HEALTH CONSULTATION

INITIAL – PUBLIC COMMENT RELEASE

Florida State Fire College

Per- and Polyfluoroalkyl Substances (PFAS)

Report 2

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

11661 NW Gainesville Road
Ocala, Florida 34482

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

March 15, 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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If you have questions or comments about this report, we encourage you to contact us.

Please write to: Division of Disease Control and Health Protection
Bureau of Environmental Health, Public Health Toxicology
Florida Department Health
4052 Bald Cypress Way, Bin # A-08
Tallahassee, FL 32399
phtoxicology@flhealth.gov

Or call us at: Toll free at 877-798-2772

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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 the Lhoist Mine Site in Marion County, Florida. This assessment was prompted by findings of PFAS in groundwater and soil at the adjacent Florida State Fire College (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 implications 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 1940s. 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 preeclampsia (pregnancy-induced hypertension). 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.

The Lhoist Mine Site is located at 11661 NW Gainesville Road, Ocala, Marion County, Florida. Two businesses operate on the site; The Lhoist Mine by Lhoist North America of Tennessee, Inc., (***Lhoist Inc.***) and the CCC Transportation, LLC (***CCC***). Each business

[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.

uses its own supply well. Both well waters were tested for PFAS in 2018. The water samples contained combined PFOA and PFOS concentrations of 12,380 ng/L and 127 ng/L for Lhoist Inc. and CCC, respectively. Both concentrations exceed EPA's lifetime HAL.

This assessment evaluates the possible health risks of workers associated with exposure to PFOA, PFOS, PFNA and PFHxS via drinking water at Lhoist Inc. and CCC. FDOH used provisional health guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR) in the assessment.

Based on review of available environmental data and ATSDR health guidelines for PFOA, PFOS, PFNA and PFHxS, FDOH reached the following conclusions for human exposure to PFAS at Lhoist Inc. and CCC:

Human exposure to PFAS at Lhoist Inc. via drinking water

Conclusion # 1:

Workers, who drank water at Lhoist daily for two weeks or longer with 2018/2019 levels of ***PFOA, PFOS*** and ***PFHxS*** (380, 12,000 and 6,200 ng/L, respectively) may be at increased risk of harmful non-cancer health effects. Immune effects are of most concern, followed by developmental and thyroid effects.

Basis for Conclusion #1

The estimated exposures for two weeks or longer (*intermediate and chronic durations*) to PFOA, PFOS and PFHxS exceed ATSDR's provisional health guidelines for intermediate exposure. This assessment considered all workers, including those who planned to become pregnant, as well as pregnant and lactating women. The estimated exposures for PFOA are close to levels predicted to cause developmental effects. The estimated exposures for PFOS are close to levels predicted to cause immune and developmental effects in humans. The estimated exposures for PFHxS are close to levels predicted to cause thyroid effects. PFAS exposure has also been associated with other health effects, including effects to liver, serum cholesterol and reproduction, as well as, preeclampsia although findings are inconsistent.

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

Fetuses, breastfeeding infants and future children of workers, who drank water at Lhoist Inc. during 2018/2019, could be at risk of developmental effects.

Conclusion # 2:

Levels of ***PFNA*** (24 ng/L) in water during 2018/2019 at Lhoist Inc. is not expected to increase risk of harmful non-cancer health effects in ***workers***, who drank the water daily for two weeks or longer. However, PFNA could have contributed to the overall PFAS exposure.

Basis for Conclusion #2

The estimated exposures for ***PFNA*** are below ATSDR's provisional health guideline for intermediate exposure.

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, PFAS, PFNA and PFHxS have similar toxic actions, it is possible, but uncertain, that the combined risk of all PFAS found at Lhoist Inc. could be higher than the risk found for each individual compound. For Lhoist Inc., PFOS is the predominant contaminant and the individual contributions of PFOA, PFNA, PFHxS and other PFAS are low in comparison.

Conclusion # 3:

Some health risk evaluations for drinking water at Lhoist are limited.

a. Exposure before 2018/2019 cannot be evaluated.
b. Exposure after 2018/2019 is unlikely to occur.
c. Cancer risk for ***workers*** who drank water daily for one year or longer with PFAS levels found during 2018/2019 is uncertain.

Basis for Conclusion #3a+b

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

Future exposure (after 2018/2019) to PFAS via drinking water at Lhoist Inc. is unlikely. Bottled water was immediately provided at Lhoist Inc. In August 2019, FDEP installed a granular activated carbon (GAC) filter on the well supplying water to Lhoist Inc. FDOH and FDEP remain in active communication with Lhoist Inc. to ensure that workers remain informed. FDEP will continue to supply bottled water for drinking until the agency approves a long-term solution for clean drinking water.

Note: The most current, preliminary results indicate that the GAC filter is efficiently removing PFAS from the water.

Basis for Conclusion #3c

Levels of ***PFOA*** found in 2018/2019 in drinking water at Lhoist Inc. are below levels expected to increase risk of cancer in ***workers,*** who drank the water for one year or longer.

The estimated increased cancer risk for workers exposed to PFOA via drinking is less than one in a million, which in general, is 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 in general.

Next Steps:

FDEP is working on a long-term solution for clean water at Lhoist Inc. A GAC filter has been installed on the well that supplies water to Lhoist Inc. for drinking, showering and other activities. FDEP will continue to supply bottled water for drinking, until FDEP approves the GAC filter as a long-term solution.

Until the long-term solution has been approved, it is recommended that workers continue to use the bottled water supplied to Lhoist, Inc for drinking. Based on ATSDR's recommendations for PFAS, FDOH recommends that bottled water is used for drinking.

FDOH recommends that visiting children are kept under supervision and prevented from consuming PFAS-contaminated water at Lhoist Inc., until the long-term solution has been approved. PFAS exposure has been associated with developmental effects such as reduced birth weight, childhood obesity and small developmental delays.

FDOH recommends periodic monitoring of the GAC filter (via well and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated tap water at Lhoist Inc. FDOH and FDEP remain in active communication with Lhoist Inc. to ensure that workers remain informed.

Human exposure to PFAS at Lhoist Inc. via showering

Conclusion # 4:

Workers, who showered daily for two weeks or longer at Lhoist Inc. with water containing levels of ***PFAS*** found in 2018/2019 are not likely to experience health effects due to PFAS exposure via showering. While showering exposure alone is not expected to have increased risk of non-cancer health effects, it could have contributed to overall PFAS exposure at the site.

Basis for Conclusion #4

The estimated exposures for ***PFOA and PFOS*** levels found in 2018/2019 are below ATSDR's provisional health guidelines for intermediate exposure.

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

Dermal and inhalation exposure via showering are generally considered minor pathways for PFAS; however, because these exposures contribute to overall exposure, they may increase the total risk from all exposure routes and all PFAS.

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 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 Lhoist Inc. could be higher than the risk found for each individual compound. For Lhoist Inc. PFOS is the predominant contaminant and the individual contributions of PFOA, PFNA, PFHxS and other PFAS are low compared to PFOS

Conclusion # 5:

Some health risk evaluations for showering at Lhoist Inc. are limited.

a. Exposure before 2018/2019 cannot be evaluated.
b. Exposure after 2018/2019 is unlikely to occur.
c. Cancer risk for ***workers*** who showered at Lhoist Inc. daily for one year or longer with PFAS levels found in 2018/2019 is uncertain.

Basis for Conclusion #5a+b

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

Future exposure (after 2018/2019) to PFAS via showering at Lhoist Inc. is unlikely. In August 2019, FDEP installed a GAC filter on the well supplying water to Lhoist Inc. FDOH and FDEP remain in active communication with Lhoist Inc. to ensure that workers remain informed.

Note: The most current, preliminary results indicate that the GAC filter is efficiently removing PFAS from the water.

