



HARVARD T.H. CHAN
SCHOOL OF PUBLIC HEALTH



MILITARY FIREFIGHTER EXPOSURE TO PERFLUOROALKYL SUBSTANCES (PFAS) AND ADVERSE REPRODUCTIVE OUTCOMES



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OBJECTIVES

1

Define perfluoroalkyl substances (PFAS), describe common sources and routes of exposure, and understand why PFAS are used in firefighting foam

2

Briefly explain the toxicological and human literature on PFAS exposure and male and female reproductive health

3

Identify the clinical implications of PFAS exposure in a couple attempting conception at Wright-Patterson Air Force Base

4

Discuss the public health implications of PFAS exposure in reproductive aged couples





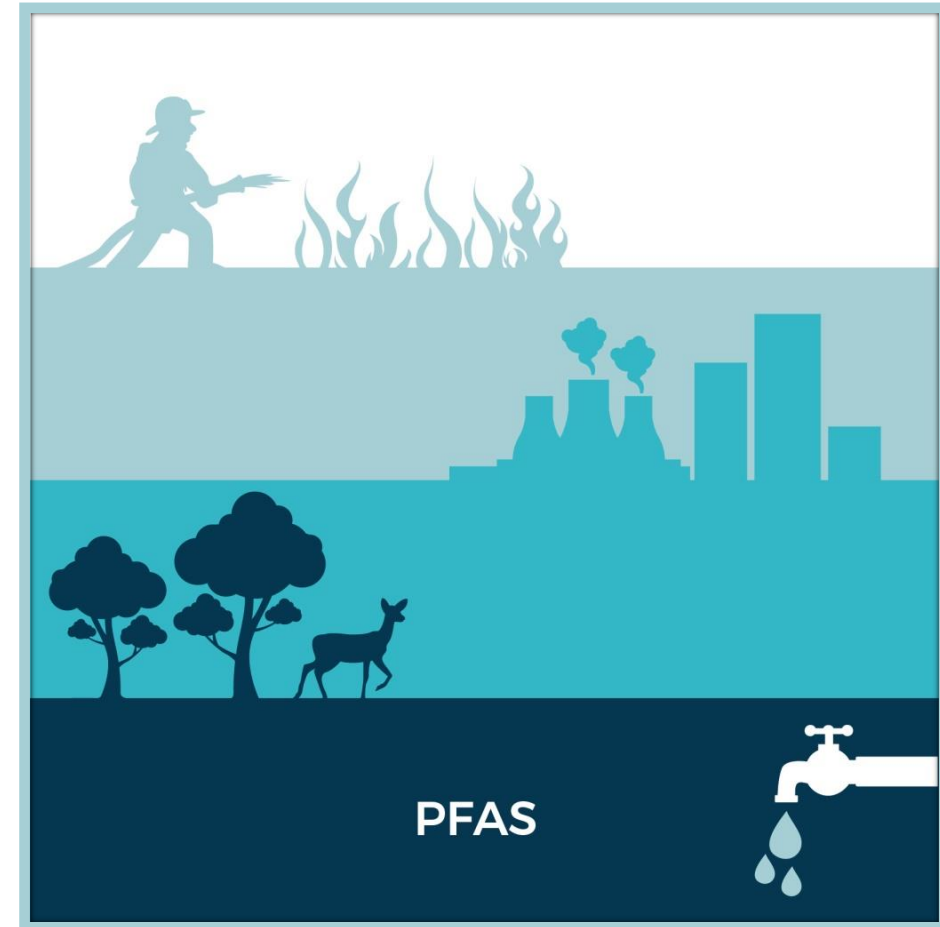
PART-1

UNDERSTANDING PERFLUOROALKYL SUBSTANCES

What are Perfluoroalkyl Substances?



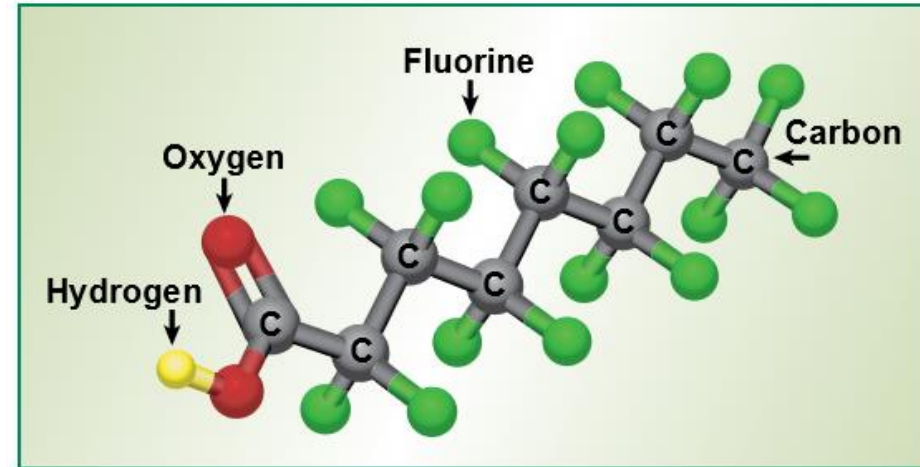
- ✓ Per- and polyfluoroalkyl substances (PFAS) are a large class of synthetic chemicals
- ✓ Widely used to make products heat, oil, stain, and water resistant
- ✓ In production since 1950s
- ✓ Previously known as perfluorinated chemicals (PFCs)
- ✓ Hundreds of different PFAS exist
- ✓ Perfluorooctyl sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are the two most well-known and well-studied



What are some of the features of PFAS?



