HEALTH CONSULTATION

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Florida State Fire College

Per – and Polyfluoroalkyl Substances (PFAS)

Report 3

Off-site private, residential well investigation of per- and polyfluoroalkyl substances (PFAS) in groundwater

11655 NW Gainesville Road
Ocala, Florida 34482

Prepared by:
Florida Department of Health
Division of Disease Control and Health Protection
Bureau of Environmental Health

February 10, 2021

Prepared by:
Florida Department of Health
Bureau of Environmental Health
Public Health Toxicology
Hazardous Waste Site Health Risk Assessment

FOREWORD

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Cooperative Agreement with
U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry

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EXECUTIVE SUMMARY

The purpose of this report is to evaluate and communicate the possibility of public health threat from exposure (contact) to per- and polyfluoroalkyl substances (PFAS) in drinking water at private wells located at residencies within a 1-mile radius of the Florida State Fire College (FSFC) in Marion County. This assessment was prompted by findings of PFAS in groundwater and soil at the adjacent FSFC in a recent investigation by the Florida Department of Environmental Protection (FDEP). The Florida Department of Health (FDOH) has conducted a Health Consultation report evaluating possible adverse health outcome from exposure to PFAS-contaminated groundwater and soil at FSFC. The report is available at:

floridahealth.gov/environmental-health/hazardous-waste-sites/Reports/hw-public-comments.html

PFAS are a large group of chemical compounds used in various industrial and consumer products since the 1950s. Most people are exposed to low levels of PFAS in their daily lives. Increasing scientific information suggests that exposure to elevated levels of PFAS could cause adverse health effects in humans. Studies have found associations between PFAS exposure and health effects including immune and developmental effects, changes to serum cholesterol, liver, thyroid, reproduction, as well as, increased risk of pregnancy-induced hypertension (preeclampsia). Some PFAS may cause cancer. Most studies to date have focused on two main PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS, also known as perfluorooctane sulfonic acid). Limited information is also available for some other PFAS, including perfluorononanoic acid (PFNA) and perfluorohexane sulfonate (PFHxS, also known as perfluorohexane sulfonic acid).

Since 2018, FDEP's Site Investigation Section has conducted several PFAS studies and it has been demonstrated that PFAS-based firefighting foams (a type known as aqueous film forming foam (AFFF)) have been a source of groundwater contamination. When contaminated groundwater is used to supply drinking and irrigation water systems, people can be exposed to the contamination. For these reasons, firefighter training facilities, including the FSFC, warrant closer investigation.

In early August 2018, FDEP contacted the FSFC in Ocala and confirmed that AFFF has been used for training on-site. FDEP also learned that the facility has an on-site water supply well, which is used for drinking and other household purposes. In early September 2018, FDEP collected a water sample from this well for PFAS analysis. The combined concentration of PFOA and PFOS was 250 nanogram per liter (ng/L) exceeding the United States Environmental Protection Agency (EPA) lifetime health advisory level (HAL[1]) of 70 ng/L.

[1] HAL – Health Advisory Level. The U.S. Environmental Protection Agency (EPA) developed a lifetime health advisory level (HAL) for combined PFOA and PFOS of 70 nanograms per liter (ng/L). The HAL is a guidance level to help states flag possible concern. Levels below HAL are considered safe over a lifetime by the EPA. Levels above HAL do not necessarily mean health effects will occur but trigger further evaluation.

Community members/residents living in Marion County near the FSFC are concerned that drinking water from their private wells could pose a potential health risk. Therefore, FDOH additionally conducted a health assessment specifically for the residential population within a 1-mile radius of the FSFC, evaluating possible health threats associated with drinking PFOS, PFOA, PFHxS and PFNA contaminated water. FDOH used provisional health guidelines provided by the Agency for Toxic Substances and Disease Registry (ATSDR) in the assessment.

Based on review of the available environmental data and national health guidelines, FDOH reached the following conclusions for human exposure to PFOS, PFOA, PFHxS and PFNA via drinking and showering using well water within 1-mile radius to the FSFC:

Note: Even though all private wells within a 1-mile radius of the FSFC were sampled for PFAS, **ONLY** those exceeding ATSDR's health-based comparison values/screening levels (see Section 3.3.1 for more details) were further investigated and discussed in this health assessment. *ATSDR's screening levels are estimates of chemical concentrations in the environment (water, soil, air, etc.) that a person can be typically exposed to without considerable health risk*.

Human exposure to PFAS in private well water via drinking

Conclusion # 1:
For all residents including children (birth to 16 years), adolescents and adults, who drink unfiltered private well water within a 1-mile radius of the FSFC that exceeded ATSDR's screening levels for PFAS, ***PFOS*** is the predominant contaminant of concern compared to ***PFOA, PFHxS and PFNA***.

Basis for Conclusion #1

The estimated exposure for 2018/2019 PFOS levels exceeding ATSDR's screening levels of 14 ng/L (child) and 52 ng/L (adult), respectively, are close to levels predicted to cause immune effects for **all exposed populations** (birth to adulthood - considering all adults, including those who plan to become pregnant, as well as pregnant and lactating women), while the estimated exposure for 2018/2019 PFOA, PFHxS and PFNA levels are not close to levels predicted to cause immune effects in any of the exposed population.

Current information on the combined effects of PFAS mixtures is very limited and poorly understood. However, for some other chemical classes, it is known that compounds with similar toxic action can contribute to a combined increased effect. In other words, the mixture of compounds could increase the potential risk of developing non-cancer health effects compared to the effect of each individual compound. If PFOA, PFHxS and PFNA have similar toxic actions, it is possible,

but uncertain, that the combined risk of all PFAS chemicals found at residential properties could be higher than the risk found for each individual compound.

Conclusion # 2:

Residents including children (birth to 16 years), adolescents and adults, who drink unfiltered private well water within a 1-mile radius of the FSFC that contained PFOS levels of 16 ng/L and above may be at increased risk of harmful health effects. Some levels of PFOA, PFHxS and PFNA may contribute to the overall PFAS exposure and to possible adverse health effects in some of the residential population. [*This assessment considered all residential population (birth to adulthood), including adults who plan to become pregnant, as well as pregnant and lactating women*.]:

Basis for Conclusion #2

In general, any levels of PFAS such as PFOA, PFOS and PFHxS could contribute to an overall PFAS exposure and possible adverse health effects.[2]

People with underlying health conditions such as a compromised immune system may be at increased risk of health effects.

Note: Possible health effects associated with PFAS exposure via breastfeeding cannot be evaluated due to current data limitations. PFAS can be transferred to infants via breastfeeding. Based on current knowledge, ATSDR recommends that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

A woman's decision to breastfeed is individual and involves many considerations in addition to chemical contamination. Women with concerns regarding findings at the FSFC may find it helpful to discuss breastfeeding with their health care provider. ATSDR has produced a PFAS-guidance document for health care professionals: https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf.

PFOS

2018/2019 PFOS levels of 140 ng/L and greater are far above ATSDR's provisional, intermediate health guidelines for children and adults.

[2] Current information on the combined effects of PFAS mixtures is very limited and poorly understood. Though, for some other chemical classes, it is known that compounds with similar toxic action can contribute to a combined increased effect. In other words, the mixture of compounds could increase the potential risk of developing non-cancer health effects compared to the effect of each individual compound. If PFOA, PFAS, PFNA and PFHxS have similar toxic actions, it is possible, but uncertain, that the combined risk of all PFAS found at the residential properties within a 1-mile radius of the FSFC. could be higher than the risk found for each individual compound. PFOS is the predominant contaminant and the individual contributions of PFOA, PFNA, PFHxS and other PFAS are low compared to PFOS.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **16 ng/L** and above are close to levels predicted to cause immune health effects in all residential population (children, adolescents and adults including pregnant and lactating woman).

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **140 ng/L** and above are close to levels predicted to cause developmental health effects in children from birth to less than 1 year, in addition to the immune effects.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **250 ng/L** and above are close to levels predicted to cause developmental health effects in children from 1 year to less than 2 year, in addition to the immune effects.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **550 ng/L** and above are close to levels predicted to cause developmental health effects in children 2 year and older, as well as adolescents and adults, in addition to the immune effects.

PFOA

The 2018/2019 PFOA level of **54 ng/L** is above ATSDR's provisional, intermediate health guidelines for children. The estimated exposures associated with drinking these PFOA levels in water are close to levels that can cause neurodevelopmental health effects in children birth to less than 1 year.

PFHxS

2018/2019 PFHxS levels of 170 ng/L and greater are far above ATSDR's provisional, intermediate health guidelines for children and adults.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFHxS levels in water of **630 ng/L** and above are close to levels predicted to cause thyroid health effects in children from birth to less than 1 year.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFHxS levels in water of **940 ng/L** and above are close to levels predicted to cause thyroid health effects in children from 1 year to less than 2 year.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFHxS levels in water of **1,200 ng/L** and above are close to levels predicted to cause thyroid health effects in children from 2 year to less than 6 year.

PFNA

2018/2019 PFNA levels of 0.4 to 6.8 ng/L are below ATSDR's provisional, intermediate health guidelines. Health guidelines are set far below levels known to cause harmful effects. If an estimated dose for a site is lower than the guideline, an increased health risk is not expected from exposure to the specific chemical.

Even though the PFNA levels by themselves are not expected to cause an increased risk of developing harmful non-cancer health effects in children and adults, current information on the combined effects of PFAS mixtures is very limited and poorly understood. Though, for some other chemical classes, it is known that compounds with similar toxic action can contribute to a combined increased effect. In other words, the mixture of compounds could increase the potential risk of developing non-cancer health effects compared to the effect of each individual compound. If PFOA, PFAS, PFNA and PFHxS have similar toxic actions, it is possible, but uncertain, that the combined risk of all PFAS found at the residential properties within a 1-mile radius of the FSFC. could be higher than the risk found for each individual compound. PFOS is the predominant contaminant and the individual contributions of PFOA, PFNA, PFHxS and other PFAS are low compared to PFOS.

Conclusion # 3

Some health risk evaluations such as exposures before and after 2018/2019 as well as increased cancer risk via drinking of well water with 2018/2019 PFAS levels are limited.

a. Exposure before 2018/2019 cannot be evaluated.
b. Exposure after 2018/2019 is unlikely to occur.
c. Cancer risk for ***residents*** who drank well water with 2018/2019 PFAS levels is uncertain.

Basis for Conclusion #3a+b

Exposure before 2018/2019 cannot be evaluated, because no data exist for PFAS in residential well water before this time. Without data, FDOH is not able to evaluate the likelihood of harmful health effects to former residents who may have been exposed to PFAS in private well water via drinking before 2018/2019.

Future exposure (after 2018/2019) to PFAS via drinking well water at private residences is unlikely when an alternative, permanent drinking water source is supplied.

Basis for Conclusion #3c

2018/2019 levels of ***PFOA*** in well water at private residences are below levels expected to increase risk of developing cancer in ***residents.***

The estimated increased cancer risk for residents exposed to ***PFOA*** via drinking is less than one in a million, which in general, would be considered extremely low. However, current limitations of scientific knowledge prevent comprehensive evaluation of the cancer risk, which must therefore be considered uncertain.

Note: Current information on the ability of PFAS to cause cancers in humans is very limited**.** Epidemiological studies have associated ***PFOA*** exposure with kidney, prostate and testicular cancers. The current cancer estimation for PFOA is based on testicular cancer from an animal study.

PFOS, PFNA and PFHxS are currently not classified as human carcinogens. Present knowledge limits the ability to estimate increased cancer risk for PFAS exposure in general.

Next Steps:

FDOH recommends that residents, including children (birth to 16 years), adolescents and adults avoid consumption of PFAS-contaminated private well water and find an alternative water source for cooking, brushing teeth, etc. until a more permanent solution for clean water has been found and approved by FDEP, e.g., hook up to municipal water supply or installation of a granulated activated carbon (GAC) filter. A GAC filter can prevent exposure to PFAS-contaminated well water. If such filter is installed, FDOH recommends periodic monitoring of the GAC filter (via well water and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated water on-site.

FDOH recommends that visiting children are kept under supervision to prevent exposure to PFAS-contaminated water. PFAS exposure has been associated with developmental effects such as reduced birth weight, childhood obesity and small developmental delays.

Human exposure to PFAS in private well water via showering

Conclusion #4:

Residents, ***including children (birth to 16 years), adolescents*** and ***adults***, who showered at their residences within a 1-mile radius of the FSFC with water containing 2018/2019 levels of ***PFOA and PFOS*** daily for two weeks or longer are not likely to experience an increased risk of developing harmful non-cancer health effects due to PFAS exposure via showering.

Though, even when exposure via showering alone is not expected to contribute to an increased risk of developing harmful non-cancer health effects, it could have contributed to an overall PFAS exposure.

Basis for Conclusion #4

2018/2019 levels of ***PFOA and PFOS*** in well water at residences within a 1-mile radius of the FSFC are below levels expected to increase risk of harmful non-

cancer health effects residents (birth to adulthood), who showered in the water daily for two weeks or longer.

Due to limited scientific information, risk via showering exposure cannot be evaluated for ***PFNA and PFHxS***.

Showering is generally considered a minor pathway for PFAS; however, it could contribute to a combined exposure of all exposure routes.

Current information on the combined effects of PFAS mixtures is very limited and poorly understood. For some other chemical classes, it is known that compounds with similar toxic action can contribute to a combined increased effect. Meaning, the mixture of compounds could increase the potential risk of developing health effects compared to the effect of each individual compound. If PFOA, PFAS, PFNA and PFHxS have similar toxic actions, it is possible, but uncertain, that the combined risk of all PFAS found at the FSFC could potentially be higher than the risk found for each individual compound. However, it should be considered that at the FSFC site, PFOS is the predominant contaminant causing toxicity and the individual toxicity contributions of PFOA, PFNA, PFHxS and other PFAS are low compared to PFOS.

Conclusion #5:

Some health risk evaluations regarding showering at residents within a 1-mile radius of the FSFC are limited.

a. Exposure before 2018/2019 cannot be evaluated.
b. Exposure after 2018/2019 is unlikely to occur.
c. Cancer risk for ***residents*** who showered at their residence daily for one year and longer with 2018/2019 PFAS levels found in well water is uncertain.

Basis for Conclusion #5a+b

Exposure before 2018/2019 cannot be evaluated because no data exist for PFAS in well water at the residences within a 1-mile radius of the FSFC before this time. Without data, FDOH is not able to evaluate the likelihood of harmful health effects to former residents who may have been exposed to PFAS from water via showering before 2018/2019.

Future exposure (after 2018/2019) to PFAS via showering at private residences is unlikely when an alternative, permanent water source for showering is supplied.

Basis for Conclusion #5c

2018/2019 levels of ***PFOA*** in private well water at private residences within a 1-mile radius of the FSFC are below levels expected to increase risk of cancer in ***residents*** who showered in the water for one year or longer.

The estimated increased cancer risk for residents exposed to PFOA via showering is less than one in a million, which in general, would be considered extremely low.

However, current limitations of scientific knowledge prevent comprehensive evaluation of cancer, which must therefore be considered uncertain.

Note: Current information on the ability of PFAS to cause cancers in humans is very limited**.** Epidemiological studies have associated ***PFOA*** exposure with kidney, prostate and testicular cancers. The current cancer estimation for PFOA is based on testicular cancer from an animal study.

PFOS, PFNA and PFHxS are currently not classified as human carcinogens. Present knowledge limits the ability to estimate increased cancer risk for PFAS in general.

Next Steps:

FDOH does not consider it a risk to shower at the private residential properties within a 1-mile radius of the FSFC. Though, based on ATSDR's recommendations for PFAS, FDOH suggests that an alternative water source be used for cooking, brushing teeth and drinking until a more permanent solution for clean water has been found and approved by FDEP, e.g., hook up to municipal water supply or installation of a GAC filter. A GAC filter can prevent exposure to PFAS-contaminated well water. If such filter is installed FDOH recommends periodic monitoring of the GAC filter (via well water and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated water on-site.

