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Per- and Polyfluoroalkyl Substances (PFAS) in Solid Waste

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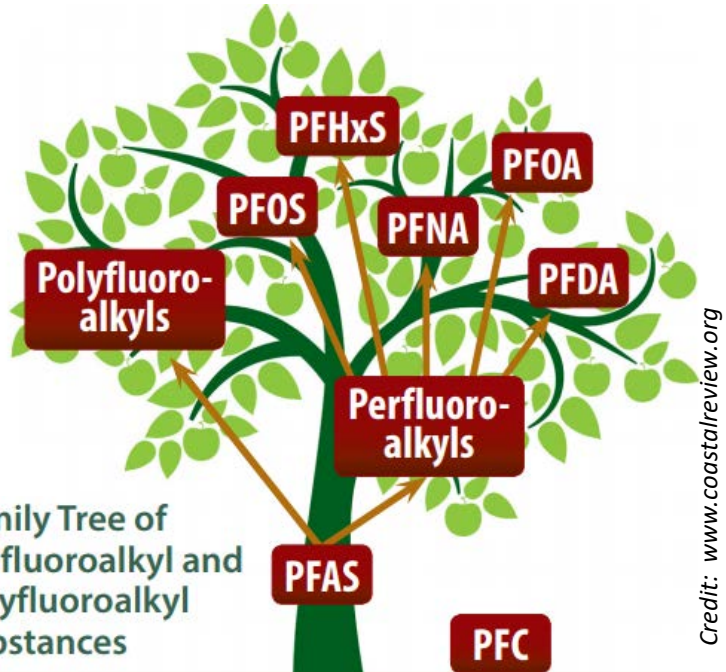
President & CEO



Credit: www.coastalreview.org

What are PFAS?

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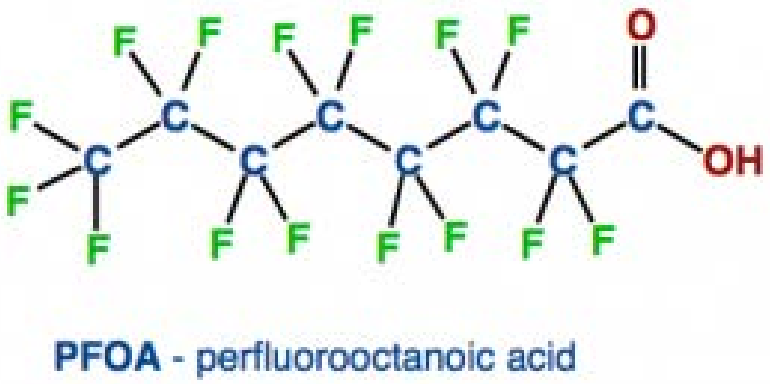
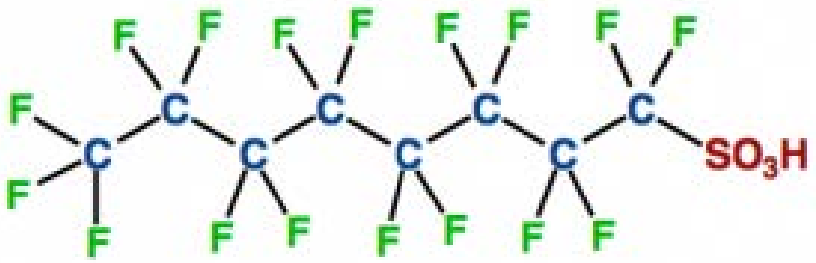
- Per- and polyfluoroalkyl substances (PFAS) are a group of man-made, highly fluorinated chemicals
- Varying length of carbon chain, from C4 – C16
  - C4 – C6 → typ. short chain
- Manufactured since the 1940's, but PFOA/PFOS voluntarily phased out in 2006 globally, but before this these were most common
- Manufacturers have developed new PFAS as others were phased out
- Currently many other PFAS compounds (possibly hundreds) are estimated to exist



PFOA - perfluorooctanoic acid



PFOS - perfluorooctanesulfonic acid

PFAS Properties

- Have oil, stain and water repellant properties which makes them highly desirable for various products
- Flame retardance make them important for fire fighting
- Persistent and do not readily break down
  - Referred to as “forever chemicals”
  - Carbon-Fluorine bond is strong and stable
  - Some (fluorotelomer alcohols) degrade to more stable forms (PFCAs), making them more recalcitrant
- Highly mobile in the environment in both liquid and air
- Due to this, PFAS have been detected nearly everywhere on the globe, including the North Pole

What Products Contain PFAS?