- ✓ All PFAS contain carbon (C) and fluorine (F) atoms
- ✓ C-F bonds: strongest covalent bonds in organic chemistry
- ✓ Properties (and name) change based on the length of the carbon chain in the PFAS molecule
- ✓ PFOA is referred to as C8 because there are 8 carbon atoms in the chain
- ✓ Highly resistant: thermal and chemical stability



PFOA, also known as C8, has 8 carbons.



Non stick cookware
(e.g., Teflon pans)



Water and/or stain resistant
carpet, textiles, and clothing
(e.g., Scotch guard)



Paper and
cardboard food
packaging
(e.g., pizza boxes,
cooking paper)



Aqueous Film Forming Foam
(AFFF) Fire Fighting Foam





PFAS BRAND NAMES

- Teflon
- Scotchgard
- Stainmaster
- Stainsafe
- Silverstone
- Polartec
- Texapore
- Gore-Tex

“nonstick”
“water-repellent”
“weather-protective”
“stain-resistant”
“fluoro” or “perfluoro”

PFAS
WORDS
to AVOID





PFAS Uses

Opinion

The New York Times

NICHOLAS KRISTOF

Chemicals in Your Popcorn?



By Nicholas Kristof June 4, 2015

What do a pizza box, a polar bear and you have in common?

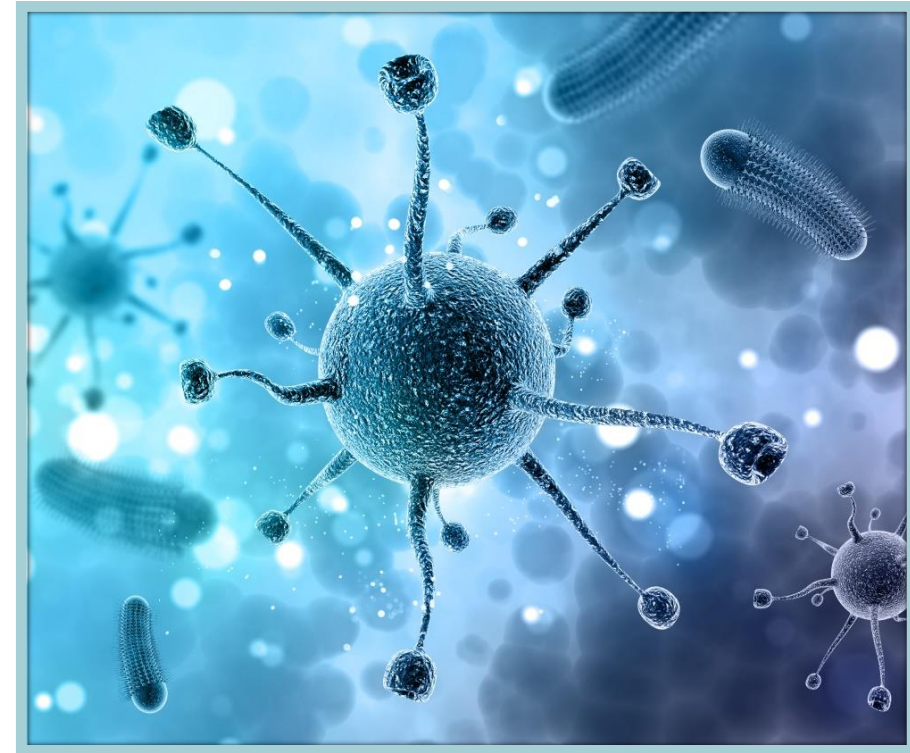
All carry a kind of industrial toxicant called poly- and perfluoroalkyl substances, or PFASs, that do two things: They make life convenient, and



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- ✓ **Drinking contaminated water:** private wells and municipal systems
- ✓ **Ingesting contaminated food:** food packaging; bioaccumulation of meat and fish; produce grown in contaminated soil and water
- ✓ **Hand-to-mouth transfer from surfaces/products:** migrate from PFAS consumer goods
- ✓ **Inhalation of air and dust:** house dust; workplace air exposure
- ✓ **Dermal absorption:** contact with textiles, clothing, sofa seating, other





