Per- and Poly-Fluorinated Alkyl Substances Chemical Action Plan (PFAS CAP) – 2019 Updates

Economic Analysis Chapter

In 2017, the Washington State departments of Ecology and Health shared draft PFAS CAP chapters with external parties for review and comment. Comments received are available online.
Ecology and Health are sharing CAP documents with interested parties prior to the May 15 2019 PFAS CAP webinar. Updates will be discussed during the April webinar. We expect to publish the entire Draft PFAS CAP around June 2019 followed by a 60-day comment period.

In May 2019, Ecology and Health will host a PFAS CAP webinar (May 15th) to:

- Briefly review activities underway: firefighting foam, food packaging, drinking water.
- Review updated/new chapters – comments will be accepted on the updated chapters. Responses will be provided after the 2019 public comment period (summer 2019).
- Discuss preliminary recommendations – requesting comments and suggestions from interested parties – due a week after the webinar.
- Submit comments online.

Quick summary of PFAS CAP efforts:

- PFAS CAP Advisory Committee and interested parties met in 2016, 2017 and 2018.
- September 2017 Draft PFAS CAP chapters posted:

Intro/Scope	Environment
Biosolids	Health
Chemistry	Regulations
Ecological Toxicology	Uses/Sources

- March of 2018, Ecology and Health published the Interim PFAS CAP.
- The 2019 updated PFAS CAP "chapters" to be posted (in the order we expect to post on the PFAS CAP website):

Biosolids	Chemistry
Ecological Toxicology	*Analytical methods (new)*
Environment	*Fate and Transport (new)*
Regulations	*Economic analysis (new)*
Uses/Sources	*Preliminary*
Health	*Recommendations (new)*

Questions - contact Kara Steward at kara.steward@ecy.wa.gov.

This document is posted on the PFAS CAP Website - https://www.ezview.wa.gov/?alias=1962&pageid=37105

Economic Analysis

Introduction

The Persistent Bioaccumulative Toxins rule (Chapter 173-333 WAC) requires that, as part of Chemical Action Plans (CAPs), Ecology should "identify costs of implementing the recommendations. This may include a qualitative and/or quantitative analysis of the probable benefits and costs of the CAP." This chapter of the CAP is intended to meet these requirements. Here, we identify and estimate, to the extent possible, the costs of implementing the recommendations of the CAP. Where possible, we identify the costs and benefits of implementing the recommendations.

Cost estimates in this chapter include external costs borne by parties other than the Department of Ecology or Department of Health. CAP recommendations include estimates of agency implementation costs.

The Department of Ecology's analyses compare potential actions to the state of the world without them. This is the baseline, and it reflects legal requirements that exist regardless of whether proposed actions are taken (e.g., state dangerous waste regulations). The baseline can also include actions that are already planned or occurring (e.g., ongoing removal, disposal, and replacement of aqueous film forming foam, or AFFF, at military facilities).

Because of developing knowledge about per- and polyfluorinated alkyl substances (PFAS) – from scientific research, to testing and identification, to understanding the extent of use and contamination – our ability to fully quantify implementation costs and resulting costs and benefits is limited. Where full quantification (total costs or benefits) was not possible, we have included what partial quantification was possible, such as unit costs, costs per event, or costs per firm. Where no quantification was possible, we have included qualitative discussion of impacts.

Recommended actions analyzed

- Action 1.1 Identify funding for PFAS drinking water mitigation
- Action 1.2: Technical support for site characterization, source investigation, and mitigation at contaminated sites:
    - Ecology will continue to collaborate with and provide technical assistance to involved parties at PFAS contamination sites in the state. These efforts will help to better understand the sources, composition, and distribution of PFAS contamination in soil and water. Evaluation of appropriate cleanup actions and their costs will be informed by this work.
- Action 1.3 Seek funding for biomonitoring to support impacted residents and help answer important health questions
- Action 2.2: Partner with local organizations in communities with contaminated water or contaminated sites
- Action 2.3: Work to prevent PFAS releases from firefighting foam use and manufacturing processes:

    - Ensure that industrial use of AFFF provides for containment procedures along with collection of AFFF and contaminated soil/sediment for proper designation/disposal. Costs to industrial users to collect and dispose of released PFAS-containing AFFF include plan development, employee training, methods for containment and disposal of waste.
- Action 3.1: Reduce PFAS exposure from carpet and carpet care products:
    - Implement a purchasing preference policy for PFAS-free carpet. Work with vendors on the flooring contract to offer PFAS-free carpet on all state master contracts and all agency contracts.
- Action 3.3: Implement reduction actions for PFAS in priority consumer products:
    - Establish a purchasing preference policy for PFAS-free products. Work with vendors to offer PFAS-free textiles, furniture, paints, and building supplies. Apply this policy to all state master contracts and all agency contracts.
- Action 4.2: Evaluate PFAS in landfill leachate and air emissions:
    - For this action, Ecology would consider adding requirements for PFAS testing, monitoring, and reporting.

Additional options analyzed

During the development of this Chemical Action Plan, Ecology considered additional actions that were ultimately not recommended. They include:

- Requiring municipal WWTPs to test influent and effluent.
- Recommending that the Legislature require alternatives assessments for specific products.

Costs of recommended actions

Action 1.1 Identify funding for PFAS drinking water mitigation

When concentrations of PFAS above the health advisory are detected in a drinking water supply, timely mitigation may be needed to protect human health. PFAS mitigation creates an immediate cost to the water system. The provider needs to communicate with customers and may purchase water from a neighboring system or distribute bottled water or water filters to customers. The water system needs to explore ways to mitigate the problem in the near-term and long-term and may need to install an expensive filtration system to remove PFAS. Without funding to defray these costs, public water systems and their ratepayers must absorb the costs of response.

Total costs for PFAS mitigation in drinking water will not be known until further water testing defines the scope of the problem in our state. At this time a few illustrative examples are available of drinking water mitigation, some examples do not separate the investigation costs.

- The city of Issaquah spent more than $1 million to install a filter on the one PFAS-contaminated city well. Filter maintenance and monitoring also require ongoing expenditures. In addition, water systems may incur costs associated with investigation of the source of the contamination.

- The Naval Air Station Whidbey Island spent $1.37 million, to date, for investigation and mitigation efforts, including providing bottled water and filters to impacted residences. Adding an activated carbon treatment system to the city of Coupeville's water system is estimated to cost $1.5 million.[1]

- In response to PFAAs detection in April 2017, the public water system of Airway Heights shut down their contaminated wells and used an emergency intertie with the City of Spokane water system to flush their system with clean water. Flushing included draining reservoirs and water towers. During the flushing, Fairchild AFB provided bottled water to water customers. The city has since added another connection to the City of Spokane to supply drinking water while they pursue treatment options for the contaminated wells. This water purchase could cost over $687 thousand in the first year, for over 439 million gallons of drinking water, for which the Air Force has agreed to pay the city.[2]

- Treatment of drinking water in Lakewood, using activated carbon filtration, is estimated to cost $5.2 million in initial capital costs, with ongoing operating and maintenance costs of $96 thousand per year.[3]

- At Joint Base Lewis McChord – McChord Field System – treatment of water from three wells, using activated carbon filtration, is estimated to cost $10.3 million in initial capital costs, with ongoing operating and maintenance costs of $830 thousand per year.[4]

Action 1.2: Technical support for site characterization, source investigation, and mitigation at contaminated sites.

Parties that released PFAS into the environment are responsible for cleaning it up and may also need to reimburse the water purveyor or Ecology for cleanup or exposure-mitigation activities. As part of the cleanup process, Ecology establishes cleanup levels, which are concentrations of hazardous substances in the environment that are considered sufficiently "protective of human health and the environment under specified exposure conditions." Action 1.2 includes the recommendation that Ecology collaborate with and provide technical support to involved parties at PFAS contamination sites in the state. These efforts will help to better understand the sources, composition, and distribution of PFAS contamination in soil and water. Evaluation of appropriate cleanup actions and their costs will be informed by this work.

The costs of developing and evaluating methods for investigating and cleaning up PFAS contamination are currently difficult to estimate due to significant uncertainties in our understanding of:

- How most PFAS affect people, animals, and plants, and in what concentrations.
- How to best measure the types and amounts of PFAS in the environment.

---

[1] WA Department of health, 2019.
[2] Sokol, 2017.
[3] WA Department of Health, 2019.
[4] Ibid.

- How PFAS move through the environment and change over time.
- How to best clean up environmental PFAS contamination, including consideration of protectiveness, feasibility, and cost.