Basis for Conclusion #5c

Levels of ***PFOA*** in well water found in at Lhoist Inc. are below levels expected to increase risk of cancer in ***workers***, who showered with the water for one year or longer.

The estimated increased cancer risk for workers exposed to PFOA via showering is less than one in a million, which in general, is 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:

FDEP is working on a long-term solution for clean water at Lhoist Inc. A GAC filter has been installed on the well that supplies water to Lhoist Inc. for drinking and showering. FDEP will continue to supply bottled water for drinking, until FDEP approves the GAC filter as a long-term solution.

Until a long-term solution has been approved, it is recommended that workers continue to use the bottled water supplied to Lhoist, Inc for drinking. Based on ATSDR's recommendations for PFAS, FDOH recommends that bottled water is used for drinking.

FDOH recommends that visiting children are kept under supervision and prevented from consuming PFAS-contaminated water at Lhoist Inc., until a long-term solution has been approved. PFAS exposure has been associated with developmental effects such as reduced birth weight, childhood obesity and small developmental delays.

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 tap water at Lhoist Inc. FDOH and FDEP remain in active communication with Lhoist Inc. to ensure that workers remain informed.

Human exposure to PFAS at CCC via drinking water

Conclusion # 6:

The drinking water taps inside the CCC building were not accessible to ***workers*** during 2018/2019 and therefore did not pose a risk of exposure to PFAS.

Basis for Conclusion #6

The building at CCC was not occupied during 2018/2019. Therefore, ***CCC workers*** could not access and drink water from this building during 2018/2019. Human exposure can only occur if contact with the contamination is possible. Therefore, CCC workers are not at increased risk of harmful non-cancer or cancer health effects via drinking of water from CCC.

Conclusion # 7:

Evaluation of probable health outcomes due to PFAS exposure via drinking water at ***CCC before and after 2018/2019*** cannot be assessed due to lack of data.

Basis for Conclusion #7

Exposure before and after 2018/2019 cannot be evaluated. No data exist for PFAS in well water at CCC before 2018/2019. Future PFAS water levels cannot be predicted. Without data, FDOH is not able to evaluate the likelihood of harmful health effects to former and future workers, who may have been or may be exposed to PFAS in drinking water at CCC before and after 2018/2019.

Next Steps:

It is recommended that CCC workers do not commence use of the drinking water at CCC without prior testing and health risk assessment.

Human exposure to PFAS in surface water (dermal and incidental ingestion) and fish (consumption) at the Lhoist Mine Site

Conclusion # 8:

Possible health risks for workers and potential trespassers potentially exposed to PFAS via swimming and/or consumption of fish in the quarry lakes before, during and after 2018/2019 are uncertain.

Basis for Conclusion #8

It is unknown if the quarry lakes were or are contaminated with PFAS. Without data, it is not possible to evaluate risk of health outcomes for ***workers and potential trespassers*** potentially exposed to PFAS via swimming and/or consumption of fish in the quarry lakes ***before, during and after 2018/2019***. It is unknown if trespassing occurs at the site, however it is known that some Lhoist Inc. workers have been using the quarry lakes for recreational purposes.

Next Steps:

Out of precaution, it is recommended that workers, visitors and trespassers do not use the quarry lakes for swimming, fishing or other recreational purposes prior to testing and health risk assessment.

FDOH further recommends sampling of quarry lake surface water for PFAS testing. If PFAS are detected in either of the quarry lakes, further fish sampling and testing, as well as a health risk assessment, may be warranted.

Additional Conclusions

Conclusion # 9:
The risk of health effects to ***visitors*** of Lhoist Inc. workers cannot be evaluated.

Basis for Conclusion #9

For this health assessment, there is too much uncertainty in the frequency and duration of possible visits to perform a correct assessment that would not under- or overestimate potential risk.

Conclusion # 10:
The risk of ***breastfeeding*** cannot be assessed. Possible health effects associated with PFAS exposure via breastfeeding cannot be evaluated.

Basis for Conclusion #10

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

Conclusion # 11:
The possible risk of health effects due to ***acute, short-term exposure*** of less than two weeks to PFOA, PFOS, PFNA and PFHxS cannot be evaluated.

Basis for Conclusion #11

No health guidelines are available to evaluate acute exposure to PFAS.

Next Steps:

It is recommended that visiting children are kept under supervision to prevent exposure to contaminated drinking water and access to the quarry lakes.

It is recommended that workers, visitors and trespassers, who were/are/will be present at the Lhoist Mine Site for less than two weeks follow the recommendations made for longer term exposure over two weeks. It is unknown when health guidelines for short-term exposure may become available.

A decision to breastfeed is an individual choice, which involves many considerations in addition to chemical contamination. Women with concerns about the findings at the Lhoist Mine Site may find it helpful to discuss breastfeeding with their health care provider. Guidance for health care professionals regarding PFAS can be found here:

https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf

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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 when groundwater contamination occurred, when the contamination reached groundwater concentrations found in 2018/2019, or how contaminant concentrations in groundwater varied over time. FDOH health assessors also do not know exactly how much water each individual drinks, or how much soil each person is exposed to 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).

People at the Lhoist Mine Site are exposed to a PFAS mixture as well as several different exposure routes including those from consumer products. The current tools available to perform risk estimation for PFAS do not allow assessment of risk caused by multiple PFAS compounds and routes of exposure. Therefore, risk is estimated separately for each PFAS compound (*i.e.*, PFOA, PFOS, PFNA or PFHxS) and route (e.g., drinking water). 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 chemicals at the Lhoist Mine Site.

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 results 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 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 lifestyle.

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 regarding the Lhoist Mine Site 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
CCC	Commercial Carrier Corporation
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 Dose
Inc.	Incorporated
LLC	Limited liability company
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) 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 1940s [ITRC 2020a]. 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]. People who come in contact with PFAS-contaminated air, soil, water, plants, animals, food and indoor dust can be exposed to PFAS. In fact, PFAS are so common that most people are exposed to some level of PFAS in their daily lives, and most of the U.S. population are expected to have measurable PFAS levels in their bodies [ATSDR 2017].

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 Lhoist Mine Site is the second 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 1 mile of the Florida State Fire College.

The ***Lhoist Mine Site*** hosts two businesses - the Lhoist Mine by Lhoist North America of Tennessee, Inc., (***Lhoist Inc.***) and the CCC Transportation, LLC (***CCC***). Each business obtains drinking water from separate supply wells. Both wells were tested for PFAS in 2018. The water samples contained combined PFOA and PFOS concentrations of 12,380 ng/L and 127 ng/L for Lhoist Inc. and CCC, respectively. Both concentrations exceed EPA's lifetime HAL[1].

The current health consultation evaluated the possible health implications of PFAS contamination for workers at the Lhoist Mine Site, i.e., workers at Lhoist Inc. and CCC. FDOH reviewed the following items specifically for the Lhoist Mine Site:

- available environmental data for PFAS,
- possible PFAS exposure pathways[2] and
- the possibility of increased cancer and non-cancer health risks associated with PFAS exposure.

This assessment considered four PFAS 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] An exposure pathway (or route) describes the way by which people can come in contact with a chemical (e.g., ingestion of water). This includes the path a chemical moves from where it was released to the point of human contact (e.g., disposal → groundwater → water tap). FDOH considers the possible pathways at the Lhoist Mine Site for three timeframes: before 2018/2019, 2018/2019 and after 2018/2019.

2. BACKGROUND

2.1 Site Description

The Lhoist Mine Site encompasses an area of about 600 acres at 11661 NW Gainesville Road in Ocala, Marion County, Florida (Figure 1). The parcel borders the FSFC to the west, the Florida Department of Correction to the southwest and private residences to the north and east.

