Review of Proposed Maximum Contaminant Levels for PFOA and PFOS in Drinking Water for the Commonwealth of Pennsylvania

By
The Drexel PFAS Advisory Group

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Summary: The proposed rule published by the Environmental Quality Board is predicted to have a significant economic benefit to Pennsylvania because it will reduce exposure to PFOA and PFOS in drinking water and subsequently reduce health care problems associated with PFAS. Annual health care costs in the state of Pennsylvania as a result of PFAS contamination of drinking water are estimated to range from $2.2 to $3.5 billion. The Proposed MCL for PFOA of 14 PPT and for PFOS of 18 PPT will provide health benefits to Pennsylvanians. The cost to mitigate PFAS contamination across Pennsylvania could be as high as $378 million per year. Determining the costs required to specifically meet the proposed MCL in drinking water across Pennsylvania requires further study.

1. Health Care Benefits:

To predict the value of those health care benefits, the DPAG used two approaches – the value transfer method and the counterfactual method. The value transfer method applies and scales quantitative estimates of health care impact costs from one study site to another. (Johnston 2015) The counterfactual method assumes that reduction in exposure to PFOA and PFOS from drinking water will result in a health care cost benefit equal to estimated health care costs attributable to the base exposures to PFOA and PFOS. Although each of these methods have their limitations, it is possible to create an estimate of projected savings from reducing exposure to PFOA and PFOS.

The health care analysis was broken down into three steps: 1) testing whether the selected MCL will result in hypothetical serum levels known to be associated with disease specific critical effects identified by the DPAG working group, 2) applying the counterfactual method to data derived from a study of a subpopulation of Pennsylvanians near a PFAS contaminated site to estimate health care benefits for that group, and 3) deriving a value transfer estimate from other health care impact studies.

1.A. Toxicokinetic modeling of PFOA and PFOS MCLs.

The Drexel PFAS Advisory Group had determined that the critical effect for PFOA was impairments of bone growth and neuromotor activity. Drexel (2021) A small number of studies have been able to identify human serum PFOA levels associated with an elevated risk for low birth weight which is a manifestation of this critical effect. Malits et al analyzed National Health and Nutrition Examination Survey data from 2003 to 2004 for exposure response relationship between PFOA level and low birth weight. (Malits 2018) The authors of that study selected a maternal serum level of 3.1 ng/mL as a reference level. Below this level, the adverse health effect on low-birth-weight infants would be reduced (sensitivity analysis: 1 to 3.9 ng/mL). The 3.1 ng/mL level represents the upper limit of the lowest tertile in the study by Maisonet and colleagues. (Maisonet 2012). To be clear, this does not represent (Bach 2015) a safe PFOA exposure level. Rather, it is the point above which statistically significant associations have been demonstrated when median serum or plasma levels during pregnancy were above approximately 3.1 ng/mL (Maisonet 2012; Fei 2007; Wu 2012). Note, one study with median levels above this level found no significant association (Darrow 2013).

It is possible to model PFOA and PFOS toxicokinetics in adults using a modified one-compartment exponential decay model with adjustment for background exposures

(Olsen et al. 2007; Bartell 2017) Bartlett (2017) published a JavaScript serum PFAS calculator, available at this site: https://www.ics.uci.edu/~sbartell/pfascalc.html. Using this calculator, one enters a proposed water PFOA or PFOS concentration and an initial serum concentration, and the web calculator returns results based on the modified one-compartment model for adults. For purposes of this report, the target population was set at "females, premenopausal or perimenopausal," since developmental effects and breast-feeding infants were the target populations for critical effects. The remaining pharmacokinetic parameters and background contribution to serum levels can be adjusted or set as per the suggested parameters.

