in marine organism's protein-rich tissues. Responses include lung pathology, immuno-suppression, nutritional deficiencies, and lesions. Toxic heavy metals include mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic and zinc. These pollutants can also bioaccumulate in aquatic species (Tanaka, et al., 2004).

Currently, coal ash (waste from coal burning power plants) can be found in soil and surface water throughout southeastern North Carolina. Even though Duke Energy was required to relocate their coal ash waste to dry, lined storage, some coal ash spills remain unmonitored and coal ash has also been utilized as a soil fill (Duke Today, 2020).
Contaminants still found in North Carolina waters resulting from the residue includes the carcinogen, hexavalent chromium.

Similarly, to PFAS, heavy metals and VOCs are industrial pollutants that can be toxic to marine life and are known to bioaccumulate in aquatic species (Tanaka, et al., 2004).

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization
Implementation of Filtration Systems	• Decreases PFAS, heavy metals, and VOC 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 advanced systems for Wastewater Treatment	• Reduces PFAS and other industrial pollutants levels • Promotes safe drinking water sources	Local Municipalities
Use of Public Water Supplies as an alternative to private wells	• Reduces consumption of contaminated water	Local Municipalities

With public knowledge of industrial pollutant management being relatively new, there is a lack of confidence in the effectiveness of the few processes utilized to filter chemicals from water. The EPA has identified effective ways to treat PFAS in drinking water using four different technologies:

- First, granular activated carbon (GAC) causes chemicals to adsorb to small pieces of carbon as the water passes through the filter. GAC has been used for almost 15 years and is successful in adsorbing some PFAS in water (Kluck, et al., 2021).
- Powdered activated carbon (PAC) adds powdered carbon to water and then chemicals like PFAS will adsorb to the particles (Environmental Protection Agency, 2018).
- Ion exchange resins are small beads made of plastics that cause charged 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 as a barrier that stops chemicals and particles from entering drinking water.

Similarly, reverse osmosis, membrane filtration, ion exchange, and adsorption 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 VOCs and other endocrine disruptors according to the Water Quality Association (Scavetta, 2021).

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 to filter out "forever chemicals" from drinking water that supplies about 200,000 people (Barnes, 2021). Similarly, Brunswick County approved a bid for $137 million to develop a similar filtration system that will remove PFAS within the next two years (Barnes, 2021).

Also, using alternative water sources is another means of halting the consumption of contaminated 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 harmful Chemicals in their Processes	• Reduces industrial pollutant contamination in local waters and drinking water supplies • Protects the natural habitat and aquatic life
Improved Industrial Wastewater Treatment at the Local Level	• Reduces industrial pollutant discharge at a larger-scale, city-wide • Reinforces healthy fish populations and aquatic ecosystems

Development of New Advanced Water Treatment Technologies	• Decreases PFAS, heavy metals, and VOCs 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 safer alternatives would decrease the level of contaminants from entering local waters.

Though a few cities have begun to invest in new infrastructure, the need for improved water supply 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 effectiveness 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 also currently being developed to assist in treating coal ash found in water bodies. One company, Saltworks Technologies, treats coal ash pond water through biological, reverse osmosis, and filtering membrane methods (Saltworks Technologies, 2019).

Industry Working Group Gap Analysis: Industrial Pollution Infrastructure Priorities

