Supplement 1

Complementary Reviews for PFAS-John G. Watson and Judith C. Chow

The CR provided much detail and justification for relating PFOA to testicular and kidney cancers. The environmental concerns of PFAS are much broader in scope, however, with a large range of PFAS compounds, human exposure pathways, and adverse health effects. An increasing number of other review articles has been published on these topics, several since the CR was finalized, and a sampling of the most useful publications are highlighted here. Each of these provides an extensive bibliography that can be used to "drill-down" to greater detail. Buck et al. (2011) provide the most comprehensive and understandable introduction to PFAS, sorting through the chemical terminologies and suggesting the shortened mnemonics (e.g. PFOA, PFOS) that are in current use as identifiers. Their supplemental tables are useful look-up guides that relate the 42 PFAS families and sub-families to more than 250 specific compounds, while the main text associates the chemical structures with production methods and uses. A useful list of PFAS acronyms in current use has been compiled by the (ITRC, 2020). Sunderland et al. (2019) construct a model of sources exposure pathways and identify diet, dust (mostly house dust), tap water, food packaging, inhalation, and dermal absorption pathways for PFOA, PFOS, PFBA (perfluorobutanesulfonic acid), PFHxA (perfluorohexanoic acid), PFDA(perfluorodecanoate, perfluorodecanoic acid), and PFDoDA (perfluorododecanoate, perfluorododecanoic acid). The reviewed studies show widely varying fractions of exposure, with diet being the largest contributor, followed by tap water. Food packaging was found important in only one of the studies, and inhalation of airborne PFAS were mostly <10% of exposure. With respect to adverse health effects, Ojo et al. (2021) summarize studies relating various PFAS compound exposures to developmental toxicity, neurotoxicity, reproductive toxicity, genotoxicity, immunotoxicity, cardiovascular toxicity, and endocrine disruption. However, many of these studies involve animals rather than humans and the doses needed to detect adverse reactions are much higher than those found in the different exposure pathways. Sinclair et al. (2020) estimate hazard coefficients (HQ), ratio of the potential exposure to a substance and the level at which no adverse effects are expected, in various countries and states using reported measurements in wastewater treatment effluents. No HQs exceeded unity for PFOS, and only Singapore showed a HQ>1, considered high risk. Currently used water treatment technologies were not developed to remove PFAS. Wanninayake

(2021) evaluates approaches for PFAS separation, for subsequent collection and disposal, and destruction. Separation is accomplished with absorbing biomaterials, minerals, ion exchange resins, and polymers. PFAS are destroyed by advanced oxidation, ultrasonication, biological remediation, and plasmas. Although these have been demonstrated in the laboratory, they have large energy and equipment requirements and more advances are needed for their scaling to industrial capacities. Owing to the complexity and cost of PFAS sampling and analyses, measurements are sporadic and focused mostly on drinking water and wastewater. Laboratory containers and surfaces often contain PFAS (e.g., Teflon), and these must be replaced with non-PFAS materials. Menger et al. (2021) explore emerging technologies to point-of-sampling PFAS measurements in the form of test kits. Promising developments include impregnated papers with colorimetric analysis (possible with modern smartphones), fluorescence of PFAS coupled with various dyes, resonance light scattering, nanoparticle absorbents, and quantum microdots. These methods have yet to achieve the specificity and detection limits needed for routine measurements, and they will probably not be as accurate as the laboratory analyses. However, they appear to be promising as screening and alert tools that can early on detect a potential hazard.

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