Assuming the level of PFOA in consumed water was the MCLG of 8 PPT, this calculator developed by Bartell (Bartell 2017) predicts that a woman of childbearing age would reach a steady state PFOA serum level of 2.5 ng/mL. The same model predicts a steady state serum PFOA level of 3.1 ng/mL if the consumed water was at the proposed MCL of 14 PPT. (See figure 1) Only by reducing ongoing PFOA exposures outside of drinking water, the proposed MCL would result in a lower serum level (possibly as low as 1.6 ng/mL if all PFOA exposure outside of drinking water was eliminated). Given the elimination of PFOA from consumer products, reducing non-drinking water exposure to PFOA may not be an unreasonable assumption. Furthermore, the Bartell calculator confirms that the proposed MCL of 14 PPT would be a 90% improvement over the serum level predicted if the individual consumed water at the former EPA recommendation of 70 PPT (predicted serum level 8.9 ng/mL).

In a prior report, the DPAG determined that the critical effect for PFOS was diminished immune response. Grandjean (2012) reported their findings that elevated exposures to PFOS were associated with reduced humoral immune response to routine childhood immunizations in children aged 5 and 7 years. In that report, the geometric mean and inter quartile range (IQR) of the PFOS concentration for mothers was 27.3 ng/mL 23.2 to 33.1 mg/mL, respectively. For children age 5 they were 16.7 ng/mL and 13.5 to 21.1 ng/mL, respectively. Reductions in antibody response in the age 5 children were noted as PFOS levels rose above the lowest detected level of 6 ng/mL. The method developed by Bartell predicts that in women of childbearing age the PFOS MCLG of 14 PPT would result in a steady state serum level of 6.8 ng/mL and the proposed MCL of 18 PPT would result in a steady state serum level of 7.2 ng/mL. Note that if a woman of childbearing age was able to eliminate PFOS exposures from other sources and drank water with the proposed MCL of 18 PPT, she would ultimately have a steady state serum PFOS level of 2.1 ng/mL. Although the literature does not provide a reference level for PFOS and immune response, the Bartell model of the proposed MCL for PFOS predicts a serum level below the lower bound of IQR of the geometric mean in mothers in the Grandjean study.

In conclusion, only the MCLG is considered to be a level protective of health. Nonetheless, according to a toxicokinetic model, the proposed MCLs selected for PFOA and PFOS do not lie above thresholds that are known to model out to mean serum levels reported to be associated with adverse effects.

1.B. . Counterfactual estimate of health care costs associated with PFOA and low birthweight for one community in Pennsylvania.

Malits (2018) estimated that the total socioeconomic cost of PFOA-attributable low birthweight births in the United States from 2003 through 2014 was $13.7 billion.

The authors modeled reduction in observed low birth weight infants attributable to PFOA exposure. The authors relied on the meta-analysis performed by Johnson (2014), which estimated that a 1-ng/mL increase in serum or plasma PFOA was associated with a –18.9 g (95% CI: –29.8, –7.9) difference in birth weight. Applying this to the NHANES data, the authors were able to estimate the number of low-birth-weight infants attributable to PFOA. During the studied time period, PFOA serum levels dropped from a median of 3.3 to 1.6 ng/mL. The fall in PFOA levels and the concomitant reduction in the fraction of low-birth-weight infants attributable to PFOA provided a counterfactual estimate of the cost of exposure to PFOA. These costs included the direct hospital costs at the time of birth and lost economic productivity due to low birthweight births being associated with longer-term outcomes such as lower lifetime earning potential. To determine what this would mean in Pennsylvania, DPAG applied a value transfer method that assumes a scalable relationship between impacts of PFOA–attributable low birthweight births quantified by Malits in the total United States population. Since 4.0 % of the US population lives in Pennsylvania, the total costs due to low birth weight from PFOA exposure for the same period (2003 – 2014) are calculated to $548 million (approx. $637.58 million in 2022 dollars). This equates to $583 million in 2022 dollars if the population considered is only the 11.9 million served by community and nontransient, noncommunity public water systems.

In 2018, Nair (2021) from the Pennsylvania Department of Health studied communities near two former military bases in Pennsylvania that were exposed for several decades to PFAS through contaminated drinking water. The population in that community was estimated to be 84,000. Serum PFAS levels were compared with the national averages for 2013-2014 and their relationships with demographic and exposure characteristics were analyzed. The average levels of PFOA and PFOS among the study participants were 3.13, 10.24 ng/mL respectively. Overall, 75 and 81 % of the study participants had levels exceeding the national average for PFOA (1.94 µg/L), and PFOS (4.99 µg/L), respectively. This study places that 2018 community in the same broad category as the 2003 National Health and Nutrition Examination Survey (NHANES) data for the US population. A similar value transfer analysis suggests that the total health care costs associated with PFOA exposure in that community alone over a similar time period (11 years) would be $4.3 million in 2022 dollars. Assuming that PFAS levels fell in the community in the same manner that they fell nationally, the costs would average to $390,000 per year.