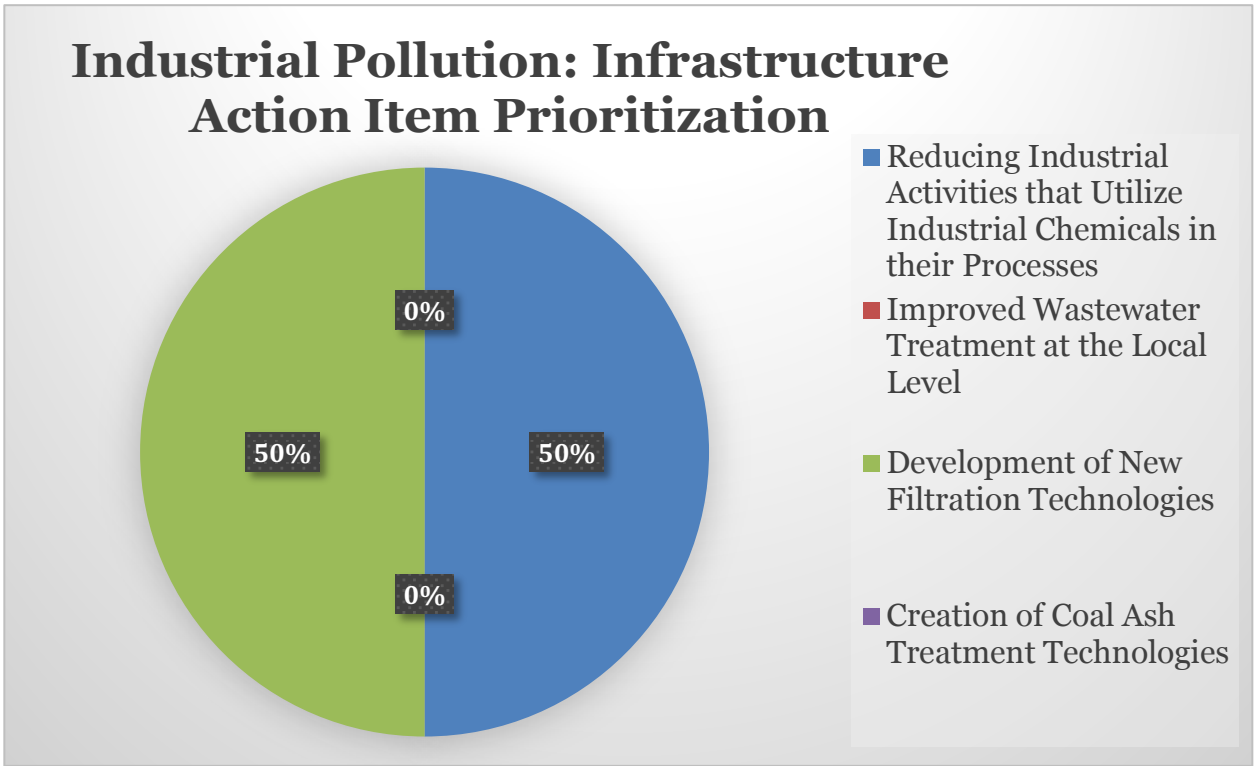

CHART 7: *Industrial Pollution Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both reducing industrial activities that utilize industrial chemicals in their process and the development of new filtration technologies have been identified as top priorities in 2021-22.

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 environmental exposure from industrial activities	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
National Defense Appropriations Act	• Reduces environmental contamination by decreasing the 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 NC coastal watersheds	NC PFAST Network ncpfastnetwork@unc.edu NC General Assembly 919.733.4111
Public Utilities are State-Mandated to Have Discharge Permits	• sets allowable 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) Fifth Unregulated Contaminant Monitoring Rule	• Monitors concentrations of 30 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 • 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 from 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 in drinking water 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 (NCDWR) 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 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 (POTWs) with pretreatment programs, and industrial dischargers located within the Cape Fear River Basin to acquire state permits. Their goal is to monitor a group of emerging compounds in this area's wastewater. All participants in the permitting program were required to sample 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's, 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.

Under the Safe Drinking Water Act, every five years EPA is required to issue a new list of unregulated contaminants to be monitored by public water systems. The EPA's current Fifth Unregulated Contaminant Monitoring Rule identifies 30 chemical contaminants, 29 being PFAS and 1 being lithium, that would require sample collection to establish data on frequency and levels.