Human exposure to PFAS in private well water via irrigation

Conclusion #6:

An increased risk of harmful health effects to ***residential children, adolescents, and adults,*** as well as ***visitors*** and ***trespassers*** when exposed to PFAS such as ***PFOS, PFOA, PFHxS*** and ***PFNA*** contaminated well water via irrigation at residences within a 1-mile radius of the FSFC is possible, but an in-depth risk evaluation cannot be conducted at this time.

Basis for Conclusion #6

Residential children, adolescents, and adults, as well as visitors and trespassers could potentially be exposed to PFAS via dermal contact with the irrigation water. ATSDR currently has no screening levels or health guidelines available to evaluate the potential health risk of dermal exposure to PFAS contaminated irrigation water. Though, the possibility of exposure from inhaling water or through dermal contact is limited and typically considered a minor pathway.

PFAS are fairly water soluble and are known to accumulate. It is known that PFAS can be taken up by home-grown fruits and vegetables when irrigated with water containing PFAS. However, there is no current data for home-grown fruits and vegetables that are watered by irrigation wells.

However, scientific knowledge is limited to evaluate the uptake and impact on human health via this consumption exposure route.

In general, irrigation water should not be used as a drinking source.

Next Steps:

While the inhalation and dermal exposure to PFAS containing irrigation water, as well as the consumption of home-grown fruits and vegetables that were irrigated with PFAS containing water were considered, FDOH currently has no data to evaluate possible health threats from these exposure scenarios. FDOH recommends evaluation once more information and data become available.

****

Limitations of Findings

All health assessments, to varying degree, require the use of assumptions, judgments and incomplete data, which introduce some uncertainties to final risk estimates. Some specific sources of uncertainty in this health consultation include exposure parameter estimates, use of modeled exposure doses, and current toxicological knowledge.

FDOH health assessors do not know exactly how much water each individual drinks on a daily basis. Furthermore, toxicological knowledge for PFAS is limited. The tools used to predict increased non-cancer and cancer risk for this health consultation report are based on data from epidemiological and animal studies, which lead to uncertainty in risk estimates. Suggestive (uncertain) evidence has linked PFOA to three types of cancers: kidney, prostate and testicular cancer. Due to data limitations, however, the value used to estimate increased cancer risk associated with PFOA is based only on data for one type of cancer (testicular). Risk is estimated separately for each PFAS compound (*i.e.*, PFOA and PFOS). Because of these and other uncertainties, health assessors may have overestimated or underestimated health risk. This health consultation does not represent an absolute estimate of risk to persons exposed to PFAS in drinking water.

The FDOH health assessment process is conducted to protect human health. Therefore, assumptions and judgments in the assessment of the site's impact on public health erred on the side of caution and may have overestimated public health risk.

This health consultation used screening levels and health guidelines developed by the ATSDR. These levels are lower than EPA's HAL and therefore offer a more protective assessment, which result in estimated risk at drinking water levels below the HAL. All guidelines made to assess public health are precautionary. It is important to note that findings of risk do not mean that health effects are certain to happen.

This health consultation addendum provides specific public health recommendations based on toxicological literature, site-specific levels of environmental contaminants, evaluation of possible exposure pathways, duration of exposure and characteristics of the exposed population.

Contaminant exposure does not always lead to harmful effects. The risk of harmful effects to a human depends on the type and amount of contaminant the human is exposed to, how exposure occurs, how well the contaminant is absorbed, how frequent and for how long exposure occurs, as well as on individual genetics and lifestyles.

For More Information

If you have concerns about your health or the health of your children, contact your health care provider. For further health evaluation information about the Florida State Fire College Residential Addendum Report, contact FDOH at phtoxicology@flhealth.gov or toll free at 877-798-2772.

ACRONYMS AND ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
AFFF	Aqueous Film-Forming Foam
CSF	Cancer Slope Factor
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FSFC	Florida State Fire College
HAL	Health Advisory Level
HED	Human equivalent doses'
mg/kg	Milligrams per kilogram
mg/kg/day	Milligrams per kilogram per day
MRL	Minimal Risk Level
ng/L	Nanograms per liter
PFAS	Per- and polyfluoroalkyl substances
PFHxS	Perfluorohexane sulfonate/perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate/ perfluorooctane sulfonic acid
ppt	Parts per trillion

1. STATEMENT OF ISSUES

In 2018, the Site Investigation Section of the Florida Department of Environmental Protection (FDEP) began environmental assessments of fire training facilities throughout Florida, including the Florida State Fire College (FSFC) located in Ocala. Investigations assessed potential contamination with per- and polyfluoroalkyl substances (PFAS) associated with aqueous film-forming foams (AFFF, also known as firefighting foam) used in firefighting. Findings of PFAS in groundwater at the FSFC started an expansion of FDEP's investigation off-site to ensure that the full extent of contamination was addressed. The ongoing investigation is being conducted by FDEP in collaboration with the Florida Department of Health (FDOH) and the local County Health Department. The off-site investigation includes well sampling at the Lhoist Mine Site, as well as, private, residential well sampling within a 1-mile radius of the FSFC.

PFAS are a large group of manufactured chemicals, which have been used in a wide range of industrial and consumer products since the 1950s [ATSDR 2018a; EPA 2017]. PFAS are utilized in consumer products for their ability to make products resistant to heat, water, oil and grease. Examples of consumer products that contain PFAS include, but are not limited to, some nonstick cookware, electrical wire insulation, stain-resistant carpets and fabrics, waterproof clothing, food packaging, cosmetics and other personal care products. PFAS do not break down easily after use and disposal, but can persist for a long time in the environment, where they can enter waterways and human food chains [ATSDR 2018a; EPA 2017].

Today, PFAS are ubiquitous contaminants found in air, soil, water, plants, animals, food and indoor dust [Ahrens 2011; Scher et al. 2018; Scheringer et al. 2014, Sunderland et al. 2019]. People who come in contact with PFAS contaminated air, soil, water, plants, animals, food and indoor dust can be exposed to PFAS. Most of the U.S. population have measurable levels of PFAS in their bodies [ATSDR 2019a]. The main source of PFAS exposure in humans is through ingestion of PFAS-contaminated water and food [ATSDR 2019a].

In recent years, an increasing number of studies have linked PFAS groundwater contamination to locations that produced, used, stored and/or disposed of AFFF [Backe et al. 2013; Hatton et al. 2018; Moody and Field 1999]. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS; also known as perfluorooctane sulfonic acid), in particular, have been prevalent components of AFFF [EPA 2017]. Increasing scientific information suggests that exposure to elevated levels of PFOA and PFOS can cause adverse health effects in humans [ATSDR 2018a; EPA 2017]. Limited but increasing information is also becoming available for additional PFAS including perfluorononanoic acid (PFNA) and perfluorohexane sulfonate (PFHxS, also known as perfluorohexane sulfonic acid).

The current health consultation report for the residential wells within a 1-mile radius of the FSFC is the third of three assessments conducted by FDOH to evaluate the potential health implications of PFAS contamination originating from the FSFC:

Report 1: On-site investigation of per- and polyfluoroalkyl substances (PFAS) in groundwater and surface soil.

Report 2. Off-site investigation of PFAS in groundwater at the Lhoist Mine Site

Report 3: Off-site investigation of PFAS in groundwater at private residences within a 1-mile radius of the Florida State Fire College.

Testing of private well water within a 1-mile radius of the FSFC discovered that some of the well water contained a combined PFOA and PFOS level above the United States Environmental Protection Agency (EPA) lifetime health advisory level (HAL[1]) of 70 ng/L [EPA 2016].

In this report, FDOH health assessors evaluated possible health implications of PFAS contamination in off-site private wells within a 1-mile radius of the FSFC. The FDOH health assessors reviewed the following items specifically for the residential evaluation:

- available environmental data for PFAS,
- possible pre 2018/2019, 2018/2019 and post 2018/2019 PFAS exposure pathways[3] and
- the possibility of increased cancer and non-cancer health risks associated with PFAS.

This assessment considered four PFAS chemicals for which health risk assessment data are available: PFOA, PFOS, PFNA and PFHxS.

Note: Data limitations and gaps in current knowledge of PFAS toxicology contributed to uncertainty in evaluating possible health threats. Precautionary assumptions and judgment were used to derive conclusions that may overestimate risk but are protective of public health.

2. BACKGROUND

2.1 Site Description

The FSFC is located in Ocala in Marion County, Florida (Figure 1). The FSFC is surrounded by the Florida Department of Correction facilities to the west and south, Lhoist North America, Inc., to the northeast, east and southeast, as well as private residences to the north/northwest. Private well water was sampled from approximately 75 residential residences within a 1-mile radius of the FSFC (Figure 1).

[3] An exposure pathway (or route) describes the way by which people can come in contact with a chemical (e.g., ingestion of water), including the path a chemical moves where it was released to the point of human contact (e.g., disposal → groundwater → water tap). FDOH considered the possible pathways for pre 2018/2019, 2018/2019, and post 2019 time frames at the residences within 1-mi radius of the FSFC.

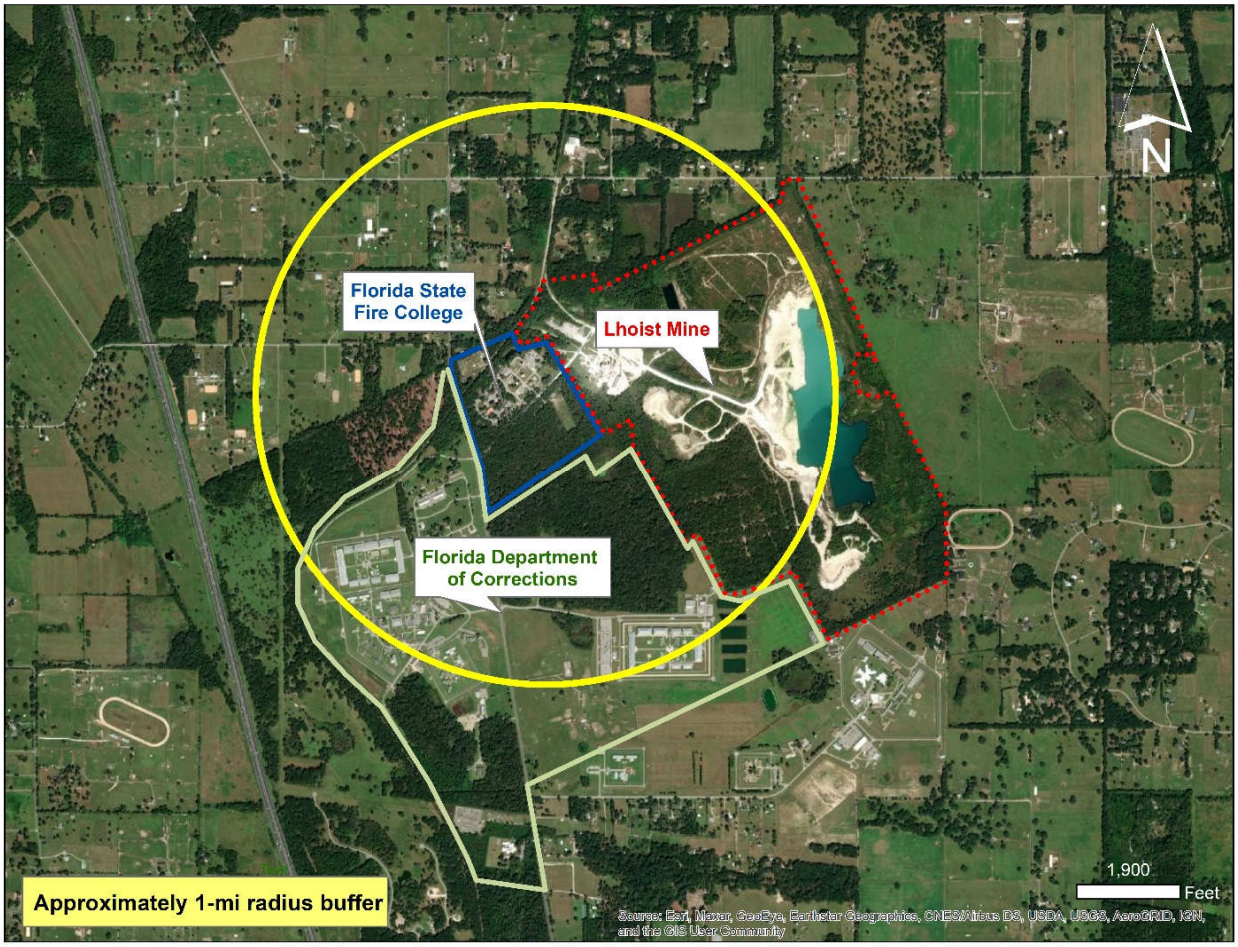

Figure 1: Florida State Fire College as well as 1-mile radius buffer (yellow).

2.2 Site History

In early August 2018, the FDEP confirmed storage and previous use of PFAS-based firefighting foam at the FSFC. FDEP tested the FSFC supply well water and the combined concentration of PFOA and PFOS exceeded the EPA lifetime HAL[1], leading to additional investigations, including off-site groundwater testing.

Since 2018, FDOH, in collaboration with FDEP and local county health departments (CHDs), has been testing private wells within a 1-mile radius of the FSFC. In June 2019, FDEP installed monitoring wells in the area. Well testing is currently ongoing.

From the approximately 75 sampled residencies, 16 private wells exceeded the Agency for Toxic Substances and Disease Registry (ATSDR) health-based comparison values[4] (see Section 3.3.1 and Appendix B) and were evaluated further to assess the possible health implications associated with the consumption of PFAS contaminated water in the area within 1-mile radius of the FSFC.

3. DISCUSSION

3.1. Evaluation Process

Human health risk assessments are conducted for contaminated sites to evaluate and characterize the risk of chemical contaminants to cause possible harm to human health. Assessments are completed via four main steps:

- hazard identification (and initial planning),
- exposure assessment
    - evaluation of available environmental data,
    - evaluation of possible exposure pathways,
- health effects assessment and
- risk characterization and communication.

For this health consultation, FDEP was responsible for the initial hazard identification including planning, collection and first evaluations of environmental data (chemical concentrations in well water). FDOH completed the exposure assessment (A), the health effects assessment (B) and the risk characterization (C), which are described briefly in the following (further detailed in Appendix A):

A. Exposure Assessment

- Exposure Pathway Analysis (Section 3.2)
- Environmental Data Screening (Section 3.3)

The exposure assessment evaluates if and how the population can come in contact with the contaminant(s). If exposure is possible, the relevant environmental data (chemical concentrations in exposure elements such as water, soil and air) are evaluated by comparing the levels with federal **screening levels**[4]. If a chemical concentration for a site exceeds the chemical's screening level, the chemical is of concern and must be evaluated further to assess possible health risk.

B. Health Effects Assessment

- Non-Cancer and Cancer Health Risk Evaluation (3.4)

The likelihood of health effect caused by the chemical of concern depends on how exposure occurs (ingestion, incidental swallowing, breathing and/or skin contact), the amount of chemical present, how often (frequency) exposure takes place and how long (duration) a person is in contact with the chemical. Many of these factors are determined by human behavior and current health conditions, which vary with genetics and population type (e.g., child or adult, worker or resident). Therefore, the health assessor

[4] **Screening levels** are estimates of chemical concentrations in the environment (water, soil, air, etc.) that a person can be exposed to without considerable health risk. Screening levels are health-based and set far below levels known to cause harmful effects. The value of a screening level is called a comparison value (CV), because it is used to compare with. If a chemical concentration at a site is higher than its CV, the chemical is of ***potential*** concern and needs further evaluation.

identifies site-specific population scenarios, for which relevant daily **exposure doses**[5] can be estimated. The estimated daily doses are compared with federal **health guidelines**[6] to determine if site-related doses are of concern. This health consultation used ATSDR's **provisional minimal risk level (MRL) for PFOA, PFOS, PFNA and PFHxS**. If an estimated dose is higher than the health guideline, the possible health implications are evaluated and communicated for each possible pathway.