1.C. Total Health Care Costs

In 2019 the Nordic Council of ministers published a socio-economic analysis of environmental and health impacts linked to exposure in PFAS in the Nordic countries. (Goldenham 2019) The goal of the study was to establish a framework for estimating costs for society related to impacts on health and the environment associated with PFAS exposure and to provide monetary values and case studies. It was acknowledged that data is limited in the academic literature and that in some cases assumptions are required. Data from Nordic countries was employed when available, but the study also drew on cost data from European, US and Australia.

To calculate health related costs to society, the study group focused on PFAS related health impacts to the liver, increased serum cholesterol as a prequel to hypertension, immune response, thyroid disease, fertility, pregnancy induced hypertension, preeclampsia, low birthweight, and testicular and kidney cancer. Exposure levels were broken into three categories: occupational or high exposures, elevated or moderate exposures in communities near chemical plants or in communities with PFAS in their drinking water, and background or lower exposures due to exposure to PFAS in consumer products and other background levels. The health endpoints for occupational exposure was kidney cancer. Health endpoints for elevated exposures to communities with high PFAS levels in drinking water were all-cause mortality, low birth weight, and increased infections (decreased immune response) in children. The endpoint for background exposure was hypertension in adults as a consequence of elevated cholesterol.

In the study, the total population of the Nordic countries was 20.7 million. The annual monetized impact of elevated mortality due to PFA'S exposures ranged from €2.8 - €4.6 billion. Converting to dollars and adjusting for inflation in 2022 from 2019, this would result in $3.5 to $5.7 billion of annual health impact related cost of exposure to PFAS in the Nordic Countries. Adjusted for the 13 million population of Pennsylvania, this produces a value transfer estimate of $2.2 to $3.5 billion annual health care impact related cost. This may seem to be an excessive figure until it is compared to the $4.5 trillion dollars of annual health care spending in the US. The Kaiser Family Foundation (KFF 2022) estimated the 2014 Pennsylvania per capita spending on health care was $9258.00 which projects to $120 billion for the entire state annually without inflation adjustment. This suggests that PFAS contamination in drinking water may account for 2 to 3% of the annual health care costs in Pennsylvania. This seemingly large percentage is consistent with the model employed with predicts a high lifetime health care cost impact of low birth weight children and the ubiquitous impact of background exposure resulting in adult hypertension.

In conclusion, these projections are meant to guide regulation and not be explicit return on investment guarantees for mitigation of PFAS in drinking water. Nonetheless, health care is one of the most expensive commodities in society today, and the adverse impacts on health from a variety of sources have staggeringly high costs.

2. Non-health related costs

The non-health related costs include monitoring, health assessments, provision of water to replace contaminated supplies on a temporary basis, new pipelines, upgraded water treatment works, maintenance, and excavation and treatment of contaminated soils.

The US Chamber of Commerce estimates that across the US, private sector cleanup costs at Superfund sites alone for PFOA and PFOS are estimated to cost between $700 million and $800 million in annualized costs ($11.1 billion and $22 billion present value costs).

Not all of the non-health related costs will be borne by the private sector, but the cumulative numbers may be staggering. In Pennsylvania, the US Department of Defense has already spent $15 million at the Willow Grove military base; $16 million at Warminster for environmental investigations and clean-up and $762,500 on environmental investigations: $234,600 at Letterkenny Army Depot; $12,900 at North Penn U.S. Army Reserve Center; $43,700 at Harrisburg International Airport; $127,700 at Horsham; $171,800 each at Pittsburgh Air Force; and $171,800 at Pittsburgh Air Force Reserve Command.

The town of Ridgewood NJ will spend $3.5 million to treat drinking water for 62,000 customers and Garfield NJ has spent $2 million for 233,000 customers.

