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Biomonitoring of per- and polyfluoroalkyl substances in minority angler communities in central New York State ☆

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Abstract

Onondaga Lake in central New York State was listed as a Superfund site in 1994 due to industrial disposal of pollutants. A biomonitoring program was conducted to assess exposure to over 70 legacy contaminants and contaminants of emerging concern in populations disproportionately at risk for exposure residing near Onondaga Lake and to educate these communities on how to reduce exposures. The populations of focus were refugees from Burma and Bhutan and low-income, primarily African American, anglers (urban anglers). These communities consume locally caught fish for economic as well as cultural reasons and therefore may be at higher risk of exposure. This study focuses on assessment of exposure to per- and polyfluoroalkyl substances (PFAS) and associations

with local fish consumption. Using respondent driven sampling, 311 refugees and 89 urban anglers were enrolled in the study. Following informed consent, study participants provided blood and urine specimens and completed a questionnaire. Percentiles of locally caught fish meals in the past 12 months by race/ethnicity groups showed that the Burmese participants of Karen ethnicity were the highest consumers, with a median of 135 meals compared to 103 meals for the other Burmese participants, 70 meals for the urban anglers, and 44 meals for the Bhutanese participants. Compared to the National Health and Nutrition Examination Survey (NHANES) 2015–16 sample of the general U.S. population, the Karen participants had markedly elevated perfluorooctane sulfonic acid (PFOS) and perfluorodecanoic acid (PFDA) levels with median serum concentrations 9.5 times greater (41.6 ng/mL vs. 4.4 ng/mL) and 26.9 times greater (2.69 ng/mL vs. 0.10 ng/mL), respectively; the other Burmese participants had moderately elevated levels of PFOS and PFDA with median serum concentrations 3.0 times greater (13.3 ng/mL vs. 4.4 ng/mL) and 7.3 greater times greater (0.73 ng/mL vs. 0.10 ng/mL), respectively; and, PFAS levels were not elevated in the Bhutanese or urban angler cohorts. Male gender was consistently the strongest predictor of PFAS exposure among all study cohorts. A positive association between local fish consumption was indicated only for PFOS among urban anglers. An association between local fish consumption and PFAS was not statistically significant among the refugee cohorts, perhaps due to the lack of ‘lower-end’ exposure or exposure variability. Community events were held by the program staff to present the biomonitoring results and distribute community outreach materials with visual aids specific for the study populations to promote safe fish eating.

Introduction

Per- and polyfluoroalkyl substances (PFAS), also known as perfluorochemicals (PFCs), were introduced as industrial chemicals in the 1950s, and the global commercial applications of PFAS became seemingly endless, ranging from non-stick coatings on cookware to industrial surfactants and fire-resistant foams (Lindstrom et al., 2011). Production and use of these chemicals in the United States has decreased over the past decade; however, they persist in the environment and are found worldwide (Giesy and Kannan, 2001; Ahrens and Bundschuh, 2015). Perfluorooctane sulfonic acid (PFOS) levels

have been declining in the general U.S. population over time (Calafat et al., 2007; Kato et al., 2011; CDC, 2021). Because of their toxicity and bioaccumulative potential, PFAS have been routinely measured in environmental matrices, fish, wildlife, and humans (Boulanger et al., 2004; Lau et al., 2007; Delinsky et al., 2010; Kato et al., 2011; Ye et al., 2018; Fair et al., 2019). PFOS and perfluorodecanoic acid (PFDA), long-chain PFAS compounds, dominated in frequency of PFAS occurrence in fish samples from U.S. urban rivers and the Great Lakes (Sinclair et al., 2006; Stahl et al., 2014). Several studies have demonstrated that dietary fish is an important source of human exposure to PFOS and PFDA (Christensen et al., 2016; von Stackelberg et al., 2017; Christensen et al., 2017). Drinking contaminated water is another main source of non-occupational PFAS exposure (ATSDR, 2019), particularly for perfluorooctanoic acid (PFOA) (Emmett et al., 2006).

Concern over the health effects of PFAS has recently gained momentum and global attention. Many studies have examined possible relationships between concentrations of specific PFAS in human biological specimens and various health effects. Most studies have focused on PFOS and PFOA, prominent PFAS compounds, which remain in the human body for years (ATSDR, 2021). The epidemiological findings from these studies are not definitive, but suggest a wide spectrum of possible adverse effects including cardiovascular disease, liver damage, thyroid disease, reduced vaccine efficacy, reproductive complications, and low birth weight (ATSDR, 2019; Ballesteros et al., 2017; Fitz-Simona et al., 2013; Gallo et al., 2012; Huang et al., 2018; Looker et al., 2014; Maisonet et al., 2012).