C. Risk Characterization and Communication

- Conclusions (Section 4)
- Recommendations (Section 5)
- Public Health Action Plan (Section 6)

Based on the findings of Step A and B, conclusions and recommendations are made. A public health action plan is developed and communicated to the community of concern. FDOH can make recommendations but has no regulatory jurisdiction.

3.2 Exposure Pathway Analysis

Chemical contamination is a concern for human health, if people can get exposed to (come in contact with) the chemical. Without human contact, the chemical cannot enter the body and cause harmful effects. If exposure is possible, several aspects determine the actual risk of harm. These aspects are evaluated in the health risk evaluation (Section 3.4).

The Exposure Pathway Analysis evaluates if, what, where, how, and for whom exposure is possible and considers the following five elements:

- a **source** of chemical contamination,
- an **exposed environmental element**,
- an **exposure point** where chemical contact can happen,
- an **exposure route** by which the chemical can enter the body and
- an **exposed population**.

Once all possible pathways have been identified, the health assessor evaluates the likelihood for each pathway to occur. The pathways are classified as completed, potential or eliminated. A **completed pathway** is a pathway, where all five elements can be verified and for which all data exist to conduct a health risk assessment. A **potential pathway** is a likely pathway for which one or more elements are uncertain. Completed and potential pathways are further evaluated in the health risk evaluation (Section 3.4). An **eliminated**

[5] An **exposure dose** is the amount of chemical taken up by a person per body weight per day (milligram chemical/kilogram body/day). Chemicals can be taken up via ingestion, breathing and over the skin.
[6] A **health guideline** is an estimate of the daily chemical exposure dose that a person can be exposed to without considerable health risk. Health guidelines are set far below levels known to cause harmful effects. If an estimated dose for a site is higher than the guideline, health risk is possible and must be further evaluated. ATSDR's health guideline is called the minimal risk level (MRL).

pathway is a pathway for which one or more elements are missing and is usually not further evaluated.

Health assessors considered three timeframes of exposure for the health assessment of the residential properties and their private well water exceeding ATSDR's health based comparison[4] values within a 1-mile radius of the FSFC:

- Pre 2018/2019 (before PFAS testing)
- 2018/2019 (start of PFAS testing)
- Post 2018/2019 (after PFAS mitigation was initiated)

3.2.1 Pathway Identification for Private Wells

The FDOH health assessors identified all pathways by which people at private residents within a 1-mile radius of the FSFC could have been, could be or could become exposed to on-site PFAS contamination:

	ELEMENT	***PRIVATE RESIDENTS***
✓	the ***source*** of chemical contamination	historical use and storage of AFFF
✓	the ***environmental element*** to hold or transport the chemical(s)	groundwater (private well supply, irrigation)
✓	the ***exposure point*** where people can come in contact with the chemical(s)	water taps and showers (via private well)
✓	the ***exposure route*** through which the chemical(s) can enter the body	Ingestion (intended and incidental), dermal (skin) contact, inhalation
✓	the ***exposed population/community***	residential children, adolescents, adults, visitors, trespasser

PFAS contamination at the residences within a 1-mile radius of the FSFC most likely originates from previous use and storage of PFAS-based firefighting foam at the FSFC [***source***]. PFAS-based foam spilled or leaked onto the ground at the FSFC contaminating on-site soil [***exposed element***]. Periods of rain could have contributed to moving PFAS from surface soil into deeper soil and groundwater [***exposed elements***]. Once dissolved, PFAS can remain in water for long periods of time. At an unknown point in time, PFAS contamination from the FSFC spread to surrounding groundwater and impacted well water at nearby residential properties.

Completed Pathways

Residents including children, adolescents and adults within a 1-mile radius of the FSFC could be exposed to PFAS-contaminated groundwater via private wells used to supply water for drinking and showers [***exposure points***]. Residents [***exposed population***]

could be exposed to PFAS by ingestion of PFAS-contaminated drinking water [***exposure route, tap water***], and, via dermal contact and inhalation during showering [***exposure routes, shower***].

Ingestion of PFAS-contaminated drinking water is likely the main exposure route for PFAS at the residential properties. PFAS are not easily absorbed over the skin and do not vaporize easily [ATSDR 2018b; EPA 2016]. Thus, dermal and air contact are generally not considered major pathway elements for PFAS. However, dermal contact and inhalation (from evaporation of PFAS-contaminated water) could occur while showering and were therefore considered completed exposure routes for residents.

Potential Pathways

If one or more elements were uncertain, a pathway was identified as a ***potential pathway*** for residents within a 1-mile radius of the FSFC:

- ✓ pre 2018/2019 exposure to contaminated water via drinking, irrigation use and showering - residents
  - ➔ Exposure to PFAS-contaminated water via drinking, cooking, brushing teeth, watering grass/gardens/swimming, etc. and/or showering may have occurred, but this time frame lacks environmental data.
- ✓ post 2018/2019 exposure to unmitigated contaminated water via drinking, irrigation use and showering – residents
  - ➔ Exposure to PFAS-contaminated water via drinking cooking, brushing teeth, irrigation, etc. and/or showering could occur in the future if the water is not mitigated (e.g., new water source or water filter installment).
- ✓ pre 2018/2019 and 2018/2019 exposure to contaminated well water via drinking, irrigation use and showering – visitors
  - ➔ FDOH considered that exposure to PFAS-contaminated water via drinking, cooking, brushing teeth, watering grass / gardens / swimming, etc. and/or showering may have occurred during visits. Exposure data are however limited for this pathway.
- ✓ pre 2018/2019 and 2018/2019 exposure to contaminated well water via irrigation– trespassers
  - ➔ FDOH considered that exposure to PFAS-contaminated water via irrigation may have occurred during trespassing. Exposure data are however limited for this pathway.

Eliminated Pathways

If one or more elements were missing, a pathway was identified as an ***eliminated pathway***:

- ✓ post 2018/2019 exposure to contaminated water via drinking, irrigation use and showering
  - ➔ Alternative drinking water sources as well as the installation of a water filter at the source of the water (private well) could prevent future exposure to PFAS-contaminated water via drinking, cooking, brushing teeth, showering, irrigation use and any other household activities that involve the use of the well water
- ✓ pre 2018/2019, 2018/2019, and post 2018/2019 exposure to soil
  - ➔ Past, present and future exposure to PFAS in soil is very unlikely. Soil contamination did not occur on residential properties.

All exposure pathways for the residential properties within 1-mile radius of the FSFC Site are illustrated in Figure 2.

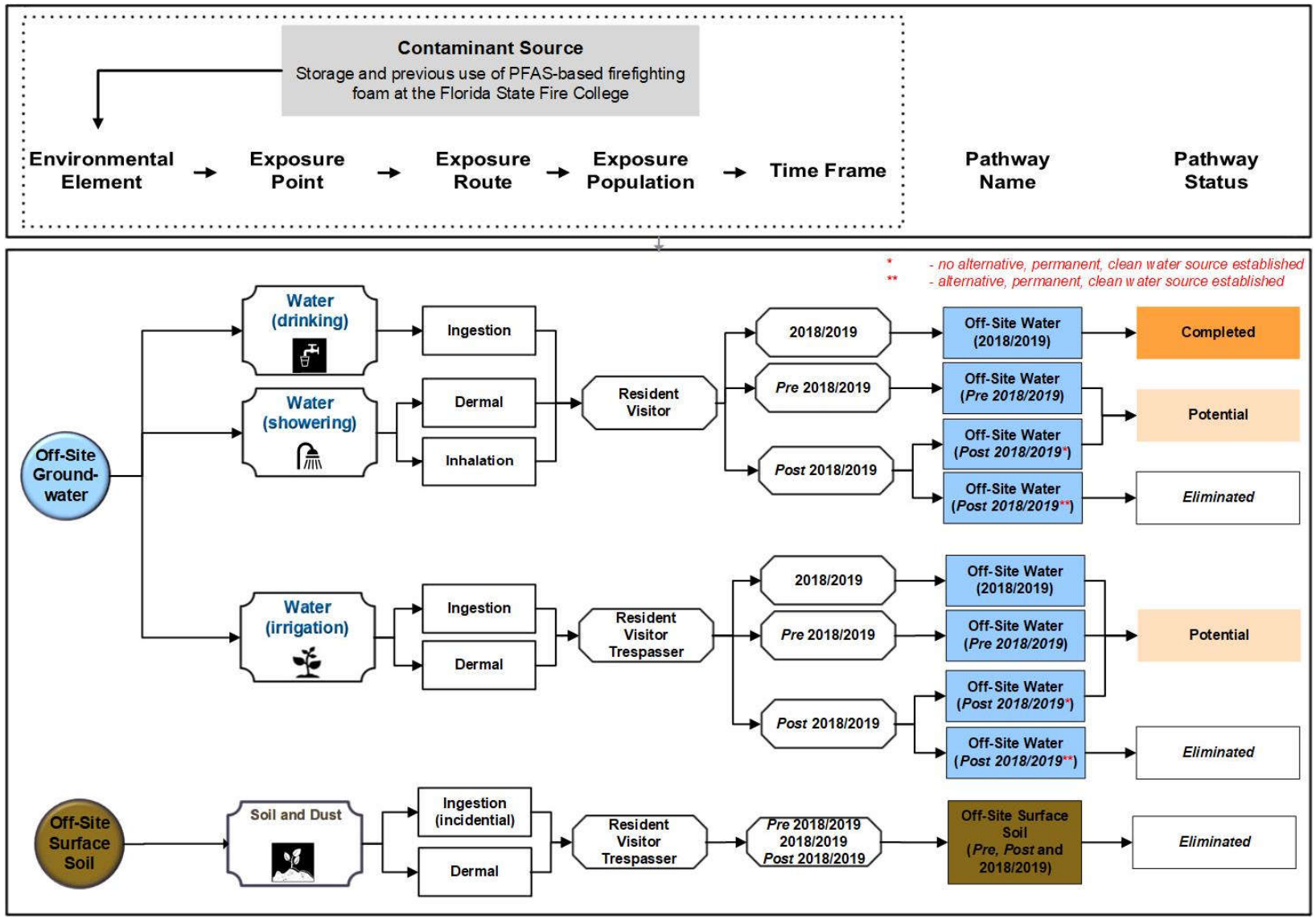

Figure 2: Overview of exposure pathways for well water at residential properties within a 1-mile radius of the Florida State Fire College, Marion County.

3.3. Environmental Data Assessment

3.3.1. Environmental Data Screening

Environmental data (chemical concentrations in groundwater) were evaluated to determine the need for further evaluation of possible health risks to the off-site FSFC community. PFAS concentration data for the site were screened with ATSDR's health-based comparison values (CVs)[4]. Chemicals with concentrations greater than their CVs are identified as chemicals of potential concern (see Section 3.3.2). A concentration above the CV is not necessarily a health threat, but it indicates the need for further health effects assessment (Section 3.4).

Note: PFAS are a large group of many compounds. Many PFAS were detected in the samples. This assessment evaluates four PFAS: PFOA, PFOS, PFNA and PFHxS. At the time of assessment, ATSDR has concluded that toxicological information is only sufficient to develop health guidelines[6] and associated CVs for these four PFAS [ATSDR 2018b]. FDOH adheres to ATSDR's recommendation that all four PFAS must be evaluated in depth (in Section 3.4), whenever one or more of these exceed their CV. FDOH acknowledges that the combined risk of all PFAS may be higher than what might be expected from any one of these four PFAS individually.

Water

In 2018/2019 FDOH collected water samples from the off-site residential private wells located within 1-mile radius of the FSFC (Tables 1 and 2, Appendix B, Table B-1):

Table 1: Maximum concentration (ng/L) of PFOA, PFOS, PFNA and PFHxS collected from residential properties within 1-mile radius of the Florida State Fire College and their respective ATSDR comparison values.

	Maximum Concentration (ng/L)	***ATSDR Comparison Value (ng/L)[4]***	***Above ATSDR Comparison Value?***
PFOA	35	21	**Yes**
PFOS	2,300	14	**Yes**
PFNA	6.8	21	No
PFHxS	1,200	140	**Yes**

Water from private drinking wells was collected from approximately 75 residential properties. The maximum water concentrations of PFOA, PFOS and PFHxS exceed their respective ATSDR health-based CVs (Table 1). ATSDR's environmental media evaluation guides for childhood intermediate exposure were used as they are the most protective values. In accordance with ATSDR recommendations, all PFAS, including PFNA, were further evaluated in the health risk assessment (Section 3.4).

3.3.2. Identification of Chemicals of Potential Concern

If screened chemical concentrations are above ATSDR's health-based CVs (see Section 3.3.1), the FDOH health assessor classifies these as chemicals of potential concern, which are evaluated further to assess if they pose risk to public health.

Table 2: Summary of screening results for maximum PFOA, PFOS, PFNA and PFHxS concentrations and their respective ATSDR health-based Comparison Values (CVs)[4].

	Exceedance of ATSDR Comparison Value Residential Private Well
PFOA	**Yes**
PFOS	**Yes**
PFNA	No
PFHxS	**Yes**

Based on the comparison results (Table 1), PFOA, PFOS and PFHxS are of potential concern in residential private wells located within a 1-mile radius of the FSFC.

In accordance with ATSDR's recommendations, all four PFAS, including PFNA, were further evaluated for drinking water because a minimum of one of these PFAS exceeded its CV for water.

3.4. Non-Cancer & Cancer Health Risk Evaluation

When exposure pathways and chemicals of potential concern have been selected for further evaluation, daily ***exposure doses***[5] are estimated to assess risk of non-cancer and cancer health effects (See Appendix B for detailed description of dose estimation). A daily ***exposure dose*** is the amount of a chemical a person is exposed to in their ambient environment in a day. The ***exposure dose*** calculation uses site-specific input parameters (*e.g.*, chemical concentrations) and population-specific input parameters (*e.g.*, age, intake rates, age-specific body weight) (Appendix B, Tables B-4 to B-5).

When evaluating a possible, harmful non-cancer health risk, the estimated daily exposure doses are compared with ATSDR's minimal risk levels (MRLs)[7]. An MRL is an estimated safe dose, which is considered unlikely to cause adverse effect in humans for a given exposure scenario. Thus, if an estimated exposure dose is lower than the MRL, harmful non-cancer health effects are considered unlikely. If an estimated exposure dose is equal to or exceeds the MRL, harmful non-cancer health effects could be possible. When estimated doses exceed the MRL, the potential non-cancer health risks are more carefully evaluated and communicated to the relevant community. Further information on the possible non-cancer illnesses caused by PFOA, PFOS, PFNA and PFHxS exposure is presented in Section 3.4.1 and Appendix C.

Cancer risk is evaluated as the potential of ***increased cancer risk*** (see Appendix A). In general, one of every three Americans is expected to be diagnosed with cancer at least once in their lifetime. FDOH considers an ***increased cancer risk*** of one-in-a-million extremely low (one in a million = 10^{-6}, 1E-06 in the results tables, Appendix C). It means

[7]A **minimal risk level (MRL)** is developed to protect the most sensitive populations. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without considerable risk of adverse non-cancer health effects over a specified route and duration of exposure. To derive an MRL, the lowest chemical daily dose observed to cause the most sensitive health effect (for example a developmental effect) is identified. Then this chemical dose is lowered by applying one or more numbers called uncertainty factors. This way the MRL is set far below any daily dose known to cause the most sensitive effect known.

that in a population of one million 'exposed' people, one additional occurrence of cancer is expected compared to an 'unexposed' population. The risk of ***increased cancer*** is generally communicated as follows:

1 in 10 (10^{-1})	"very high" increased cancer risk
1 in 100 (10^{-2})	"high" increased cancer risk
1 in 1,000 (10^{-3})	"moderate" increased cancer risk
1 in 10,000 (10^{-4})	"low" increased cancer risk
1 in 100,000 (10^{-5})	"very low" increased cancer risk
1 in 1,000,000 (10^{-6})	"extremely low" increased cancer risk

Increased cancer risk is evaluated for populations exposed to PFOA for one year or longer. Increased cancer risk is not evaluated for exposure less than one year. PFOS, PFNA and PFHxS are currently not classified as potential carcinogens and therefore not evaluated for increased cancer risk. Cancer risk estimation for PFAS is generally very uncertain due to lack and/or limitation of toxicological information.