Research under the 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, allows the federal government to regulate any listed 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 regulations governing hazardous wastes, specifically Superfund Sites, in North Carolina date 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

In 2021, the House of Representatives passed the PFAS Action Act of 2021 and, as of the fall of 2021, the bill had entered the Senate. This legislation would require that the EPA list PFAS as hazardous substances under CERCLA (PFAS Action Act of 2021, 2021). As a result of this act, the EPA would test for PFAS, companies would be required to disclose use of PFAS, and national drinking water regulations would be set and enforced.

The NCDWR 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, NC needs enforceable statewide PFAS drinking water standards that establish maximum contaminant levels (MCL) for municipal water.

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 was created to assist in determining whether 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.

One way to prioritize the regulating of specific chemical classes would be to use their persistence in the environment as a determining characteristic. Also, measures have been suggested such as banning products that use PFAS or limiting the use of hazardous chemicals to instances where they are uniquely essential to public health (Kwiatkowski, 2020). Meanwhile, encouraging the use of replacements could greatly reduce impacts on fisheries.

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 relying solely on health advisories. In NC, ten different 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 manufacture, 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, it is important to provide additional funding for researching treatment and disposal methods for PFAS chemicals. Also, it would help if the federal agencies would hold guilty contaminating companies accountable for their contamination to prevent recurring pollution and to deter other operators as well.