The Nordic Council of Ministers report examined the non-health environmentally related costs to society compiled from direct costs incurred by communities taking measures to reduce PFAS exposure through remediation of drinking water. Where no data were available estimates were employed. Total cost included monitoring, health assessments, provision of water to replace contaminated supplies on a temporary basis, new pipelines, upgraded water treatment works, maintenance, and excavation and treatment of contaminated soils. The total cost for Nordic countries was estimated to range between €46 million - €11 billion over a 20-year period which included the low and high outlier estimates. Adjusted for exchange rate, this is a total with a range of $51 million to $12.2 billion ($2.5 million to $610 million per year). Using a value transfer approach for Pennsylvania, this would equate to a 20-year cost with a range of $1.6 million to $378 million per year. Given the wide range, the Nordic Council study went on to develop a final, best estimate of aggregated costs by excluding the low and high outliers of approximately €1 billion ($1.1 billion) over a 20-year period or $55 million per year. This scales to $34 million per year for Pennsylvania.

EQB (2022) aggregated costs of water treatment to a total annual figure of $115 million per MGD plus $6 million in compliance costs (EQB 2022: Table 18). This was based on averages but did not eliminate the high and low estimates from granular activated charcoal (GAC) and anion exchange (IX) treatment costs. Point of use treatment was not considered and should be factored into the cost/benefit consideration where possible. Establishing an estimate across the state will require further information such as the number of consumers served by water supplies that exceed one or both of the proposed MCLs.

Alternative methods besides GAC and IX exist to treat PFAS contaminated water. Nanofiltration (NF) and reverse osmosis (RO) are pressure-driven separation processes that utilize semi-permeable, dense membranes to remove dissolved substances and fine (colloidal) particles from fluids. During membrane treatment of water, a portion of the incoming feed water is forced across the membrane generating a “cleaner” permeate (or produce) stream, while the remaining water is known as the concentrate, brine, retentate, or reject waters, which is concentrated in solutes that are “rejected” by the membrane. NF membranes have pore sizes around 0.001 micron, while RO membranes have pore sizes around 0.0001 micron. While RO membranes are typically more superior to NF membranes at removing solutes, such as PFAS (often achieving greater than 99% removal for RO membranes) Tang (2007), RO membranes require higher operating pressures (and thus higher energy costs) to achieve the same system recovery (which is defined as the ratio of the permeate flow to feed flow rate) as NF membranes. For example, transmembrane pressures for RO membranes typically range from 500 to 8000 kPa for RO membranes but only achieve system recoveries of approximately 60-90%, while transmembrane pressures for NF membranes range from 200 to 1500 kPa with system recoveries of approximately 75-90%. Because of the small pore sizes of NF and RO membranes, they are often prone to fouling due to inorganic, organic, biological, and colloidal impurities, which could also reduce limit their efficiency.

Wang (2015), Franke (2019) Therefore, efficient NF and RO membrane treatment for removal of PFAS may only be feasible for source waters with low organic matter and other impurities or where pre-treatment is implemented to remove these impurities prior to membrane separation. Although lab- and pilot-scale studies suggest that it is feasible for NF and RO processes to produce permeate streams with concentrations of PFAS below current regulatory and health advisory levels, their high energy costs and the generation of PFAS contaminated concentrate streams that need to be treated as hazardous waste make them less desirable options for treatment of PFAS. Patterson (2019) Despite these drawbacks of NF and RO membrane treatment of PFAS, commercially available RO membrane filtration systems have been shown to be effective at removing PFAS and the use of these membrane processes in combination with other treatment technologies are being investigated. Patterson (2019) Das (2022)

Home water treatment systems that reduce the levels of PFAS in drinking water should be considered as well. They can be installed the point of entry or at the point of use. Point of entry (POE) water treatment systems, or whole house treatment systems, treat all the water entering the household plumbing system. Point of use (POU) water treatment systems treat the water at a specific location within the house, typically the kitchen sink or primary source of water for drinking and cooking (some also provide water to the refrigerator). Pros and Cons exist for these systems. While they may greatly reduce the total volume of water that needs to be treated, they impose considerable burdens on water suppliers who become responsible for supporting the maintenance of a large number of household treatment devices. The economics are generally most favorable when the majority of exposure to the contaminant of concern is from direct ingestion of water, such that a single point of use treatment device that provide all the potable water for the household effectively reduces exposure. Additional devices can be used, for example to treat shower water for volatile compounds, but will tend to decrease any economic advantage of point of use treatment compared to centralized treatment. Past experience has been that point of use treatment generally does not dramatically alter the overall cost-effectiveness of standards but can play an important role in addressing affordability concerns in small systems where the number of treatment devices to be maintained is manageable.