Ongoing research continues to expand our knowledge base on these issues and may significantly alter the way that the Toxics Cleanup Program (TCP) approaches cleanup in the future. TCP is currently working with the City of Issaquah and the Eastside Fire District to identify possible sources of the PFAS groundwater contamination affecting the city's drinking water. As of the end of 2018, Ecology has contributed $330 thousand to this investigation.[5]

Environmental PFAS Contamination in Washington and Examples of Cost of Interim Cleanup Actions in Washington and Elsewhere

Known sites

Known areas with PFAS contamination in drinking water in Washington include:

- Issaquah (Eastside Fire and Rescue)
- Joint Base Lewis-McChord
- Naval Air Station Whidbey Island
- Fairchild Air Force Base, including Airway Heights.
- Cities of Lakewood, DuPont and Tacoma

In some of these areas, concentrations of PFOA and PFOS in groundwater used for drinking water exceed the EPA health advisory level. The primary source of contamination at all of these areas is believed to be releases of legacy PFAS-based firefighting foam (AFFF). Investigation and exposure reduction actions in and around the military bases are being conducted by the Department of Defense. The City of Issaquah has installed a filtration system to reduce PFAS concentration in its finished drinking water. As noted above, TCP is currently working with the City of Issaquah and the Eastside Fire District to identify possible sources of the PFAS groundwater contamination affecting the city's drinking water. Detections of PFOA and PFOS at levels below the EPA health advisory level resulted in removing wells from operation.

Potential sites

In addition to fire suppression, PFAS have many industrial uses. Future investigations may identify releases at or near these types of facilities:

- Civilian airports
- Civilian fire department training areas
- Tanneries
- Shoe manufacturing facilities
- Textile treatment facilities
- Plastics manufacturing facilities

---

[5] WA Department of Ecology, 2019. Project management and negotiations, work plans, soil characterization, groundwater sampling and monitoring, reports, and waste management.

- Metal plating facilities

Also, AFFF may have been released at many locations to extinguish fires particularly petroleum fires. If PFAS releases are suspected at these types of facilities, testing should be conducted to evaluate the presence of environmental contamination.

Cost of remediation are difficult to estimate and are expected to depend on variables such as:
- Extent and attributes of contamination
- Affected populations
- Geographic location and site attributes
- Amount of contamination in soil versus groundwater

Example costs

Moreover, the total cost of remediation for PFAS contaminated groundwater is not yet known. Ecology is not aware of any completed cleanups of PFAS contamination. Instead, we are including illustrative costs of interim actions and options to scale them to full cleanup cost. There are a number of PFAS contaminated sites undergoing mitigation and investigation, but no site has yet completed remediation.

- The City of Issaquah shut down their smallest well, and invested $1 million in a water treatment system.
- The Naval Air Station Whidbey Island spent $1.37 million, to date, for investigation and cleanup efforts.
- $3.5 million has been spent, with ongoing maintenance costs of $300,000 per year, for a granular activated carbon system to treat groundwater at a site in Moose Creek, Alaska. This does not include investigation costs or bottled water for 9,000 residents.
- Hoosick Falls, New York has budgeted $10 million for temporary municipal and private residential water filtration systems and investigation into an alternate drinking water source.
- At three sites in Minnesota, $49 million has been spent over 10 years on treatment of surface water, groundwater, sediment and soil.

Potential total cost of a cleanup
The MTCA Biennial Report provides data on remediation costs by stage for addressing contaminated sites. These are costs associated with characterizing the site, mitigating the impact if drinking water is affected, and cleanup of contaminated soil and groundwater. The table below summarizes how costs are typically distributed between site investigation and cleanup phases.

Table 1: Percentage of cost by remedial activity phase

Remedial Activity Category	2013-15 Biennium	2015-17 Biennium
Cleanup	67%	72%
Investigations	26%	16%
Other	7%	12%

Scaling the cost examples related primarily to investigation and pre-cleanup activities using the MTCA remediation ratios could result in overall remediation costs (excluding interim mitigation costs) of between $5.3 million and $62.8 million. Additionally, spending on interim solutions such as filtering or alternative sources of drinking water could result in ten-year costs of $6.5 million to $10 million.

Cleanup or mitigation?

Additional complexity in estimating potential costs comes from the developing nature of PFAS drinking water cleanups. Additional unknowns resulting in uncertainty include:

- The degree of remedial and preventative soil cleanup, to reduce ongoing and future groundwater contamination.
- The best remediation method(s) and their cost-effectiveness in balance with mitigation efforts. This includes comparisons between actions such as:
    - Only treating drinking water prior to consumption.
    - Pumping, treating, and returning water to the aquifer.
    - Treatment at a single point versus multiple wells.
    - Treatment limiting the scope or spread of existing contamination.
- Multiple types of PFAS that might be contaminating groundwater but do not immediately have viable test methods.
- Size of populations consuming contaminated groundwater.
- Liability to other property owners, water purveyors, or consumers.
- Developing knowledge in PFAS toxicity to humans and the environment.
- Ability of liable parties to cover cleanup costs. Parties such as small firefighting districts, that provide crucial services, may not be able to fund remedial actions on the same time scale or size as larger entities. Extending timeframes could increase interim mitigation costs and potential scope of contamination.

Action 1.3 Seek funding for biomonitoring to support impacted residents and help answer important health questions.

This action involves finding funding sources to offer subsidized biomonitoring for residents in areas impacted by PFAS-contaminated drinking water. Biomonitoring would let people know their exposure level relative to national averages and relative to other populations with elevated PFAS exposure. This information could help residents connect to health information that becomes available in the future.

Testing costs vary by number of analytes and whether they include drawing blood:

- Tests for perfluorooctanoic acid (PFOA) or PFOA and perfluorooctane sulfonic acid (PFOS) that do not include blood draws range cost about $300 per test.[6]
- Tests for 13 PFAS analytes cost between $450 and $500.[7]

[6] Wagner & Bagenstose, 2017. "Local, National Labs offer PFC Blood Tests". Pennsylvania Intelligencer, February 3, 2017.
[7] Ibid.

- Tests including drawing blood or a blood sampling and mailing kit cost between $528 and $797.[8]

Testing performed by a centralized company or agency may receive different rates (e.g., bulk rates) but incur additional administrative costs, resulting in different and variable average per-person testing costs:[9]

- Serum testing of over 69 thousand people in the mid-Ohio Valley for PFAS, for $70 million, averaged approximately $1 thousand per person tested.
- The state of New York tested 3 thousand people in Hoosick, NY for $3 million, averaging $1 thousand per person tested.
- The Centers for Disease Control (CDC) and the state of New Hampshire tested 1,600 people in Pease, NH for nearly $340 thousand, averaging $211 per person tested.
- Under a CDC grant to the state of Pennsylvania, the state tested 250 people for $175 thousand, averaging $700 per person tested.

Action 2.2: Partner with local organizations in community outreach and support community involvement

This action involves providing funding to local organizations to engage communities affected by PFAS contamination. This could involve example activities including (as demonstrated in other states' public involvement):

- Educational materials
- Rapid response information

Ecology's Public Participation Grant (PPG) program funds activities similar to what is included in this recommendation. The PPG program, however, is already limited in funds it provides for such activities, applies to a broad set of activity types, and is not likely to have funding available for PFAS activities. Additional funding under this action would be directed specifically to PFAS-related impacts to communities, rather than competing with (and potentially displacing) existing PPG grantees.

A component of the PPG program that funds information for communities impacted by contaminated sites is the Contaminated Site Project category of grants. An example of this type of grant project is the multi-component Futurewise program for communities affected by contamination in Algona stemming from past Boeing manufacturing activities. The two-year, $120 thousand grant covered a larger scope of activities, but included $25 thousand for educational materials:

- Printed and electronic education and outreach materials
- Display booth
- Health fair
- Translated materials

---

[8] Ibid.
[9] Bagenstose, 2018. "Study: High PFAS blood levels in Bucks, Montgomery County residents" Pennsylvania Intelligencer, November 26, 2018.

This action is likely to cover the types of activities listed above, as well as potential engagement of disadvantaged populations in problem solving and collective action. These educational materials and information provision would be helpful to communities that are at elevated risk of PFAS exposure. The degree and types of activity covered would depend on the funds available, as well as the number and types of projects requesting funding.

Examples of larger types of community-based action

While not envisioned as part of this recommended action, we note there are additional types of action taken through community-based grant programs in other states, in response to PFAS drinking water contamination and exposure.

- Population PFAS testing
- Public meetings
- Health guidance and information provision
- Information fairs
- Involvement/representation in public processes for PFAS regulation

PFAS projects developed under funding from this action are envisioned to be significantly smaller in scope, primarily intending to avoid displacing projects already using the PPG program.

The $120 thousand grant agreement for the Futurewise project covered (between 10/1/2013 and 6/30/2015) the activities below. Depending on the types of community engagement that would occur, based on circumstances and grant applications, this action could include similar additional components.

