Per- and Polyfluoroalkyl Substances (PFAS) in Solid Waste

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What are PFAS?

- 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.
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?

• PFAS are in hundreds of products we use frequently
PFAS Production

Fabric, leather and carpet 41%

Industrial surfactants, additives and coatings 11%

Paper and packaging 45%

Aqueous film forming foam 3%

(Schultz, et al, 2003)

PFAS CHEMICALS FOUND IN FAST FOOD CONTAINERS

DESSERT AND BREAD WRAPPERS: 56%
BURGER AND SANDWICH WRAPPERS: 38%
PAPERBOARD: 20%
PAPER CUPS: 0%
Health Implications

- 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
PFAS “Receiving Facilities”

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

- 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

- 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

- 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.

<table>
<thead>
<tr>
<th>Type</th>
<th>PFOA</th>
<th>PFOS</th>
<th>PFOA + PFOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate¹</td>
<td>712 (30 - 5000)</td>
<td>117 (3 - 800)</td>
<td>829</td>
</tr>
<tr>
<td>Wastewater Influent²</td>
<td>5.06 (ND – 64.6)</td>
<td>8.6 (ND – 499.4)</td>
<td>13.66</td>
</tr>
</tbody>
</table>

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

• 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

• 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

• 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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