The health risk assessment for the residential properties near FSFC is site-specific. Possible health risk was evaluated for residents who may have been exposed to PFAS in drinking, showering or activities associated with irrigation use in 2018/2019 and are considered the exposed population.

Although visitors are possibly exposed to PFAS in the water during short visits at the residences, there are too many uncertainties regarding exposure duration and frequency for this population to conduct a meaningful exposure assessment. For members of the community, who are concerned about the possible health risks posed to their visitors, it is recommended to follow the general recommendations made for themselves.

3.4.1. PFAS Health Effects – A General Overview

PFAS is a family with more than 4,000 identified compounds [ITRC 2020a]. However, sufficient information needed to evaluate possible health threats is only available for relatively few PFAS [ITRC 2020b]. The lack and/or limitation of toxicological information and the extensive level of effort needed to develop other parameter values needed for health risk evaluation prevent the establishment of compound-specific health guidelines for most PFAS [ATSDR 2018b].

Most of the current human health effects information for PFAS is derived from epidemiological studies, which have linked PFAS exposure with increased frequency of some health outcomes. Epidemiological studies are important to help indicate possible effects of chemical exposure. Though, dose-effect relationships necessary to produce health guidelines cannot be established without controlled studies. Therefore, current PFAS health guidelines rely on controlled animal studies, which have shown similar effects in animals dosed with known (often high) PFAS concentrations. However, it is not certain that humans will respond to the same concentrations with the same type and degree of effect.

As of today, human epidemiological and animal studies have not found consistent links for PFAS causing cancer. Epidemiological studies have suggested links between PFOA exposure and elevated rates of kidney, prostate and testicular cancers, whereas animal studies have observed increased rates in liver, pancreatic and testicular cancers. Results of animal studies provide suggestive evidence of a link between PFOS exposure and increased incidences of liver, thyroid and mammary tumors [ATSDR 2018b]. A causal link between PFOS exposure and human cancers is lacking. Other PFAS than PFOA may have the potential to cause cancers but further research and toxicological information is needed.

Scientists are still learning about the health effects of PFAS, though possible non-cancer health effects include effects to the liver, thyroid, serum cholesterol, immune and reproductive systems. Pregnant and lactating women, and, women and men who plan to become parents, could be at risk of health effects in their unborn or nursing children, including reduced birth weight, childhood obesity [Braun 2017] and developmental effects such as small delays in puberty. Pregnant women exposed to PFAS could be more susceptible to pre-eclampsia (hypertension during pregnancy), though findings are inconsistent [Borghese et al. 2020; Savitz et al. 2012; Stein et al. 2009; Wikström et al. 2019]. People with pre-existing conditions such as compromised liver or immune system, or elevated serum cholesterol may be more sensitive to PFAS exposure. Table 3 below provides a summary of possible health effects of PFAS exposure in humans based on epidemiological data. This general overview does not necessarily reflect possible health risk at the residential properties with wells tested above ATSDR's comparison values.

Table 3: General overview of possible health effects from PFAS exposure in humans based on epidemiological data.

Organ/system	*Associated health effect*	*PFOA*	*PFOS*	*PFNA*	*PFHxS*
Cardiovascular	Preeclampsia	**X**	**X**	**X†**	**X‡**
Liver	Liver damage (increase in serum enzymes, decrease in bilirubin)	**X**	**X**		**X**
Blood	Increased serum lipids (mainly total cholesterol and low-density lipoprotein (LDL) cholesterol)	**X**	**X**	**X**	
Thyroid	Increased risk of thyroid disease	**X**	**X**		
Immune	Decreased antibody response to vaccines	**X**	**X**		**X**
Respiratory	Increased risk of asthma diagnosis	**X**			
Reproductive	Increased risk of reduced fertility	**X**	**X**		
Developmental	Small decreases in birth weight	**X**	**X**		
Carcinogenicity	Kidney, prostate, testicular cancer	**X**			

Adapted from ATSDR's draft toxicological profile for PFAS [ATSDR 2018b].
†[Wikström et al. 2019], ‡[Borghese et al. 2020]

More detailed information about PFAS in general and about the possible health effects of exposure to PFOA, PFOS, PFNA and PFHxS can be found in Appendix D.

3.4.2. PFAS Health Risk Evaluation for Private Wells within a 1-mile radius of the FSFC

Residents

Health assessors estimated daily doses for 2018/2019 residents from birth to adulthood (21 years and older) including pregnant and lactating woman, exposed to PFAS from private well water located within a 1-mile radius of the FSFC.

Residents were assumed to be exposed to the water via drinking for seven days a week, 50 weeks per years for up to 33 years (Appendix B, Tables B-4 to B-5). Showering exposure (inhalation and dermal exposure) was evaluated for PFOA and PFOS using a software model (Shower Model) developed by ATSDR. Showering input parameters are presented in Appendix B, Table B-5. PFNA and PFHxS can currently not be evaluated using the Shower Model. However, showering is in general considered as a minor pathway for PFAS due to their poor absorption over the skin and minimal vaporization into the air (inhalation).

Detailed information regarding the calculation process are provided in Appendix A. Detailed results of exposure doses and risk estimates can be found in Appendix C, Tables C-1 to C-29, respectively.

Exposure to PFAS via drinking private well water

Pre 2018/2019: Data for private well water does not exist before 2018/2019. Therefore, FDOH is not able to evaluate the likelihood of harmful health effects to residents who may have been exposed to PFAS in their private well water before 2018/2019.

2018/2019: Estimated daily doses[5], MRLs[7], non-cancer risk and increased cancer risk for exposure to ***PFOA, PFOS, PFNA and PFHxS*** are presented in Appendix C.

> ***Non-cancer health risk:*** Estimated doses for ***PFNA*** are less than its respective, ATSDR provisional MRL. Estimated doses for ***PFOA, PFOS and PFHxS*** are greater than their respective ATSDR provisional MRLs. When estimated doses are greater than MRLs, health risk is further evaluated.
>
> Residents, including children, adolescents, adults including those who plan to become pregnant, and, pregnant and lactating women who drank private well water at their residences with 2018/2019 levels of ***PFOA, PFOS and PFHxS*** could be at increased risk of harmful, non-cancer health effects. ***PFNA*** levels in the private well water during 2018/2019 likely do not pose a risk of non-cancer health effects via drinking but may contribute to overall PFAS exposure for residents.
>
> FDOH health assessors evaluated the estimated ***PFOA, PFOS and PFHxS*** doses for residents drinking water in more detail by comparing them with human

exposure doses predicted from animal studies (see Appendix A, Section 2 for more detail).

PFOS is the main chemical of concern at private residential properties within a 1-mile radius of the FSFC where PFAS levels were discovered in well water exceeding ATSDR health-based Comparison Values (CVs)[4]. ATSDR's environmental media evaluation guides for childhood intermediate exposure were used as they are the most protective values.

The estimated doses for this chemical exceed doses predicted to cause immune effects in humans (Appendix C). Therefore, immune effects are of concern for residents during 2018/2019. Based on human epidemiological studies, the most likely immune effect from PFOS exposure is reduced antibody response to vaccines. Human epidemiological studies have also associated PFOA and PFHxS exposure with this type of immune effect. Although the associated doses cannot be inferred for PFOA and PFHxS from available studies, these compounds may increase the risk of immune effects compared to PFOS exposure alone.

PFOS and PFOA exposure may have increased the risk of developmental effects in fetuses, infants and children, who drank water at private residences during 2018/2019 with PFOS and PFOA levels of 140 ng/L (PFOS) and above or 54 ng/L (PFOA). Based on human epidemiological studies, the most likely developmental effect of PFOS and PFOA exposure is a small reduction in birth weight. Animal studies have also observed small delays in development in animals exposed to PFOA, PFOS and PFNA. However, these types of effects have not been verified in human studies. The risk of developmental effects is of particular concern for residents who breastfeed, or who were or became pregnant during this time. Current human scientific information regarding transmission of PFAS from mothers to fetuses and infants is insufficient and limited. Though, the fetus can be exposed to PFAS in-utero and mothers can pass PFAS onto to their child via the breastmilk. Therefore, avoiding exposure to PFAS is important for lactating women and women of childbearing age even though there is no expected health risk for the mother.

The current understanding of ***PFHxS*** toxicology is more limited than for PFOS and PFOA. The most sensitive target of PFHxS toxicity known to date is the thyroid, [ATSDR 2018b]. ***PFHxS*** exposure may have increased the risk of developmental effects in fetuses, infants to less than 1 year, children of 1 year to less than 2 year and children 2 years to less than 6 years, who drank water at private residences during 2018/2019 with PFHxS levels of 630 ng/L and above, 940 ng/L and above, or 1,200 ng/L, respectively. The estimated doses for PFHxS are close to predicted doses for thyroid effects in humans. Thyroid effects of PFHxS exposure have only been confirmed in animal studies. Human epidemiological studies, however, have linked PFOS and PFOA exposure with increased risk of thyroid disease [reviewed in ATSDR 2018b]. Therefore, it is possible that exposure to PFHxS and other PFAS at private well located on residential properties during 2018/2019 near the FSFC could have increased risk of thyroid effects in children up to 6 years.

In addition to immune, developmental and thyroid effects, PFAS have been associated with various health effects including effects to liver, serum cholesterol and reproduction [reviewed in ATSDR 2018b]. PFOA, PFOS, PFNA and PFHxS exposures have also been linked to preeclampsia, although results have varied from study to study (Section 3.4.1). Sensitive populations including pregnant and lactating women, men and women planning to become pregnant, and people with pre-existing health conditions such as compromised liver or immune function, or, elevated cholesterol levels may be at increased risk of health effects following PFAS exposure.

FDOH health assessors acknowledge that residents were exposed to additional PFOA, PFOS and PFHxS, as well as, low levels of other PFAS compounds via other sources such as showering, furniture and consumer products. While PFOS remains the compound of most concern, the combined exposure to two or more compounds and sources may increase risk of developing harmful non-cancer health effects compared to either one alone. Due to the limited understanding of PFAS mixture effects, the actual combined risk cannot be evaluated at this time. Drinking water exposure is likely the dominant pathway for PFAS exposure at the residential properties, with PFOS being the main contaminant of concern.

Increased cancer health risk: The estimated increased cancer risk for residents exposed to PFOA via drinking is less than one in a million, which in general, would be considered extremely low. However, current limitations of scientific knowledge prevent comprehensive evaluation of cancer, which must therefore be considered uncertain.

Epidemiological studies have associated ***PFOA*** exposure with kidney, prostate and testicular cancers. The above cancer estimation is based on testicular cancer from an animal study. ***PFOS, PFNA and PFHxS*** are currently not classified as human carcinogens. Current knowledge limits the ability to estimate increased cancer risk for PFAS in general. Therefore, the assessment of increased cancer risk should be considered uncertain.

Post 2018/2019: Future exposure (after 2018/2019) to PFAS via drinking well water at private residences is unlikely when an alternative, permanent drinking water source is supplied.

Further, FDOH is unable to evaluate the likelihood of harmful health effects to residents post 2018/2019, who may drink water that has not been mitigated as it is unknown if and how PFAS levels will change over time, therefore no data are available, and post 2018/2019 PFAS concentrations in private tap water cannot be predicted.

Exposure to PFAS via showering using private well water

Pre 2018/2019: No well water data are available prior to 2018/2019. Therefore, FDOH was not able to evaluate the likelihood of harmful health effects to former residents, who

may have been exposed to PFAS at residential properties via showering before 2018/2019.

2018/2019: Estimated daily doses (for inhalation and dermal contact), minimal risk levels (MRLs), non-cancer risk and increased cancer risk for exposure to ***PFOA and PFOS*** are presented in Appendix C.

> ***Non-cancer health risk:*** Estimated daily exposure doses for ***PFOA*** and ***PFOS*** via showering are less than their respective MRLs. When doses are less than MRL, the risk of experiencing non-cancer health effects is considered unlikely.
>
> Residents who showered at private residential properties with 2018/2019 levels of PFOA and PFOS are not likely to experience non-cancer illnesses from PFOA and PFOS exposure via showering alone.
>
> ***PFNA*** and ***PFHxS*** currently cannot be evaluated using the Shower Model. However, showering is generally considered a minor pathway for PFAS due to their poor absorption over the skin and minimal vaporization into the air (inhalation).
>
> FDOH health assessors acknowledge that residents could have been exposed to additional PFOA and PFOS, as well as, low levels of other PFAS compounds via other sources such as drinking water, furniture and consumer products. By contributing to total PFAS exposure, showering exposure may increase the total risk of non-cancer health effects for residents. Due to the limited understanding of PFAS mixture effects, the actual combined risk cannot be evaluated at this time. Drinking water exposure is likely the dominant pathway for PFAS exposure for residents near the FSFC with PFOS being the main contaminant of concern.
>
> ***Increased cancer health risk:*** The estimated increased cancer risk for residents exposed to PFOA via showering is less than one in a million, which in general, would be considered extremely low. However, current limitations of scientific knowledge prevent comprehensive evaluation of cancer, which must therefore be considered uncertain.
>
> Epidemiological studies have associated ***PFOA*** exposure with kidney, prostate and testicular cancers. The above cancer estimation is based on testicular cancer from an animal study. ***PFOS, PFNA and PFHxS*** are currently not classified as human carcinogens. Current knowledge limits the ability to estimate increased cancer risk for PFAS in general. Therefore, the assessment of increased cancer risk should be considered uncertain.

Post 2018/2019: It is unknown if and how PFAS levels will change over time. Therefore, future PFAS concentrations in private well water cannot be predicted. Further, without data, FDOH is unable to evaluate the likelihood of harmful health effects to residents, who may shower with PFAS contaminated well water.

Residential Visitors

Residents may have visitors who spend short periods of time at the residential properties. Visitors may have been exposed to PFAS in the private well water. However, because receptor-specific parameters such as frequency and duration of exposure are uncertain, it was not possible to perform a meaningful assessment. Although visitors may only spend short periods of time at the residential properties, it is recommended that visitors read the conclusions made for residents who were exposed to 2018/2019 PFAS contaminated well water.

Potential Trespassers

It is unknown if people trespass at residential properties located within a 1-mile radius of the FSFC. Potential trespassers are unlikely to access drinking water at private residences, but there could be exposure to PFAS-contaminated water when used for irrigation purposes. Without data, FDOH was unable to evaluate the likelihood of harmful health effects to trespassers, who may get exposed to PFAS via irrigation water at the residential properties of concern.

Breastfeeding Woman

Previous health consultations for PFAS-contaminated sites have attracted questions about the risk of breastfeeding [ATSDR 2020].

Possible health effects associated with PFAS exposure via breastfeeding cannot be evaluated due to current limitations in toxicological data. It is known that PFAS can be transferred to infants via breastfeeding [ATSDR 2018a]. Based on current knowledge, ATSDR recommends that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

The decision to breastfeed is an individual choice and involves many considerations other than just the chemical contamination. Women with concerns may find it helpful to discuss breastfeeding with their health care provider. Guidance for health care professionals regarding PFAS can be found here [ATSDR 2019b]: https://www.atsdr.cdc.gov/pfas/resources/info-for-health-professionals.html.

Women with concerns regarding findings at their residences may find it helpful to discuss breastfeeding with their health care provider.