- Administration ($13,625)
  - Tracking of spending and objectives
  - Evaluation and reporting
  - Final project report
- Public events and outreach ($81,230)
  - Immediate resident audience
    - One-to-one outreach
    - House parties with invited speakers such as health consultants
    - Healthy home visits
    - Outreach specialist
    - Translation to relevant languages
  - Greater Algona audience
    - Attending annual community-wide public events
    - Creating exhibits, games, and interactive activities for education
    - Holding a health fair
    - Fact sheets: contamination, cleanup, participation in the Ecology public process
    - Community meeting with speakers and cleanup updates
  - Business audience
    - One-to-one outreach identifying questions and concerns

        - Business-specific outreach materials
        - Two outreach events with speakers and updates
    - Student audience
        - Outreach to teachers and other adult youth leaders about cleanup and groundwater science
        - Outreach events and engaging youth volunteers in youth education and involvement
- Education tools ($25,145)
    - Printed and electronic education and outreach materials
        - PowerPoint presentations
        - Factsheets
        - Display materials for event tables
        - Meeting agendas
        - Evaluation tools
    - Display booth
    - Health fair
    - Translated materials

Action 2.3: Work to prevent PFAS releases from firefighting foam use and manufacturing processes.

One of the recommended actions is to ensure that industrial use of AFFF provides for containment procedures along with collection of AFFF and contaminated soil/sediment for proper designation/disposal. Costs to industrial users to collect and dispose of released PFAS-containing AFFF include plan development, employee training, methods for containment and disposal of waste.

For this action, Ecology would need to inform users of AFFF of the requirements and provide guidance on how to comply with them. Then users of AFFF would need to collect, treat, and properly dispose of PFAS-containing waste from AFFF use.

To prevent discharge of AFFF to the environment (or minimize it), industry would need to:

- Develop a plan for compliance.
- Purchase and carry compliance equipment.
- Collect runoff containing PFAS.
- Treat and dispose of runoff.

Runoff collection plan - We assumed development of a runoff collection plan would require 80 hours of technical, administrative, and managerial staff time at AFFF-using facilities. Assuming third-party median environmental engineer hourly wages of $46.89,[10] loaded with additional

[10] US Bureau of Labor Statistics, 2017.

overhead costs to reflect higher consultant prices,[11] and updated for inflation,[12] the loaded hourly wage for this work would be $89.77. The cost per facility for this task would be $7,182.

Training - We assumed four personnel would need to be trained in the runoff collection plan facilities using AFFF. Using the median firefighting wage of $35.28 per hour,[13] updated for inflation and overhead to $68.51 per hour,[14] this cost becomes $22 thousand per facility.

Training costs are, of course, more nuanced. Training materials may need to be developed, as well as labels and signage reminding firefighters of best practices. These materials may be generated by one party, and then shared with, or sold to, other facilities. Highly location-specific training needs, as well as staff turnover, may result in additional materials, instruction, and hours of employee time.

Containment, collection, and disposal - Effectively containing, collecting, and disposing of AFFF-contaminated runoff would likely entail measures such as:

- Portable booms, berms, and drain blocks.
- Pumps, hoses, and tanks.
- Potential pre-disposal treatment.
- Disposal of untreated or treated runoff.
- Disposal of treatment byproducts such as filters, sorbents, or solidifiers.

While these measures could be taken individually, facilities are likely to hire a specialist in wastewater and runoff management to properly manage PFAS-containing runoff.[15] While volumes of existing product are identifiable to some extent, actual volumes of runoff captured, treated, and disposed of will vary by site and firefighting activities (e.g., how much water is used, site characteristics). We could not, therefore, estimate total costs. We have, however, identified unit costs associated with elements of capture, treatment, and disposal.

Portable booms, berms, and drain blocks - Depending on the style and length of boom, the per-foot cost ranges between $10 and $45, with a median price of $26 per foot.[16] At typical purchasing lengths of up to 100 feet, this cost would be $260 per boom, at the median.

Similarly, depending on the style and length of berm, the per-foot cost ranges between $22 and $81, with a median price of $34 per foot.[17] At typical purchasing lengths of up to 12 feet, this cost would be up to $408 per berm, at the median.

---

[11] WA Department of Ecology, 2018.
[12] US Bureau of Labor Statistics, 2019.
[13] US Bureau of Labor Statistics, 2017.
[14] US Bureau of Labor Statistics, 2019. WA Department of Ecology, 2018.
[15] US Department of Defense, 2003.
[16] Grainger, 2019.
[17] Ibid.

Drain blocks and seals vary in size and quality, but range between $110 and $581,[18] with a median price of $238.

These prices do not include additional labor required for set-up during AFFF use, which will vary by site and firefighting characteristics.

Pumps, hoses, and tanks - Depending on the size needed, and location of use, purchasing a portable trailer pump and tank (rather than hiring a contractor) could cost tens of thousands of dollars. A smaller-volume (50 gallon) portable pump and tank could cost up to $5 thousand.[19]

Treatment and disposal - The cost of on-site treatment of AFFF-contaminated runoff water varies significantly by technology and type of product disposed. A United States Department of Defense study comparing multiple treatment technologies and disposal products at large facilities indicates:[20]

- Existing off-site treatment and disposal costs ranged between $0.14/lb and $0.44/lb, with an average cost of $0.25/lb, if waste is approximately the density of water.[21]
- Rental generators to run treatment would cost $137/day with anticipated work days lasting 8 hours to treat 24 thousand to 48 thousand gallons of wastewater.
- A potential treatment technology could incur capital costs of $236 thousand to $306 thousand, but result in 94 percent reductions in disposal costs by reducing water waste to sludge.

Existing stored product - The exact makeup of most AFFF products is confidential business information (CBI), making a detailed economic analysis of replacement products impossible. However, technical documents from the United Nations' (UN) Stockholm Convention (2012) provide a general assessment on replacing AFFF that contain PFOS, which may translate to PFAS replacement activities. Using this assessment as a guide, costs would likely be incurred during PFAS AFFF replacement from the:

- Destruction or storage of the retired chemicals.
- Cleanup of impacts areas.
- Replacement of or upgrades to existing equipment.
- Potential changes in operations. (UN, 2012, p. 23-24).

In lieu of ongoing use of AFFF, facilities have options of either disposal or other removal of the product, and replacement with an alternative PFAS-free product. Other removal options include selling to facilities in states with less-restrictive regulations, or transporting to another facility under the same organization (such as another military facility).

---

[18] Ibid.
[19] Edson, 2019. JME Ellsworth, 2019.
[20] Costs updated to 2018 values. US Bureau of Labor Statistics, 2019.
[21] Note that $0.10/lb value reflects a per-gallon cost of approximately $0.82.

Large scale replacement costs have included $6.2 million for replacement of AFFF at 180 US Air Force facilities.[22] More remote facilities incur higher transportation costs to airlift in new AFFF.[23] A recent US Department of Defense contract opportunity offered $5 million for removal, destruction, and disposal of AFFF from three geographic regions of facilities, but without replacement.[24] The existence of these ongoing replacement and disposal activities, however, indicates that some of the costs of this action are part of the baseline (happening regardless of recommendations).

AFFF is a state-only dangerous waste in Washington, and must therefore be managed in compliance with WAC 173-303, Dangerous Waste Regulations. Small quantity generators may transport their own hazardous waste, whereas medium and large quantity generators must hire a hazardous waste contractor. Small quantity generators (generating less than 220 lbs of dangerous waste in any month) may take waste to a facility licensed to accept hazardous waste. These facilities vary by county and charge their own set of fees, ranging up to $100 per ton equivalent. Equipment used in deploying AFFF may need to be retrofitted or replaced. This largely depends on the change in viscosity of the replacement product.

Medium and large quantity generators must dispose of their AFFF at permitted Transfer, Storage, and Disposal facilities, via a licensed hazardous waste contractors. This can cost in the tens of thousands of dollars, depending on the quantities of product being disposed of, and hauling distance.

There may also be costs associated with changing existing operations due to differing requirements of new AFFF products. The Stockholm Convention alternatives documents suggested that some AFFF users reported no change in operational costs when retiring PFOS chemicals, while others incurred higher costs.[25]

Action 3.1: Reduce PFAS exposure from carpet and carpet care products

One of the recommended actions is to implement a state agency purchasing preference policy for PFAS-free carpet.

Recent and previous research has shown carpet to be a repository for pollutants and that indoor air quality declines when carpeted areas are disturbed.[26] According to the Carpet and Rug Institute (CRI), carpet accounts for 51 percent of the U.S. flooring market.[27] PFAS, largely used for stain repellent in carpet, were worth close to $1 billion worldwide in 2006 for this use.[28] Two North American studies frequently detected PFAS particles in significant concentrations in

[22] For context, we note that the US Air Force budget is in the hundreds of billions of dollars.
[23] US Air Force, 2017.
[24] US Department of Defense, 2018.
[25] UN, 2012.
[26] Becher et al, 2018.
[27] CRI, 2018.
[28] Renner, 2006

vacuum cleaner bags. The studies found a significant correlation between the presence of PFAS and the age of the house and floor covering type.[29]

For this action, Ecology would develop a purchasing preference policy (for purchases by the State of Washington) for carpet. A purchasing preference policy would not ban state purchases of PFAS-containing carpet. Instead, the policy could give points to state contract bidders, when they declare (and provide supporting data) that their carpet does not contain PFAS. These points would be part of the bid scoring process. This would create incentive for bidders to provide PFAS-free carpet to state agencies and municipalities that use the state contracting process.