Finally, other non-health care costs include diminished property values. In a study of the impact of PFAS groundwater contamination on property value in Oakdale Minnesota and other affected communities, Sunding (2017) found that the value of properties sold after PFAS contamination of groundwater decreased by 7.3% in Oakdale and 4.4% in other affected communities. The report calculated cumulative past (dating back to 1971), present, and future (out to 2050) lost home value in the affected communities. The total was $1.5 billion in total lost home value damages due to PFAS contamination in the East Metro area Minneapolis- St. Paul, MN.

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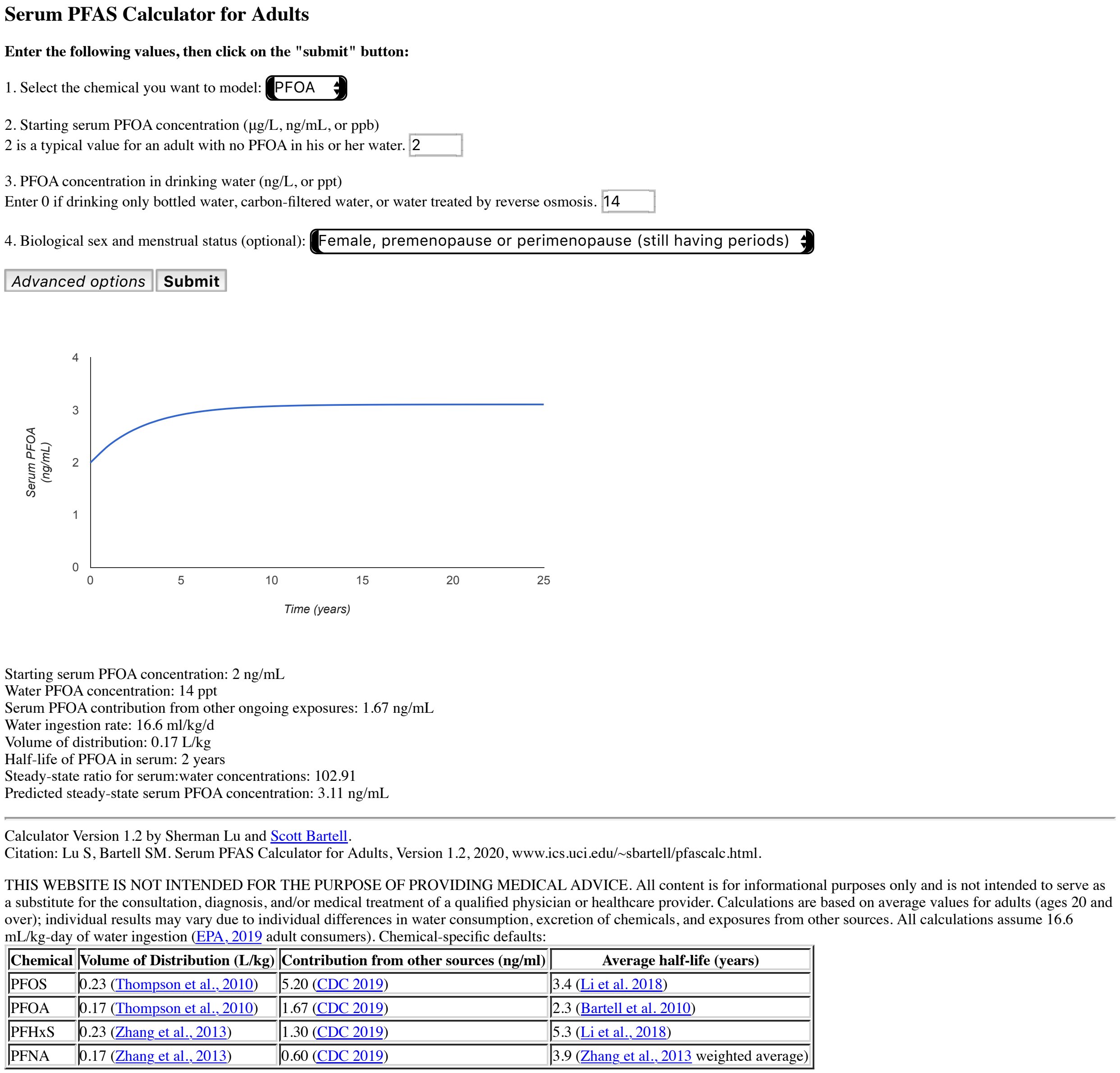
Figure 1: Steady state PFOA level predicted in females childbearing age consuming water with PFOA of 14 PPT