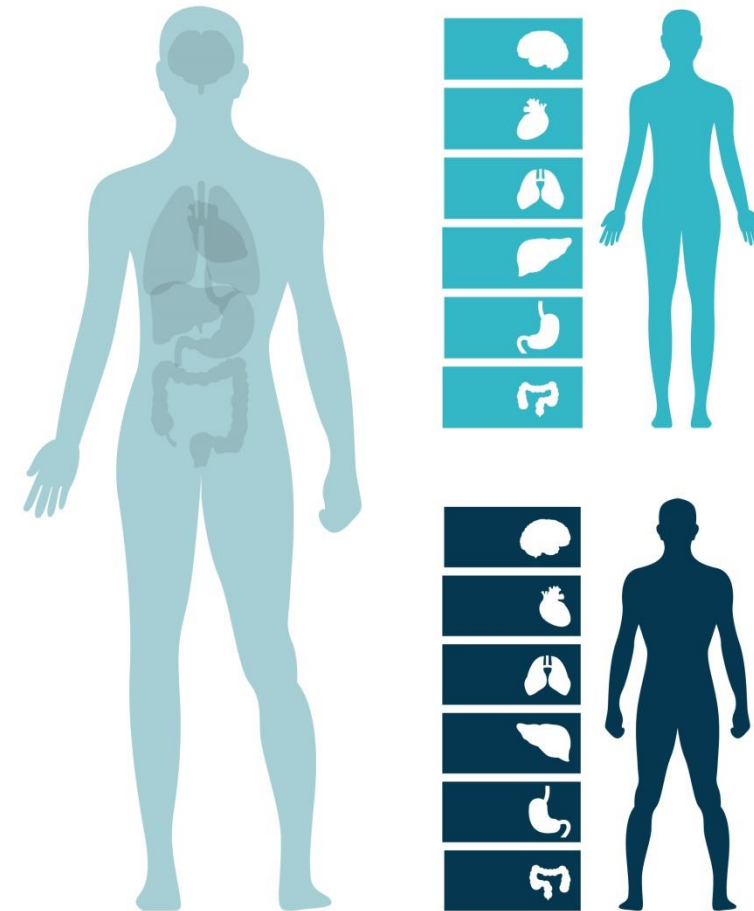
- ✓ Drinking water can be a source of exposure in communities where these chemicals have contaminated water supplies
- ✓ Contamination: localized, usually associated with a specific facility
 - Parkersburg, West Virginia
 - <http://highline.huffingtonpost.com/articles/en/welcome-to-beautiful-parkersburg/>
 - Oil refineries, airfields or other locations used for firefighting



PFAS Accumulation and Elimination in Humans



- ✓ Bind to protein molecules in serum upon absorption
- ✓ Bioaccumulate but not in fatty tissue
- ✓ Renal clearance: influenced by GFR, eliminated in urine
- ✓ Shorter chain PFAS faster clearance than long chain PFAS
- ✓ Variability in accumulation and elimination by sex
- ✓ Detected in: serum, seminal fluid, amniotic fluid, cord blood, breast milk, liver tissue
- ✓ Efficient placental transfer





- ✓ Unique physical and chemical properties make them highly persistent in our environment and in our bodies
- ✓ Elimination half-life in humans: 2.3 to 8.5 years

PFAS	HALF LIFE
Perfluoroactonoic acid (PFOA)	3.8 years
Perfluorooctanesulfonate (PFOS)	5.4 years
Perfluorohexane sulfonic acid (PFHxS)	8.5 years

Why are PFAS used in Firefighting Foam?



- ✓ Chemical diversity in types of PFAS → multifunctional uses
- ✓ Resist degradation and oxidation → they don't break down
- ✓ Thermal stability primarily attributed to the strength of the C-F bond in the fluoroalkyl tail
- ✓ HIGHLY resistant to heat degradation even at extreme temperatures
- ✓ Some PFAS decompose and mineralize at temperatures >1000C



- ✓ Widespread use of PFAS chemicals over the last 60+ years and their long elimination half lives have resulted in ubiquitous general population exposure
- ✓ Concern regarding the persistence, bioaccumulation, and possible ecological and human health effects of long-chain PFAS led to manufacturers developing replacement short-chain PFAS chemistries
- ✓ Replacement chemistry: Short-chain alternatives
- ✓ Regrettable substitution

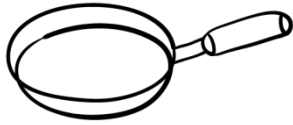




PFAS Analytes*	Women 2007-2008 Concentration (µg/l)			
	PERCENTILE			
	GM***	50 th	75 th	95 th
PFOS	10.7	10.8	17.2	33.6
PFOA	3.56	3.70	5.20	8.30
PFNA	1.33	1.30	1.90	3.40
PFHxS	1.46	1.40	2.60	7.50
PFDA	0.27	0.30	0.40	0.80

*PFOS, perfluorooctane sulfonate; PFOA, perfluorooctanoate; PFNA, perfluorononanoate; PFHxS, perfluorohexane sulfonate; PFDA, perfluorodecanoate; **Limit of detection (LOD) 0.1 for all analytes except PFHxS (0.2); ***GM, Geometric Mean

Which of the following products do not contain PFAS?