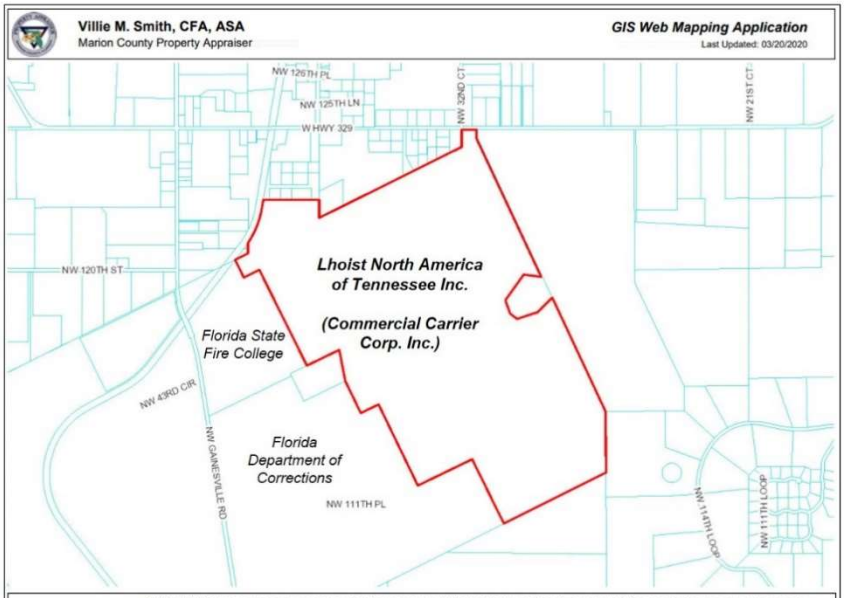

Figure 1: Lhoist Mine Site (red border). [GIS Web Mapping Application; Marion County Property Appraiser, 2020].

Two businesses operate on the site including Lhoist North America of Tennessee Inc. (***Lhoist Inc.***) and the CCC Transportation, LLC (***CCC***).

The site comprises eleven buildings, gravel roads and mine operation areas, as well as one small and one large quarry lake[3] (Figure 2). The small lake is a former quarry lake, no longer used by the mine, while the large lake is the current quarry lake and is utilized for mine activities. Lhoist Inc. employs 32 staff on the site. CCC has an unoccupied office building on the site. At present, CCC only uses the site to park their trucks.

Each business utilizes its own supply well as drinking water supply (Figure 2). Lhoist Inc. uses the water for showering and drinking water purposes. The CCC supply water is not currently in use because the office building is closed.

2.2 Site History

In 2011, Lhoist moved to its current location.

In early August 2018, FDEP confirmed storage and previous use of PFAS-based AFFF at the FSFC, which is located adjacent to the Lhoist Mine Site. (Figure 1 and 2). 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.

[3] Quarry lake: A lake formed after a quarry has been dug through a mining operation.

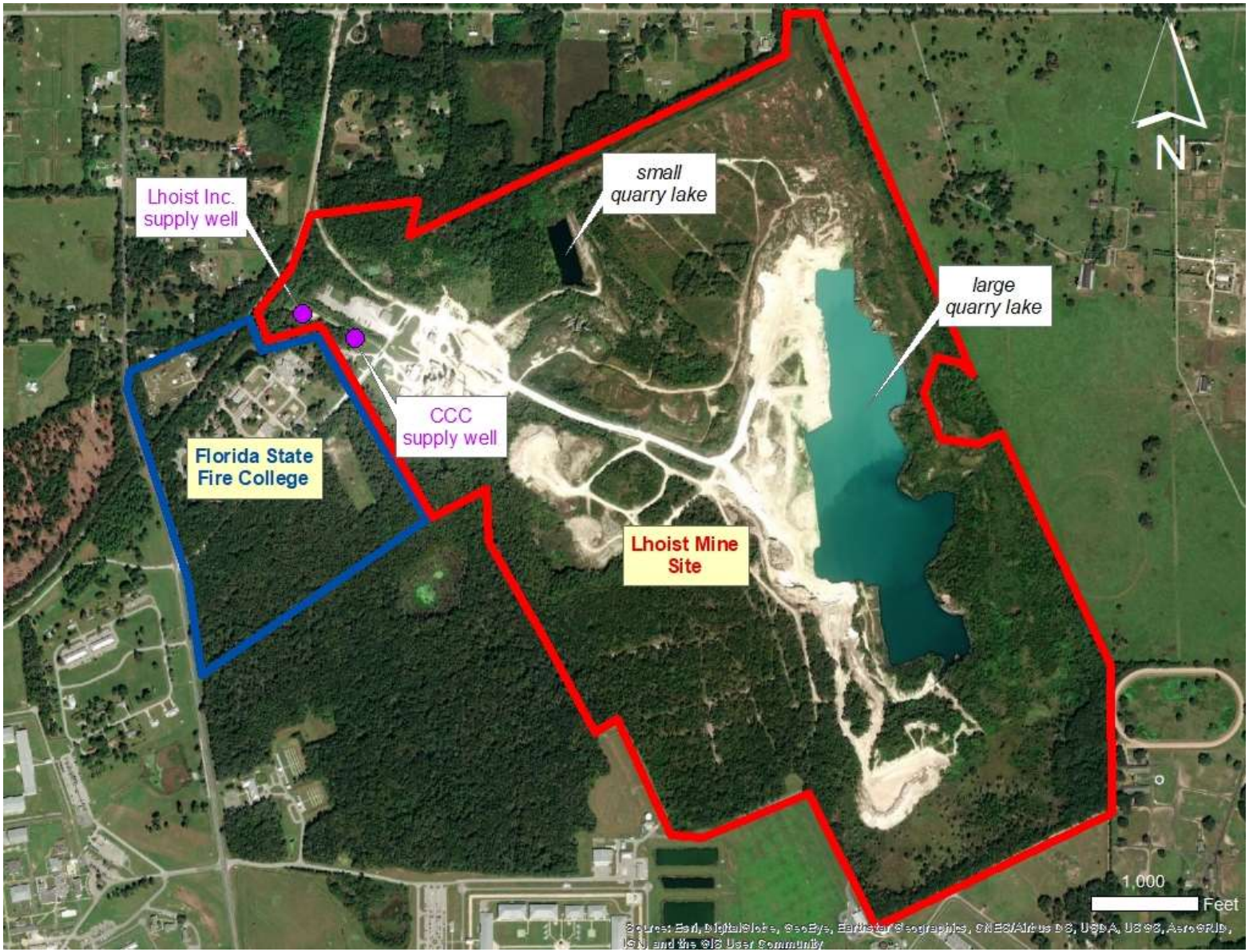

Figure 2: Lhoist Mine Site, Marion County, Florida.

Therefore, in October and November 2018, FDEP sampled and tested the Lhoist Inc., as well as the CCC supply well (Figure 2). Both wells had combined PFOA and PFOS above the EPA lifetime HAL[1].

Since October 2018, FDOH, in collaboration with FDEP and local county health departments (CHDs), has been testing private wells in a 1-mile radius of the FSFC. In June 2019, FDEP installed monitoring wells in the area. Well testing is currently ongoing. FDEP is also conducting ongoing soil testing to determine the extent of soil contamination at the FSFC. All properties including private residences with impacted wells have been supplied with clean bottled water or a filter to clean water for drinking, cooking and brushing teeth.

FDEP installed filters at the Lhoist Inc. wells in August 2019. The filter is being monitored to test its efficiency in removing PFAS. Preliminary results indicate that the filters are efficiently reducing PFAS, including PFOA and PFOS to below EPA's lifetime HAL.

3. DISCUSSION

3.1 Evaluation Process

Human health risk assessments are conducted for contaminated sites to evaluate and characterize the risk posed to human health by the chemical contaminant(s) detected at the site. 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 drinking 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 and 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] referred to as **comparison values (CVs)**. If a chemical concentration for a site exceeds the chemical's screening level, the chemical is of potential concern and must be evaluated further to assess possible health risk.