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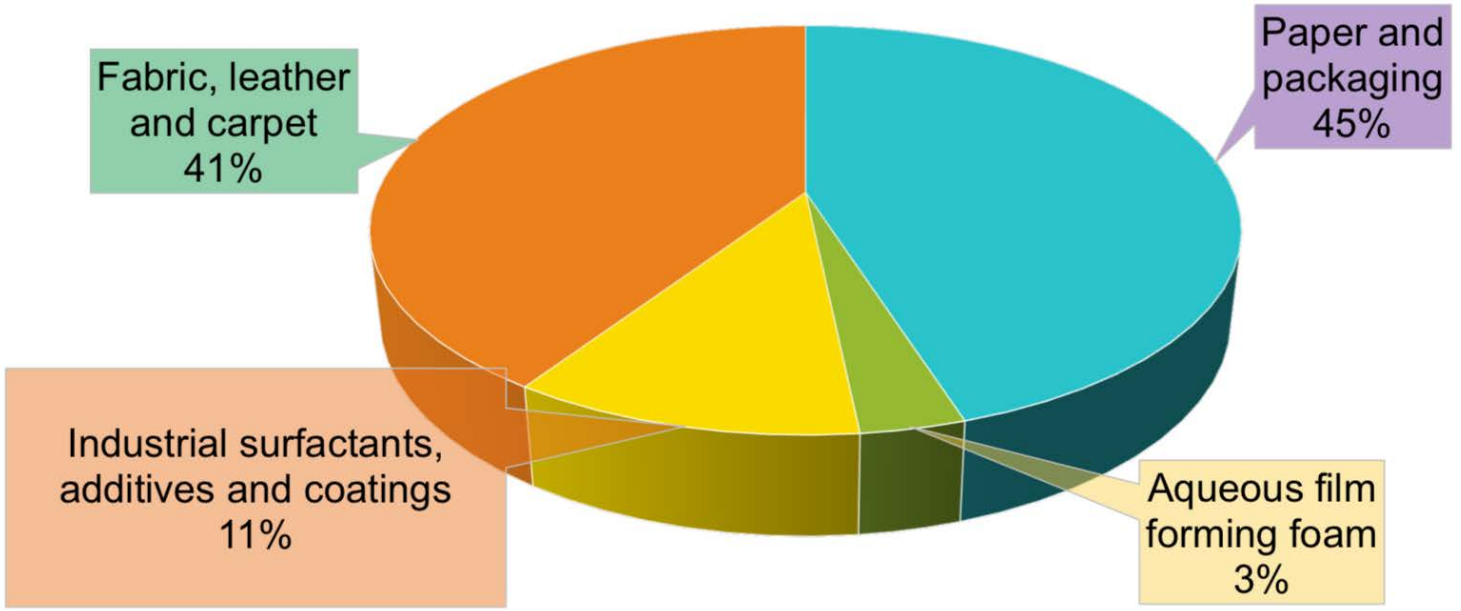
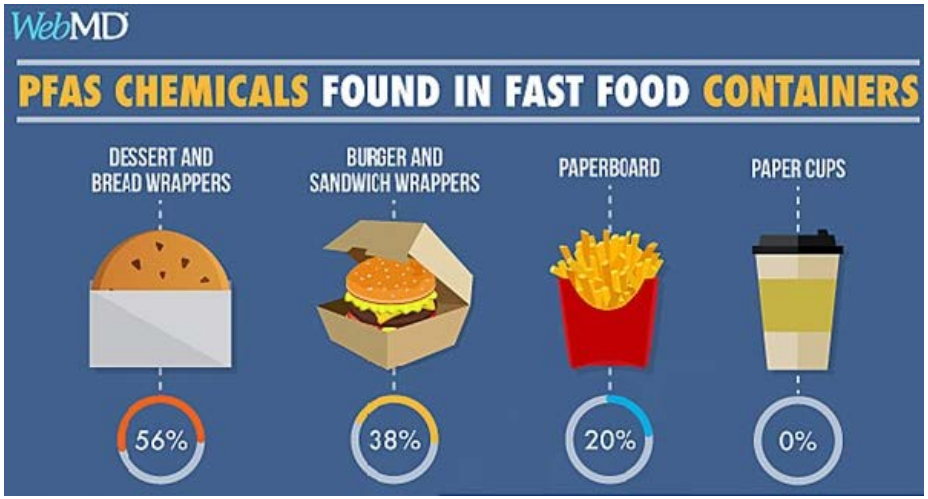
- PFAS are in hundreds of products we use frequently