A

Non-Stick Cookware



B

Stain-Repellant Upholstery



C

Cellophane Wrap



D

Certain fire fighting foams



E

Wooden dishware



PART-2

PFAS AND REPRODUCTIVE HEALTH



RODENT ANIMAL MODELS

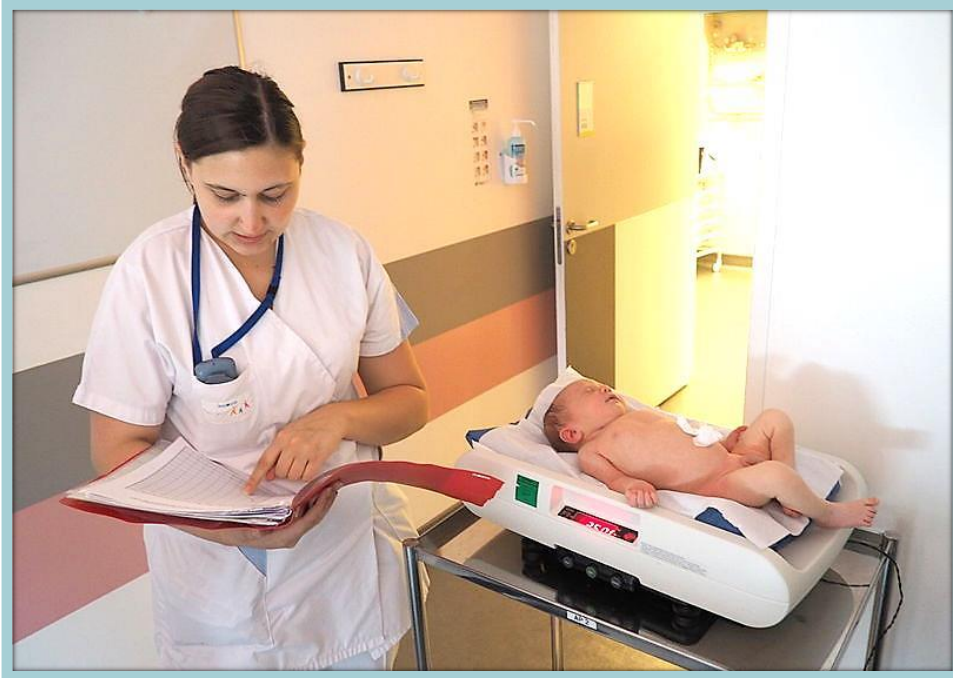
- Reduced testosterone levels
- Reduced birth weight and gestational length
- Increased pregnancy loss and neonatal mortality
- Birth Defects: Ventricular Septal Defect, cleft palate
- Delays in postnatal growth

Fenton, 2009. EFSA, 2008. CDC, 2017



HUMAN: FERTILITY AND PREGNANCY OUTCOMES

- Possible association with longer time to pregnancy, reduced fecundity, and increased risk of pregnancy loss
- Increased risk of pregnancy induced hypertension and pre-eclampsia
- Higher PFOS exposure may be associated with morphologically abnormal sperm and possible infertility
- Perturbation of spermatogenic epigenetic processes
- No studies have examined the role of paternal PFAS exposure on pregnancy loss and other birth outcomes