B. Health Effects Assessment

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

The likelihood of health effect caused by the chemical of concern depends on how exposure occurs (intended and incidental ingestion, 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 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 mainly a concern for human health when people can come in contact with the chemical. Without human contact, the chemical cannot enter the body

[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 concern and needs further evaluation.

[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.

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 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 Lhoist Mine Site:

- 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 the Lhoist Mine Site

The FDOH health assessors identified all pathways by which people at the Lhoist Mine Site could have been, could be or could become exposed to PFAS contamination:

	ELEMENT	***Lhoist Mine Site***
✓	the ***source*** of chemical contamination	historical use and storage of AFFF at the adjacent fire college
✓	the ***environmental element*** to hold or transport the chemical(s)	groundwater, surface water (quarry lakes), fish (quarry lakes)
✓	the ***exposure point*** where people can come in contact with the chemical(s)	drinking water and showering taps, quarry lakes, fish consumption
✓	the ***exposure route*** by which the chemical(s) can enter the body	Ingestion (intended and incidental), dermal (skin) contact, inhalation
✓	the ***exposed population/community***	workers, visitors, trespassers

PFAS contamination at the Lhoist Mine Site most likely originates from past use and storage of PFAS-based AFFF at the FSFC [***source***]. PFAS-based AFFF 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 properties including the Lhoist Mine Site. It is currently unknown if the quarry lakes (surface water) at the Lhoist Mine Site have been contaminated.

Completed Pathways

Workers **[*exposed population*]** at the Lhoist Mine Site could be exposed to PFAS-contaminated groundwater via the supply wells. PFAS exposure via indoor water taps **[*exposure point groundwater*]** includes ingestion via drinking as well as inhalation and dermal contact via showering **[*exposure routes water*]**.

Ingestion of PFAS-contaminated drinking water is likely the main exposure route for PFAS exposure at Lhoist.

PFAS are not easily absorbed over the skin and do not vaporize easily [ATSDR 2018b]. 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 workers.

Potential Pathways

If one or more elements were uncertain, a pathway was identified as a ***potential pathway*** at Lhoist:

- ✓ pre 2018/2019 exposure to contaminated drinking and showering water at Lhoist Inc. – workers
  - ➔ Exposure to PFAS-contaminated water via drinking and showering may have occurred at Lhoist Inc. before 2018/2019, but this time frame lacks environmental data.

- ✓ exposure to contaminated drinking water at Lhoist Inc. – visitors
  - ➔ FDOH considered that visitors of Lhoist Inc. workers could have been exposed to PFAS if they drank water from there during visits. Exposure data are however limited for this pathway to evaluate if visitors drink the water, and, how often and for how long visitors visit.

- ✓ pre and post 2018/2019 exposure to contaminated drinking water at CCC – workers

- ➔ Exposure to PFAS-contaminated drinking water at CCC may have occurred before 2018/2019, but this time frame lacks data.
- ➔ Exposure to PFAS-contaminated drinking water at CCC could occur in the future, if the water supply (well water) is not cleaned up before going to or from the indoor tap, and if workers begin to drink the water. It is however not possible to predict future PFAS levels in the water of the supply well.

- ✓ exposure to contaminated surface water and fish (Lhoist Mine Site quarry lakes) – workers
  - ➔ It is currently unknown if the quarry lakes have been contaminated with PFAS. Some Lhoist workers use the lakes for fishing and recreational purposes (Lhoist Inc., personal communication, 2021).

- ✓ exposure to contaminated surface water and fish via quarry lakes – potential trespassers
  - ➔ It is currently unknown if the quarry lakes have been contaminated with PFAS and if trespassing takes place at the Lhoist Mine Site. FDOH considered trespassing a possibility, because trespassers could potentially be exposed to PFAS in quarry lakes.

Eliminated Pathways

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

- ✓ post 2018/2019 exposure to contaminated drinking water at Lhoist Inc. via drinking and showering
  - ➔ The supply of bottled water as well as the installation of a water filter at the tap water source (the supply well) will prevent future exposure to PFAS-contaminated water via drinking and showering at Lhoist Inc.

- ✓ 2018/2019 exposure to contaminated drinking water at CCC via drinking
  - ➔ The CCC drinking water taps are currently not accessible to workers, as the office is currently closed.

All exposure pathways for the Lhoist Mine Site are illustrated in Figure 3.

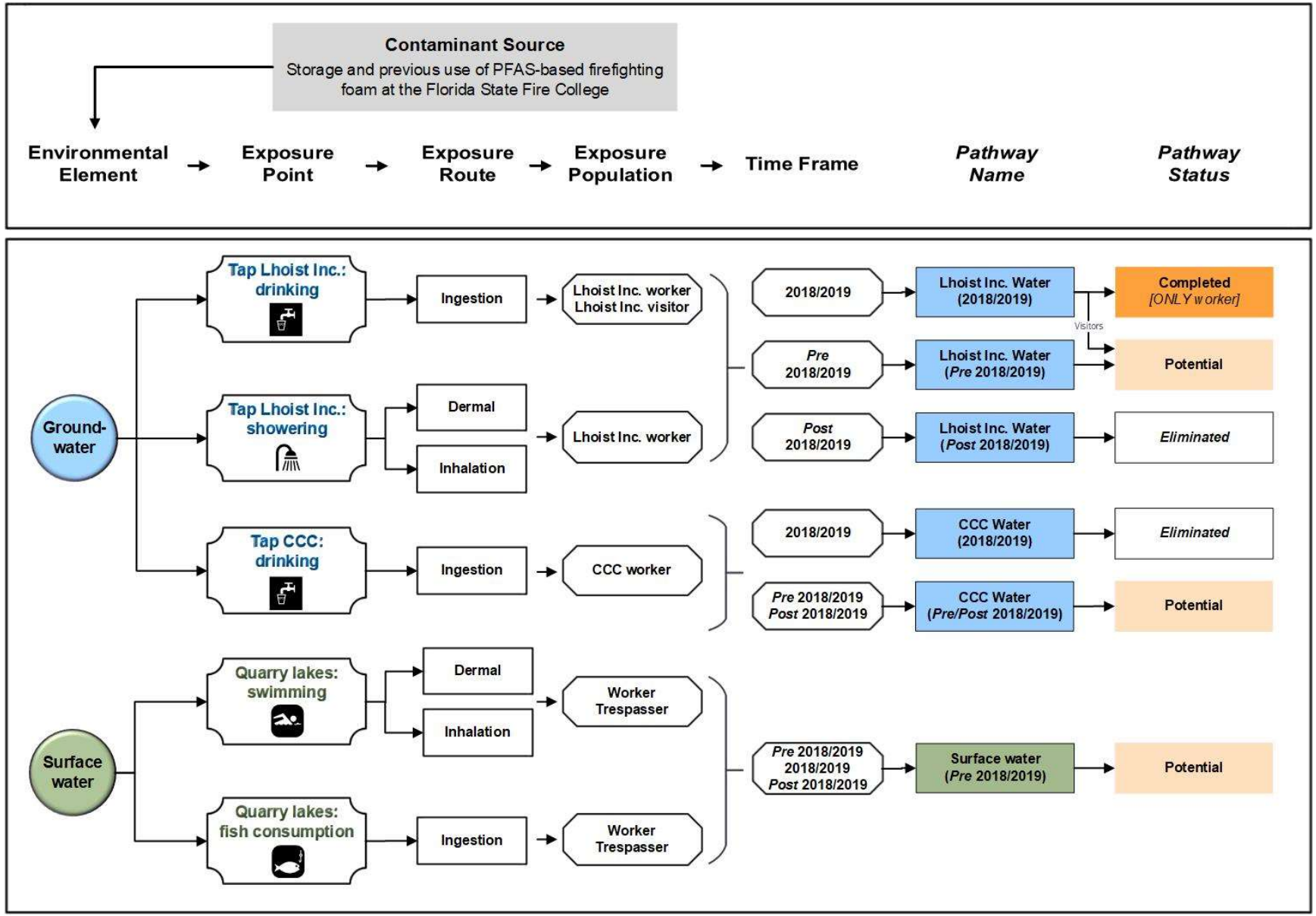

Figure 3: Overview of exposure pathways for well water at Lhoist Mine Site, Marion County.