Industry Working Group Gap Analysis: Industrial Pollution Policy Priorities

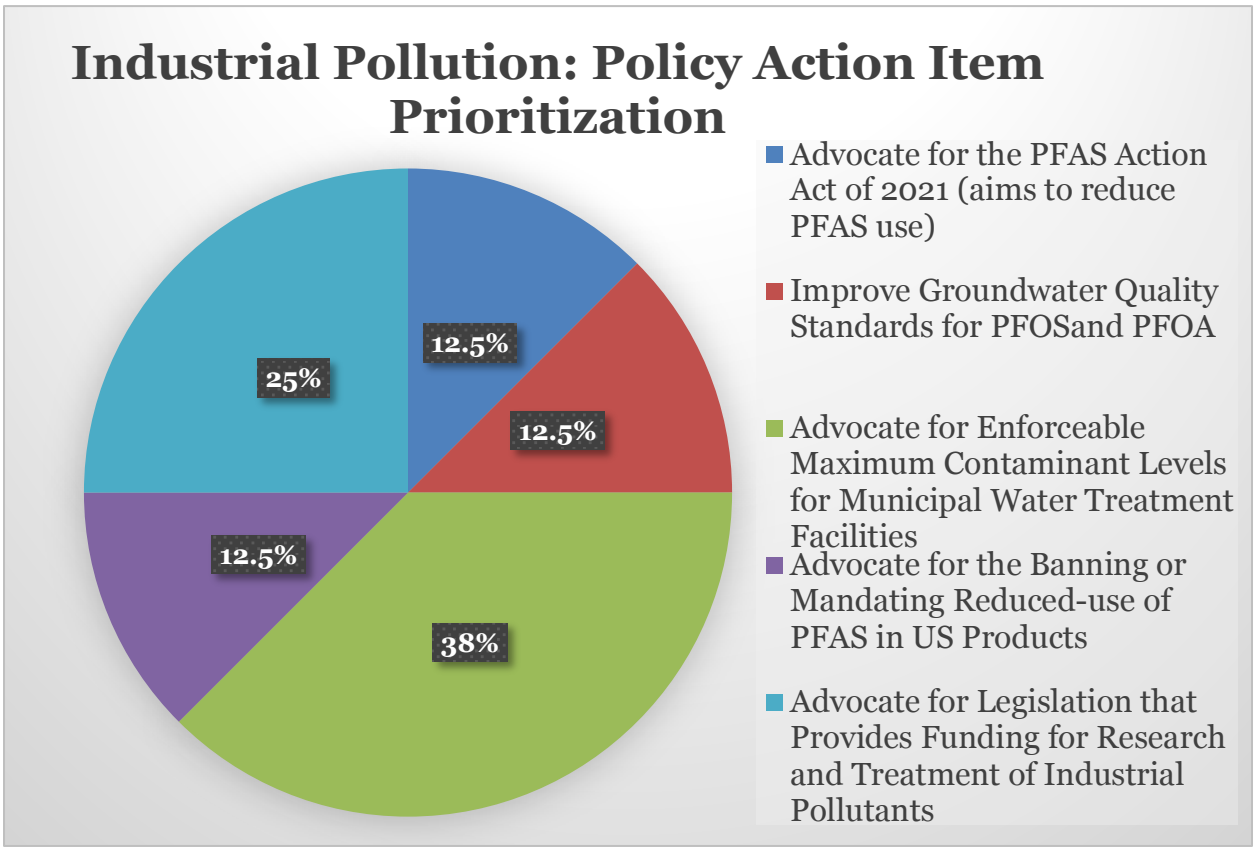

CHART 8: *Industrial Pollution Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for policy that enforces the maximum contaminant levels for municipal water treatment facilities has been identified as the top priority in 2021-22.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
PFAS Testing Network Research	• Evaluates risk 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 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's 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 local community members are made aware of the risks.

Similarly, the Michael and Annie Falk Foundation's 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 the 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).

Researchers have also completed studies focused on the effects of heavy metals on fish populations. Heavy metals are a common pollutant resulting from industrial and agricultural activities. A study conducted on bowfin in the Cape Fear River found that 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 fish population health issues such as disease, reproductive decline, and loss of prey.

Coal ash residue research has been conducted to assess the impacts of the residue and resulting selenium concentrations on fisheries in Lake Sutton, a body of water 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, used to cool steam condensers in the facility is then discharged into Lake Sutton to cool. Finally, the water is then returned to the river.

The lake was contaminated with selenium, causing 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, Lepomis spp. showed abnormalities 28.9% of the time, a biological indicators of selenium poisoning (Lemly, 2014). In 2013, the LV. Sutton Steam Plant started transitioning from 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 (including VOCs) have been researched by scientists due to the recent knowledge of their prevalence in North Carolina water bodies. 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. Due to the decreased use of legacy chemicals such as DDT and mercury (ScienceDaily, 2016). Additionally, the EPA has been conducting fish tissue studies to analyze the concentration of these chemicals in fish populations.

The authors of the *Aquatic Pollutants Report* made similar findings and suggests that emerging chemicals will increase in the coming decades (Beeler, et al., 2021). The author 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 to 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 materials will greatly assist in developing support for the utilization of these methods. Currently, there are not a significant amount of widely accepted water filtration technologies that have the capacity to filter water sources. 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 NC 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.