Credit: www.sixclasses.org

PFAS Production



(Schultz, et al, 2003)



Health Implications

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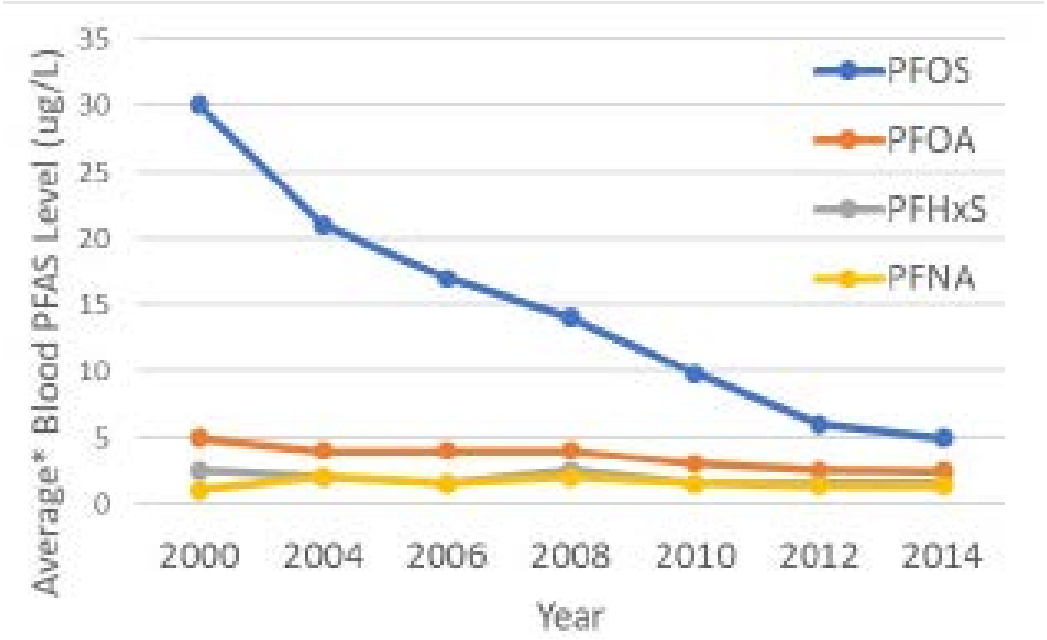
- Due to widespread use and exposure, PFAS are found in blood of > 99% of Americans
  - Long half-lives in human body (Kidneys: 3.8 yrs – PFOA; 5.4 yrs – PFOS)
- Levels of PFOS/PFOA in humans have been declining, but limited info is available for most other PFAS compounds
- Most research done on PFOA/PFOS at significant exposure levels (C8 Science Panel)
  - Cancer
  - Ulcerative colitis
  - Thyroid disease
  - Elevated cholesterol
  - Pre-natal impacts