3.3 Environmental Data Assessment

3.3.1 Environmental Data Screening

Environmental data (chemical concentrations in drinking water) were evaluated to determine the need for further evaluation of possible health risks to the Lhoist Mine Site community. PFAS concentration data for the site were screened with ATSDR's health-based comparison values (CVs)[7]. Chemicals with concentrations greater than their CVs were 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 (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 at Lhoist Inc.

In October and November 2018, FDEP collected water samples from the Lhoist Inc. supply well used to supply indoor water taps (Table 1 and Appendix B, Table B-1).

Table 1: Maximum concentration (ng/L) of PFOA, PFOS, PFNA and PFHxS in water collected from the Lhoist Inc. supply well and their respective ATSDR comparison values[7].

	Maximum Concentration (ng/L)	***ATSDR Comparison Value (ng/L)[7]***	***Above ATSDR Comparison Value?***
PFOA	380	21	**Yes**
PFOS	12,000	14	**Yes**
PFNA	24	21	**Yes**
PFHxS	6,200	140	**Yes**

The maximum water concentrations found for PFOA, PFOS, PFNA and PFHxS exceed their ATSDR CVs (Table 1). All four PFAS were selected for further evaluation in the health risk assessment (Section 3.4).

Water at CCC

In November 2018, FDEP collected water samples from the CCC supply well used to supply indoor water taps. The CCC indoor drinking water taps are currently not accessible

[7] ATSDR's environmental media evaluation guides for childhood intermediate exposure were used as they are the most protective values. These concentrations are not expected to cause harmful non-cancer health effects in humans, including sensitive populations (i.e., children).

to workers because the building is closed. Therefore, this pathway is not possible and was not further evaluated. The data are presented for information only (also see Appendix B; Table B-2). It is noted that PFOS and PFHxS maximum concentrations exceed their CVs.

Table 2: Maximum concentration (ng/L) of PFOA, PFOS, PFNA and PFHxS in water collected from the CCC supply well and their respective ATSDR comparison values[7].

	Maximum Concentration (ng/L)	***ATSDR Comparison Value (ng/L)[7]***	***Above ATSDR Comparison Value?***
PFOA	7	21	No
PFOS	120	14	**Yes**
PFNA	0.87	21	No
PFHxS	210	140	**Yes**

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.

The Lhoist Inc. supply well has been tested three times since October 2018. Concentrations of PFOA, PFOS, PFNA and PFHxS exceed their screening values at least once during this time (Table 1 above and Appendix B, Table B-1). Based on these comparison results, PFOA, PFOS, PFNA and PFHxS are all chemicals of potential concern in Lhoist Inc. drinking water.

The CCC drinking water is currently not used because the office building is closed, and the indoor water taps are not accessible to workers. This pathway of exposure can therefore be eliminated and was not further evaluated. However, PFOS and PFHxS concentrations exceed their CVs and would have been considered chemicals of potential concern if this water was used for drinking. Thus, a future assessment may be needed if people occupy the building and start using the water (Appendix B, Table B-2).

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 [ATSDR 2016]. 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-3 and B-4).

When evaluating a possible, harmful non-cancer health risk, the estimated daily exposure doses[5] are compared with ATSDR's minimal risk levels (MRLs)[8]. 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 D.

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 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 are 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 Lhoist Mine Site is site-specific. Possible health risk was evaluated for Lhoist Inc. workers, who may have been exposed to PFAS in drinking and showering water in 2018/2019 (Appendix B, Tables B-3 and B-4).

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

[8]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.

The CCC office building is currently closed and the drinking water taps are not accessible to workers.

The potential exposure of potential trespassers cannot be evaluated due to data limitations.

3.4.1 PFAS-Related 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 are 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. 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 infants drinking breastmilk. Effects could include reduced birth weight, developmental effects such as small delays in puberty, as well as, childhood obesity [Braun 2017]. Pregnant women exposed to PFAS could be more susceptible to preeclampsia (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 Lhoist Mine Site.

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 Lhoist Mine Site PFAS Health Risk Evaluation

Lhoist Inc. Workers

Health assessors estimated daily doses[5] for Lhoist Inc. workers aged 16 and older, including pregnant and lactating women, exposed to PFAS in water via drinking and showering. Doses were estimated using maximum concentrations found in October and November 2018 in the Lhoist Inc. supply well used to supply drinking water (Section 3.3.1 and Appendix B, Table B-1).

Workers were assumed to be exposed to drinking water five days per week, 50 weeks per year and for up to 30 years (Appendix B, Tables B-3 and B-4).

The health risk evaluation used a higher than average water intake rate of 3.588 liters per day (Appendix B, Tables B-3 and B-4). This intake rate is equivalent to the reasonable maximum average for lactating women [ATSDR 2016]. Workers at the mine perform strenuous outdoor work. Due to the elevated temperatures and humidity during most of the year in Florida and the physical nature of the work, it is likely that mine workers have higher drinking water intake rates than the average population. For more information see Report 1 for the FSFC:

Health risks from ***showering*** (inhalation and dermal contact) were estimated for PFOA and PFOS using a software model (Shower Model) developed by ATSDR. Showering input parameters are presented in Appendix B, Table B-4. PFNA and PFHxS are currently not included in 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).

Note: Acute effects from less than two weeks of exposure could not be assessed because no health guidelines exist for short term exposure.

Exposure to PFAS at Lhoist Inc. via drinking water

Pre 2018/2019: Data for PFAS in Lhoist drinking water do not exist before 2018. Therefore, FDOH is not able to evaluate the likelihood of harmful health effects to former workers, who may have been exposed to PFAS in Lhoist Inc. drinking water before 2018.

2018/2019: Estimated daily doses[5], minimal risk levels (MRLs)[8], non-cancer risk and increased cancer risk for exposure of two weeks or longer to ***PFOA, PFOS, PFNA and PFHxS*** are presented in Appendix C, Table C-1.

Non-cancer health risk: Estimated doses for ***PFNA*** are less than its respective, provisional MRL. Estimated doses for ***PFOA, PFOS and PFHxS*** are greater than their respective MRLs. When estimated doses are greater than MRLs, health risk is further evaluated.

Workers, including pregnant and lactating women, who drank water at Lhoist Inc. with 2018/2019 levels of ***PFOA, PFOS and PFHxS*** could be at increased risk of harmful, non-cancer health effects. ***PFNA*** levels in water at Lhoist Inc. during 2018/2019 likely do not pose a risk of non-cancer health effects via drinking but contribute to overall PFAS exposure for Lhoist Inc. workers.

FDOH health assessors evaluated the estimated ***PFOA, PFOS and PFHxS*** doses for Lhoist Inc. 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 Lhoist Inc. The estimated doses for this chemical exceed doses predicted to cause immune effects in humans (Appendix A, Section 2). Therefore, immune effects are of concern for workers who drank water at Lhoist Inc. during 2018/2019. Human epidemiological studies have found associations between PFOS exposure and decreased antibody response to some vaccines. These studies did not find an association with increased rates of vaccine-preventable diseases. Therefore, it is uncertain if the studied immune responses would lead to adverse health effects. Similar 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 of workers, who drank water at Lhoist Inc. during 2018/2019. The estimated ***PFOS*** and ***PFOA*** doses for Lhoist Inc. workers are lower, but close to doses predicted to be able to cause developmental effects in descendants of exposed parents (Appendix A, Section 2). 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 (Appendices A and D, and reviewed by ATSDR [2018b]). However, these types of effects have not been verified in human studies. The risk of developmental effects is of particular concern for Lhoist Inc. workers, who breastfed, or, were or became pregnant during this time. The doses used to evaluate risk for Lhoist Inc. workers were estimated for individuals aged 16 years and older. Animal studies have observed effects in offspring of parents exposed to some PFAS [ATSDR 2018b]. It is also known that the human fetus can be exposed to PFAS in-utero and that lactating mothers can pass PFAS onto to their infants via the breastmilk [ATSDR 2018a].