4. CONCLUSIONS

Based on the available environmental data and federal guidelines for PFOA, PFOS, PFHxS, and PFNA, FDOH health assessors made the following conclusions for the private residential properties within a 1-mile radius of the FSFC using well water:

Exposure to PFAS in unfiltered private well water via drinking

Based on the calculated results, exposure to PFAS-contaminated water at private residential properties has the potential to cause harmful health effects. Developmental, immune and thyroid effects are of concern when residents within a 1-mile of the Florida State Fire College are exposed to unfiltered private well water. Table 4 below summarizes the health effects that correspond to the PFAS chemicals of concern at this site.

- ✓ Children (birth to less than 1 year), who drank well water daily with 2018/2019 PFOS levels of 16 ng/L and above may be at increased risk of harmful immune health effects. In addition, they may be at increased risk of harmful developmental health effects when exposed to PFOS levels of 140 ng/L and above, and PFOA levels of 54 ng/L.
- ✓ Children (1 year to less than 2 years), who drank well water daily with 2018/2019 PFOS levels of 36 ng/L and above may be at increased risk of harmful immune health effects, followed by developmental health effects when exposed to PFOS levels of 250 ng/L and above.
- ✓ Children (2 years and older), adolescents, adults including those who plan to become pregnant, and, pregnant and lactating women, who drank well water daily with 2018/2019 PFOS levels of 59 ng/L and above may be at increased risk of harmful immune health effects, followed by developmental health effects when exposed to PFOS levels of 550 ng/L and above.
- ✓ Children (birth to less than 1 year), who drank well water daily with 2018/2019 PFHxS levels of 630 ng/L and above may be at increased risk of harmful thyroid health effects.
- ✓ Children (1 year to less than 2 years), who drank well water daily with 2018/2019 PFHxS levels of 940 ng/L and above may be at increased risk of harmful thyroid health effects.
- ✓ Children (2 years to less than 6 years), who drank well water daily with 2018/2019 PFHxS levels of 1,200 ng/L and above may be at increased risk of harmful thyroid health effects.
- ✓ The 2018/2019 PFNA levels in well water at private residential properties within a 1-mile radius of the FSFC are not expected to increase risk of harmful non-cancer health effects for residents, who drank the water daily. However, PFNA may have contributed to the overall PFAS exposure and could have increased the overall risk of developing non-cancer health effects.

*Table 4: Summary of potential health effects when exposed to PFAS-contaminated well water at residential properties within 1-mile radius of the FSFC via **drinking**.*

Well #	Developmental Effects		Thyroid Effects	Immune Effects
	PFOA	PFOS	PFHxS	PFOS
AAR1407		Birth to < 1 year		Birth to Adult
AAR1408		Birth to Adult	Birth to < 2 years	Birth to Adult
AAR2515	Birth to < 1yr	Birth to Adult	Birth to < 6 years	Birth to Adult
AAR2529		Birth to Adult		Birth to Adult
AAR2541		Birth to Adult		Birth to Adult
AAR2542		Birth to Adult	Birth to < 1 year	Birth to Adult
AAR2585				Birth to Adult
AAR2587		Birth to Adult	Birth to < 1 year	Birth to Adult
AAR2590				Birth to < 2 years
AAR4081		Birth to Adult	Birth to < 1 year	Birth to Adult
AAR4573		Birth to < 1 year		Birth to Adult
AAR4576		Birth to < 2 years		Birth to Adult
AAR4591				Birth to Adult
AAI2122				Birth to < 1 year
AAI2124				Birth to < 1 year

Exposure to PFAS in unfiltered private well water via showering

- ✓ Residents who showered with well water at private residential properties within a 1-mile radius of the FSFC with 2018/2019 levels of PFAS are not likely to be at increased risk of non-cancer health effects due to PFAS exposure via showering.

Additional conclusions

- ✓ Conclusions regarding increased cancer risk due to exposure to 2018/2019 PFAS levels in residential private well water via drinking, showering and/or irrigation use are uncertain.
- ✓ Probable risks of adverse health outcomes due to PFAS exposure via drinking, showering and/or irrigation use at private residential properties within a 1-mile radius of the Florida State Fire College before 2018/2019 cannot be assessed.
- ✓ PFAS exposure via drinking, showering and/or irrigation use at private residential properties within a 1-mile radius of the Florida State Fire College after 2018/2019 is unlikely when an alternative water source is used.
- ✓ The risk of health effects to ***visitors*** and ***trespassers*** at private residential properties within a 1-mile radius of the Florida State Fire College cannot be evaluated.

- ✓ The possible risk of health effects associated with PFAS exposure to infants via breastfeeding cannot be evaluated.
- ✓ While some individual PFAS levels and exposure routes are not expected to cause non-cancer health effects, they could contribute to the overall PFAS exposure at the site. The combined risk from multiple exposures may be higher than the risk from one exposure alone.

5. RECOMMENDATIONS

1. Residents of all ages, including those who plan to become pregnant, and, pregnant and lactating women, should avoid consumption of private well water exceeding ATSDR's health-based comparison values/screening levels for PFAS at residential properties within a 1-mile radius of the FSFC. Based on ATSDR's recommendations for PFAS, FDOH suggests that a long-term, alternative water source should be used, such as a Granulated Activate Carbon (GAC) filter or municipal water.
2. If a GAC filter is installed, periodic monitoring of the filtered well water and maintenance of the filter is recommended to ensure the function of the filter and to prevent exposure to PFAS-contaminated well water.
3. Visitors and trespassers, who were/are/will be present at the residential properties of concern should follow the recommendations made for long-term exposure greater than 1 year. It is unknown when health guidelines for short-term exposure may become available.
4. Visiting children should be kept under supervision to prevent exposure to contaminated water.
5. A decision to breastfeed is an individual decision, which involves many considerations in addition to chemical contamination. Women with concerns may find it helpful to discuss breastfeeding with their health care provider.

6. PUBLIC HEALTH ACTION PLAN

Actions Completed	
October 2018	- FDOH commenced private well sampling.
November 2018	- Notification of private well water results. - FDEP installed a water filter at one private residence.
February 2019	- FDEP installed further water filters at private residences.
June 2019	- FDEP sent notification letters to 49 properties in the potential groundwater plume area. - FDOH held an open house at the FSFC, for community members including private property owners and residents.
Ongoing Actions	
	- FDEP continues to provide an alternative drinking water supply. - Health consultations have been completed for the FSFC (Report 1), the Lhoist Mine Site (Report 2) and for private drinking water wells in a 1-mile radius around the FSFC (this report). The reports are released for public comments. - DOH continues to perform private well sampling and conduct outreach to homeowners encouraging their participation.
Actions Planned	
TBA	Analytical results will determine the most appropriate course of action regarding possible future assessment and outreach.

*****FDOH staff will ask for public comments on this draft report and address them in the final version.*****

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APPENDIX A. EXPLANATION OF HUMAN HEALTH EVALUATION (CALCULATION) PROCESS

1. Screening Process

To evaluate environmental data (e.g., PFAS levels in groundwater and soil), FDOH uses comparison values/**screening levels**[1] to determine which chemicals need further health evaluation. In accordance with ATSDR recommendations, FDOH always uses the lowest available CV for screening because this results in the most protective assessment. ATSDR's CVs are based on daily exposure doses set far below those known to cause health effects (further detailed in Section 2 of this appendix). Then the doses are converted to environmental concentrations (*e.g.,* PFAS in water or soil), which represent estimated safe levels that a person can be exposed in their environment without risk of health effects. ATSDR develops CVs for both non-cancer health effects and cancer. For PFAS, the lowest CVs available are ATSDR's CVs for non-cancer health effects. We used the following CVs for PFAS in this report:

Environmental Media Evaluation Guides (EMEGs) — ATSDR estimates EMEGs for specific media (*e.g.*, water and soil), as well as for specific durations of exposure. Acute exposure is defined as 14 days or less, intermediate exposure is defined as 15-364 days, and when exposure is longer than 1 year it is considered chronic. FDOH used the EMEGs developed for childhood intermediate exposure (Appendix B, Tables B-1 to B-3), because these CVs are the most protective.

If a chemical concentration for a site is higher than the CV, the chemical is of concern and health risk must be evaluated. For example, if it is found that a chemical level in the indoor tap water is higher than its CV, and if people drink or may drink that water, a health effects assessment is warranted.

2. Estimation of Exposure Dose and Exposure Factor

The presence of chemical contamination alone does not necessarily cause harm. The likelihood of adverse health effect depends on factors such as the amount of chemical that humans come in contact with, how well it is taken up by the human body, how often (frequency) and for how long the contact with the chemical occurs (duration). Many of these factors are determined by body weight, sex, behavior, occupation, indoor and/or outdoor exposure, residential exposure, and so on. As human health risk cannot be assessed only from chemical concentrations, exposure doses are estimated for **site- and population/receptor-specific scenarios**.

[1] **Screening levels** are estimated 'safe' chemical concentrations in the environment (chemical amounts in water, soil, air, etc.). Screening levels are health-based and set far below levels known to cause harmful effects. The value of a screening level is also called a comparison value (CV), because it is used to compare with. If a chemical concentration at a site is higher than the CV, the chemical is of concern and needs further evaluation.

An **exposure dose** is the amount of chemical taken up by a person per body weight per day (milligram chemical/kilogram body/day). The contaminant can be taken up from water, soil or air, and it can be taken up via ingestion, absorption over the skin, or via inhalation (breathing it in). Doses are calculated per body weight, because the same amount of chemical is not likely to cause the same magnitude of health effect in a large adult as it would in a small child.

To estimate doses, health assessors used ATSDR's Public Health Assessment Site Tool program (PHAST), which applies the following equations (Eq. B-1 and B-2):

$$\textbf{Dose} = (C \times IR \times EF \times CF) / BW$$

C = *Chemical concentration in the environmental element (e.g., milligram chemical per liter of water (mg/L))*
IR = *Ingestion Rate (e.g., liter of water consumed per day (L/day))*
EF = *Exposure Factor (no unit)*
CF = *Conversion Factor (chemical-specific) (no unit)*
BW = *Body weight (kg)*

Equation A-1: Dose calculation

$$\textbf{EF} = (EFr \times ED) / AT$$

EFr = *Exposure Frequency (days per week, or, days per year)*
ED = *Exposure Duration (days or years)*
AT = *Averaging Time (days or years)*

Equation A-2: Exposure Factor calculation

For example:

*For an adult person of **80 kg** body weight working at a facility for **5 days per week, 50 weeks per year** (assuming 2 weeks of annual leave) for **10 years**, and **ingesting 3 liters of water** a day that contains an average **contaminant concentration of 1 mg/L**, the exposure dose is estimated as follows:*

Dose = (1 mg/L x 3 L/day x EF x 1) / 80 kg = 0.026 mg/kg/day

$EF_{chronic}$ = (5 days/week x 50 weeks/year) x 10 years / 3,650 days = 0.68

The above example represents a simple scenario for exposure via drinking water. Other types of exposure involve more receptor-specific considerations. When dermal exposure doses are estimated, the assessor must also account for the skin surface area available for exposure and this varies with age. The FSFC and population/receptor-specific human health cancer and non-cancer risk evaluation input parameter and results for the dose calculations are listed in Appendix B and C, respectively.

The estimated daily doses are compared with national **health guidelines.**[2] This health consultation used ATSDR's **provisional minimal risk level (MRL) for PFOA, PFOS, PFNA and PFHxS**. To be protective of the most sensitive populations, MRLs are based on the highest dose, where no effect was observed for the most sensitive endpoint (health effect), or, by the lowest dose observed to cause that endpoint. Then several uncertainty factors are applied to lower the dose to make it as protective as possible. An example of an uncertainty factor is a number to account for human variability because some people are more sensitive to certain effects than others.

- **Estimation of non-cancer risk:**

Non-cancer health effects refer to all health effects, such as immune and developmental effects, except cancer. The risk of non-cancer health effect is assessed by screening (comparison) of the estimated dose with the respective health guideline[2], in this case the provisional MRL. This comparison is done by dividing the estimated dose by the MRL resulting in an **'Hazard Quotient'** (HQ):

$$\mathbf{HQ = D / MRL}$$

HQ = Hazard Quotient
D = Exposure Dose (mg/kg/day),
MRL = Minimal Risk Level (mg/kg/day)

Equation A-3: Hazard Quotient calculation

An estimated exposure dose lower than the MRL derives a hazard quotient (HQ) of less than 1, meaning a non-cancer health risk is unlikely. An estimated exposure dose equal to or higher than the MRL derives an HQ equal to or higher than 1, meaning non-cancer health risk is possible. The higher the HQ, the higher the possibility of non-cancer health risk.

If an estimated dose is higher than the health guideline, the possible health implications are evaluated in more detail for the population of concern and communicated.

The health assessor may compare estimated doses directly with doses known to cause effect to evaluate what types of effects may be of most concern. The health assessor also uses professional judgement in the evaluation. When estimated doses are close to the guideline value, the health assessor may use extra precaution if the population in question could be considered more sensitive than the average population (*e.g.*, an elderly population may be particularly susceptible to immune effects).

The evaluation for the residential wells within a 1-mile radius of the FSFC included in-depth assessment of some estimated doses for PFOS, because they exceeded the

[2] **Health guidelines** are estimated 'safe' chemical daily exposure doses in humans (chemical amount ingested or otherwise taken in per body weight per day). Health guidelines are set far below levels known to cause harmful effects, and they are used to compare with doses estimated for a site. If an estimated dose is higher than the guideline, health risk is possible and needs further evaluation. ATSDR's health guideline is called the minimal risk level (MRL).

provisional MRL. Health assessors compared the estimated PFOS doses with 'human equivalent doses' (HED) predicted from animal studies. This evaluation used HED derived for PFOS for developmental and immune effects by ATSDR [ATSDR 2018[3], 2020[4]]. Developmental and immune effects were selected for the evaluation as these are the most sensitive endpoints found for PFOS to date.

Predicted human equivalent doses (HED) for PFOS
based on lowest observed adverse effect levels (LOAEL) found in animal studies

Effect type	LOAEL, HED	Study Reference
Developmental effect	0.0021 mg/kg/day	Luebker et al. 2005
Immune effect	0.00041 mg/kg/day	Dong et al. 2011
Immune effect	0.000031 mg/kg/day	Guruge et al. 2009

HEDs were derived from the study references by ATSDR [ATSDR 2018[3], 2020[4]].

- **Estimation of increased cancer risk:**

Cancer risk is referred to as 'increased' cancer risk because there is always some risk of cancer. One in every three Americans is expected to be diagnosed with cancer in their lifetime. Increased cancer risk is calculated using a chemical-specific standard called a 'cancer slope factor' (CSF). CSFs only exist for chemicals known to cause cancer. The International Agency for Research on Cancer (IARC) has classified PFOA as possibly carcinogenic to humans [IARC 2017[5]] PFOS is not classified as a human carcinogen [ATSDR 2018[3]; EPA 2017[6]]. For chemicals for which cancer-association data lack, the derivation of a CSF is impossible. Thus, a CSF is available for PFOA but not for PFOS, PFNA and PFHxS. To assess the possibility of increased cancer-risk, the estimated dose is multiplied by the chemical-specific CSF:

Increased cancer risk = D x CSF

D = Exposure Dose (mg/kg/day),
CSF = Cancer Slope Factor (mg/kg/day)$^{-1}$

Equation A-4: Cancer risk calculation

Because of uncertainties involved in estimating cancer risk, ATSDR employs a weight-of-evidence approach in evaluating relevant data [ATSDR 2018[3]]. Therefore, the increased risk for cancer is described in words (qualitatively) rather than giving a numerical risk

[3][ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Toxicological profile for Perfluoroalkyls. (Draft for Public Comment). Atlanta, GA [updated 2019 September 26, accessed 2019. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237.