Serum PFAS Calculator for Adults

Enter the following values, then click on the "submit" button:

1. Select the chemical you want to model: PFOA

2. Starting serum PFOA concentration (µg/L, ng/mL, or ppb)
2 is a typical value for an adult with no PFOA in his or her water. 2

3. PFOA concentration in drinking water (ng/L, or ppt)
Enter 0 if drinking only bottled water, carbon-filtered water, or water treated by reverse osmosis. 14

4. Biological sex and menstrual status (optional): Female, premenopause or perimenopause (still having periods)

Starting serum PFOA concentration: 2 ng/mL
Water PFOA concentration: 14 ppt
Serum PFOA contribution from other ongoing exposures: 1.67 ng/mL
Water ingestion rate: 16.6 ml/kg/d
Volume of distribution: 0.17 L/kg
Half-life of PFOA in serum: 2 years
Steady-state ratio for serum:water concentrations: 102.91
Predicted steady-state serum PFOA concentration: 3.11 ng/mL

Calculator Version 1.2 by Sherman Lu and Scott Bartell.
Citation: Lu S, Bartell SM. Serum PFAS Calculator for Adults, Version 1.2, 2020, www.ics.uci.edu/~sbartell/pfascalc.html.

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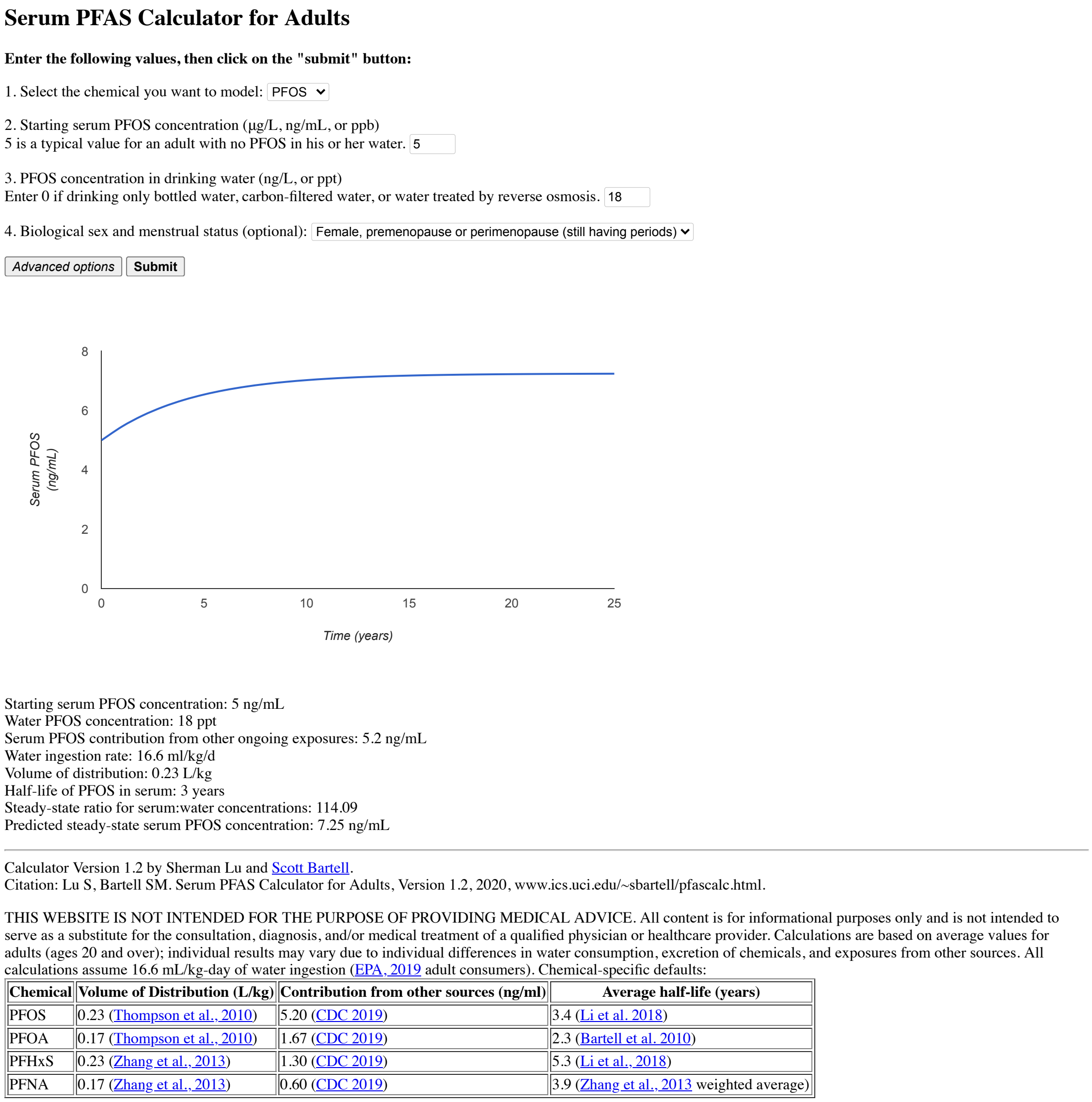
Chemical	Volume of Distribution (L/kg)	Contribution from other sources (ng/ml)	Average half-life (years)
PFOS	0.23 (Thompson et al., 2010)	5.20 (CDC 2019)	3.4 (Li et al. 2018)
PFOA	0.17 (Thompson et al., 2010)	1.67 (CDC 2019)	2.3 (Bartell et al. 2010)