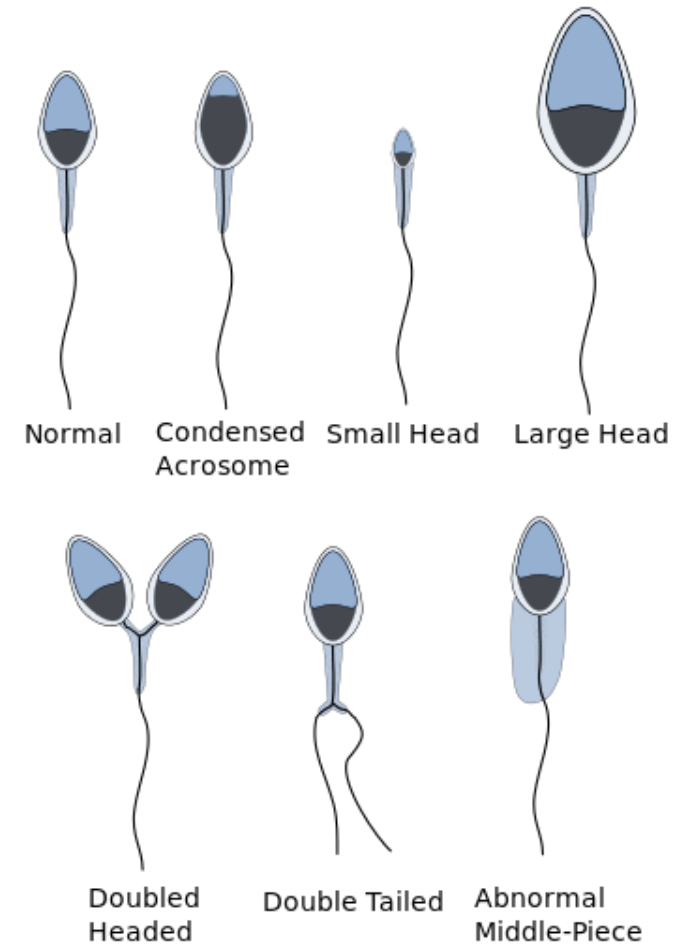
HUMAN: BIRTH OUTCOMES

- Decreased birth weight
- Small for gestational age
- Preterm birth

Which of the following is a potential reproductive health effect of PFAS exposure?



- a) Decreased Antral Follicle Count
- b) Macrosomia (Large Infant)
- c) Still Birth
- d) Abnormal Sperm Shape





PART-3

CLINICAL IMPLICATIONS OF PFAS EXPOSURE IN COUPLES ATTEMPTING CONCEPTION



Clinical Vignette

- ✓ 36-year-old nulliparous female TSgt and 38-year-old male TSgt are referred for an infertility work up.
- ✓ They are both Air Force service members, and have worked in the Civil Engineering Squadron as fire fighters, since their enlistment at the ages 18 and 20, respectively.
- ✓ They have tried unsuccessfully for two years to conceive.





Clinical Vignette

- ✓ There has been much discussion over the last two years within their squadron, regarding the Air Force's uses of PFOA and PFOS
- ✓ Ground water at Wright Patterson Air Force Base in Dayton, OH has been contaminated
- ✓ The couple wonders if this, and similar exposures over the last 15 years has lead to their infertility problems

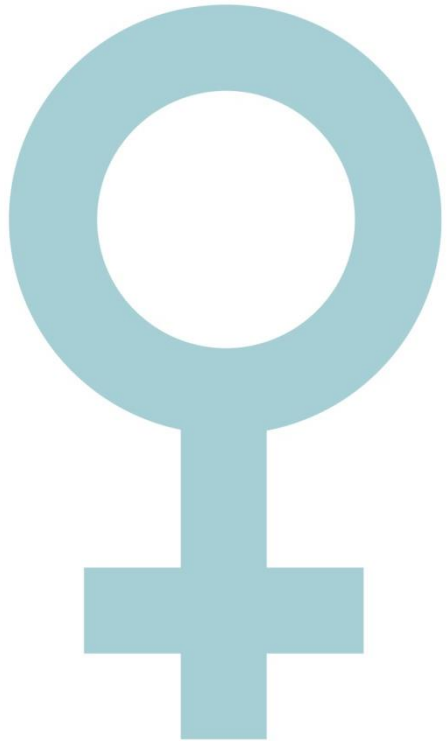




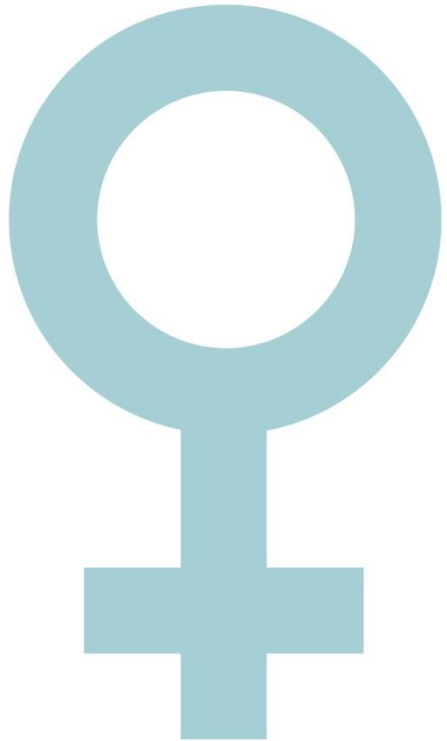
Live Fire Training Exercise



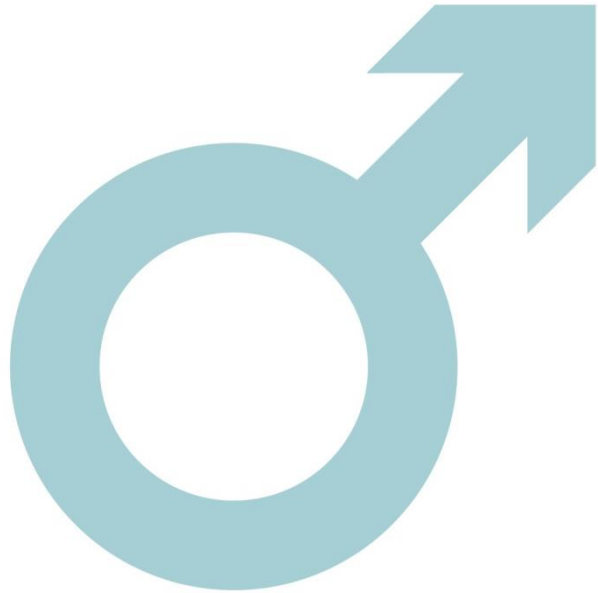
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FSH	15 IU/L
LH	10 IU/L
AMH	2 ng/ml
Prolactin	20 ng/dl
Progesterone	0.9 ng/ml
AFC	5 (Left), 4 (Right)
TSH, T4, TPO-Antibodies	2.8 mIU/L, 6 ug/dl, Antibody-negative