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[6][EPA] United States Environmental Protection Agency. 2017. Technical Fact Sheet - Perfluorooctane Sulfonate (PFOS and Perfluorooctanoic acid (PFOA). (EPA 505-F-17-001). Washington DC [updated 2017 November; accessed 2020 May]. Available from: https://www.epa.gov/sites/production/files/2017-12/documents/ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf.

estimate only. Numerical risk estimates must be considered in the context of the variables and assumptions involved in calculating those estimates and in the broader context of biomedical opinion, host factors, and actual exposure conditions.

The risk of increased cancer can generally be communicated as following:

1 in 10 (10^{-1})	“very high” increased cancer risk
1 in 100 (10^{-2})	“high” increased cancer risk
1 in 1,000 (10^{-3})	“moderate” increased cancer risk
1 in 10,000 (10^{-4})	“low” increased cancer risk
1 in 100,000 (10^{-5})	“very low” increased cancer risk
1 in 1,000,000 (10^{-6})	“extremely low” increased cancer risk

FDOH considers increased cancer risk of one-in-a-million extremely low (10^{-6}, 1E-06 in the results tables, Appendix C), because it indicates that in a population of one million ‘exposed’ people, only one additional occurrence of cancer is expected compared to an ‘unexposed’ (normal) population.

Note: Current information on the ability of PFAS to cause cancers in humans is very limited. Epidemiological studies have associated PFOA exposure with kidney, prostate and testicular cancers. The current cancer estimation for PFOA is based on testicular cancer from an animal study.

PFOS, PFNA and PFHxS are currently not classified as human carcinogens. Present knowledge limits the ability to estimate increased cancer risk for PFAS in general.

APPENDIX B. HUMAN HEALTH CANCER AND NON-CANCER RISK EVALUATION INPUT PARAMETERS

Table B-1. Contaminants of concern in non-remediated private wells within 1-mile of the FSFC. Only investigated private wells with PFAS levels above the ATSDR recommended screening level for PFOA, PFOS, PFHxS and PFNA are listed.

Well ID	Water Concentration ng/L			
	PFOA	PFOS	PFHxS	PFNA
AAR1407	4.8	140	230	0.5
AAR1408	16	550	940	1.5
AAR2515	54	2,300	1200	6.8
AAR2529	1.4	59	88	0.96
AAR2541	15	750	400	4.9
AAR2542	27	1,400	700	3.9
AAR2585	2.3	59	110	0.4
AAR2587	32	900	890	3.8
AAR2590	11	36	7.4	0.96
AAR4081	35	1,000	630	2.5
AAR4573	3.5	230	400	0.96
AAR4576	5.6	250	230	0.93
AAR4591	2.3	88	170	0.92
AAI2122	3.8	21	17	0.41
AAI2124	7.9	25	12	0.53
AAI2272		16		
ATSDR recommended screening level: Intermediate EMEG child	**21**	**14**	**140**	**21**
ATSDR recommended screening level: Intermediate EMEG adult	**78**	**52**	**520**	**78**

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
ID - Identification number
ng/L - Nanograms per liter
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

**Intermediate EMEG Child - The intermediate EMEG child is protective for child intermediate (15-364 d) exposure via ingestion of drinking water.*

Table B-2. Contaminants of concern in non-remediated private wells within 1-mile of the FSFC below the ATSDR recommended screening level for PFOA, PFOS, PFHxS and PFNA.

Well ID	Water Concentration [ng/L]				
	Range	PFOA (97/100)	PFOS (85/100)	PFHxS (90/100)	PFNA 100/100
All Residential Wells with PFAS concentration below the recommended ATSDR child screening level	**MIN**	0.89	0.36	0.36	0.39
	MAX	16	11	110	6.8
ATSDR recommended screening level: Intermediate EMEG child*		**21**	**14**	**140**	**21**
ATSDR recommended screening level: Intermediate EMEG adult		**78**	**52**	**520**	**78**

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
ID - Identification number
ng/L - Nanograms per liter
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

**Intermediate EMEG Child - The intermediate EMEG child is protective for child intermediate (15-364 day) exposure via ingestion of drinking water.*

Table B-3. Contaminants of concern in private wells with within 1-mile of the FSFC pre-, mid- and post-filter installation.

Well ID	Filter	Water Concentration [ng/L] PFOA	PFOS
AAR2587	Pre-	15-32	570-900
	Mid-	0.36	0.89
	Post-	0.36	0.89
ATSDR recommended screening level: Intermediate EMEG child		**21**	**14**
ATSDR recommended screening level: Intermediate EMEG adult		**78**	**52**

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
ID - Identification number
ng/L - Nanograms per liter
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

**Intermediate EMEG Child - The intermediate EMEG child is protective for child intermediate (15-364 d) exposure via ingestion of drinking water.*

RECEPTOR SPECIFIC PARAMETERS

Table B-4. Residential exposure Input Parameters and Exposure Factors used to evaluate the possible risk to human health by ingesting drinking water contaminated with PFAS above the ATSDR recommended screening level.

Exposure Group	Body Weight (kg)	Age-Specific Exposure Duration (years)	Default Intake Rate (L/day)
Birth to < 1 year	7.8	1	1.11
1 to < 2 years	11.4	1	0.893
2 to < 6 years	17.4	4	0.977
6 to < 11 years	31.8	5	1.4
11 to < 16 years	56.8	5	1.98
16 to < 21 years	71.6	5	2.44
Adult	80	33	3.09
Pregnant Women	73	NA	2.59
Lactating Women	73	NA	3.59

Duration	Days	Weeks	Years	Non-Cancer Exposure Factor	**EF cancer** = EF non-cancer x Age-Specific Exposure Duration (years)/78 years
Acute				1	
Intermediate	7	50		1	
Chronic	7	50	33	0.96	

Acute = *Exposure duration of 1 to 14 days*
Chronic = *Exposure duration of 365 days or longer*
EF = *Exposure Factor*
Intermediate = *Exposure duration of 15 to 364 days*
kg = *Kilogram*
L/day = *Liters per day*
ng/L = *Nanograms per liter*
NA = *Not applicable*
PFOA = *Perfluorooctanoic acid*
PFOS = *Perfluorooctane sulfonate*
< = *Less than*

Table B-5. Residential exposure Input Parameters for ATSDR Showering and Household Water-use Exposure Model.

Exposure Group	Body Weight (kg)	Skin Area (cm^2)		Breathing Rate (L/min)		Average Daily Exposure (min/day)		
		Hand Surface Area	Total Skin Surface Area	Shower	Main House	Shower	Main House	Away from House
Birth to < 1 year	7.8	211	3,992	7.60	3.75	25	815	600
1 to < 2 years	11.4	300	5,300	12.00	5.56			
2 to < 6 years	17.4	348	7,225	11.25	6.81			
6 to < 11 years	31.8	510	10,800	11.00	8.33			
11 to < 16 years	56.8	720	15,900	13.00	10.56			
16 to < 21 years	71.6	830	18,400	12.00	11.32			
Adult	80	980	19,650	12.35	10.55			
Pregnant Women	73	890	18,160	15.50	15.50			
Lactating Women	73	890	18,160	15.50	15.50			

cm^2 = square centimeter
kg = Kilogram
L/min = Liters per minute
min/day = minutes per day
PFOA = Perfluorooctanoic acid
PFOS = Perfluorooctane sulfonate
< = Less than

APPENDIX C. HUMAN HEALTH NON-CANCER AND CANCER RISK EVALUATION OUTPUT RESULTS

RESIDENTIAL DRINKING WATER EXPOSURE

*Table C-1. Estimated doses, non-cancer and increased cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOA concentration of 27 ng/L within 1-mile of the FSFC. [Well ID: AAR2542]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL# (mg/kg/day)	Chronic Hazard Quotient	Increased Cancer Risk
Birth to < 1 year	**2.7E-05**	3.7E-06	**3E-06**	1.2	2.3E-08** (<1E-06)
1 to < 2 years		2.0E-06		0.68	
2 to < 6 years		1.5E-06		0.48	
6 to < 11 years		1.1E-06		0.38	
11 to < 16 years		9.0E-07		0.30	
16 to < 21 years		8.8E-07		0.29	
Adult		1.0E-06		0.33	
Pregnant Women		9.2E-07		0.31	
Lactating Women		1.3E-06		0.42	

#ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.
** PFOA cancer slope factor = 0.07 $(mg/kg/day)^{-1}$

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOA	*= Perfluorooctanoic acid*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-2. Estimated doses, non-cancer and increased cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOA concentration of 32 ng/L within 1-mile of the FSFC. [Well ID: AAR2587]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL# (mg/kg/day)	Chronic Hazard Quotient	Increased Cancer Risk
Birth to < 1 year	**3.2E-05**	4.4E-06	**3E-06**	1.5	2.8E-08** (<1E-06)
1 to < 2 years		2.4E-06		0.80	
2 to < 6 years		1.7E-06		0.57	
6 to < 11 years		1.4E-06		0.45	
11 to < 16 years		1.1E-06		0.36	
16 to < 21 years		1.0E-06		0.35	
Adult		1.2E-06		0.40	
Pregnant Women		1.1E-06		0.36	
Lactating Women		1.5E-06		0.50	

#ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.
** PFOA cancer slope factor = 0.07 $(mg/kg/day)^{-1}$

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOA	*= Perfluorooctanoic acid*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-3. Estimated doses, non-cancer and increased cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOA concentration of 35 ng/L within 1-mile of the FSFC site. [Well ID: AAR4081]*

Exposure Group	EPC (mg/L)	Maximum Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Maximum Chronic Hazard Quotient	Maximum Increased Cancer Risk
Birth to < 1 year	**3.5E-05**	4.8E-06	**3E-06**	1.6	3.0E-08** (<1E-06)
1 to < 2 years		2.6E-06		0.88	
2 to < 6 years		1.9E-06		0.63	
6 to < 11 years		1.5E-06		0.49	
11 to < 16 years		1.2E-06		0.39	
16 to < 21 years		1.1E-06		0.38	
Adult		1.3E-06		0.43	
Pregnant Women		1.2E-06		0.40	
Lactating Women		1.6E-06		0.55	

[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.
** PFOA cancer slope factor = 0.07 $(mg/kg/day)^{-1}$

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOA	*= Perfluorooctanoic acid*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-4. Estimated doses, non-cancer and increased cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOA concentration of 54 ng/L within 1-mile of the FSFC site. [Well ID: AAR2515]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL# (mg/kg/day)	Chronic Hazard Quotient	Increased Cancer Risk
Birth to < 1 year	**5.4E-05**	7.4E-06	**3E-06**	2.5	4.7E-08** (<1E-06)
1 to < 2 years		4.1E-06		1.4	
2 to < 6 years		2.9E-06		0.97	
6 to < 11 years		2.3E-06		0.76	
11 to < 16 years		1.8E-06		0.60	
16 to < 21 years		1.8E-06		0.59	
Adult		2.0E-06		0.67	
Pregnant Women		1.8E-06		0.61	
Lactating Women		2.5E-06		0.85	

#ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.
** PFOA cancer slope factor = 0.07 $(mg/kg/day)^{-1}$

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOA	*= Perfluorooctanoic acid*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-5. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 16 ng/L within 1-mile of the FSFC site. [Well ID: AAI2272].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.6E-05**	2.2E-06	**2E-06**	1.1
1 to < 2 years		1.2E-06		0.60
2 to < 6 years		8.6E-07		0.43
6 to < 11 years		6.8E-07		0.34
11 to < 16 years		5.3E-07		0.27
16 to < 21 years		5.2E-07		0.26
Adult		5.9E-07		0.30
Pregnant Women		5.4E-07		0.27
Lactating Women		7.5E-07		0.38

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-6. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 21 ng/L within 1-mile of the FSFC site. [Well ID: AAI2122].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.1E-05**	2.9E-06	**2E-06**	1.4
1 to < 2 years		1.6E-06		0.79
2 to < 6 years		1.1E-06		0.57
6 to < 11 years		8.9E-07		0.44
11 to < 16 years		7.0E-07		0.35
16 to < 21 years		6.9E-07		0.34
Adult		7.8E-07		0.39
Pregnant Women		7.1E-07		0.36
Lactating Women		9.9E-07		0.49

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-7. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 25 ng/L within 1-mile of the FSFC site. [Well ID: AAI2124].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.5E-05**	3.4E-06	**2E-06**	1.7
1 to < 2 years		1.9E-06		0.94
2 to < 6 years		1.3E-06		0.67
6 to < 11 years		1.1E-06		0.53
11 to < 16 years		8.3E-07		0.42
16 to < 21 years		8.2E-07		0.41
Adult		9.3E-07		0.46
Pregnant Women		8.5E-07		0.43
Lactating Women		1.2E-06		0.59

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-8. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 36 ng/L within 1-mile of the FSFC site. [Well ID: AAR2590].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**3.6E-05**	4.9E-06	**2E-06**	2.5
1 to < 2 years		2.7E-06		1.4
2 to < 6 years		1.9E-06		0.97
6 to < 11 years		1.5E-06		0.76
11 to < 16 years		1.2E-06		0.60
16 to < 21 years		1.2E-06		0.59
Adult		1.3E-06		0.67
Pregnant Women		1.2E-06		0.61
Lactating Women		1.7E-06		0.85

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-9. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 59 ng/L within 1-mile of the FSFC site. [Well ID: AAR2529 and AAR2585]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**5.9E-05**	8.1E-06	**2E-06**	4.0
1 to < 2 years		4.4E-06		2.2
2 to < 6 years		3.2E-06		1.6
6 to < 11 years		2.5E-06		1.2
11 to < 16 years		2.0E-06		1.0
16 to < 21 years		1.9E-06		1.0
Adult		2.2E-06		1.1
Pregnant Women		2.0E-06		1.0
Lactating Women		2.8E-06		1.4

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-10. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 88 ng/L within 1-mile of the FSFC site. [Well ID: AAR4591]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**8.8E-05**	1.2E-05	**2E-06**	6.0
1 to < 2 years		6.6E-06		3.3
2 to < 6 years		4.7E-06		2.4
6 to < 11 years		3.7E-06		1.9
11 to < 16 years		2.9E-06		1.5
16 to < 21 years		2.9E-06		1.4
Adult		3.3E-06		1.6
Pregnant Women		3.0E-06		1.5
Lactating Women		4.1E-06		2.1

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-11. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 140 ng/L within 1-mile of the FSFC site. [Well ID: AAR1407]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.4E-04**	1.9E-05	**2E-06**	9.6
1 to < 2 years		1.1E-05		5.3
2 to < 6 years		7.5E-06		3.8
6 to < 11 years		5.9E-06		3.0
11 to < 16 years		4.7E-06		2.3
16 to < 21 years		4.6E-06		2.3
Adult		5.2E-06		2.6
Pregnant Women		4.8E-06		2.4
Lactating Women		6.6E-06		3.3

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-12. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 230 ng/L within 1-mile of the FSFC site. [Well ID: AAR4573]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.3E-04**	3.1E-05	**2E-06**	16
1 to < 2 years		1.7E-05		8.6
2 to < 6 years		1.2E-05		6.2
6 to < 11 years		9.7E-06		4.9
11 to < 16 years		7.7E-06		3.8
16 to < 21 years		7.5E-06		3.8
Adult		8.5E-06		4.3
Pregnant Women		7.8E-06		3.9
Lactating Women		1.1E-05		5.4

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-13. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 250 ng/L within 1-mile of the FSFC site. [Well ID: AAR4576]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.5E-04**	3.4E-05	**2E-06**	17
1 to < 2 years		1.9E-05		9.4
2 to < 6 years		1.3E-05		6.7
6 to < 11 years		1.1E-05		5.3
11 to < 16 years		8.3E-06		4.2
16 to < 21 years		8.2E-06		4.1
Adult		9.3E-06		4.6
Pregnant Women		8.5E-06		4.3
Lactating Women		1.2E-05		5.9

