Dermal Exposure Potential and PFAS: Recent Research

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Recent Studies Addressing Dermal Exposures and PFAS

Type of Study	Number
General studies addressing dermal exposures and PFAS	3
Studies assessing dermal exposures to PFAS using animal models	3
PFAS and dermal exposures to cosmetics	4
PFAS and dermal exposures to house dust	2
PFAS and dermal exposures to personal care or personal hygiene products	3
Specific occupational or consumer dermal exposure scenarios involving PFAS	4
Clothing and dermal exposures to PFAS	1
Measurement of dermal exposures to PFAS	1

Limited information currently available to assess human dermal exposures to PFAS. Increasing numbers of studies have been published since 2019 (3 in 2019; 3 in 2020; 7 in 2022; 7 in 2023). However, significant data gaps remain.

General Findings Related to Dermal Exposures to PFAS

- Among a sample of 61 adults from Oslo, Norway, dietary exposures appeared to be the predominant pathway for PFAS exposure, followed by ingestion of house dust, inhalation of indoor air, and dermal absorption; however considerable variability was observed (Poothong et al. 2020).

- Not surprisingly, dermal exposures to PFAS are hard to estimate or extrapolate from other substances due to the unique physico-chemical properties of the substances and the wide range of different types of PFAS compounds (Ragnarsdottir et al. 2022).

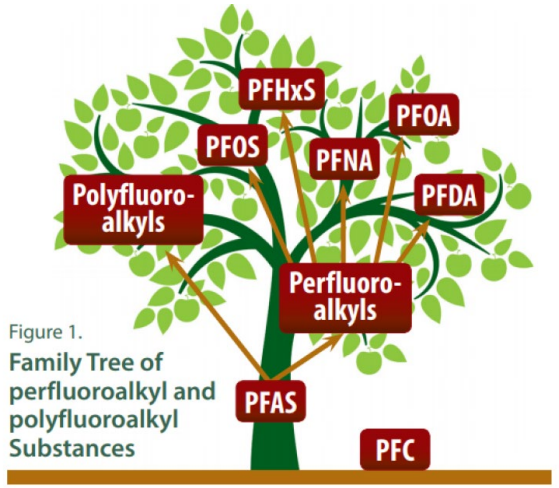
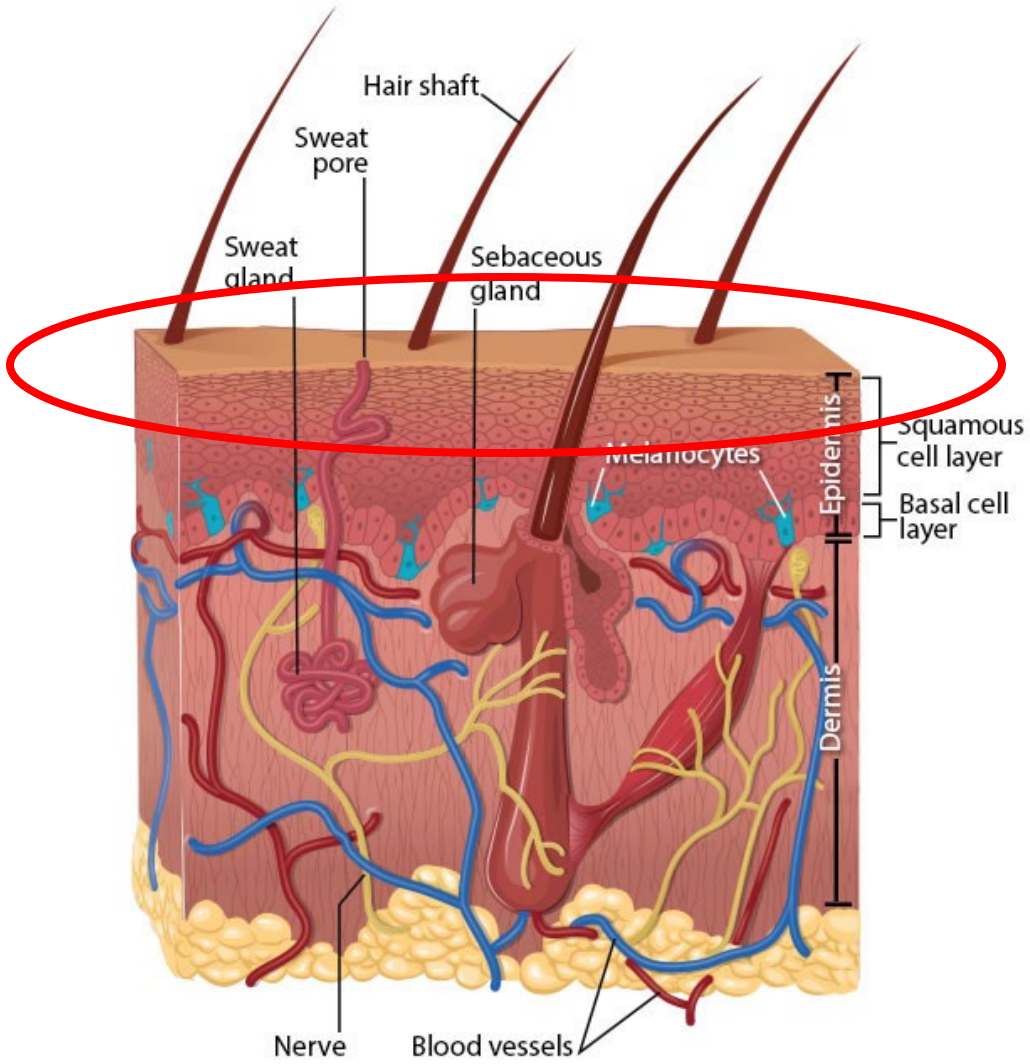