PFOA	7 ug/ml (NHANES, 2009: ref mean 3.56)
PFOS	23 ug/ml (NHANES, 2009: ref mean 10.7)
Hysterosalpingograph	Within Normal Limits
Transvaginal U/S	Uterus and ovaries have a normal appearance



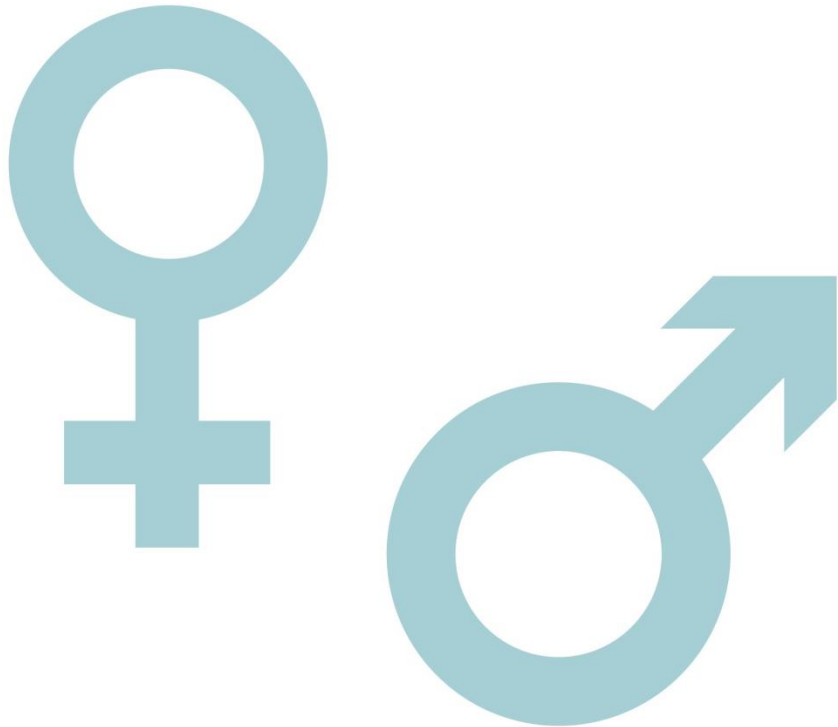
Testosterone	700 ng/dl
FSH	3 mIU/mL
PFOA	6 ug/l (NHANES, 2009: ref mean 4.47)
PFOS	28 ug/l (NHANES, 2009: ref mean 23.2)

Is the semen analysis normal?



✓ Yes

✓ No



Volume, 2.2 ml

Appearance, normal

Morphology

✓ 23% normal

✓ 72% head defect

Count

✓ 30 million/ml

Motility

✓ Rapid Progression, 27%

✓ Immotile, 30%



SEMEN ANALYSIS

NORMAL RESULTS



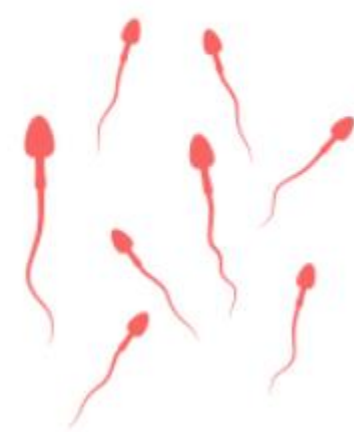
ABNORMAL RESULTS



MOTILITY
<40%



MORPHOLOGY
>4%



CONCENTRATION
<15 million/ml



HOW WILL THEIR EXPOSURE TO PFAS AFFECT THE PREGNANCY?

- a) There is a no need to monitor blood pressure more often during the pregnancy
- b) Health effects of PFAS are not specific, and can be caused by other factors
- c) There is an association with PFAS and pre-eclampsia
- d) Pregnancy induced hypertension occurs in many pregnancies and the specific etiology is often not known