The Agency for Toxic Substances and Disease Registry (ATSDR) and the New York State Department of Health (NYSDOH) conducted a biomonitoring program to assess exposure to over 70 legacy contaminants (GLWQB, 1985) and contaminants of emerging concern (Klečka et al., 2010), including PFAS, on populations consuming fish from the Great Lake Basin's Onondaga Lake and nearby water bodies in central New York State (NYS). Onondaga Lake was declared a Superfund site in 1994 due to industrial waste dumped directly into the lake for almost a century (EPA, 2019). The restoration of Onondaga Lake has spanned many decades, and the water quality of the lake has improved dramatically. Part of Onondaga Lake remains a Superfund site with fish advisories in place, and swimming from the shore was prohibited at the time of this study. Persistent toxic

substances such as mercury, polychlorinated biphenyls (PCBs), and PFAS are still monitored in the lake's water, sediment, fish and wildlife (NYSDEC, 2014; NYSDEC, 2018). A study conducted in 2004 found elevated concentrations of PFOS in Lake Onondaga surface water (median level 756 ng/L), and PFOS was the most abundant PFAS compound in fish from 20 inland NYS lakes popular with anglers (Sinclair et al., 2006).

Our biomonitoring program focused on two human populations in central New York State at risk for exposure: 1) refugees from Burma (currently Myanmar) and Bhutan, and 2) urban anglers. Study cohorts were low-income and known to eat fish from local waterbodies. Therefore, both may be highly exposed to contaminants in fish and may bear disproportionally high health burdens from the exposure. The biomonitoring data provide important information to guide state and local public health actions to protect people within their jurisdiction. Our study cohorts, particularly the refugee cohorts, offer an opportunity to add novel information to existing data on human exposure to PFAS in very high-end fish consumers residing in the Great Lakes Basin. The overall program follows an earlier (2013–2014) biomonitoring program that included fish eating communities in western New York state, and a comprehensive list of contaminants measured for both biomonitoring programs has been previously published (Savadatti et al., 2019). This article is the first publication for the central NYS program and presents serum PFAS concentrations in the study cohorts and an assessment of potential exposure sources. In this study we examined demographic, behavioral, dietary, and other characteristics of survey participants as predictors of serum PFAS concentrations with a focus on locally caught fish consumption.

Section snippets

Participant recruitment and clinic visit

All study activities were approved by the federal Office of Management and Budget (Control Number 0923–0052) and the NYSDOH Institutional Review Board. To reach these “hidden” populations with no known sampling frame, the NYSDOH used

respondent driven sampling (RDS) to recruit participants from each refugee population and the urban angler population (Heckathorn, D.D., 2011; Sabin, 2011; Liu et al., 2018a). The NYSDOH formed an advisory committee and partnered with local non-profit and…

RDS recruitment

Between September 2015 and January 2016, 311 refugees (including 7 seeds) enrolled in the project over 16 sampling events. A total of 711 referral coupons were distributed, of which 327 (46%) were redeemed. Of those redeeming the coupons and completing the eligibility screening survey, 23 were ineligible. The final sample was derived from six active seeds, with 58% of participants derived from one seed (all but one were Burmese participants), and 20% and 18% derived from the next two seeds (all …

Discussion

PFAS substances have emerged globally as persistent organic pollutants in the environment which bioaccumulate in fish and wildlife (Lau et al., 2007; Buck et al., 2011; Kannan, 2011). PFOS is the most predominant PFAS found in fish samples with higher concentrations typically present in fish blood, followed by liver, brain, and muscle tissue (Becker et al., 2019) and whole fish compared to fillets (Fair et al., 2019). PFAS were detected in fish from all the Great Lakes with PFOS levels higher…

Conclusions

The Burmese subpopulation in our study, particularly those of Karen ethnicity, had elevated levels of PFOS and other PFAS compounds typically associated with consuming fish and seafood. Since 1999–2000, NHANES data have shown an apparent downward trend in PFOS concentrations in the U.S. population (CDC, 2021). More data are needed to characterize current PFAS levels in fish samples from Onondaga Lake and connecting waters where these communities fish. Burmese persons fish and hunt as part of…

Authors contribution statement

Wendy A. Wattigney: Funding acquisition, Conceptualization, Methodology, Formal analysis, Writing – original draft preparation, Visualization, Investigation, and Project administration. Sanghamitra S. Savadatti: Methodology, Data curation, Writing – review & editing, and Project administration, Ming Liu: Data curation, Writing – review & editing, Marian Pavuk: Investigation, Writing – review & editing, Elizabeth Lewis-Michl: Writing – review & editing, Kurunthachalam Kannan: Methodology,…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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