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-14. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 550 ng/L within 1-mile of the FSFC site. [Well ID: AAR1408]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**5.5E-04**	7.5E-05	**2E-06**	38
1 to < 2 years		4.1E-05		21
2 to < 6 years		3.0E-05		15
6 to < 11 years		2.3E-05		12
11 to < 16 years		1.8E-05		9.2
16 to < 21 years		1.8E-05		9.0
Adult		2.0E-05		10
Pregnant Women		1.9E-05		9.4
Lactating Women		2.6E-05		13

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-15. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 750 ng/L within 1-mile of the FSFC site. [Well ID: AAR2541]*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**7.5E-04**	0.00010	**2E-06**	51
1 to < 2 years		5.6E-05		28
2 to < 6 years		4.0E-05		20
6 to < 11 years		3.2E-05		16
11 to < 16 years		2.5E-05		13
16 to < 21 years		2.5E-05		12
Adult		2.8E-05		14
Pregnant Women		2.6E-05		13
Lactating Women		3.5E-05		18

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-16. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 900 ng/L within 1-mile of the FSFC site. [Well ID: AAR2587*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**9.0E-04**	0.00012	**2E-06**	62
1 to < 2 years		6.8E-05		34
2 to < 6 years		4.8E-05		24
6 to < 11 years		3.8E-05		19
11 to < 16 years		3.0E-05		15
16 to < 21 years		2.9E-05		15
Adult		3.3E-05		17
Pregnant Women		3.1E-05		15
Lactating Women		4.2E-05		21

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-17. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 1,000 ng/L within 1-mile of the FSFC site. [Well ID: AAR2587].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.0E-03**	0.00014	**2E-06**	68
1 to < 2 years		7.5E-05		38
2 to < 6 years		5.4E-05		27
6 to < 11 years		4.2E-05		21
11 to < 16 years		3.3E-05		17
16 to < 21 years		3.3E-05		16
Adult		3.7E-05		19
Pregnant Women		3.4E-05		17
Lactating Women		4.7E-05		24

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-18. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 1,400 ng/L within 1-mile of the FSFC site. [Well ID: AAR2542].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.4E-03**	0.00019	**2E-06**	96
1 to < 2 years		0.00011		53
2 to < 6 years		7.5E-05		38
6 to < 11 years		5.9E-05		30
11 to < 16 years		4.7E-05		23
16 to < 21 years		4.6E-05		23
Adult		5.2E-05		26
Pregnant Women		4.8E-05		24
Lactating Women		6.6E-05		33

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-19. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFOS[1] concentration of 2,300 ng/L within 1-mile of the FSFC site. [Well ID: AAR2515].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.3E-03**	0.00031	**2E-06**	160
1 to < 2 years		0.00017		86
2 to < 6 years		0.00012		62
6 to < 11 years		9.7E-05		49
11 to < 16 years		7.7E-05		38
16 to < 21 years		7.5E-05		38
Adult		8.5E-05		43
Pregnant Women		7.8E-05		39
Lactating Women		0.00011		54

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFOS	*= Perfluorooctane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-20. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 170 ng/L within 1-mile of the FSFC site. [Well ID: AAR4591].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.7E-04**	2.3E-05	**2E-05**	1.2
1 to < 2 years		1.3E-05		0.64
2 to < 6 years		9.2E-06		0.46
6 to < 11 years		7.2E-06		0.36
11 to < 16 years		5.7E-06		0.28
16 to < 21 years		5.6E-06		0.28
Adult		6.3E-06		0.32
Pregnant Women		5.8E-06		0.29
Lactating Women		8.0E-06		0.40

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-21. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 230 ng/L within 1-mile of the FSFC site. [Well ID: AAR4576, AAR1407].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**2.3E-04**	3.1E-05	**2E-05**	1.6
1 to < 2 years		1.7E-05		0.86
2 to < 6 years		1.2E-05		0.62
6 to < 11 years		9.7E-06		0.49
11 to < 16 years		7.7E-06		0.38
16 to < 21 years		7.5E-06		0.38
Adult		8.5E-06		0.43
Pregnant Women		7.8E-06		0.39
Lactating Women		1.1E-05		0.54

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-22. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 400 ng/L within 1-mile of the FSFC site. [Well ID: AAR2541, AAR4573].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	4E-04	5.5E-05	2E-05	2.7
1 to < 2 years		3.0E-05		1.5
2 to < 6 years		2.2E-05		1.1
6 to < 11 years		1.7E-05		0.85
11 to < 16 years		1.3E-05		0.67
16 to < 21 years		1.3E-05		0.65
Adult		1.5E-05		0.74
Pregnant Women		1.4E-05		0.68
Lactating Women		1.9E-05		0.94

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-23. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 630 ng/L within 1-mile of the FSFC site. [Well ID: AAR4081].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**6.3E-04**	8.6E-05	**2E-05**	4.3
1 to < 2 years		4.7E-05		2.4
2 to < 6 years		3.4E-05		1.7
6 to < 11 years		2.7E-05		1.3
11 to < 16 years		2.1E-05		1.1
16 to < 21 years		2.1E-05		1.0
Adult		2.3E-05		1.2
Pregnant Women		2.1E-05		1.1
Lactating Women		3.0E-05		1.5

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-24. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 700 ng/L within 1-mile of the FSFC site. [Well ID: AAR2542].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	7E-04	9.6E-05	2E-05	4.8
1 to < 2 years		5.3E-05		2.6
2 to < 6 years		3.8E-05		1.9
6 to < 11 years		3.0E-05		1.5
11 to < 16 years		2.3E-05		1.2
16 to < 21 years		2.3E-05		1.1
Adult		2.6E-05		1.3
Pregnant Women		2.4E-05		1.2
Lactating Women		3.3E-05		1.6

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-25. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 890 ng/L within 1-mile of the FSFC site. [Well ID: AAR2587].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**8.9E-04**	1.2E-04	**2E-05**	6.1
1 to < 2 years		6.7E-05		3.3
2 to < 6 years		4.8E-05		2.4
6 to < 11 years		3.8E-05		1.9
11 to < 16 years		3.0E-05		1.5
16 to < 21 years		2.9E-05		1.5
Adult		3.3E-05		1.6
Pregnant Women		3.0E-05		1.5
Lactating Women		4.2E-05		2.1

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-26. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 940 ng/L within 1-mile of the FSFC site. [Well ID: AAR1408].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**9.4E-04**	1.3E-04	**2E-05**	6.4
1 to < 2 years		7.1E-05		3.5
2 to < 6 years		5.1E-05		2.5
6 to < 11 years		4.0E-05		2.0
11 to < 16 years		3.1E-05		1.6
16 to < 21 years		3.1E-05		1.5
Adult		3.5E-05		1.7
Pregnant Women		3.2E-05		1.6
Lactating Women		4.4E-05		2.2

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-27. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a PFHxS[1] concentration of 1,200 ng/L within 1-mile of the FSFC site. [Well ID: AAR2515].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient
Birth to < 1 year	**1.2E-03**	1.6E-04	**2E-05**	8.2
1 to < 2 years		9.0E-05		4.5
2 to < 6 years		6.5E-05		3.2
6 to < 11 years		5.1E-05		2.5
11 to < 16 years		4.0E-05		2.0
16 to < 21 years		3.9E-05		2.0
Adult		4.4E-05		2.2
Pregnant Women		4.1E-05		2.0
Lactating Women		5.7E-05		2.8

[1]PFHxS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR	*= Agency for Toxic Substances and Disease Registry*
Chronic	*= Exposure duration of 365 days or longer*
EPC	*= Exposure Point Concentration*
kg	*= Kilogram*
mg/L	*= Milligrams per day*
mg/kg/day	*= Milligrams per kilogram per day*
MRL	*= Minimal Risk Level*
ng/L	*= Nanograms per liter*
PFHxS	*= Perfluorohexane sulfonate*
<	*= Less than*
	= Potential risk (hazard quotient above 1)

*Table C-28. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing a maximum PFNA[1] concentration of 6.8 ng/L within 1-mile of the FSFC site. [Well ID: AAR2515].*

Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL[#] (mg/kg/day)	Chronic Hazard Quotient (HQ)
Birth to < 1 year	**6.8E-06**	9.3E-07	**3E-06**	0.3
1 to < 2 years		5.1E-07		0.2
2 to < 6 years		3.7E-07		0.1
6 to < 11 years		2.9E-07		0.1
11 to < 16 years		2.3E-07		0.1
16 to < 21 years		2.2E-07		0.1
Adult		2.5E-07		0.1
Pregnant Women		2.3E-07		0.1
Lactating Women		3.2E-07		0.1

[1]PFNA is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR = *Agency for Toxic Substances and Disease Registry*
Chronic = *Exposure duration of 365 days or longer*
EPC = *Exposure Point Concentration*
kg = *Kilogram*
mg/L = *Milligrams per day*
mg/kg/day = *Milligrams per kilogram per day*
MRL = *Minimal Risk Level*
ng/L = *Nanograms per liter*
PFNA = *Perfluorononanoic acid*
< = *Less than*

RESIDENTIAL SHOWER EXPOSURE

*Table C-29. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing maximum PFOA concentrations measured within a 1-mile radius of the FSFC via **showering**. [Model based maximum input: 4-person household, two adult showers and two child baths, fan on, gone during the day – 10hrs]. [Well ID # AAR2515: 54 ng/L = 5.4E-05 mg/L]*

Exposure Group	EPC	ATSDR MRL# (mg/kg/day)	Inhalation Dose (mg/kg/day)	Dermal Dose (mg/kg/day)	Combined Dose (mg/kg/day)	Chronic Hazard Quotient (combined)	Cancer Risk (combined)
Birth to < 1 year	**5.4E-05 mg/L [1] 5.7E-08 mg/m^3 [2] 9.7E-10 mg/m^3 [3]**	**3E-06**	1.80E-11	2.00E-08	2.00E-08	6.67E-03	<1E-06**
1 to < 2 years			1.80E-11	1.80E-08	1.80E-08	6.01E-03	
2 to < 6 years			1.50E-12	1.60E-08	1.60E-08	5.33E-03	
6 to < 11 years			9.80E-12	1.30E-08	1.30E-08	4.34E-03	
11 to < 16 years			7.00E-12	1.10E-08	1.10E-08	3.67E-03	
16 to < 21 years			5.90E-12	1.00E-08	1.00E-08	3.34E-03	
Adult	**5.4E-05 mg/L [1] 7.7E-08 mg/m^3 [2] 3.9E-09 mg/m^3 [3]**		9.70E-12	6.40E-09	6.41E-09	2.14E-03	
Pregnant Women			1.50E-11	6.70E-09	6.72E-09	2.24E-03	
Lactating Women			1.50E-11	6.70E-09	6.72E-09	2.24E-03	

[1] – EPC Water [2] – EPC Air, Shower [3] – EPC Air, Main House

#ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.
** PFOA cancer slope factor = 0.07 (mg/kg/day)$^{-1}$

ATSDR = Agency for Toxic Substances and Disease Registry
Chronic = Exposure duration of 365 days or longer
EPC = Exposure point concentration
mg/kg/day = Milligram contaminant per kilogram body weight per day
MRL = Minimal risk level
mg/L = Milligrams per liter
mg/m^3 = Milligrams per cubic meter
ng/L = Nanograms per liter
< = Less than
<1E-06 = Less than one in a million

*Table C-30. Estimated doses and non-cancer risk for **residents** exposed to **2018/2019** drinking water containing maximum PFOS[1] concentrations measured within a 1-mile radius of the FSFC via **showering**. [Model based maximum input: 4-person household, two adult showers and two child baths, fan on, gone during the day – 10hrs]. [Well ID # AAR2515: 2,300 ng/L = 0.0023 mg/L]*

Exposure Group	EPC	ATSDR MRL[#] (mg/kg/ day)	Inhalation Dose (mg/kg/day)	Dermal Dose (mg/kg/day)	Combined Dose (mg/kg/day)	Chronic Hazard Quotient (combined)
Birth to < 1 year	**0.0023 mg/L [1] 1.7E-07 mg/m^3 [2] 2.9E-09 mg/m^3 [3]**	**2E-06**	6.7E-8	0.0015	1.50E-06	7.50E-01
1 to < 2 years			6.7E-8	0.0014	1.40E-06	7.00E-01
2 to < 6 years			5.4E-8	0.0012	1.20E-06	6.00E-01
6 to < 11 years			3.6E-8	0.00098	9.80E-07	4.90E-01
11 to < 16 years			2.6E-8	0.00081	8.10E-07	4.05E-01
16 to < 21 years			2.2E-8	0.00074	7.40E-07	3.70E-01
Adult	**0.0023 mg/L [1] 2.3E-07 mg/m^3 [2] 1.2E-08 mg/m^3 [3]**		3.6E-8	0.00048	4.80E-07	2.40E-01
Pregnant Women			5.5E-8	0.00050	5.00E-07	2.50E-01
Lactating Women			5.5E-8	0.00050	5.00E-07	2.50E-01

[1] – EPC Water [2] – EPC Air, Shower [3] – EPC Air, Main House

[1]PFOS is not classified as a carcinogen. Therefore, a Cancer Slope Factor as well as Cancer Risk is not available.
[#]ATSDR's provisional Intermediate MRL is used to compare with the chronic doses and calculate chronic HQs.

ATSDR = Agency for Toxic Substances and Disease Registry
Chronic = Exposure duration of one year or longer
EPC = Exposure point concentration
mg/kg/day = Milligram contaminant per kilogram body weight per day
MRL = Minimal risk level
mg/L = Milligrams per liter
mg/m^3 = Milligrams per cubic meter
ng/L = Nanogram per liter
< = Less than

APPENDIX D. CHEMICAL SPECIFIC TOXICITY INFORMATION

The toxicology of PFAS is not fully understood. Available toxicological information is based on epidemiological and animal studies. ***Epidemiological studies*** have investigated populations across three levels of exposure from background to high. Most Americans are exposed to very low levels of PFAS and this is called background. Mid-level exposure is exposure to residents near facilities that use or produce PFAS and high-level exposure refers to occupational exposure for workers at such facilities.

Epidemiological studies look at disease trends (differences) in observations across such different exposure populations but are not 'controlled' experiments. This means that many important, sometimes unknown variables cannot be accounted for, such as pre-existing conditions and other factors that may affect a person's susceptibility to disease. These types of studies produce data with high uncertainty (data that are not certain to be accurate).

The results of epidemiological studies for PFAS to date have been inconclusive, and most studies have focused on PFOA and PFOS with less data available for PFNA, PFHxS and other PFAS. However, data suggest a number of possible ***non-cancer health effects*** associated with PFOA, PFOS, PFNA and/or PFHxS exposure [ATSDR 2018[1]]. Possible effects include changes to the liver, thyroid, serum cholesterol, immune and reproductive systems. Pregnant and lactating women, and, women and men who plan to become parents, could be at risk of health effects in their unborn or nursing children, including reduced birth weight and developmental effects such as small delays in puberty [ATSDR 2018[1]], as well as childhood obesity [Braun 2017][2]. Pregnant women exposed to PFAS could be more susceptible to pre-eclampsia, though findings are inconsistent [Borghese et al. 2020[3]; Savitz et al. 2012[4]; Stein et al. 2009[5]; Wikström et al. 2019[6]]. The following table outlines the possible effects of PFAS exposure as indicated by epidemiological studies to date.

[1] [ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Toxicological profile for Perfluoroalkyls. (Draft for Public Comment). Atlanta, GA [updated 2019 September 26, accessed 2019. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237

[2] Braun JM. 2017. Early-Life Exposure to EDCs: Role in Childhood Obesity and Neurodevelopment. Nat Rev Endocrinol 13(3): 161-173.

[3] Borghese MM, Walker M, Helewa ME, Fraser WD and Arbuckle TE. 2020. Association of Perfluoroalkyl Substances with Gestational Hypertension and Preeclampsia in the MIREC Study. Environ Int 141: 105789.