We estimated the difference in costs for state carpet purchases if they contain PFAS versus are PFAS-free. We were able to estimate annual quantities of carpet purchased under the state contract, based on invoiced costs.[30] Multiple types of facility purchase carpet under the state contract:

- State agencies
- Cities
- Counties
- Fire Districts
- Higher education establishments
- Libraries
- Nonprofits
- Ports
- School Districts

Total invoiced amounts were identified by quarter, and are summarized in the table below. Only one year of data was available for this analysis, and so may not be representative of all other years.

Table 2: Carpet invoices by group and quarter, 2018

Group	Q1	Q2	Q3	Q4	Annual
State	$822,883	$2,545,349	$332,531	$403,054	**$4,103,817**
Cities	$267,691	$451,481	$334,562	$373,953	**$1,427,687**
Counties	$501,283	$338,855	$194,010	$415,423	**$1,449,571**
Fire Districts	$57,094	$101,975	$186,309	$60,371	**$405,749**
Higher Education	$113,484	$702,653	$733,069	$345,657	**$1,894,863**
Libraries	$33,325	$173	$34,605	$159,470	**$227,573**
Nonprofits	$1,944	$1,431	$0	$1,771	**$5,146**
Ports	$51,053	$10,178	$5,534	$6,483	**$73,248**

[29] Fromme et al, 2008
[30] WA Department of Enterprise Services, 2018a. Invoiced carpet expenditures by quarter.

Group	Q1	Q2	Q3	Q4	Annual
School Districts	$193,700	$543,974	$3,751,886	$942,441	**$5,432,001**
ALL GROUPS	**$2,042,457**	**$4,696,069**	**$5,572,506**	**$2,708,623**	**$15,019,655**

While these invoiced amounts tell us the total cost of carpet purchases, they do not tell us the types of carpet purchased, or the square yards (quantity) purchased. We therefore made various combinations of assumptions to develop a range of square yardage potentially reflected in these invoices.

Using the multiple carpet options available under the state contract – which includes PFAS-containing and PFAS-free options or options that use alternative technologies to "permanently or inherently" make their carpet stain-resistant – we identified a price difference between carpets with and without topically applied treatment. The table below provides the summary statistics for these two types of carpet.[31]

Table 3: Percentages and pricing of carpet by stain resistance method

	Topically applied stain resistance	**Permanent or inherent stain resistance**
Percentage of offered products	35.7%	64.3%
	Price per square yard	
Minimum	$6.74	$11.43
Median	$17.06	$21.96
Maximum	$37.04	$45.56
Average	$17.09	$23.51

Uncertainty arises from whether these various types of carpet – many of which contain proprietary chemicals or fibers – do, in fact, contain PFAS. Topical treatments may or may not contain PFAS. Similarly, fiber stain-resistance technologies that are described as non-degrading and "permanent" even when subjected to heat and cleaning in addition to normal wear, may potentially contain PFAS. Without comprehensive reporting of testing or knowledge of upstream production processes and treatment chemical or technology contents, these distinctions are not possible to make with reasonable certainty.

However, because the average price of inherently stain-resistant carpet was significantly higher than the price of carpet with topically applied stain-resistance treatment, and for simplified estimation, we assumed in this estimation that carpet with topically applied treatment contained PFAS, while those with inherent stain-resistance did not. This resulted in carpet containing

[31] WA Department of Enterprise Services, 2018b. State carpet contract prices for Interface, Mannington, Mohawk, Shaw, and Tandus brands.

PFAS costing less than the PFAS-free alternatives. We have also included a worst-case cost scenario, in which all carpet currently being purchased contains PFAS, and would be incentivized under this alternative to be replaced with PFAS-free carpet, by scoring PFAS-free carpet contractors higher than those not offering documented PFAS-free carpet.

If current carpet purchases are in line with the proportions of products offered, and based on the average topically applied price of $17.09 per square yard, the total invoiced costs reflect 725 thousand square yards of carpet. In this case, 35.7 percent of purchases would be incentivized to change their purchasing under this action. The total cost increase would then be 35.7 percent of 725 thousand square yards, purchased at the difference between the average permanently stain-resistant price of $23.51 and the topically applied price of $17.09. This total cost increase statewide would be $1.7 million per year.

In a worst-case cost scenario, however, all current carpet purchases contain PFAS in some form or another, potentially because of least-cost purchasing preferences. In this case, based on the average topically applied price of $17.09 per square yard, the total invoiced costs reflect 879 thousand square yards of carpet. In this case, all buyers would be incentivized to change their purchasing under this action. The total cost increase would then be 879 thousand square yards purchased at the difference between the average permanently stain-resistant price of $23.51 and the topically applied price of $17.09. This total cost increase statewide would be $5.6 million statewide.

The table below summarizes how the cost increases under the two scenarios above would be distributed across various types of buyer.

Table 4: Total cost increase by group and scope of change, annual

Group	Cost increase if 35.7 percent switch	Cost increase if 100 percent switch
State	$454,012	$1,542,781
Cities	$157,947	$536,722
Counties	$160,368	$544,949
Fire Districts	$44,889	$152,537
Higher Education	$209,632	$712,351
Libraries	$25,177	$85,553
Nonprofits	$569	$1,935
Ports	$8,104	$27,537
School Districts	$600,951	$2,042,096
ALL GROUPS	**$1,661,648**	**$5,646,461**

We note there are also types of carpet that are not included in existing state contract rates. The prices above reflect various types of backed nylon carpet, either in tiles or broadloom. They do not include polyester carpets that do not need stain resistance added. They also exclude potential emerging new technologies in stain-resistance using alternative fibers designed to be more hard-wearing like nylon carpet is. These carpets potentially cost less than nylon PFAS-free carpets, per yard.[32]

These estimates also assume that the same quantities of carpet will be purchased. Facing higher unit prices, buyers may substitute away from carpet and choose other floor coverings that are PFAS-free instead of PFAS-free carpet. This could lower overall costs, though we note that carpet may be chosen for safety, acoustics, or other qualities, instead of other floor coverings.

Action 3.2: Implement reduction actions for PFAS in priority consumer products

One of the recommended actions is that a state agency purchasing preference policy be established for other PFAS-free products. For this action, Ecology would develop a purchasing preference policy (for purchases by the State of Washington) for:

- Cleaning products – dispersed when used and are often discharged down the drain.
- Paint – used for any surface and could release PFAS to the environment.
- Potentially other products with likely PFAS treatment, such as furniture or textiles.

A purchasing preference policy would not ban state purchases of PFAS-containing products. Instead, the policy would give points to state contract bidders, when they declare (and provide supporting data) that their product does not contain PFAS. These points would be part of the bid scoring process. This would create incentive for bidders to provide PFAS-free products to state agencies and municipalities that use the state contracting process.

Cleaning products

Due to the broad nature of cleaning products and floor finishes that potentially contain PFAS, as well as the ability of janitorial services under state contract to purchase their preferred cleaning products, we could not identify the extent of PFAS-containing or PFAS-free cleaning product use in Washington. We do note that, of the identifiable products available for direct purchase under the state green janitorial products contract, only one floor polish (sold in three sizes) is explicitly listed as being PFAS-free. Other cleaning products surveyed and identified in supplier product searches do not mention PFAS.

While there is moderate literature on the replacement of PFAS-containing cleaning products, prices and price differences specifically for PFAS are not mentioned. However, we can approximate the price difference by using the example of the price difference between green cleaning products in general, and non-green cleaning products. While this does not necessarily show PFAS contents, it is the nearest available quantification of this potential price difference.

---

[32] See, for example, Dupont's "Sorona Fiber" and Invista's "non-fluorinated Duratech"

We note also that prices will depend on green product availability and market share, as reflected in price differentials by country. These price differences for four countries are summarized below.[33]

Table 5: Green product price differential, by country

Country	Price difference between green and non-green product (%)		
	All-purpose and floor care products	**Sanitary cleaning products**	**Window cleaners**
Sweden	-74%	-82%	-9%
Germany	+36%	+148%	-36%
Spain	+131%	+92%	-94%
Czech Republic	+158%	+2%	-

In markets with long-standing incentives and regulation for certain green products, and green substitutes for toxic chemicals are more prevalent, we see that green products are generally less expensive than non-green products. Where regulation or incentives are more recent or nonexistent, green products have a more niche market, and can be significantly more expensive. Data was not reported for the United States, but we may assume that since nontoxic substitutes for PFAS are currently limited or unknown, and there are observationally few mentions of PFAS-free products in marketing and labeling, initial prices for PFAS-free products (holding other product attributes and components constant) would be higher than current prices.