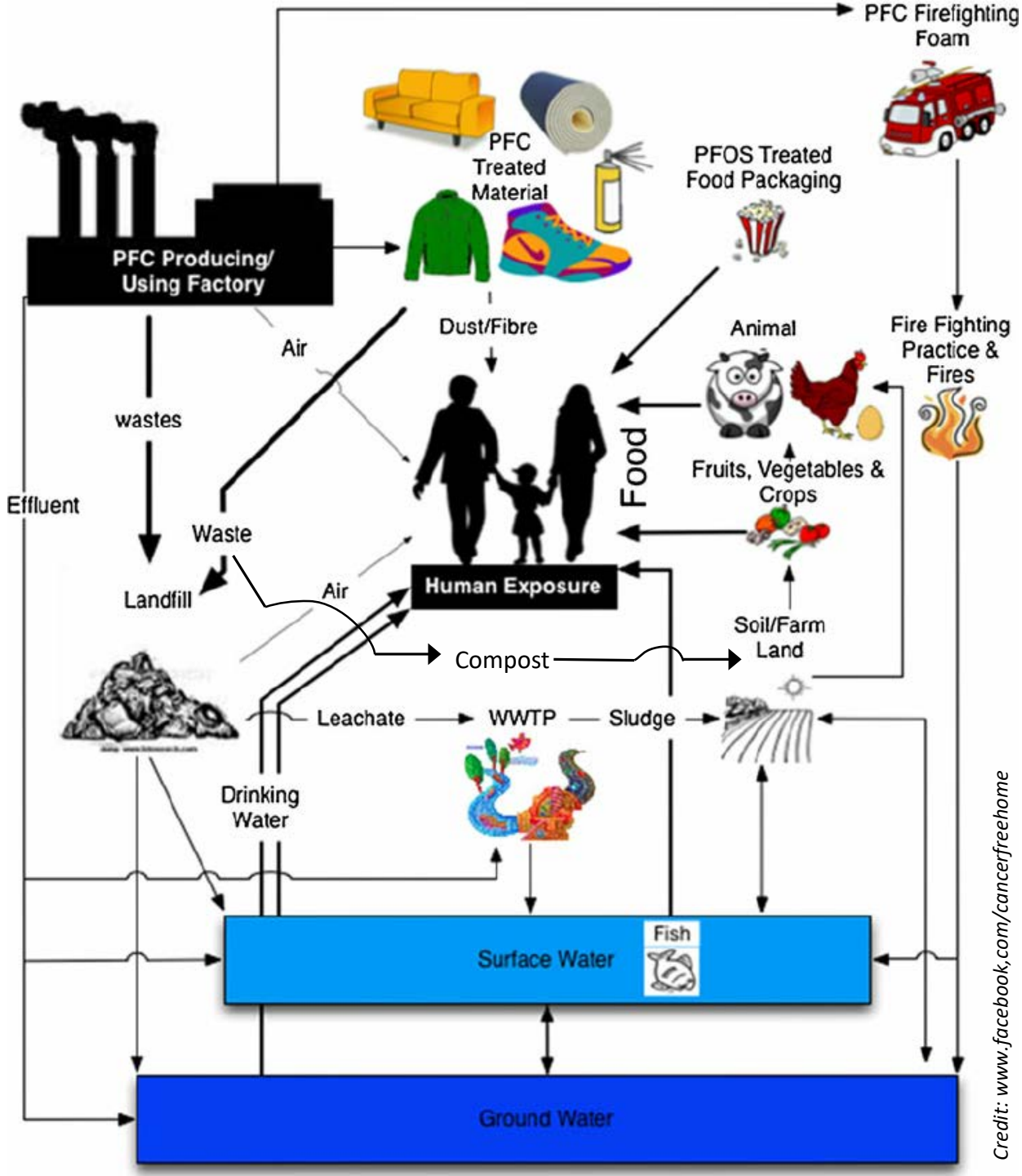
Source: Center for Disease Control (CDC), 2017

Health Implications *(cont.)*

- Much less research on short chain PFAS, which is being used more since phase-out of PFOS/PFOA
- Some research on other PFAS
  - 9 other PFAS tested show half-lives in humans ranging from 3 days to 15.3 years (Lau, 2015)
  - Confirmed/suggested toxic effects for 7 PFAS compounds beyond PFOA/PFOS (Ghisi et al., 2019)
- Research suggest behavior of PFAS can be VERY different depending on carbon length, functional group, etc.
  - Need to be cautious to extrapolate findings from PFOA/PFOS to all PFAS compounds

PFAS Exposure Pathways

- Bioaccumulates in food chain
- Inhalation
  - Indoor Dust
  - Airborne particulates
- Oral
  - Food
  - Drinking water
- Dermal *(suggested as unlikely) (MI PSAP, 2018)*



Credit: www.facebook.com/cancerfreehome

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PFAS “Receiving Facilities”

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PFAS are ubiquitous in engineered infrastructure

- Influent to publicly owned treatment works
  - Water Treatment
    - From surface water, runoff, air deposition(?)
    - From groundwater (typ. near ‘hot spots’)
  - Wastewater Treatment Plants (WWTPs)