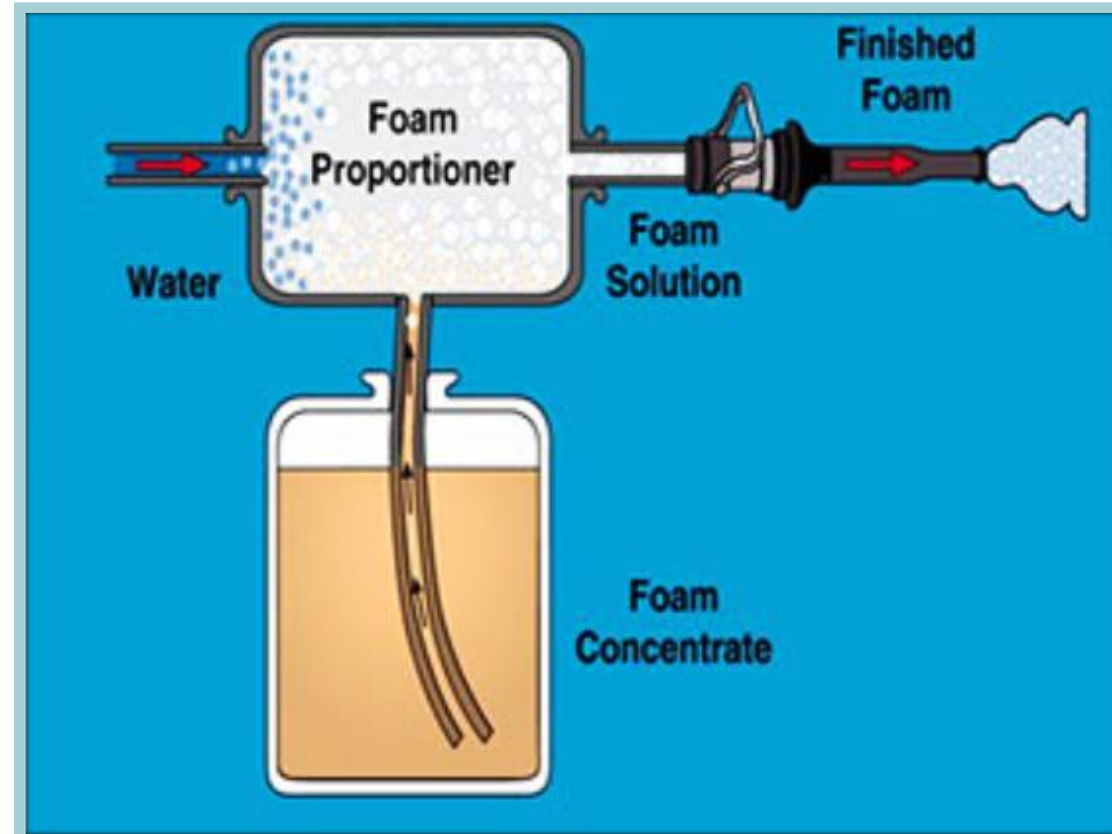
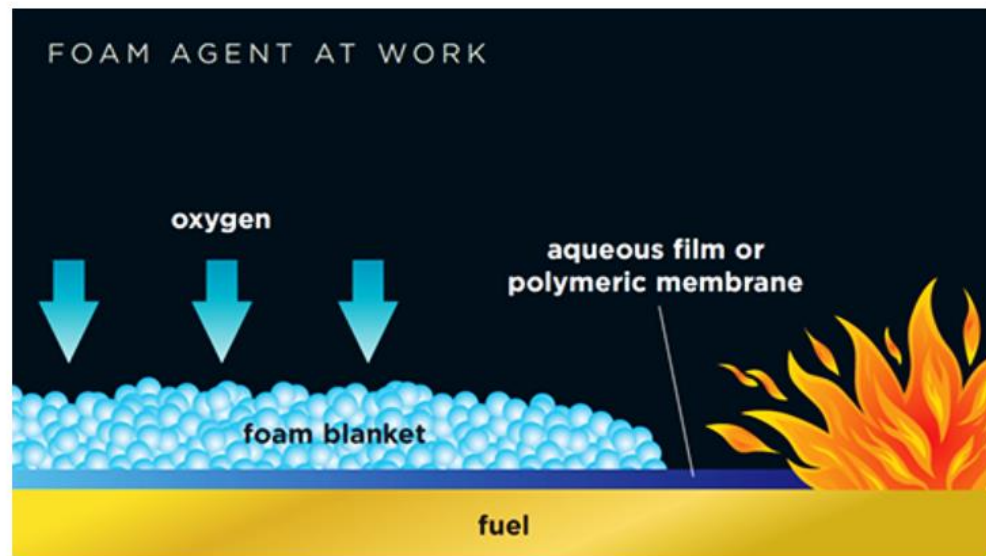
PART-4