Paint

We based cost estimation for paints on historic bids for state waterborne road marking paint contracts.[34] This use is more likely to prefer the qualities PFAS provides for products, of reduced adherence and staining. The quantity of different types of paint varied, as summarized below. The total quantity and types of paint purchased are expected to vary annually by the needs of planned projects and locations.

Table 6: Paint quantities purchased, by type

Paint type	Quantity (gallons)
Standard, white, sold by the truckload	216,750
Standard, yellow, sold by the truckload	137,750
Standard, white, sold by less than truckload	12,500

[33] UNEP, 2008. "Sustainable Procurement Guidelines for Cleaning Products and Services".
[34] WA Department of Enterprise Services, 2018c. Bid sheet for state contract for waterborne road marking paint.

Paint type	**Quantity (gallons)**
Standard, yellow, sold by less than truckload	8,500
Cold weather, white, sold by the truckload	18,000
Cold weather, yellow, sold by the truckload	18,000
Cold weather, white, sold by less than truckload	0
Cold weather, yellow, sold by less than truckload	0
High build, white, sold by truckload	0
High build, yellow, sold by the truckload	0
High build, white, sold by less than truckload	0
High build, yellow, sold by less than truckload	0
TOTAL	**411,500**

Across all paint types and quantities, prices were generally consistent across brands. The table below provides summary statistics for waterborne road marking paint prices in the current state contract.

Table 7: Paint price per gallon

	Price per gallon
Minimum	$ 8.50
Median	$10.99
Maximum	$19.79
Average	$11.93

Based on existing prices reflected in state contracts, and allowing for variance in the types of paint purchased, we estimate that purchasing the quantities of paint shown in Table 5 would currently cost between $3.5 million and $8.1 million per year.

At this time, it is not possible to identify which road paints do or do not contain PFAS. Acceptable road paint choices are based on a large set of usability, functionality, and wear criteria, some of which may be tied to PFAS or other surfactant contents, but use of PFAS is not identified in choice criteria. Comprehensive paint contents is proprietary, so it is similarly difficult to directly identify PFAS use in existing contracted paints by brand and type. It is therefore also difficult to ascertain, from the literature, the pricing of adequate alternatives, or whether such alternatives are sufficiently available. The limited studies explicitly addressing road paint indicate that further study of alternatives is needed[35] or that water-based alternatives are available that meet the same functionality and durability criteria, without identifying price differences.

Action 4.2: Evaluate PFAS in landfill leachate and air emissions.

For this action, Ecology would consider adding requirements for PFAS testing, monitoring, and reporting for landfill leachate.

It is important to note that PFAS is a state-only dangerous waste under existing Washington state regulations, at concentrations above 100 parts per million. This means it must be reported, managed properly, and disposed of correctly, according to WAC 173-303, Dangerous Waste Regulations.

Landfill leachate

Landfills in Washington are regulated by local health districts under rules authored by Ecology. Chapters 173-350 and 173-500 WAC allow health districts to include stipulations in permits that require landfills to sample for additional constituents (e.g. PFAS). If, for some reason, a health district does not want to make that stipulation, then a rule change would be necessary to ensure sampling for PFAS. The process to adopt landfill leachate regulations into rule would likely span over several rulemakings as the science and policy surrounding PFAS continues to evolve. Ecology would likely pursue a single complex rulemaking to create the initial policy followed by a series of less complex rule updates to incorporate new science.

The request for landfill testing for PFAS in leachate would be generated by Ecology and local Health Districts. The cost to a landfill operator to test for PFAS would depend on the frequency of monitoring and of there are requirements to test monitoring wells. Current laboratory cost to analyze for PFAS ranges from $1,000 to $1,500 per sample. The landfill operator would need to add PFAS to their existing landfill monitoring plan.

There are 63 landfills identified as operating in the state: limited purpose, inert waste, and municipal solid waste. Limited purpose and inert waste landfills, however, are not required to collect leachate. Some limited purpose landfills may collect it voluntarily.

Costs of other options analyzed

During the development of this Chemical Action Plan, Ecology considered additional actions that were ultimately not recommended. They include:

- Requiring municipal WWTPs to test influent and effluent. The costs of this option are unknown without the development of individual monitoring plans.

[35] Kougoulis, et al., 2012. "Revision of EU European Ecolabel and Development of EU Green Public Procurement Criteria for Indoor and Outdoor Paints and Varnishes"

- Recommending that the Legislature require alternatives assessments for specific products. (Discussion of costs below.)

Alternatives assessments

For this action, Ecology could have recommended that the Legislature:

- Allocate funding for Ecology to conduct alternatives assessments of the use of PFAS in products, or
- Require manufacturers of PFAS-containing products (specific products or industries) to work with independent third-party contractors conduct alternatives assessments of the use of PFAS in their products.

We identified 13 industries operating in Washington that are likely to use PFAS in their production processes:

Table 8: Industries likely to use PFAS

Industry	North American Industrial Classification System (NAICS) code
Plastics product manufacturing	326199
Automobile manufacturing (plating activity)	3361
Carpet rug mills	314110
Corrugated solid fiber box manufacturing	322211
Electroplating, plating, polishing, and anodizing	332813
Leather hide tanning finishing	316110
Other fabricated wire product manufacturing	331222
Paper mills (except newsprint)	322121
Paper bag coated treated paper manufacturing	322220
Paperboard mills	322130
Pulp mills	322110
Semiconductors related devices manufacturing	334413
Textile fabric finishing mills	31320

Cost if Ecology assesses alternatives

Ecology assumes that an alternatives assessment costs $400 thousand and takes up to two years. Costs and time would vary by:

- Stakeholder interest and involvement
- Project scope
- Robustness of analysis

The most significant expenditure for a robust alternatives assessment comes from completing the hazardous chemical assessment, which Ecology typically contracts out to a third-party toxicology consultant.

For this analysis, Ecology anticipates completing an alternatives assessment for each of the most common applications of PFAS chemicals in secondary products. PFAS polymer treatments are widely used to provide stain, grease, or water resistance to materials such as carpets and apparel. PFAS are also added to formulated products such as paints and sealers both to improve surface characteristics and to promote even wetting and spreading (fluorosurfactants). Alternative assessments may be appropriate for any or all of these typical PFAS product categories:

- Paint
- Textiles
- Cosmetics
- Cleaning products
- Floor and car waxes
- Water proofing sprays (for leather, carpet or textiles)
- Automotive fluids

The process to complete an alternatives assessment for one product is estimated to be two years long, and cost of $400 thousand for each contract. Actual costs would depend on product category breadth and complexity. Oversight of the contractor and review of the assessment would require one staff person for 0.25 FTE per year for two years for each assessment. At a cost of $400 thousand per assessment, the cost to complete assessments of all 7 product categories would total $2.8 million.[36]

[36] $2.8 million estimate is in nominal terms, reflecting the total cost if all costs are incurred immediately (i.e., all seven alternatives assessments are done at once). If one alternatives assessment is done at a time, the equivalent present value is $1.6 million using a 1.03 percent discount rate (historical average (1998 to present) real rate of return on US Treasury Department I Bonds. US Treasury Department, 2018.

Cost if industry assesses alternatives

If industry, as a group, contracts alternatives assessments to consultants, all assessments could be completed in the first two-year cycle. Assuming all assessments begin in the first year, and assessments were completed for the seven applications as assumed for Ecology alternatives analyses, this action would cost $2.8 million, but assessments would be completed significantly sooner than the Ecology option.

Price impacts to products

If the alternative chemicals identified and subsequently required are significantly more costly than PFAS, then the prices of products could increase. Since we cannot know before an alternatives assessment is completed what the attributes are of substitute chemicals, we cannot determine with certainty whether assessments will identify viable alternatives that are significantly more costly than currently used PFAS. This is the nature of recommended actions that involve research and investigation. For potential price differences for carpet, cleaning products, and paints, see discussion for Actions 3.1 and 3.2, above.

Benefits of recommended actions

Current state of economic and scientific knowledge about PFAS

Research on the human health and environmental impacts from PFAS exposure is emerging. Because of this, it is not possible to succinctly quantify health and environmental-related economic benefits of reduced PFAS exposure. However, the literature on relationships between PFAS exposure and impacts to human health and the environment is robust enough to provide a high-level discussion of those impacts and potential costs resulting from those impacts.

There are several key reasons for the poor resolution in the literature on PFAS exposure and health and environmental costs. A significant amount information pertaining to the exact compositions of PFAS is confidential business information and unavailable to independent researchers. Molecular composition can vary widely among different producers, even within particular uses of PFAS, and this information is not available to the public. Studies suggest that PFAS manufacturing data be made public as a method to reduce public health expenditures on toxicology research and to better understand the global effects of PFAS.[37] Unlike previous substances focused on in Ecology's CAPs, little is known about the prevalence, locations, exposure, and quantitative effects of PFAS, which is largely related to the lack of reporting and disclosure requirements.