Industry Working Group Gap Analysis: Industrial Pollution Research Priorities

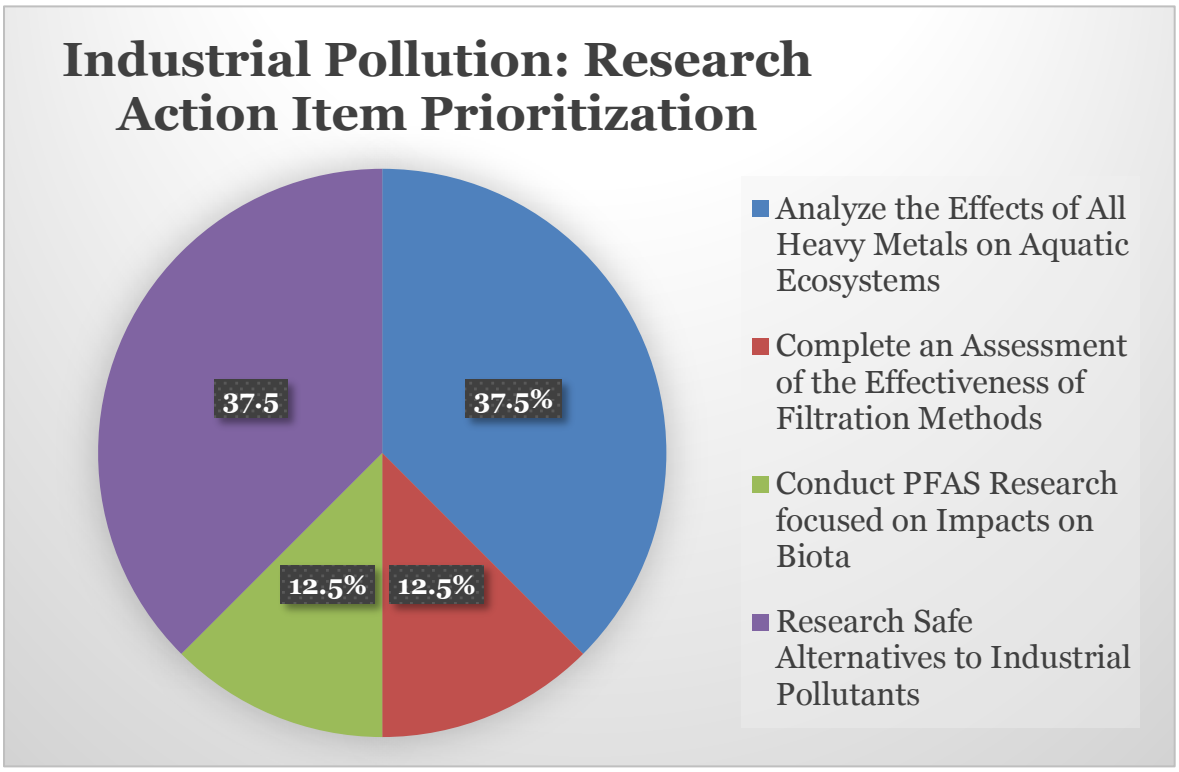

CHART 9: *Industrial Pollution Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both analyzing the effects of all heavy metals on aquatic ecosystems and researching safe alternatives to industrial pollutants have been identified as the top priorities in 2021-22.

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 industries to eliminate PFAS use and pollution • Protects communities and aquatic ecosystems against health and environmental implications	Southern Environmental Law Center 434.977.4090 Cape Fear River Watch 910.762.5606 Haw River Assembly

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 for and understanding of industrial contamination in eastern North Carolina's waterways has increased tremendously.

Environmental non-governmental organizations (NGOs) increase awareness by using their platforms and advocating for the public and wildlife. NGOs may also 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 Duke Energy's coal ash spill in the Dan River.

The coal ash spill contaminated drinking water with a cancer-causing substance made of bromides. In 2020, the SELC reached an agreement with Duke that required them to remove the coal ash from the lagoon to dry, lined storage further from the river. Haw River Assembly was also represented by SELC reaching a settlement with the City of Greensboro and NC regulators to limit Greensboro's 1,4 dioxane discharge and require DEQ to investigate sources of 1,4-dioxane in the Cape Fear River Basin. (SELC, 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 available 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 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 power as consumers will also raise awareness about the health and environmental impacts of chemicals such as PFAS on communities and aquatic ecosystems. Organizations can utilize the outreach techniques employed by groups 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. sharing this information should greatly reduce the amount of PFAS chemicals made, used, and ultimately 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 overall increase in demand for products that do not use hazardous 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 in-home filtration systems. 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 percentage of citizens. Therefore, lobbying the government to increase funding for these water supply treatment systems would greatly assist in protecting the health of low-income citizens or communities unable to install in-home filters..