UNDERSTANDING PUBLIC HEALTH IMPLICATIONS OF PFAS EXPOSURE IN REPRODUCTIVE AGED COUPLES

AFFF Mechanism of Action

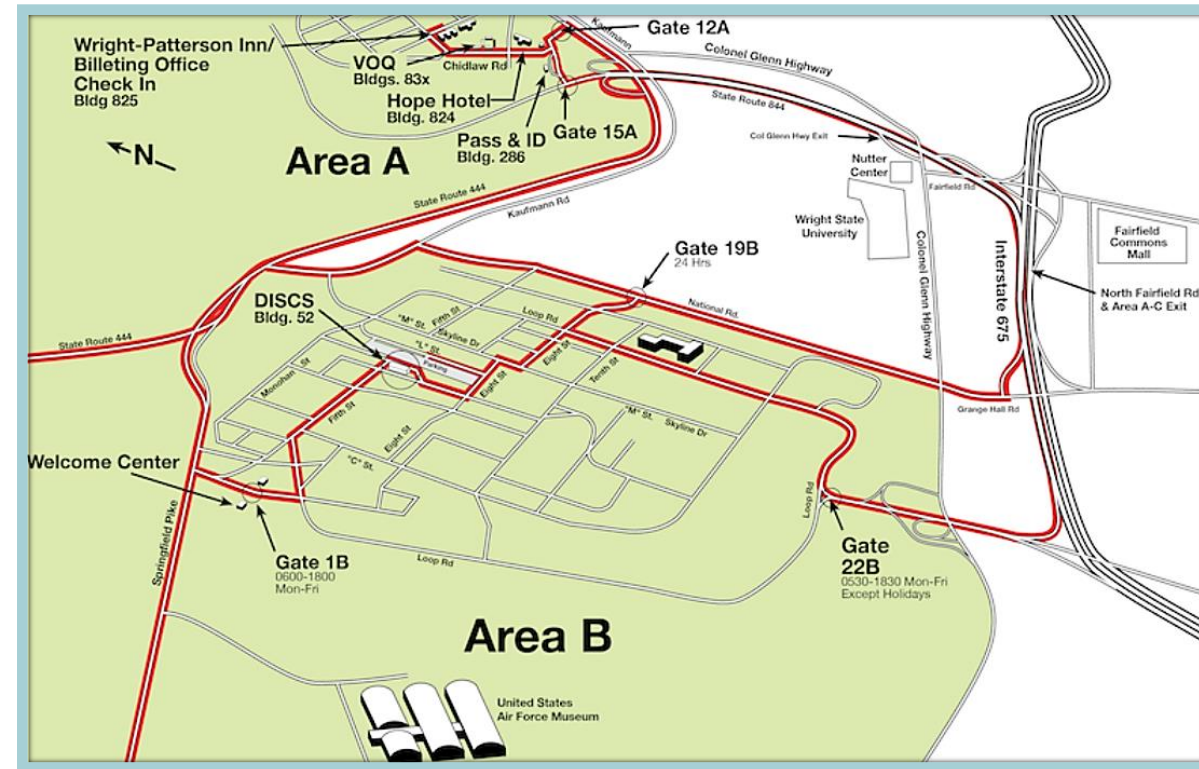


AFFF HAS BEEN USED BY THE AIR FORCE
SINCE THE 1970s





- ✓ OH EPA Director shut down two wells in Area A of Wright Patt and required monthly testing of other wells to detect potential contamination
- ✓ Levels exceeded the new EPA lifetime exposure standard of 70 parts per trillion





- ✓ The Air Force awarded a \$6.2 million contract to ICL Performance Products in August 2015 for 418,000 gallons of Phos-Chek 3 percent.
- ✓ Phos-Chek 3 percent was marketed as an environmentally responsible foam; it is a 6 carbon chain AFFF developed under the EPA's Stewardship Program
- ✓ Delivery of the product began in August 2016, and all foam in fire stations was replaced by 2017
- ✓ Regrettable substitution





- ✓ The Air Force was also awarded a contract to retrofit all aircraft rescue and firefighting vehicles (>800) with a mobile foam test system
- ✓ Fire vehicle operational checks and required annual foam tests will be performed without discharging AFFF into the environment
- ✓ Retrofitting will be complete in 2018
- ✓ Viable strategy





THE AIR FORCE DISCONTINUED REGULAR FOAM DISCHARGE TESTS
IN JULY 2015





- ✓ The Air Force has restricted AFFF for emergency use only.
- ✓ When AFFF is used, Air Force hazardous materials teams will treat the response scene as a hazardous site, and remove/destroy foam residue before contamination can occur
 - Training exercises performed in double lined pits to prevent soil and groundwater contamination
 - Tanks and ponds to collect burn pit effluent
 - Incineration disposal facilities
- ✓ Viable strategy





- ✓ **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)**
 - Assess, Inspect, Investigate, Clean-up
- ✓ **If lifetime EPA limit is exceeded due to the Air Force mission, the Air Force will provide alternative drinking water sources**
 - Bottled water
 - Water filtration systems
 - Connecting private wells to public drinking water supplies







- ✓ PFAS/PFOA exposure was believed to contribute to this couples' infertility
- ✓ Air Force initiatives may decrease future occupational exposures
- ✓ Infertility affects 15% of couples
- ✓ Male factor infertility is diagnosed in 20-30% of couples seeking treatment
- ✓ Understanding how environmental chemicals like PFAS increases the risk of infertility and pregnancy loss is a research gap and public health goal