Human health and wellbeing benefits

Poor human health and related healthcare expenditures are generally associated with lower macroeconomic growth, which results from reductions in:

[37] Scheringer et al, 2014.

- Consumer spending on non-medical goods
- Worker productivity
- Capacity for public investment in areas outside of healthcare.[38]

An increase in human health and productivity would affect macroeconomic benefits.

Despite the emerging nature of PFAS health impact literature, several trends in human health conditions associated with PFAS exposure are easily identified within the literature. These include:

- Increased risk of thyroid disease and endocrine system disruptions.
- Increased risk of certain cancers.
- Higher cholesterol levels.
- Reduced antibody response to vaccinations.

The Health Chapter discusses the general effects of these health issues in detail. Each of these health issues are associated with direct and indirect costs. Some are terminal illnesses, while others, like high cholesterol and immune deficiencies increase risk for other illnesses and are associated more with their secondary costs.

The health conditions associated with PFAS exposure not only affect the lives of sick individuals and their families, but influences economy-wide productivity losses. Among all sicknesses and diseases, absenteeism and presenteeism[39] impacts to business productivity can be twice as high as medical and pharmacy costs.[40] The Commonwealth Fund estimated a nationwide impact of $260 billion in 2003, 2.4 percent of gross domestic product at the time, for reduced worker productivity, sick days, and the loss of adults from the workforce due to chronic disease and disability.[41]

Children who are sick often and miss school may see long-term economic impacts. Recent research established a negative relationship between a child's school absenteeism and their overall performance on tests.[42] Studies dating back over 40 years have found positive associations between a person's educational attainment and their earnings and one recent study linked high school GPA (academic performance) with annual salary, particularly during young adulthood.[43]

Costs from likely PFAS-related health conditions

Because PFAS exposure thresholds associated with these health issues have not been established, it is not possible to quantify healthcare costs associated with PFAS chemicals at this time,

[38] World Health Organization, 2009.
[39] Presenteeism occurs when workers are present at their job, but function at a reduced capacity because of a health issue; depression is often cited as an example of a condition that affects presenteeism.
[40] Loeppke et al, 2009.
[41] Davis, 2005.
[42] García and Weiss, 2018.
[43] French et al, 2015

however, Ecology assumes that rates of PFAS exposure are positively correlated with rates of the previously identified health outcomes. A reduction in exposure to PFAS chemicals would logically reduce the risk of these associated health issues and related costs.

In lieu of a detailed quantitative analysis of the healthcare costs related to PFAS exposure, we provide a review of potential economic impacts by reviewing costs associated with conditions likely related to PFAS exposure. As the science linking PFAS exposure with particular health conditions gains resolution, more detailed analyses of the health and economic impacts will be possible. Until then, it is not possible to determine how much of a condition's economic effects are related to PFAS exposure. The following discussion does not assume particular correlations between health-related costs and PFAS exposure, but is meant to be a high-level discussion of the costs of associated health outcomes.

Thyroid disease and endocrine disruption

Some studies have found significant associations between PFAS exposure and endocrine disruption.[44] Research generally shows a positive relationship between thyroid hormone levels and exposure to PFAS, but more research is needed to confirm the relationship and establish exposure thresholds. Both thyroid disease and its associated illnesses are responsible for significant costs to those impacted and society at large.

According to the Endocrine Society and the Agency for Healthcare Research and Quality, thyroid disease treatment costs for females over age 18 in the US approached $4.3 billion, with a per person mean expenditure of $409 for ambulatory services and $116 for prescriptions.[45,46] Thyroid disease and endocrine disruptions are significantly more common in females than males. From 1996 to 2006, the occurrence of thyroidectomies in the U.S. has increased for both inpatient and outpatient services, with the most significant increases among Medicare and Medicaid patients.[47] At this time, we cannot estimate the proportion of thyroid disease specifically caused by PFAS exposure, or its interactive or complementary affects in combination with other chemicals or behaviors.

Cancer risk

Studies have linked exposure to PFAS and cancer for over 20 years with varying degrees of significance.[48] Several distinct populations may have elevated risk of testicular and/or kidney cancer, including:

- Workers directly exposed in chemical plants to PFOA.
- Communities where PFOA exposure is significantly elevated (typically water supply contamination or close to an industrial facility releasing PFOA).

---

[44] Ballesteros et al, 2017.
[45] Endocrine Society, 2018.
[46] Soni, 2008.
[47] Sun et al, 2013.
[48] Australian Department of Health, 2018.

- Those with high rates of background exposure.[49]

At this time, it is not possible to estimate the percentage of testicular and kidney cancer cases associated with PFAS exposure.

Cancers are generally shown to have the highest associated medical and pharmaceutical costs among common illnesses.[50, 51] Annual charges for an individual with kidney or testicular cancer are estimated at $39,841 and $33,747, respectively.[52] National expenditures for kidney cancer care in 2017 were $4.7 billion, while those related to testicular cancer approached $22 million.[53, 54]

The average annual productivity loss per employee due to cancer is commonly estimated at over $1,600. Accounting for medical costs and lost productivity, annual cancer impacts to an average-sized company (10,000 employees) can approach $2.5 million.[55] In 2005, productivity losses in the U.S. from testicular cancer were about $500 million, while kidney cancer was responsible for $3.4 billion[56] in losses.[57]

Higher cholesterol levels

Several studies show links between PFAS exposure and increased cholesterol levels, although the extent to which PFAS exposure is responsible for increased cholesterol is not known.[58] Current science suggests that diet is the most significant influencer of high cholesterol.[59] Although research does not suggest that PFAS exposure plays a significant role in health outcomes related to increased or high cholesterol nationally, there may be economic benefits from even slight reductions in population-wide cholesterol levels, given the widespread occurrence of the condition in the U.S. It is not possible to estimate what percentage of this impact is related to PFAS exposure at this time.

Between 2011 and 2012, just under forty percent of U.S. adults had cholesterol levels high enough to be considered at risk for heart disease or stroke, dangerous conditions that are associated with significant costs.[60] The CDC estimates that over 43 million U.S. adults took cholesterol-lowering medications between 2005 and 2012.[61] The cost of these drugs, known as statins, vary significantly, ranging from $36 to over $600 per month.[62] According to the

[49] International Agency for Research on Cancer, 2017
[50] Loeppke et al, 2009.
[51] Mitchell and Bates, 2011.
[52] United States Department of Health and Human Survives, 2012.
[53] Ibid.
[54] Aberger et al, 2014
[55] Mitchell and Bates, 2011.
[56] This figure includes productivity losses from both kidney and renal pelvis cancers.
[57] National Cancer Institute, 2018.
[58] CDC, 2018a
[59] Mayo Clinic, 2017.
[60] CDC, 2018b.
[61] Mercado et al, 2015.
[62] Consumer Reports, 2014.

American Heart and Stroke Associations, costs associated with heart disease and stroke in the U.S. exceed $316 billion, including both medical expenditures and lost productivity. Similar costs related to heart disease alone approached $200 billion in 2012 to 2013.[63]

Secondary immunodeficiency disorders

A number of studies have found associations between PFOA and PFOS exposure and immunodeficiency conditions, including reduced antibody response to vaccinations and hypersensitivity.[64,65,66,67] The literature suggests that PFAS serum concentrations may have significant negative correlations with antibody concentrations in both children and adults, resulting in a reduced protection against pathogens treated by vaccines including tetanus, diphtheria, and rubella.[68,69,70] These health conditions are very rare in the U.S. today, largely because of widespread immunization. A reduction in the effectiveness of these immunizations would increase the occurrence of the conditions and their associated societal costs, but it is not possible to estimate potential costs related to PFAS exposure at this time. Even so, we assume that an increase in the effectiveness of vaccinations would have economic benefits.

Asthma is a familiar hypersensitivity-related health outcome.[71,72] Affecting over eight percent of people living in the U.S., asthma's economic impacts in this country are significant. It is not, however, possible at this time to determine the proportion of asthma cases related to PFAS exposure. Because cost estimates of this relationship are not available, we will review total health costs related to asthma in the U.S.

Between 2008 and 2013, the estimated average annual medical cost per person associated with asthma was $3,266 and the total national cost was $50.3 billion.[73] The same study suggested that asthma was responsible for 8.7 million and 5.2 million missed days of work and school, respectively, representing a total productivity loss of $3 billion from 2008 to 2013. In all, total economic loss associated with medical expense, productivity, and mortality was estimated to be $81.9 billion.[74]

---

[63] American Heart Association/American Stroke Association, 2017
[64] Chang et al, 2016.
[65] European Food and Safety Authority, 2016.
[66] National Toxicology Program, 2016.
[67] Stein et al, 2016.
[68] Grandjean et al, 2012.
[69] Osuna et al, 2014
[70] Stein et al, 2016.
[71] National Toxicology Program, 2016.
[72] European Food and Safety Authority, 2016.
[73] Nurmagambetov, Kuwahara, and Garbe, 2018.
[74] Ibid.