- Solid Waste
  - Recycled materials
  - Compost
  - Discards to Landfill
    - Leachate
    - Landfill Gas

- As a sink for PFAS containing materials, WWTPs and landfills, in particular, may aggregate/collect PFAS
- Such facilities are also highly regulated, making it easy for agencies to control PFAS going to the environment

PFAS in Recycled Materials

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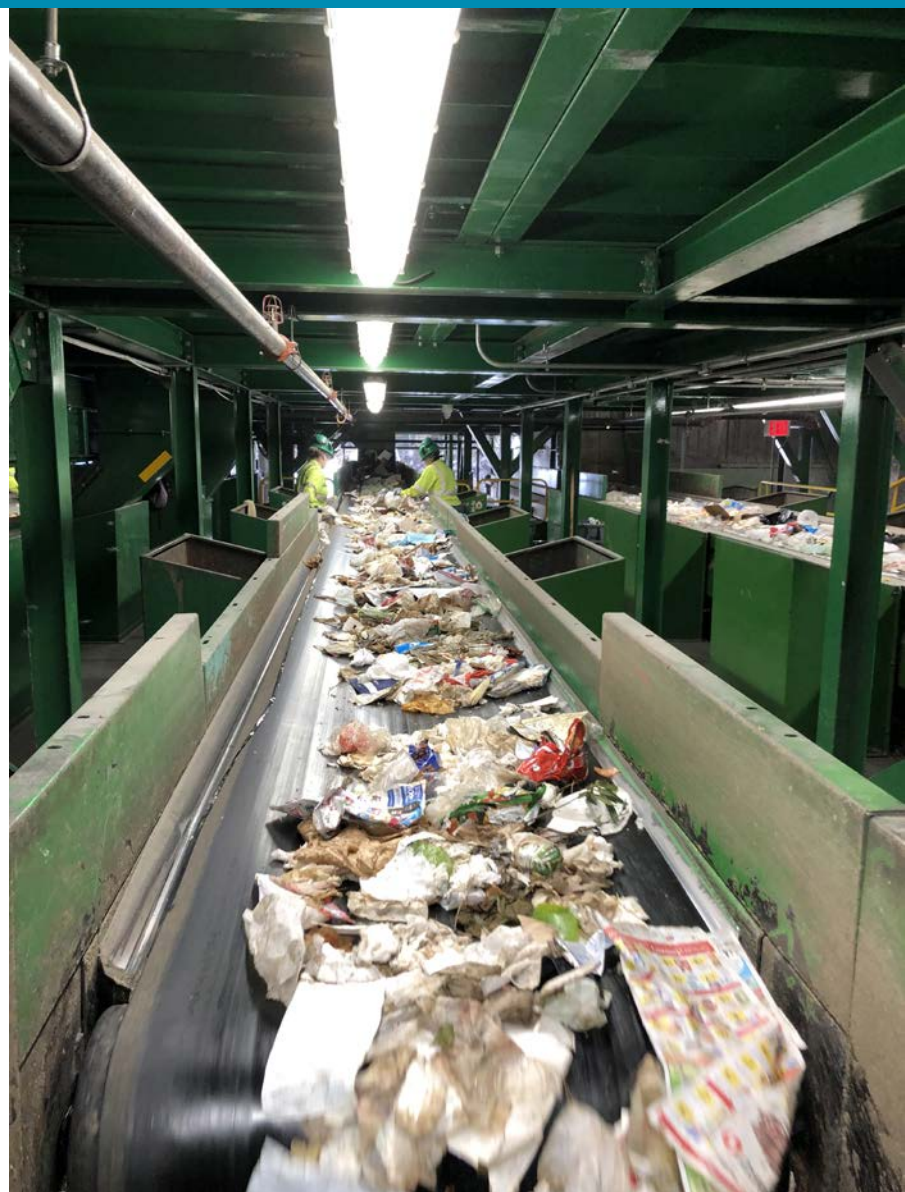
- Very little is known regarding whether or not PFAS persist in recycled materials
- Materials that are recycled may contain PFAS (e.g. food packaging)
- If they do, recycling could accumulate PFAS compounds in products that use recycled content
  - More research is needed to determine if this a significant issue
  - If reprocessed under higher temperatures, will this alter/destroy PFAS?