The current understanding of ***PFHxS*** toxicology is more limited than for PFOA and PFOS. The most sensitive target of PFHxS toxicity known to date is the thyroid, [ATSDR 2018b]. The estimated doses for PFHxS for Lhoist workers are of concern because they 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 in Lhoist Inc. drinking water during 2018/2019 could have increased risk of thyroid effects.

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 have a baby, 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 workers 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 Lhoist Mine, with PFOS being the main contaminant of concern.

Increased cancer health risk: Increased cancer risk is estimated to be less than one in a million for workers exposed to ***PFOA*** for one year or longer. Increased cancer risk of less than one in a million is generally 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[9]. 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.

Exposure to PFAS at Lhoist Inc. via showering

Pre 2018/2019: No PFAS data are available for water at Lhoist Inc. prior to 2018. Therefore, FDOH was not able to evaluate the likelihood of harmful health effects to former workers, who may have been exposed to PFAS in Lhoist Inc. water via showering before 2018.

2018/2019: Estimated daily doses[5] (for inhalation and dermal contact), minimal risk levels (MRLs)[8], non-cancer risk and increased cancer risk for exposure of two weeks or longer to ***PFOA and PFOS*** are presented in Appendix C, Table C-2.

Non-cancer health risk: Estimated daily exposure doses for ***PFOA*** and ***PFOS*** via showering are less than their respective MRLs[8]. When doses are less than MRL, the risk of experiencing non-cancer health effects is considered unlikely. 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).

Workers, including pregnant and lactating women, who showered at Lhoist Inc. with 2018/2019 levels of ***PFOA*** and ***PFOS*** are not likely to experience non-cancer illnesses from PFOA and PFOS exposure via showering alone.

FDOH health assessors acknowledge that workers 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 Lhoist Inc. workers. Due to the limited

[9] Carcinogen - A chemical that can cause cancer.

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 Lhoist Inc., with PFOS being the main contaminant of concern.

Increased cancer health risk: Increased cancer risk is estimated to be less than one in a million for workers exposed to ***PFOA*** for one year or longer. Increased cancer risk of one in a million is generally 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.

FDOH health assessors acknowledges that workers 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 Lhoist workers. 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 Lhoist Inc., with PFOS being the main contaminant of concern.

CCC Workers

The office building at CCC is and was closed during 2018/2019. Therefore, CCC drinking water was not accessible to workers, who consequently could not have been exposed to PFAS in this water during 2018/2019. Potential exposure before and after 2018/2019 are discussed below.

Exposure to PFAS via drinking water at CCC

Pre 2018/2019: No PFAS data are available for water at CCC prior to 2018 and it is unknown when or if this water was used for drinking. Therefore, FDOH was not able to evaluate the likelihood of harmful health effects to former workers, who may have been exposed to PFAS in CCC drinking water before 2018.

Post 2018/2019: It is unknown if and how PFAS levels will change over time. Therefore, future PFAS concentrations in CCC drinking water cannot be predicted. Without data, FDOH is unable to evaluate the likelihood of harmful health effects to workers, who may drink water at the CCC in the future.

The CCC supply well is currently not used for drinking purposes. This pathway of exposure is therefore eliminated (not possible). However, PFOS and PFHxS concentrations exceed their CVs and would have been considered chemicals of potential

concern if this water was used for drinking. Thus, a future assessment may be needed if people open the office building and start using the water.

Lhoist Mine Site Quarry Lakes: Exposure to PFAS via Surface Water and Fish

The quarry lake water has not been tested for PFAS at the time of assessment. It is known that some Lhoist Inc. workers use the lakes for fishing and other recreational purposes. However, as no environmental data are available, FDOH was unable to evaluate the likelihood of harmful health effects to workers, who may get exposed to PFAS via surface water and fish in the lakes at the Lhoist Mine Site.

Lhoist Inc. Visitors

Lhoist Inc. workers may have visitors, who spend short periods of time at the site during drop off and pick up. Visitors may have been exposed to PFAS if they drank water from there during visits in 2018/2019. 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 Lhoist Inc., it is recommended that visitors read and follow the conclusions made for full-time workers.

Potential Trespassers

It is unknown if people trespass at the Lhoist Mine Site. Potential trespassers are unlikely to access drinking water taps at the site; however, they may use the quarry lakes for fishing and other recreational purposes. The quarry lake water has not been tested for PFAS at the time of assessment. Without data, FDOH was unable to evaluate the likelihood of harmful health effects to trespassers, who may get exposed to PFAS via surface water and fish in the lakes at the Lhoist Mine Site.

Breastfeeding Women

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.

A decision to breastfeed is an individual choice, which involves many considerations in addition to chemical contamination. Women with concerns about findings at the Lhoist Mine Site may find it helpful to discuss breastfeeding with their health care provider. Guidance for health care professionals regarding PFAS can be found here [ATSDR 2019]:
https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf

4. CONCLUSIONS

Based on the available environmental data and federal guidelines for PFOA, PFOS, PFNA and PFHxS, FDOH health assessors made the following conclusions for the Lhoist Mine Site:

Exposure to PFAS in water at Lhoist Inc. via drinking and showering

- ✓ Workers, including those who planned to become pregnant, as well as pregnant and lactating women, who drank water at Lhoist Inc. daily for two weeks or more with 2018/2019 levels of PFOA, PFOS and PFHxS (380, 12,000 and 6,200 ng/L, respectively) may be at increased risk of harmful, non-cancer health effects. Immune effects are of most concern followed by developmental and thyroid effects.
- ✓ The 2018/2019 PFNA level (24 ng/L) in water at Lhoist Inc., alone, is not expected to increase risk of harmful non-cancer health effects in workers, who drank the water daily for two weeks or longer. However, PFNA may contributed to the overall PFAS exposure.
- ✓ Lhoist Inc. workers, who showered at Lhoist daily for two weeks or longer in water 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 alone.
- ✓ Conclusions regarding increased cancer risk due to exposure to 2018/2019 PFAS levels in water at Lhoist Inc. via drinking and/or showering are uncertain.
- ✓ Probable risks of adverse health outcomes due to PFAS exposure via drinking and showering at Lhoist Inc. before 2018/2019 cannot be assessed.
- ✓ PFAS exposure via drinking water and showering at Lhoist after 2018/2019 is unlikely because bottled water is being provided for drinking and a filter has been installed to clean the water before it goes to or from the indoor taps.

Exposure to PFAS in water at CCC via drinking

- ✓ The CCC indoor drinking water tap is not accessible to workers and therefore does not pose a risk of PFAS exposure.
- ✓ Probable risk of adverse health outcomes due to PFAS exposure via drinking water at CCC before and after 2018/2019 cannot be assessed due to lack of data.

Exposure to PFAS via the quarry lakes: surface water and fish

- ✓ Probable risks of adverse health outcomes for workers and potential trespassers from potential PFAS exposure via swimming and/or consumption of fish in the quarry lakes before, during and after 2018/2019 cannot be assessed due to lack of data. It is unknown if the quarry lakes have been contaminated.

Additional conclusions

- ✓ The risk of health effects to ***visitors*** of Lhoist Inc. cannot be evaluated.
- ✓ Possible health effects associated with PFAS exposure to infants via breastfeeding cannot be evaluated.
- ✓ The possible risk of health effects due to acute, short term exposure of less than two weeks to PFOA, PFOS, PFNA and PFHxS 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. Workers, visitors and trespassers, who were/are/will be present at the Lhoist Mine Site for less than two weeks, should follow the recommendations made for longer term exposure over two weeks. It is unknown when health guidelines for short-term exposure may become available.