Environmental benefits

Similar to health benefits, there are several themes evident in the literature regarding PFAS and environmental impacts. Most prevalent among the literature is its persistence within the environment and resulting bioaccumulation in animals, both of which will affect the services ecosystems provide to the public. PFAS are known to be very persistent in the environment and some bioaccumulate over time.[75,76,77] Given the documented negative environmental impacts of PFAS emissions and related diminished ecosystem services, Ecology assumes that a reduction in PFAS emissions to the environment would have both environmental and economic benefits.

Ecosystem services

Ecosystems provide critical functions to society, like purifying water, mitigating the spread of disease, and providing raw materials. These functions are often referred to as ecosystem services. An ecosystem's ability to continuously or predictably provide services is often related to the degree of disturbance experienced by the ecosystem.[78] Anthropogenic and natural disturbances to ecosystems often can have a more significant impact on an ecosystem's services than to the ecosystem's long-term resilience. The loss of services provided by ecosystems may threaten a society's economic well-being when the disrupted services cannot be readily substituted.[79]

Anthropogenic disruptions to ecosystems can take a variety of forms. Most pertinent to the PFAS discussion is the emission and persistence of these chemicals in the environment and their lasting impacts. One key assumption in ecosystem services economics is that the rate of emissions to an ecosystem cannot not exceed that ecosystem's ability to process the emissions without causing disruption to the provision of ecosystem services.[80] In the case of PFAS emissions, the persistence and bioaccumulation of the chemicals are shown to have negative impacts on the health of water ecosystems impacts to organisms in the environment, as discussed below. The degradation of habitat and health impacts to key members of the trophic pyramid may negatively affect Washington's economy. For example, the health of native salmon populations is significantly related to the success of other species like Southern Resident Killer Whales and the economic well-being of tribal, recreational, and commercial fisheries. Key species often have significant cultural and spiritual value, in addition to their ecological and economic significance.

[75] United States Environmental Protection Agency, 2000.
[76] United States Environmental Protection Agency, 2009.
[77] National Toxicology Program, 2016.
[78] Farley, 2012.
[79] Ibid.
[80] Daly, 1990.

Persistence and Bioaccumulation

Both short- and long-chain PFAS are distributed throughout the environment.[81] Their capacity for stability and high solubility has allowed for significant transport through marine environments.[82,83] PFAS are stable in anaerobic and aerobic conditions and are not biodegradable. No study has shown significant or complete biodegradation in perfluoroalkyl carboxylic acids (PFCAs) or perfluoroalkyl sulfonic acids (PFSAs) in normal environmental conditions.[84]

The high potential for persistence and distribution, and the soluble nature of PFAS has allowed their accumulation throughout the food chain with adverse impacts to individuals, populations, and communities.[85,8687] Although fluorinated alternatives to long-chain PFAS may be less bioaccumulative, their density in products may be higher as their performance is less, which may nullify their benefit of being less bioaccumulative.[88]

Many studies report concentrations of PFAS in marine organisms.[89,90] The studies found significant levels of several PFAS (including PFOS, PFOA, PFHxS, and PFOSA) worldwide in a wide array of mammal, bird, and fish species including grey seals, polar bears, brown pelicans, black footed albatross, bald eagles, and yellow-fin tuna. Samples taken from bald eagle fledglings and mink in the Midwestern U.S. measured up to 2,570 ng/ml PFOS (plasma) and 4,900 ng/g PFOS (liver), respectively.[91] PFAS are easily accumulated throughout all trophic levels, including at the lowest levels of grazing, filtering, and shredding invertebrates.[92] The literature demonstrates a high confidence in the association between PFOA exposure and suppressed antibody response in animals.[93]

References

Aberger, Michael, B. Wilson, J.M. Holzbeierlein, T.L. Griebling, and A.K. Nangia. 2014. “Testicular self-examination and testicular cancer: a cost-utility analysis.” *Cancer Medicine*. Vo. 3(6): 1629-1634.

[81] Scheringer et al, 2014.
[82] Pancras et al, 2016.
[83] Yamashita et al, 2005.
[84] Pancras et al, 2016.
[85] Ahrens and Bundschuh, 2014.
[86] Giesy et al, 2010.
[87] Prevedouros et al, 2006.
[88] Scheringer et al, 2014.
[89] Giesy and Kannan, 2002.
[90] Houde et al, 2011.
[91] Giesy, Kannan, and Jones, 2001.
[92] Ahrens and Bundschuh, 2014.
[93] National Toxicology Program, 2016.

Ahrens, Lutz and Mirco Bundschuh. 2014. "Fate and Effects of Poly- and Perfluoroalkyl substances in the Aquatic Environment: A Review." *Environmental Toxicology and Chemistry*. Vol 33(9): 1921-1929.

American Heart Association/American Stroke Associations (AHA/ASA). 2017. "Heart Disease and Stroke Statistics 207 At-a-Glance." https://www.heart.org/-/media/data-import/downloadables/heart-disease-and-stroke-statistics-2018---at-a-glance-ucm_498848.pdf

Australian Department of Health. 2018. "Expert Health Panel for Per- and Poly-Fluoroalkyl Substances (PFAS)." http://www.health.gov.au/internet/main/publishing.nsf/Content/C9734ED6BE238EC0CA2581BD00052C03/$File/expert-panel-report.pdf

Ballesteros, Virginia. O. Costa, C.Iniguez, T. Fletcher, F. Ballerster, M. Lopez-Espinosa. 2017. "Exposure to perfluoroalkyl substances and thyroid function in pregnant women and children: A systematic review of epidemiologic studies." *Environment International*. Vol. 99: 15-28.

Carpet and Rug Institute (CRI). 2018. Research and Resources webpage. https://carpet-rug.org/resources/research-and-resources/

Centers for Disease Control and Prevention (CDC). 2018a. "An Overview of Perfluoroalkyl and Polyfluoroalkyl Substances and Interim Guidance for Clinicians Responding to Patient Exposure Concerns." https://www.atsdr.cdc.gov/pfc/docs/pfas_clinician_fact_sheet_508.pdf

Centers for Disease Control and Prevention (CDC). 2018b. High Cholesterol Facts webpage. https://www.cdc.gov/cholesterol/facts.htm

Chang, Ellen T., H. Adami, P. Boffetta, H.J. Wedner, J.S. Mandel. 2016. "A critical review of perfluorooctanoate and perfluorooctanesulfonate exposure and immunological health conditions in humans." *Critical Reviews in Toxicology*. Vol 46(4):279-331.

Consumer Reports. 2014. "Evaluating statin drugs to treat: high cholesterol and heart disease." http://article.images.consumerreports.org/prod/content/dam/cro/news_articles/health/PDFs/StatinsUpdate-FINAL.pdf

Daly, Herman E.. 1990. "Toward some operational Principles of Sustainable Development." *Ecological Economics*. Vol 2: 1-6.

Davis, Karen, S.R. Collins, M.M. Doty, A. Ho, A.L. Holmgren. 2005. "Health and Productivity Among U.S. Workers." *The Commonwealth Fund*. https://www.commonwealthfund.org/sites/default/files/documents/___media_files_publications_issue_brief_2005_aug_health_and_productivity_among_u_s__workers_856_davis_hlt_productivity_usworkers_pdf.pdf

Edson, 2019. https://www.edsonpumps.com

Endocrine Society. 2018. Endocrine Facts and Figures webpage. http://endocrinefacts.org/health-conditions/thyroid/1-overview/

European Food Safety Authority. "Risk to human health related to the presence of perfluorooctane sulfonic acid and perfluorooctanic acid in food." *EFSA Journal*. Vol. 16(12).

Farley, Joshua. 2012. "Ecosystem services: The economics debate." *Ecosystem Services*. Vol 1: 40-49.

French, Michael T., J.F. Homer, I. Popovici, and P.K. Robins. 2015. "What You Do in High School Matters: High School GPA, Educational Attainment, and Labor Market Earnings as a Young Adult." *Eastern Economic Journal.* Vol 41: 370-386.

Fromme, Hermannm S.A. Tittlemier, W. Völkel, M. Wilhelm, D. Twardella. 2009. "Perfluorinated compounds – Exposure assessment for the general population in western countries." *International Journal of Hygiene and Environmental Health.* Vol 212: 239-270.

García, Emma and Elaine Weiss. 2018. "Student absenteeism: Who misses school and how missing school matters for performance." *Economic Policy Institute*. https://epi.org/152438

Giesy, John P., J.E. Naile, J.S. Khim, P.D. Jones, and J.L. Newsted. 2010. "Aquatic Toxicology of Perfluorinated Chemicals." *Environmental Contamination and Toxicology.* Vol 202.