[4] Savitz DA, Stein CR, Bartell SM, Elston B, Gong J, Shin H-M and Wellenius GA. 2012. Perfluorooctanoic Acid Exposure and Pregnancy Outcome in a Highly Exposed Community. Epidemiology 23(3): 386-392.

[5] Stein CR, Savitz DA and Dougan M. 2009. Serum Levels of Perfluorooctanoic Acid and Perfluorooctane Sulfonate and Pregnancy Outcome. Am J Epidemiol 170(7): 837-846.

[6] Wikström S, Lindh CH, Shu H and Bornehag C-G. 2019. Early Pregnancy Serum Levels of Perfluoroalkyl Substances and Risk of Preeclampsia in Swedish Women. Sci Rep 9(1): 9179.

Possible health effects of PFAS exposure in humans based on epidemiological data.					
Organ/system	**Associated health effect**	**PFOA**	**PFOS**	**PFNA**	**PFHxS**
Cardiovascular	Pregnancy-induced hypertension/preeclampsia	**X**	**X**	**X†**	**X‡**
Liver	Liver damage (increase in serum enzymes, decrease in bilirubin)	**X**	**X**		**X**
Blood	Increased serum lipids (mainly total cholesterol and low-density-lipid (LDL) cholesterol)	**X**	**X**	**X**	
Thyroid	Increased risk of thyroid disease	**X**	**X**		
Immune	Decreased antibody response to vaccines	**X**	**X**		**X**
Respiratory	Increased risk of asthma diagnosis	**X**			
Reproductive	Increased risk of reduced fertility	**X**	**X**		
Developmental	Small decreases in birth weight	**X**	**X**		
Carcinogenicity	*Kidney, prostate, testicular cancer*	**X**			

Adapted from ATSDR's draft toxicological profile for PFAS[1]. †[Wikström et al. 2019][6], ‡[Borghese et al. 2020][3].

Controlled animal studies can better demonstrate cause and effect than uncontrolled epidemiological studies. Animal studies cannot replace human studies. However, by studying the same endpoints (effects) observed in epidemiological studies under controlled conditions (known chemical doses, duration, etc.), animal studies can be used to support epidemiological findings.

To date, animal studies investigating PFAS have been conducted mostly with rodents but also with non-human primates (monkeys). Overall, these studies have identified liver, immune and reproductive systems, as well as development as the primary targets of toxicity for PFOA. For PFOS, animal studies have identified liver, nervous and immune systems, as well as development as sensitive targets of toxicity. Animal studies have also observed developmental effects for PFNA exposure, and liver and immune effects for PFHxS.

ATSDR used these animal studies to develop ***provisional minimal risk levels (MRLs)*** for PFOA, PFOS, PFNA and PFHxS [ATSDR 2018]. These MRLs were used as health guidelines for this health assessment. MRLs are developed to protect the most sensitive populations. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without considerable risk of adverse non-cancer health effects over a specified route and duration of exposure. To derive an MRL, the lowest chemical daily dose observed to cause the most sensitive health effect (for example a developmental effect) is identified. Then this chemical dose is lowered by applying one or more numbers called uncertainty factors. This way the MRL is set far below any daily dose known to cause the most sensitive effect known.

ATSDR found developmental effects data to be the most sensitive and robust for PFOA, PFOS and PFNA, while immune effects were found to be the most sensitive endpoint for PFHxS. Animal data also indicate that immune effects may be a more sensitive endpoint for PFOS. However, developmental effects data were used to estimate minimal risk levels for three of the four PFAS (PFOA, PFOS and PFNA). It is important to consider that the fetus and baby can be exposed to PFAS in the womb and through lactation. Furthermore, PFAS exposure to adults can cause effects in their offspring.

Developmental effects observed in animals exposed to ***PFOA*** include prenatal loss, decreased pup survival and birth weight, delayed development (e.g., eye opening, mammary gland development, skeletal changes), and increased motor activity [ATSDR 2018]. (Effects to mammary gland development did not cause effects in the offspring). The MRL for PFOA is based on the lowest dose observed to cause developmental effects in mice. The observed endpoints were altered motor activity and skeletal changes in offspring of exposed mice [Koskela et al. 2016[7]; Onishchenko et al. 2011[8]].

PFOS-associated developmental effects observed in rodent studies include lowered pup survival, lowered birth and body weight, lowered motor activity, and developmental delays [ATSDR 2018[1]]. The most sensitive endpoints observed were decreased body weight and delayed eye opening in offspring of rats, that were exposed from before mating through gestation and lactation [Luebker et al. 2005[9]]. The MRL for PFOS is based on the highest dose, for which these sensitive effects were not observed in the rats. As noted, animal data indicate that PFOS may cause immune effects (lowered immune response) at doses ten times lower than those causing developmental effects. Thus, the immune system may be a very sensitive target for PFOS exposure. The studies, which tested potential for immune effects however used a species for which it is difficult to translate animal doses to representative human doses [ATSDR 2018[1]].

More limited data are available for PFNA and PFHxS. The MRL for ***PFNA*** is based on developmental endpoints in mice (decreased body weight and delayed development) [Das et al. 2015[10]]. The dose used to estimate MRL is the highest dose tested without observable effects. Developmental toxicity has not been investigated for ***PFHxS***, which appears to target the immune system. The endpoint used for MRL estimation is thyroid follicular cell damage in a rat species [Butenhoff et al. 2009[11]]. The dose used to estimate MRL is the highest dose tested without observable effects.

The findings in animal studies support data from human epidemiological studies, which have also found associations between PFOA and PFOS exposure and small decreases

[7]Koskela et al. 2016. Effects of developmental exposure to perfluorooctanoic acid (PFOA) on long bone morphology and bone cell differentiation. Toxicol Appl Pharmacol 301:14-21.
[8]Onishchenko et al. 2011. Prenatal exposure to PFOS or PFOA alters motor function in mice in a sex-related manner. Neurotox Res 19:452-461.
[9]Luebker DJ, Case MT, York RG, Moore JA, Hansen KJ, Butenhoff JL. 2005. Two-generation reproduction and cross-foster studies of perfluorooctanesulfonate (PFOS) in rats. Toxicology 215(1–2):129–48.
[10]Das KP, Grey BE, Rosen MB, et al. 2015. Developmental toxicity of perfluorononanoic acid in mice. Reprod Toxicol 51:133–44.
[11]Butenhoff JL, Chang S, Ehresman DJ, York RG. 2009. Evaluation of potential reproductive and developmental toxicity of potassium perfluorohexanesulfonate in Sprague Dawley rats. Reprod Toxicol 27(3–4):331–41.

in birth weight (ATSDR, 2018). Further, PFOA, PFOS, PFNA and PFHxS exposure have also been linked to reduced antibody response to vaccines in human epidemiological studies [ATSDR 2018[1]].

Cancer potential: The International Agency for Research on Cancer has classified ***PFOA*** as possibly carcinogenic to humans [IARC 2017[12]]. PFOA has been associated with testicular, prostate and kidney cancer; however, epidemiological data are inconclusive. The guideline (cancer slope factor) used to evaluate increased cancer risk for PFOA was developed based on animal data for one cancer type only (testicular). There is suggestive evidence that PFOS may be able to cause liver, thyroid and mammary cancers [ATSDR 2018[1]]. At this time, ***PFOS, PFNA and PFHxS*** are not classified as human carcinogens. However, information is very limited.

[12][IARC] International Agency for Research on Cancer 2017. IARC Monographs on the identification of carcinogenic hazards to humans. Volume 110. Lyon France [updated 2020 March; accessed 2020 May]. Available from: https://monographs.iarc.fr/list-of-classifications/.

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS (per- and poly-fluoroalkyl substances) are a group of man-made chemicals found in air, soil, ground and surface water, and in people around the world. Studies about health effects of PFAS exposure in humans and animals have not reached clear conclusions. However, results do suggest that certain PFAS may be related to specific health problems, so researchers continue to study them.

The purpose of this factsheet is to provide an overview of frequently asked questions regarding PFAS in the environment and their possible health effects, as well as regulatory guidance and biomonitoring information. ***Note:** Questions discussed in this factsheet mainly focus on perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) as these are the most common and well-studied PFAS.*

General
PFAS Regulation and Advisories
Biomonitoring and Blood Testing
Individual Concerns

General Facts

What are PFAS?

PFAS do not occur naturally in the environment. They are manufactured chemicals and have been used in:

- Surface protection of non-stick cookware.
- Stain resistant carpets and fabrics.
- Waterproof mattresses and clothing.
- Grease-resistant food packaging.
- Some firefighting materials.
- Photo imaging, metal plating, printers, and copy machines.

The most common and well-studied PFAS are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Information needed for investigating PFAS such as toxicity values, screening levels and lifetime health advisory levels (HAL) as provided by the U.S. Environmental Protection Agency (EPA) are only available for these two compounds.

Why are PFAS a concern?

PFAS are widespread and global. Once released, they are very persistent in the environment and the human body. They can be found in:

- Air
- Soil
- Water (ground and surface water)
- Blood
- Urine
- Breast milk
- Umbilical cord blood

How can I be exposed to PFAS?

The main way you can be exposed to PFAS is by swallowing them when you:

- Drink contaminated water.
- Eat fish caught from waters contaminated with PFAS.
- Eat food packed in PFAS-containing material (e.g., popcorn bags).
- Transfer them hand to mouth from surfaces treated with PFAS, such as carpets.

If you work with PFAS you can also be exposed to them by breathing them in or through skin contact. The uptake of PFAS through skin contact is slow and not considered significant.

For infants and toddlers, hand-to-mouth is considered the most significant source of exposure.

How long do PFAS remain in the body?

On average, PFAS can remain in the body between two and nine years.

How can PFAS potentially affect health?

- Effects on health from exposure to low levels of PFAS are not well known. Studies in humans and animals are inconclusive but suggest that certain PFAS may cause health effects.

- Non-cancer effects appear more common and include:
  - Increased cholesterol levels
  - Impacts on human hormones
  - Impacts on human immune system
  - Fetal and infant developmental effects

Can PFAS cause cancer?

- The U.S. Environmental Protection Agency (EPA) has determined there is **some** evidence that PFAS can cause cancer.

- The International Agency for Research on Cancer has classified PFOA as **possibly** cancer causing, although, there is currently no consistent scientific evidence that PFOS and PFOA cause cancer in humans.

- Some animal studies have suggested a higher risk of certain cancers, such as prostate, kidney, or testicular cancer. Humans and animals often react differently to chemicals (including PFAS) and not all the effects seen in animal tests may occur in humans.

- Some increases in kidney, prostate, and testicular cancers have been seen in individuals exposed to higher PFAS levels, mostly in occupational exposures. Most of these exposures were in people who worked in, or lived near, PFAS manufacturing facilities.

How certain are the studies that showed health risks?

- Correlations between exposure to PFAS and health effects have been inconsistent.

- More research is needed to fully understand any health effects in humans.

- Animals (mostly rats and mice) exposed to much higher levels than most people showed several health problems, such as liver damage, developmental and reproductive effects, and changes in hormone levels.

- Some human studies have found increases in prostate, kidney, and testicular cancers in workers exposed to PFAS and people living near facilities producing PFAS. However, other studies did not report a link between cancer and PFAS.

- Studies should be interpreted carefully, since the effects were not consistent across studies, there were contradictory findings among studies, and exposure levels were much higher than seen in the general population.

PFAS Regulation and Advisories

What levels of PFAS in water are considered harmful?

- The EPA has developed a lifetime drinking water health advisory level (HAL) for PFOA and/ or PFOS of 70 ng/L. The level is equal to the amount of a shot glass (1.5 oz) in approximately 150 million gallons of water. Drinking water at or below this standard for a lifetime is not expected to harm your health.

- If testing shows that your drinking water contains PFOA and/ or PFOS above the EPA HAL, use other water sources for drinking, preparing food, cooking, brushing teeth, and other uses when you might swallow water. Because the HAL is based upon long-term exposure, a short-term increase above the HAL should not increase risk significantly.

Biomonitoring and Blood Testing

Can a test determine whether I have been exposed to PFAS?

PFAS can be measured in blood, serum, and urine. However, doctors do not conduct this test to make a diagnosis or decide on treatment.

When is testing of PFAS useful and what can the results tell me?

- Testing for PFAS can be useful when they are part of a scientific investigation or a health study to determine how often and at what levels the chemical is found in the population. One such study is the National Health and Nutrition Examination Survey.

- Blood tests can be helpful when researching health effects from PFAS among persons who have been exposed to very high concentrations of the chemical, such as workers in industries where PFAS was used.

- Results of biomonitoring can compare the PFAS results from individuals tested with national averages established through these types of studies.

What can the results from blood testing for PFAS NOT tell me?

Most people in the United States (U.S.) will have measurable amounts of PFAS in their blood. We do not know how this impacts our health. These blood tests ***will not***:

- Provide information to pinpoint whether PFAS caused a particular health problem or to decide on treatment.

- Predict or rule-out the development of future health problems related to a PFAS exposure.

- Identify how or where the PFAS exposure occurred.

What is currently known about PFAS blood levels in U.S. population?

- The National Report on Human Exposure to Environmental Chemicals Report has reported that serum levels of PFAS appear to be higher in the U.S. than in some other countries.

- For the average American the PFAS level is 2,100 and 6,300 ng/L per liter of blood, respectively. The level is equal to the amount of 30 to 90 shot glasses (1.5 oz), respectively, in approximately 150 million gallons of water. These levels have been shown to be higher if a person's drinking

water source is contaminated with PFAS or if a person is exposed at a workplace that produces the PFAS product. More information can be found at: https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf or at: https://www.pehsu.net/.

Individual Concerns

If my drinking water is above the PFAS HAL, should my pets drink it?

No. Pets should be given the same drinking water you drink. As with humans, if the drinking water contains PFAS contaminant levels above the EPA HAL, use alternative water sources.

I drank water that exceeded the HAL for PFAS while I was pregnant and lactating. What impact could it have on my child?

- We do not have data to assess past risks to you and your family.
- Exposure to PFAS from drinking water with concentrations above the HAL may affect children's developmental health, including impaired growth, learning, and behavior.
- Studies in humans and animals are inconclusive and further, intense research is needed to know for sure about possible health effects related to duration and frequency of exposure.

We have tried to get pregnant for a long time without success. Could it be due to drinking water levels above the HAL for PFAS?

Infertility can be caused by many factors, both natural and chemical. At this time, we don't know if exposure to PFAS in drinking water above the HAL can affect infertility.

If PFAS have been found in my soil and water, should I be concerned?

While garden fruits and vegetables should be considered when evaluating the risk to exposure of PFAS, no data are currently available for Florida to evaluate possible risks. However, the Florida Department of Health would consider evaluation when data become available.

Can I water my lawn with water containing PFAS?

- Watering a lawn with non-edible plants and grass poses little risk.
- PFAS (PFOA and PFOS) are not absorbed effectively through the skin, nor is inhalation of vapors from water with PFAS likely to cause health problems.
- Remember that some well water specifically used for lawn maintenance only is usually not to be used for drinking purposes. For this chemical, drinking is a main route of exposure.

Can I use reuse water for watering my home produce?

No. Reuse water should never be used for home-grown produce due to the concern for human microbial pathogens. Reuse water should also not be used for drinking.

Can I swim in my pool if it is contaminated with PFAS?

Skin contact with and breathing PFAS (PFOA and PFOS) are minor concerns because these exposures are either uncommon or very low. You can drain and replace pool water with clean water from a different source. However, if you are careful to avoid swallowing pool water which is always a good practice, the risk of exposure to PFAS from swimming should be very low.

References:

Agency for Toxic Substances and Disease Registry (ATSDR) (2018). Toxicological Profile for Perfluoroalkyls. Draft for Public Comments. https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

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United States Environental Protection Agency (2019). Drinking Water Health Advisories for PFOA and PFOS. https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

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