2. Until FDEP has approved a long-term solution for clean indoor tap water at Lhoist Inc., workers, including those planning to become pregnant, as well as pregnant and lactating women, should continue to use the bottled water supplied at Lhoist. Based on ATSDR's recommendations for PFAS, FDOH recommends that bottled water is used for drinking.

3. Periodic monitoring of the filtered tap water and maintenance of the GAC filter at Lhoist Inc. is recommended to ensure continued functionality of the filter and to prevent exposure to PFAS-contaminated water via drinking and showering.

4. CCC workers should not drink the water at CCC without prior testing and a health risk assessment.

5. Lhoist Mine Site workers, visitors and potential trespassers should not use the quarry lakes for swimming, fishing or other recreational purposes prior to testing and health risk assessment. FDOH recommends sampling of quarry lake water for PFAS testing. If PFAS are detected in the quarry lake water, further sampling and testing of fish, as well as, a health risk assessment may be warranted.

6. Visiting children should be kept under supervision to prevent exposure to contaminated drinking water and access to the quarry lakes.
7. A decision to breastfeed is an individual decision, which involves many considerations in addition to chemical contamination. Women with concerns

regarding the findings at the Lhoist Mine Site may find it helpful to discuss breastfeeding with their health care provider.

6. PUBLIC HEALTH ACTION PLAN

Actions Completed	
October 2018	- FDEP sampled and tested the Lhoist Inc. supply well. The combined PFOA and PFOS concentration was above EPA's lifetime HAL. - Drinking of the Lhoist Inc. tap water was discontinued.
November 2018	- FDEP sampled and tested the Lhoist Inc. and CCC supply wells. The combined PFOA and PFOS concentration of both wells were above EPA's lifetime HAL.
December 2018	Visit to Lhoist Inc. Water fountains had been placarded to prevent use and bottled water supply had commenced.
August 2019	- FDEP installed a water filter at the Lhoist Mine supply well.
February 2021	- FDOH released three Health Consultation reports for public comment. The reports evaluate possible health impacts to the public at the FSFC, the Lhoist Mine Site and Residential Wells within a 1-mile radius of the FSFC.
Ongoing Actions	
	- FDEP continues to provide an alternative drinking water supply. - FDOH is testing filtered water to determine a long-term clean drinking water solution for Lhoist Inc. - FDOH and FDEP remain in constant communication with Lhoist Inc. to ensure workers remain informed and continue to have access to bottled drinking water until water quality is restored through the modification of the existing well and installation of a filtration system. - FDOH is collecting public comments regarding the Health Consultation reports.
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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Authors

Anita Poulsen, PhD
Public Health Risk Assessor
Public Health Toxicology, Bureau of Environmental Health
Division of Disease Control and Health Protection

FDOH Reviewers

Division of Disease Control and Health Protection:

Gladys Liehr, PhD, CSM
Environmental Administrator
Public Health Toxicology, Bureau of Environmental Health

Elke Ursin, PMP
Section Lead/Program Administrator
Public Health Toxicology, Bureau of Environmental Health

Kendra Goff, PhD, DABT, CPM, CEHP
State Toxicologist
Chief
Bureau of Environmental Health

Carina Blackmore, DVM, PhD, Dipl ACVPM
State Epidemiologist
Director
Division of Disease Control & Health Protection

APPENDIX A. EXPLANATION OF HUMAN HEALTH EVALUATION AND CALCULATION PROCESS

1. Screening Process

To evaluate environmental data (e.g., PFAS levels in groundwater), 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' CVs are derived from health-based daily exposure doses set far below those known to cause health effects (further detailed in Section 2 of this appendix). The health-based doses are converted to environmental concentrations (*e.g.,* PFAS in water), which then 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 and intermediate exposure is defined as 15 to 364 days. 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-2), because these CVs are the most protective of all age groups.

If a chemical concentration for a site is higher than the CV, the chemical is of potential concern and health risk must be evaluated. For example, if it is found that a chemical level in 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 contamination must be able to enter the body to 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. Because human health risk cannot be assessed only

[1] **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 concern and needs further evaluation.

from chemical concentrations, exposure doses are estimated for **site- and population/receptor-specific scenarios**.

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 uses the following equations (Eq. A-1 and A-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 Lhoist- and population/receptor-specific human

health cancer and non-cancer risk evaluation input parameters 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 and to account for uncertainty. 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 a **'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, which indicates 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, which indicates 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.

When toxicological information is available, the health assessor may compare estimated doses directly with doses known to cause effect. This comparison helps 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).

[2] 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.

The evaluation for the Lhoist Mine Site included in-depth assessment of some estimated doses for PFOA, PFOS and PFHxS, because they exceeded their provisional MRLs. The health assessor compared the estimated doses with 'human equivalent doses' (HED) predicted from rodent data by ATSDR [ATSDR 2018[3], 2020[4]]. The evaluation used the most sensitive endpoints known for each compound. For PFOA, the applied HED was based on a study on neurodevelopmental effects by Koskela et al. [2016][5].

Predicted human equivalent doses (HED) for PFOA, PFOS and PFHxS
Based on lowest observed adverse effect levels (LOAEL) found in animal studies

Compound	Effect type	LOAEL, HED‡ (mg/kg/day)	Study Reference
PFOA	Developmental effect	0.00082	Koskela et al. 2016[5]
PFOS	Developmental effect	0.0021	Luebker et al. 2005[6]
	Immune effect	0.00041	Dong et al. 2011[7]
	Immune effect	0.000031	Guruge et al. 2009[8]
PFHxS	Thyroid effect	0.0073	Butenhoff et al. 2009[9]; Hoberman and York 2003[10]

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

PFOS HEDs were derived from studies on developmental and immune effects [Luebker et al. 2005[6], and, Dong et al. 2011[7] and Guruge et al. 2009[8]]. PFHxS HEDs were based on two studies on effects to thyroid by Butenhoff et al. [2009][9] and Hoberman and York [2003][10].

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- **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[11]]. PFOS is not classified as a human carcinogen [ATSDR 2018; EPA 2017[12]]. For chemicals for which cancer-association data lack, the derivation of a CSF is impossible. 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:

$$\textbf{Increased cancer risk} = D \times CSF$$

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

Equation A-4: Cancer risk calculation

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

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. (See note on the following page).

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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

WATER CONCENTRATIONS

Table B-1. Contaminants of concern in non-remediated well water at Lhoist Inc.

Contaminant	***Source of Screening Guideline***	***Comparison Value* (ng/L)***	***Concentration Range (ng/L)***	***# Above Comparison Value/Total #***
PFOA	***ATSDR Int. EMEG Child****	**21**	230 – 380‖	3 / 3
PFOS		**14**	8,000 – 12,000	3 / 3
PFNA		**21**	14 – 24‖	1 / 3
PFHxS		**140**	4,800 – 6,200	3 / 3

‖*Estimated concentration (may be overestimated).*

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
Int. - Intermediate (15 to 364 days of exposure)
ng/L - Nanograms per liter
Non-remediated - Not cleaned up by, *e.g.*, a filter
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

**Int. EMEG Child - ATSDR's screening values for child exposure were derived from known toxicological information for PFOA, PFOS, PFNA and PFHxS. Based on ATSDR's evaluation, these concentrations are not expected to cause harmful non-cancer health effects in humans, including sensitive populations (i.e., children).*

Table B-2. Contaminants of concern in non-remediated well water at the CCC Transportation, LLC (CCC).