Giesy, John P. and Kurunthachalam Kannan. 2002. "Perfluorochemical Surfactants in the Environment." *Environmental Science and Technology*.

Giesy John P., K. Kannan, and P.D. Jones. 2001. "Global Biomonitoring of Perfluorinated Organics." *The Scientific World*. Vol 1: 627-629.

Grainger, Inc., 2019. Price sheets for booms, berms, and drain blocks.

Houde, Magali, A.O. DeSilva, D.C.G. Muir, and R.J. Letcher, and. 2011. "Monitoring of Perfluorinated Compounds in Aquatic Biota: An Updated Review" *Environmental Science and Technology*.

International Agency for Research on Cancer. 2017. "IARC Monographs: Some Chemicals used as solvents and in polymer manufacture, Volume 10." https://monographs.iarc.fr/wp-content/uploads/2018/06/mono110.pdf

JME Ellsworth, 2019. Edson Model 28202 Pump Out Caddy w/ 25 Gallon Waste Collection Cart.

Kougoulis, JS, R Kaps, O Wolf, B Walsh, K Bojczuk, P Derbyshire, & T Crichton, 2012. "Revision of EU European Ecolabel and Development of EU Green Public Procurement Criteria for Indoor and Outdoor Paints and Varnishes". Green Public Procurement Background Report. June 2012.

Loeppke, Ronald, M. Taitel, V. Haufle, T. Parry, R.C. Kessler, K. Jinnett. 2009. "Health and Productivity as a Business Strategy: A Multiemployer Study." *Journal of Occupational and Environmental Medicine*. Vol 51(4): 441-428.

Mayo Clinic. 2017. High Cholesterol webpage. https://www.mayoclinic.org/diseases-conditions/high-blood-cholesterol/symptoms-causes/syc-20350800

Mitchell, Rebecca J. and P. Bates. 2011. "Measuring Health-Related Productivity Loss." *Population Health Management* Vol 14(2).

National Cancer Institute (NCI). 2018. Cancer Statistics webpage. https://www.cancer.gov/about-cancer/understanding/statistics

National Toxicology Program (NTP). 2016. "NTP Monograph on Immunotoxicity Associated with Exposure to Perfluorooctanoic Acid or Perfluorooctane Sulfonate." https://ntp.niehs.nih.gov/ntp/ohat/pfoa_pfos/pfoa_pfosmonograph_508.pdf

Nurmagambetov, Tursynbek, R. Kuwahara, and P. Garbe. (2018). "The Economic Burden of Asthma in the United States, 2008-2013.*American Thoracic Society.* Vol 15(3): 348-356.

Osuna, Christa E., P. Grandjean, P. Weihe, H.A.N. El-Fawal. 2014. "Autoantibodies Associated with Prenatal and Childhood Exposure to Environmental Chemicals in Faroese Children." *Toxicological Sciences.* Vol. 142(1): 158-166.

Pancras, T., G. Schrauwen, T. Held, K. Baker, I. Ross, H. Slenders. 2016. "Environmental fate and effects of poly and perluoroalkyl substances (PFAS). Prepared for the Concawe Soil and Groundwater Taskforce. Brussels.

Prevedouros, Konstantinos, I.T. Cousins, R.C. Buck, and S.H. Korzeniowski. 2006. "Sources, Fate, and Transport of Perfluorocarboxylates." *Environmental Science and Technology.* Vol. 40(1): 32-44.

Renner, Rebecca. 2006. "The Long and Short of Perfluorinated replacements." *Environmental Science and Technology*. January 1, 2006. P 12-13.

Scheringer, Martin, X. Trier, I.T. Cousins, P. de Voogt, T. Fletcher, Z. Wang, T.F. Webster. 2014. "Helsingør Statement on poly- and perfluorinated alkyl substances (PFASs)." *Chemosphere* (114): 337-339.

Soni, Anita. 2011. "Use and Expenditures Related to Thyroid Disease among Women Age 18 and Older, U.S. Noninstitutionalized Population, 2008." Agency for Healthcare Research and Quality. https://meps.ahrq.gov/data_files/publications/st348/stat348.pdf

Sokol, Chad, 2017. "Air Force to reimburse Airway heights for clean water after decades of chemical contamination." The Spokesman Review. Updated: Wednesday, November 18, 2017, 10:47PM.

Stein, Cheryl R., Y. Ge, M.S. Wolff, X. Ye, A.M. Calafat, T. Kraus, T.M. Moran. 2016. "Perfluoroalkyl Substance Serum Concentrations and Immune Response to FluMist Vaccination among Health Adults." *Environmental Research*. Vol. 149: 171-178.

Sun, Gordon H., S. DeMonner, and M.M. Davis. 2013. "Epidemiological and Economic Trends in Inpatient and Outpatient Thyoidectomy in the United State, 1996-2006."

UNEP, 2008. "Sustainable Procurement Guidelines for Cleaning Products and Services". Background report. Developed by ICLEI - Local Governments for Sustainability (ICLEI) for the

United Nations Environment Programme – Division of Technology, Industry and Economics (UNEP-DTIE).

United Nations Stockholm Convention on Persistent Organic Pollutants. 2012. "Technical paper on the identification and assessment of alternatives to the use of perfluorooctane sulfonic acid in open applications." https://www.informea.org/sites/default/files/imported-documents/UNEP-POPS-POPRC12FU-SUBM-PFOA-Canada-48-20161209.En.pdf

United States Air Force, 2017. "Frequently Asked Questions: Aqueous Film Forming Foam Replacement and containment".

United States Bureau of Labor Statistics, 2019. Consumer Price Index for Urban Consumers. https://data.bls.gov/timeseries/CUUR0000SA0?output_view=pct_12mths

United States Bureau of Labor Statistics, 2017. May 2017 wages by area and occupation. Washington State. https://www.bls.gov/oes/current/oes_wa.htm

United States Department of Defense, 2003. "ESTCP Cost and Performance Report: Oil/Water Emulsion and Aqueous Film Forming Foam (AFFF) Treatment Using Air-Sparged Hydrocyclone Technology".

United States Department of Defense, 2018. Contract announcement for "Removal, destruction, and disposal of Aqueous Film-Forming Foam (AFFF)." Award SP450019D0001.

United States Department of Health and Human Services. 2012. "Urologic Diseases in America." https://www.niddk.nih.gov/about-niddk/strategic-plans-reports/urologic-diseases-in-america

United States Environmental Protection Agency. 2000. "Forty-Sixth Report of the TSCA Interagency Testing Committee to the Administrator." Federal Register Volume 65, Number 323.

United States Environmental Protection Agency. 2009 "Long-Chain Perfluorinated Chemicals (PFCs) Acction Plan. https://www.epa.gov/sites/production/files/2016-01/documents/pfcs_action_plan1230_09.pdf

United States Treasury Department, 2018. Rates of return on I Bonds. https://www.treasurydirect.gov/indiv/research/indepth/ibonds/res_ibonds_iratesandterms.htm

Wagner, J & K Bagenstose, 2017. "Local, National Labs offer PFC Blood Tests". Pennsylvania Intelligencer, February 3, 2017.

Washington State Department of Ecology, 2018. "Ecology 2019 Standard Costs".

WA Department of Ecology, 2019. Invoice and budget tracking, Lower Issaquah Valley PFAS Characterization Study. Complete and ongoing work. Total invoiced through 12/28/2018.

Washington State Department of Enterprise Services, 2018a. Invoiced carpet expenditures by quarter.

Washington State Department of Enterprise Services, 2018b. State carpet contract prices for Interface, Mannington, Mohawk, Shaw, and Tandus brands.

Washington State Department of Enterprise Services, 2018c. Bid sheet for state contract for waterborne road marking paint.

Washington State Office of Financial Management, 2019. General government salary schedule. https://ofm.wa.gov/sites/default/files/public/shr/CompensationAndJobClasses/Salary%20Schedules/2019Jan1_GWA/Represented/GS_2019Jan1_Represented.pdf

Washington State Department of Health, 2019. Email communication between Scott Torpie (DOH) and Barbara Morrissey (DOH). "FW: ASDWA PFAS Workgroup - PFAS Treatment Case Studies", with attachments. Sent: Monday, March 18, 2019 4:26 PM.

World Health Organization. 2009. "WHO Guide to Identifying the Economic Consequences of Disease and Injury." https://www.who.int/choice/publications/d_economic_impact_guide.pdf

Yamashita N, Kannan K, Taniyasu S, Horii Y, Petrick G, Gamo T. 2005. A global survey of perfluorinated acids in oceans. *Marine Pollution Bulletin.* Vol 51: 658–668.

List of chemical acronyms used in this chapter.

Acronym	Chemical Name
PFAS	per- and polyfluorinated alkyl substances
PFCA	perfluoroalkyl carboxylic acid
PFHxS	perfluorohexane sulfonate
PFOSA	perfluorooctanesulfonamide
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
PFSA	perfluoroalkul sulfonic acid