Figure 1.
Family Tree of perfluoroalkyl and polyfluoroalkyl Substances

https://www.wamc.org/hudson-valley-news/2019-02-14/epa-rolls-out-pfas-action-plan

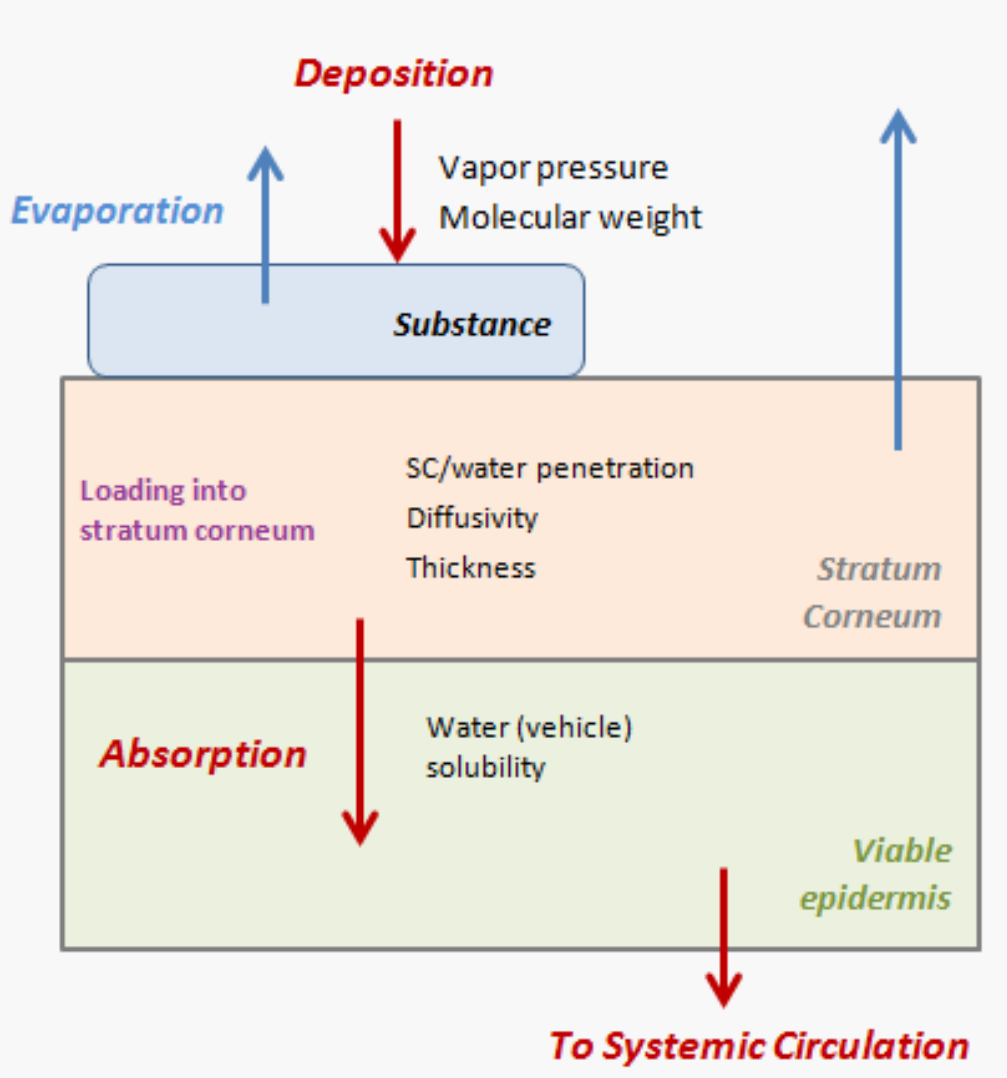
Human Skin



https://www.cdc.gov/cancer/skin/basic_info/what-is-skin-cancer.htm

- Principal barrier (homeostasis: water, temperature, external organisms) 10% of body mass, ~2 m^2 area
  - Comprised of dead flattened cells
  - SC is a thin porous membrane; not a solid impenetrable membrane
- The thickness of the stratum corneum (SC) varies across the body, but only ~15 μm thick on most of the body
  - In comparison, the typical human hair is 50-70 μm thick and 3M Scotch© tape is 25 μm thick
  - Palms and soles thicker, ~600 μm

Skin Permeation/Penetration Factors

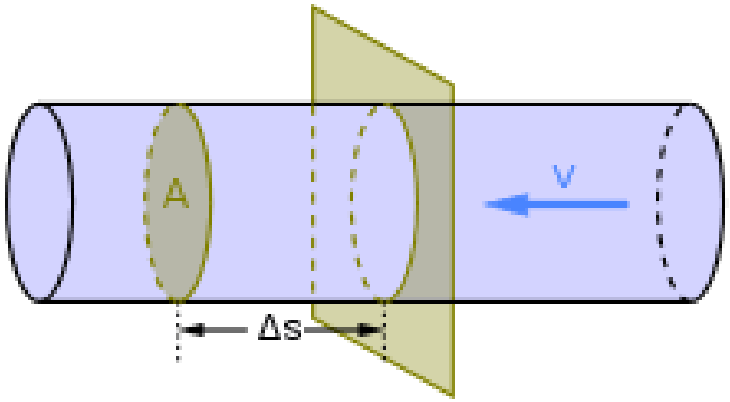


AIHA: IH SkinPerm; Tibaldi et al. 2014

- Physical/chemical properties of the substance
  - Molecule size (<MW 200 more likely to absorb), log $K_{o/w}$ (between 1 and 3 more likely to absorb), water solubility
- Vehicle properties
  - Water solubility, volatility, effects on the stratum corneum