Contaminant	***Source of Screening Guideline***	***Comparison Value* (ng/L)***	***Concentration (ng/L)***	***# Above Comparison Value/Total #***
PFOA	***ATSDR Int. EMEG Child****	**21**	7	0 / 1
PFOS		**14**	120	1 / 1
PFNA		**21**	0.87†	0 / 1
PFHxS		**140**	210	1 / 1

†*The reported concentration was between the laboratory detection limit and the laboratory practical quantitation limit.*

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
Int. - Intermediate (15 to 364 days of exposure)
ng/L - Nanograms per liter
Non-remediated - Not cleaned up by, *e.g.*, a filter
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

**Int. EMEG Child* - *ATSDR's screening values for child exposure were derived from known toxicological information for PFOA, PFOS, PFNA and PFHxS. Based on ATSDR's evaluation, these concentrations are not expected to cause harmful non-cancer health effects in humans, including sensitive populations (i.e., children).*

RECEPTOR-SPECIFIC PARAMETERS

Table B-3. Worker Input Parameters for Drinking Water Exposure Evaluation

Exposure Group		Body Weight (kg)	Age-Specific Exposure Duration *Intermediate / Chronic*	Intake Rate* (L/day)
Worker	**16 to < 21 years**	71.6	50 weeks / 5 years	3.59
	Adult	80	50 weeks / 30 years	3.59
	Pregnant Women	73	NA	3.59
	Lactating Women	73	NA	3.59

Exposure Group	Duration	Days	Weeks	Years	Non-Cancer Exposure Factor	**EF cancer:** EF non-cancer x Age-Specific Exposure Duration (years)/78 years
Worker, adult	**Chronic**	5	50	30	0.68	

Chronic - Exposure duration of one year or more
EF - Exposure factor
Intermediate - Exposure duration of 15 to 364 days
kg - Kilogram
L/day - Liters per day
NA - Not applicable
< - Less than

**Intake rate - A high intake rate of 3.59 L/d was selected a) to ensure protection of the most sensitive population, the pregnant/lactating woman, and b) to represent a realistic intake rate for workers performing strenuous labor under high temperature conditions. (See Report 1 for the FSFC for more information).*

Table B-4. Worker Input Parameters for Showering Exposure Evaluation

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
Worker	**16 to < 21 years**	71.6	830	18,400	12.00	11.32	13	827
	Adult	80	980	19,650	12.34	10.53	13	827
	Pregnant Women	73	890	18,160	15.47	15.47	13	827
	Lactating Women	73	890	18,160	15.47	15.47	13	827

cm^2 - Square centimeter
kg - Kilogram
L - Liter
L/min - Liters per minute
Min - Minutes
min/day - Minutes per day
< - Less than

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

LHOIST INC. WORKERS INDOOR TAP WATER EXPOSURE

*Table C-1. Estimated doses, non-cancer risk (hazard quotients) and increased cancer risk for **workers** exposed to **2018/2019** levels of PFOA, PFOS, PFNA and PFHxS in non-remediated water at Lhoist Inc via **ingestion (drinking)**.*

Contaminant	Exposure Group	EPC (mg/L)	Chronic Dose (mg/kg/day)	ATSDR MRL* (mg/kg/day)	Chronic Hazard Quotient	Increased Cancer Risk
PFOA	16 to < 21 years	0.00038‖	1.3E-05	3E-06	4.3	<1E-06**
	Adult		1.2E-05		3.9	
	Pregnant Women		1.3E-05		4.3	
	Lactating Women		1.3E-05		4.3	
PFOS	16 to < 21 years	0.012	0.00041	2E-06	210	Not classified as carcinogens
	Adult		0.00037		180	
	Pregnant Women		0.00040		200	
	Lactating Women		0.00040		200	
PFNA	16 to < 21 years	0.000024‖	8.2E-07	3E-06	0.27	
	Adult		7.4E-07		0.25	
	Pregnant Women		8.1E-07		0.27	
	Lactating Women		8.1E-07		0.27	
PFHxS	16 to < 21 years	0.0062	0.00021	2E-05	11	
	Adult		0.00019		9.5	
	Pregnant Women		0.00021		10	
	Lactating Women		0.00021		10	

‖*Estimated concentration (may be overestimated).*

ATSDR - Agency for Toxic Substances and Disease Registry
Chronic - Exposure duration of one year or more
EPC - Exposure point concentration (concentration in unfiltered tap water)
mg/L - Milligram contaminant per liter of water
mg/kg/day - Milligram contaminant per kilogram body weight per day
MRL - Minimal risk level (ATSDR's health guideline below which minimal risk is expected)
* - Current PFAS MRLs are provisional
** - PFOA cancer slope factor = 0.07 $(mg/kg/day)^{-1}$
- Potential risk (*i.e.*, hazard quotient above 1)

< - less than
1E-06 - one in a million
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

*Table C-2. Estimated doses, non-cancer risk (hazard quotients) and increased cancer risk for **workers** exposed to **2018/2019** levels of PFOA, PFOS, PFNA and PFHxS in non-remediated water at Lhoist Inc. via **showering**. [Model based maximum input: 4-person household, one shower a day, fan on, gone 10 hours per day]*

Contaminant	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)	Increased Cancer Risk (combined)
PFOA	16 to < 21 years	380 ng/L [1] 1.3E-08 mg/m^3 [2] 4.9E-11 mg/m^3 [3]	3E-06	2.4E-08	3.1E-08	5.4E-08	0.018	<1E-06**
	Adult			2.2E-08	2.9E-08	5.1E-08	0.017	
	Pregnant Women			3.0E-08	3.0E-08	6.0E-08	0.020	
	Lactating Women			3.0E-08	3.0E-08	6.0E-08	0.020	
PFOS	16 to < 21 years	12,000 ng/L [1] 3.6E-08 mg/m^3 [2] 1.3E-10 mg/m^3 [3]	2E-06	6.5E-11	1.7E-06	1.7E-06	0.85	PFOS is not classified as a carcinogen
	Adult			5.8E-11	1.6E-06	1.6E-06	0.82	
	Pregnant Women			8.2E-11	1.6E-06	1.6E-06	0.82	
	Lactating Women			8.2E-11	1.6E-06	1.6E-06	0.82	
PFNA	*Model does not currently calculate shower scenarios for PFNA and PFHxS*							
PFHxS								

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

ATSDR - Agency for Toxic Substances and Disease Registry
Chronic - Exposure duration of one year or more
EPC - Exposure point concentration (in non-remediated tap water/air (estimated))
mg/kg/day - Milligram contaminant per kilogram body weight per day
mg/m^3 - Milligrams per cubic meter
MRL - Minimal risk level (ATSDR's health guideline below which minimal risk is expected)
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate
* - Current PFAS MRLs are provisional
** - Cancer slope factor = 0.07 (mg/kg/day)$^{-1}$

< - less than
1E-06 - Less than one in a million

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 (hypertension during pregnancy), 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 generally use high exposure concentrations and 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 accounts for uncertainty and 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[1]]. (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]. The most sensitive endpoints observed were decreased body weight and delayed eye opening in offspring of rats, which were exposed from before mating through gestation and lactation [Luebker et al. 2005[9]]. The MRL for PFOS is based on the highest dose tested without observing these 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. This endpoint was not used for the MRL, because the studies, which tested potential for immune effects used a species for which it is difficult to translate animal doses to representative human doses [ATSDR 2018[1]]. Instead, a modification factor was added as an additional precaution to the typical uncertainty factors.

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.

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[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.

The findings in animal studies support data from human epidemiological studies, which have also found associations between PFOA and PFOS exposure and small decreases 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]. Though these studies did not find an association with increased rates of vaccine-preventable diseases.

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]. 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 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.

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PEHSU - Pedriatric Environmental Health Speciality Unit (2020). Per- and Polyfluoroalkyl Substances (PFAS) Resources. https://www.pehsu.net/PFAS_Resources.html

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Please write to: Division of Disease Control and Health Protection
Bureau of Environmental Health, Public Health Toxicology
Florida Department Health
4052 Bald Cypress Way, Bin # A-08
Tallahassee, FL 32399
phtoxicology@flhealth.gov

Or call us at: Toll free at 877-798-2772