Industry Working Group Gap Analysis: Industrial Pollution Outreach Priorities

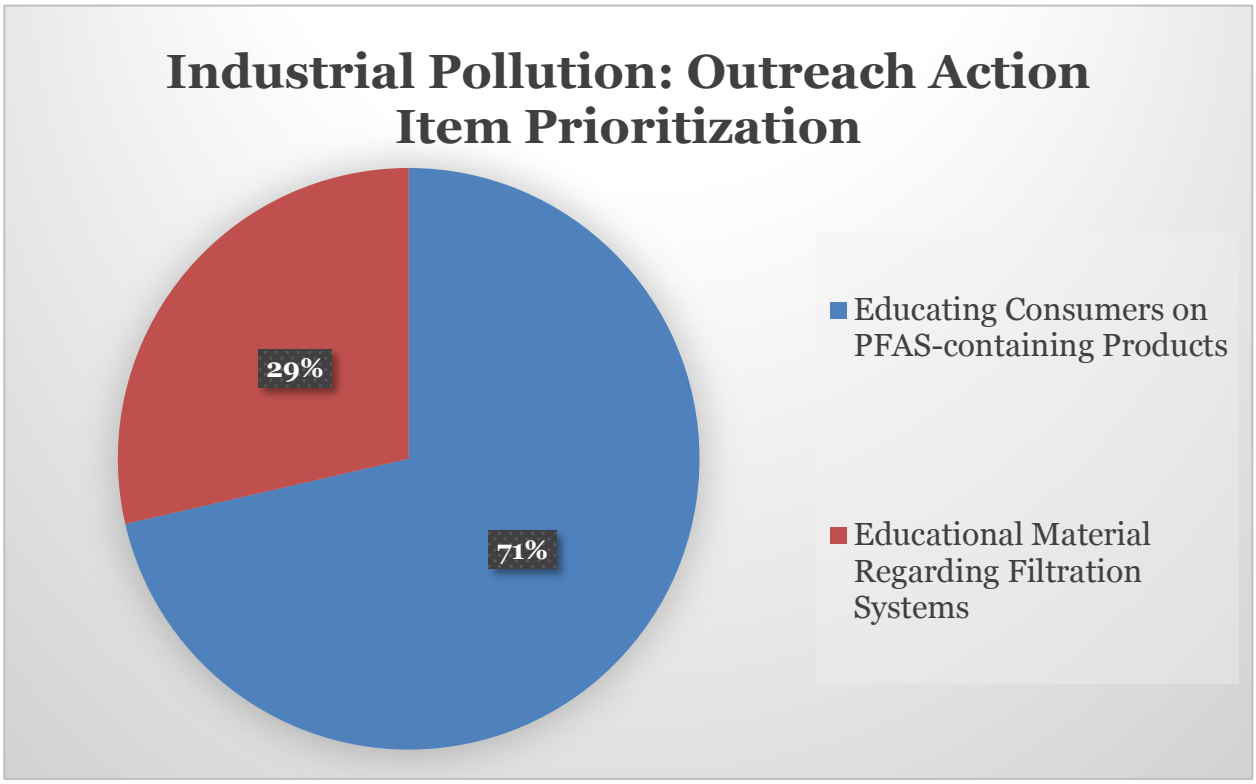

CHART 10: *Industrial Pollution Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Educating consumers on PFAS-containing products has been identified as the top priority in 2021-22.

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Industrial Pollution Assessment Revisions in 2022:

Adjusted all "Third Unregulated Contaminant Monitoring Rules" to Fifth Unregulated Contaminant Monitoring Rule to reflect most recent information. Included more info at Lee's suggestion.

Corrected sourcing of 1,4 dioxane. Corrected bioaccumulation. Expanded heavy metal info.

Included Sun et al. research at Lee's suggestion.

Added Haw River Assembly as a "lead organization" for Advocacy due to recent 1,4 dioxane settlement and involvement with PFAST Network.

Water Quality for Fisheries
2021-22 Prioritized Action Items

The Industry Working Group goals are to address water quality impacts on fisheries and recommend action items. The Industry Working Group has prioritized the following action items in 2021-22:

Industrial Pollution:

- Reduce industrial activities that utilize harmful industrial chemicals in their process and the development of new filtration technologies.
- Advocate for policy that enforces the maximum contaminant levels for municipal water treatment facilities.
- Analyze the effects of all heavy metals on aquatic ecosystems and research safe alternatives to industrial pollutants.
- Increase education efforts providing information to consumers on PFAS-containing products.