- Interactions between the skin and the substance (metabolism)
- Properties of the skin
  - Anatomical site, hydration, integrity, blood flow to the dermis, damage to skin
- Scenario specifics
  - Occlusion, amount on the skin (dose and volume), skin surface area, duration of exposure

Dermal Absorption of PFAS

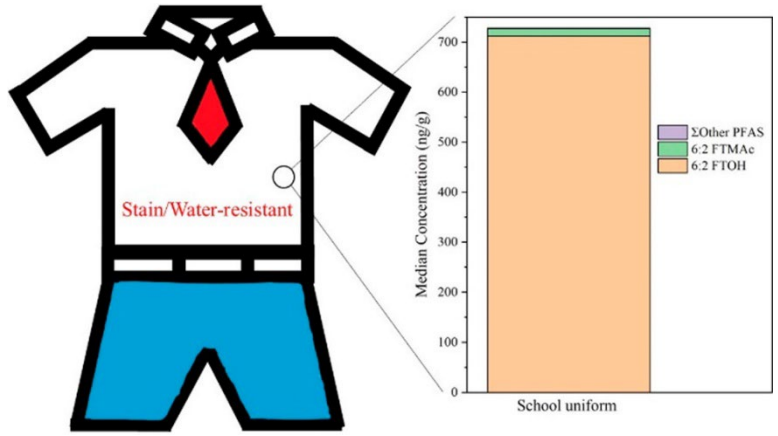
- Kissel et al. (2023) estimated potential for dermal uptake of neutral PFAS via partitioning of SVOCs from the gas phase to the skin surface using SPARC.
- 11 neutral PFAS had calculated dermal-to-inhalation (D/I) ratios >5, suggesting that direct dermal absorption may be a relevant or important exposure pathway for these substances (isomers of C4-C6: N-MeFOSE, N-EtFOSE, shorter chain: N-MeFBSE, N-MeFHxSE, N-EtFHxSE, N-EtFBSE; the others were 7 PFAS with diol and amide head groups) (Kissel et al. 2023).
- For those with a lower D/I ratio, a higher potential inhalation risk would be suggested. This group includes FTOHs and FTMAs.
- Prior research suggests only limited dermal absorption of ionic PFAS compounds (Fasano et al. 2005; Franko et al. 2012; Kissel et al. 2023).