PFHxS	0.23 (Zhang et al., 2013)	1.30 (CDC 2019)	5.3 (Li et al., 2018)
PFNA	0.17 (Zhang et al., 2013)	0.60 (CDC 2019)	3.9 (Zhang et al., 2013 weighted average)

Figure 2: Steady state PFOA level predicted in females childbearing age consuming water with PFOA of 14 PPT



Serum PFAS Calculator for Adults

Enter the following values, then click on the "submit" button:

1. Select the chemical you want to model: PFOS

2. Starting serum PFOS concentration (µg/L, ng/mL, or ppb)
5 is a typical value for an adult with no PFOS in his or her water. 5

3. PFOS concentration in drinking water (ng/L, or ppt)
Enter 0 if drinking only bottled water, carbon-filtered water, or water treated by reverse osmosis. 18

4. Biological sex and menstrual status (optional): Female, premenopause or perimenopause (still having periods)

Starting serum PFOS concentration: 5 ng/mL
Water PFOS concentration: 18 ppt
Serum PFOS contribution from other ongoing exposures: 5.2 ng/mL
Water ingestion rate: 16.6 ml/kg/d
Volume of distribution: 0.23 L/kg
Half-life of PFOS in serum: 3 years
Steady-state ratio for serum:water concentrations: 114.09
Predicted steady-state serum PFOS concentration: 7.25 ng/mL

Calculator Version 1.2 by Sherman Lu and Scott Bartell.
Citation: Lu S, Bartell SM. Serum PFAS Calculator for Adults, Version 1.2, 2020, www.ics.uci.edu/~sbartell/pfascalc.html.

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PFNA	0.17 (Zhang et al., 2013)	0.60 (CDC 2019)	3.9 (Zhang et al., 2013 weighted average)