PFAS in Compost

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- Samples from 10 compost facilities in 5 states (WA, OR, CA, MA, NC) tested for 17 PFAS compounds (Choi et al., 2019)
- All had PFAS but significant differences between facilities that accepted food packaging
  - With food packaging = 28.7 – 75.9 µg PFAS/kg compost
  - Without food packaging = 2.4 – 7.6 µg PFAS/kg compost
  - > 68 % were short-chain PFAS
- Studies show PFAS accumulates in food crops and level of uptake directly correlates to levels in soil (Ghisi, 2019)

PFAS in Leachate and Wastewater

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- Most data is for PFOA and PFOS – limited data is available for other PFAS compounds more commonly in use today

Median PFOA/PFOS Concentrations (ng/L). Range is given in parentheses.

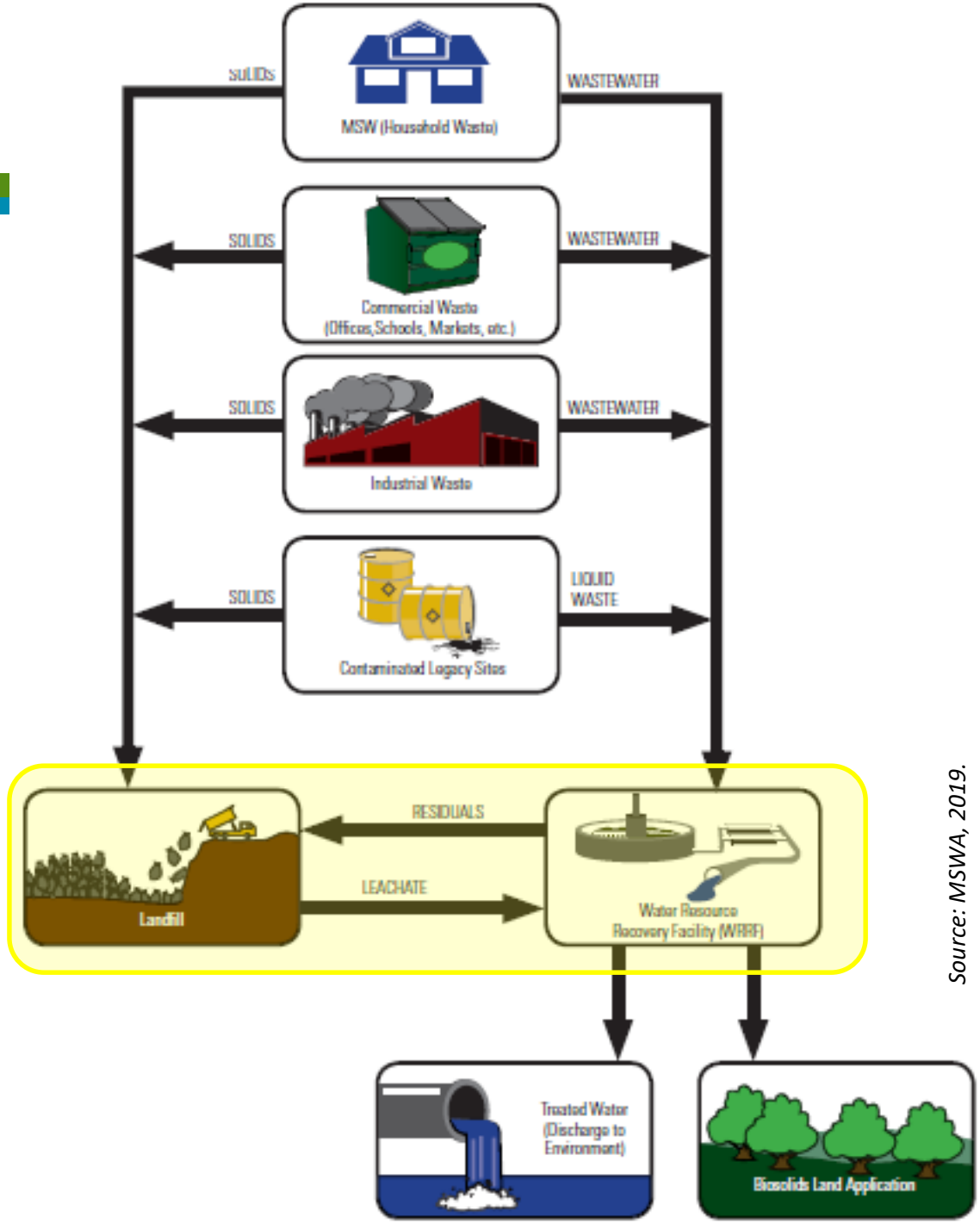
Type	PFOA	PFOS	PFOA + PFOS
Leachate[1]	712 *(30 - 5000)*	117 *(3 - 800)*	829
Wastewater Influent[2]	5.06 *(ND – 64.6)*	8.6 *(ND – 499.4)*	13.66