https://en.wikipedia.org/wiki/Mass_flow_rate

PFAS and Potential for Dermal Exposure from Cotton Clothing

- Water-repellent and other clothing has been noted to contain PFCAs, PFSAs, and FTOHs. Ionic PFAS constituted less than 5% of total PFAS in children's textiles (Ragnarsdottir et al. 2022; Xia et al. 2022).
- PFAS compounds were found in all children's textile products tested, with the most abundant compound being 6:2 FTOH followed by FTMAcs (fluorotelemer methacrylates) (Xia et al. 2022). However, transfer efficiency to skin was not tested.
- PFAS were common in school uniforms; higher PFAS levels were found in 100% cotton clothing than in synthetic fabrics. Levels were as high as or higher than outerwear (Xia et al. 2022).
- Release of PFAS following laundering is unknown (Xia et al. 2022).



Xia et al. 2022

PFAS and Potential for Dermal Exposure from DWR Clothing

- PFAS exposures from durable water repellent (DWR) clothing have been found to be low relative to exposures from dietary intake (Ragnarsdottir et al. 2022; Knepper et al. 2015).
- Inhalation from indoor air and dust ingestion associated with such clothing were both greater than dermal absorption, which was found to be relatively very low (Ragnarsdottir et al. 2022; Knepper et al. 2015).
- Minimal dermal exposure estimates are due to low estimates of the dermal absorption rate of PFAS (Ragnarsdottir et al. 2022; Knepper et al. 2015).
- Weathering may increase the potential for exposure from DWR clothing (van der Veen et al. 2020).

https://organoclick.com/textile-waterproofing/

PFAS and Dermal Exposure Potential from Consumer Products

- Ragnarsdottir et al. (2022) noted that PFAS-containing products have the potential to have prolonged contact with skin, including cosmetics and water repellent clothing.
- There is likely to be the presence of numerous unknown or unquantifiable PFAS substances in common consumer products (Xia et al. 2022).
- Sunscreen, mouthwash, and lip products were positively associated with serum PFAS (PFOA, PFTrDA, and PFOSA) (Thepaut et al. 2021).
- Face masks may be a source of dermal PFAS exposure (Muensterman et al. 2022).

https://www.epa.gov/radtown/ultraviolet-uv-radiation-and-sun-exposure

https://www.epa.gov/pmcourse/patient-exposure-and-high-particle-pollution-events

PFAS and Dermal Exposure Potential from Cosmetics

- It has been reported that certain cosmetics have contained measured levels of 13-25 different PFAS compounds that can function as surfactants, emulsifiers, and conditioning agents (Ragnarsdottir et al. 2022; Schultes et al. 2018; Whitehead et al. 2021; Namazkar et al. 2023).

- Lin et al. (2023) found that MoS and HQ values for dermal exposures to PFAS from cosmetics were acceptable, but the cumulative effects of long-term exposure are unknown.

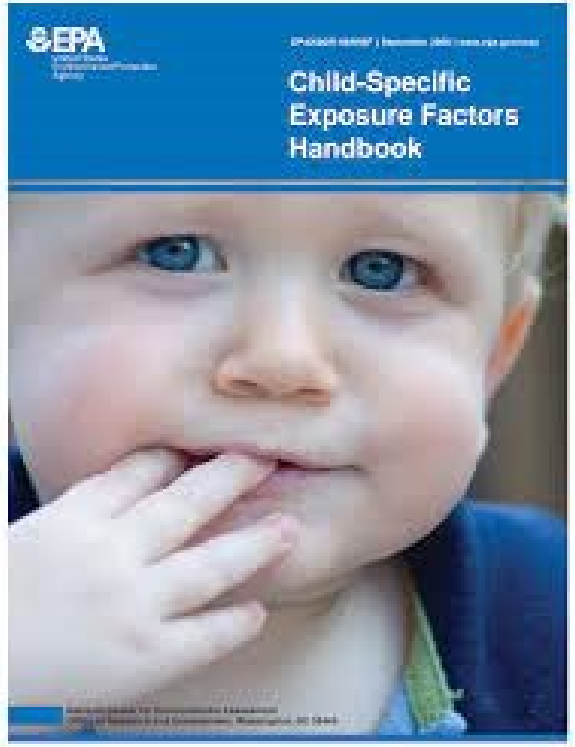
- Unlike non-polar PFAS which were relatively non-bioaccessible, PFCAs/PFAAs in cosmetics readily partitioned to artificial sweat (bioaccessible fractions 43-76%) (Namazkar et al. 2023).

https://www.rnz.co.nz/news/environment/485782/epa-proposes-broad-ban-of-forever-chemicals-in-cosmetics

https://www.exponent.com/article/update-eu-cosmetics-regulation-titanium-dioxide

PFAS and Dermal Exposures to House Dust

- Mixed results for measured levels of PFAS in hand wipe samples compared to serum PFAS levels (Ragnarsdottir et al. 2022).
- Dust ingestion found to contribute ~10-15% of total PFAS dose; hand to mouth exposures ~2-5% of total dose.
- However, for infant PFOA exposure, an estimated 40% is from hand to mouth exposures, followed by diet (35%) and dust ingestion (20%).



https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=199243

Dermal Exposure Potential to PFAS in Specific Scenarios

- Mesfin Tefera et al. (2022) found that for firefighters, incidental ingestion and dermal absorption accounted for 15% (typical) and 34% (worst case) exposure potential, with dietary exposures comprising the largest fraction of exposure potential.

- The use of PFAS in electronic products could create significant potential for PFAS exposure by the inhalation, ingestion, and dermal routes. The use of PFAS in electronics products and applications is wide ranging (Tansel 2022).

https://www.epa.gov/sciencematters/blowing-smoke-what-can-firefighters-breath-reveal-about-chemical-exposure-during

https://www.epa.gov/international-cooperation/cleaning-electronic-waste-e-waste

Measurement of Dermal Exposure Potential to PFAS

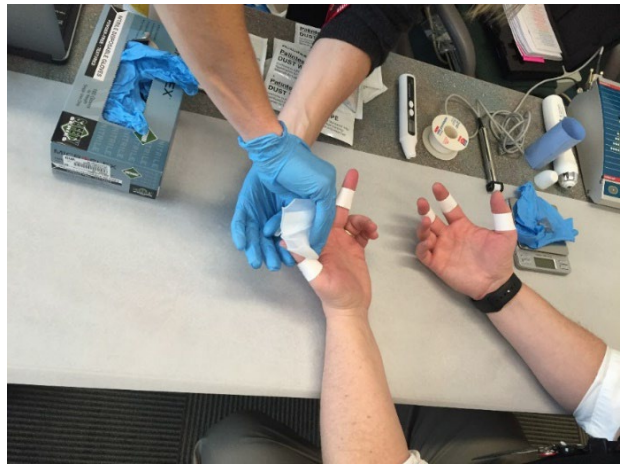
- Poothong et al. (2019) developed an analytical method to measure PFAS in hand wipes for the 60 adults from Oslo; exposures were evaluated for both hand-to-mouth and dermal contact scenarios.

- Predominant PFAS measured on the hands were polyfluoroalkyl phosphate esters (PAPs); further, these values were significantly positively correlated with PFOS and PFOA levels.

- For PFAAs, PFOA contributed the highest dermal exposures via hand to mouth and dermal contacts.

- A significant correlation between PFOS in hand wipes and EtFOSE in indoor air was found.

- Low frequency of hand washing was associated with 30-50% higher concentrations of PFAS on the hands.



Sahmel et al. 2021

Questions?

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