Source: MSWA, 2019. Notes: (1) Leachate is for the U.S. based on 3 studies and over 100 samples. (2) Wastewater values are from 39 Michigan WWTPs

- Leachate contribution to WWTP influent (mass loading)
  - PFOS: ~3.2% to WWTPs is from landfill leachate
  - PFOA: ~13.5% to WWTPs is from landfill leachate
- WWTP biosolids can contain significant PFAS concentrations
  - 0.7-241 ng/dry g PFOA; up to 110 ng/dry g PFOS (Arvaniti & Stasinakis, 2015)

Landfill/WWTP Interdependency

- Landfills and WWTPs exchange materials
  - Biosolids to LFs
  - Leachate to WWTPs
- Generally there is no direct exposure to PFAS in leachate and wastewater as these are treated
- Treated liquids are released to bodies of water where further dilution occurs



Source: MSWA, 2019.

Exposure Pathways to PFAS

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- Primary exposure to humans is from inhalation and orally (eating/drinking)
- Research is still evolving, but studies thus far suggest the following routine levels of exposure (per person)
  - Food consumption = 100 – 480 ng/day (Tittlemier, 2007)
  - Dust intake = 46 – 120 ng/day (Strynar & Lindstrom, 2008)
  - Total Dust & Food = 146 – 600 ng/day
- PFAS from diet dominated human intake when drinking water levels were < 40 ng/L (Vestergren & Cousins, 2009)
- Assuming PFAS concentrations in drinking water are equivalent to wastewater influent (13.66 ng/L)
  - a person would need to drink 10.7 to 44 L/day to same exposure as dust & food
  - represents 4.5% to 15.8% of total daily exposure
- Despite this perspective, relative assimilation in the body via these pathways is not well understood
  - it cannot be assumed that a minor exposure pathway is less significant

What We Don't Know

- Health/toxicology/environmental
  - Health risks at lower doses and from other PFAS (aka. not PFOA or PFOS)
  - Which exposure pathways are most important
  - Very little work done to assess impacts to domestic animals, agricultural crops, wildlife
  - Minimal work done to assess impact to carbon cycle, climate change, soil, air water/oceans

- PFAS Pathways
  - Mass balance will help quantify risk and exposure
  - How much PFAS are in consumer products
  - How many products are sold annually that contain them
  - Which PFAS compounds are in each
  - Transport to receiving facilities (e.g. solid waste, wastewater, stormwater runoff, etc.)

What We Don't Know - Related to Solid Waste

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- How much PFAS are released from specific products
  - During use (human exposure, release to environment)
  - During waste management activities
    - Landfilling (during anaerobic decomposition)
    - Recycling processes/material reprocessing
    - Composting
    - Anaerobic Digestion
- PFAS measurement methods
  - Only accepted method is for drinking water; others are in development
- PFAS treatment/removal
  - Limited work has been done, mostly on reverse osmosis and activated carbon
- Influence on diversion policy
  - BPI, CMA, USCC are banning or recommending bans on PFAS to compost facilities
  - WWTP biosolids contain PFAS → could be banned from land application

Key Takeaways

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- PFAS is ubiquitous in our society and the environment
  - its presence in solid waste & leachate is not surprising
- We cannot assume research findings for PFOA/PFOS (most widely used prior to 2008) are applicable to other PFAS
- Primary human exposure appears to be from dust and food
- Leachate appears to represent a minor fraction of PFAS loading to WWTPs (the primary disposal method for leachate)
- There are many unknowns, more research is needed to quantify risks and management approaches

Thank you!

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