ARTICLE

Cite This:Acad. Res. J. of Nat. and Pub. Health. 2023, 2, 86-91

Sciforce

Academic Research Journal of Nature and Public Health

Journal homepage: www.sciforce.org

Per-and polyfluoroalkyl substances (PFAS) are emerging contaminants:Review of sources, contaminations, and awareness

Shreya Chowdhury[a*]

[a]Major in Neuroscience and Cognitive Science (Freshman), Department of Neuroscience and Cognitive Science, The University of Arizona, Tucson, AZ 87521

ARTICLE INFO

Article history:
Received 20231006
Received in revised form
Accepted 20231015
Available online 20231120

Keywords:
Per- and polyfluoroalkyl substances (PFAS);
Sources for PFAS Exposure;
Pathways of Contamination;
Health Effects of PFAS;
Government Action on PFAS

ABSTRACT

Per- and polyfluoroalkyl substances(PFAS) have been a popular topic in the past few years. They are a category of “emerging contaminants" because PFAS have been detected in the environment through environmental, industrial, and infrastructural sources and causes health problems.

Some sources of PFAS exposure include drinking contaminated municipal water or private well water, eating food grown in places that used or made PFAS, eating fish caught from water contaminated by PFAS, etc. In addition, they have been also found in some products like fast food containers/wrappers, microwave popcorn bags, pizza boxes, cleaning products, personal care products (shampoo, dental floss) and cosmetics (nail polish, eye makeup), etc.

These chemicals move fromcontaminated to non-contaminatedareas since they don’t break down. This leads to contamination of water and food that we eat which causes many health effects. According to many research articles, PFAS are linked to many health issues that could affect the immune function, thyroid function, liver disease, cancer, reproductive and developmental outcomes, etc. To avoid these health problems, we need to minimize PFAS by reducing the use of products that have PFAS in them, limiting levels of PFAS in drinking water, protecting our health after being in or around lakes and streams, and practicing safe gardening habits to lower the chance of exposing ourselves to PFAS.

Regarding what action we have taken against these chemicals, the Environmental Protection Agency (EPA) has identified a “safe level” for six PFAS (PFOA, PFOS, PFNA, PFBS, HFPO-DA, and PFHxS), which are 4 ng/L, 4 ng/L, 10 ng/L, 2000 ng/L, 10 ng/L, and 9 ng/L, respectively, and some states of the United States of America (USA) created laws and/or banned the use of PFAS. Using these “safe levels,” I conducted my own research on roof-harvested rainwater and found that these contaminants were at a higher concentration than what is recommended by the EPA. The reasonfor this contamination couldbe due to the roofing materials when the roof-harvested rainwater is being collected.

In conclusion, it is important for us to regulate PFAS to avoid any future consequences of damaging our health and the environment.

∗Corresponding author. Tel.: *+1-(520)-839-6787*; e-mail: *schowdhury@arizona.edu*

Background

In the past few years, per- and polyfluoroalkyl substances (PFAS) have received a lot of media attention. PFAS are a category of “emerging contaminants" that have been detected in the environment and are linked to many toxic effects such as miscarriage[1], lower birth weight[2], increased risk of liver, kidney, and testicular cancer[3,4], increased risk of cholesterol levels[5], increased risk of asthma[6], increased risk of diabetes[7], etc., but their risk to human health is not well-understood[8].

PFAS are man-made chemicals that have been used in industry and consumer products worldwide since the 1940s[9]. They have been used to make nonstick cookware, water-repellent clothing, stain resistant fabrics and carpets, some cosmetics, some firefighting foams, and products that resist grease, water, and oil[9].

The most studied PFAS are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS)[9]. Perfluorohexane sulfonic acid (PFHxS) and perfluorononanoic acid (PFNA) are also commonly measured and studied[9].

During production and use, PFAS can travel into the soil, water, and air. Most PFAS, including PFOA and PFOS, do not break down, so they remain in the environment[9]. Because of their widespread use and their persistence in the environment, PFAS are found in the blood of people and animals all over the world and are present at low levels in a variety of food products[9]. A 2019 study by the CDC (Centers for Disease Control and Prevention, USA) indicates that 97% of Americans have PFAS in their blood[10]. Some PFAS can build up in people and animals with repeated exposure over time[9] and cause health issues.

Sources for PFAS exposure

There are many sources for PFAS exposure like drinking contaminated municipal water or private well water, eating food grown in places that used or made PFAS, eating fish caught from water contaminated by PFAS (specifically PFOS), accidentally swallowing contaminated soil or dust, eating packaged food that has materials that contain PFAS, and using some consumer products such as stain resistant carpeting and water repellent clothing[11].

There are also some products that contain PFAS like grease-resistant paper, fast food containers/wrappers, microwave popcorn bags, pizza boxes, candy wrappers, stain resistant coatings used on carpets, upholstery, and other fabrics, water resistant clothing, cleaning products, personal care products (shampoo, dental floss) and cosmetics (nail polish, eye makeup), paints, varnishes, and sealants[11].

How do PFAS travel fromcontaminated areasto non-contaminated areas?

As mentioned previously, PFAS don't break down in the environment. They travel from contaminated areas to non-contaminated areas through dust, air, water, soil, etc[12]. With that said, they can be found in many places like drinking water, soil and water near waste sites, fire extinguishing foam, manufacturing or chemical production facilities that produce or use PFAS, food, biosolids, and more[12].

There have been several places in the United States that have been investigated for PFAS, and most of these places had a high concentration of them. For example, in 2021, the groundwater plant in southern Tucson, Arizona was found to have a very high level of PFAS in it[13]. This was a big shock to the entire city because this water was used for a long time and for many purposes like drinking, showering, cleaning, etc[14]. The potential source for the contamination in the groundwater plant is the Air National Guard Base at Tucson International Airport that used firefighting foams until 2018[15]. The plant was shut down because it was getting difficult to remove the PFAS[13]. Another incident occurred in Michigan where it was found that Lake Michigan's Green Bay contained a high concentration of PFAS contamination, and the reason for it was because of a firefighting foam factory in Wisconsin[16]. As a result, this factory and several others got sued for using these PFAS chemicals in their foam[17]. Lastly, the FDA of the United States found PFAS, mostly PFOA and PFOS, in milk samples from New Mexico[18]. The reason for this is because the cows drank water that contained PFAS which came from firefighting foam in a close air force base[18]. These incidents demonstrate how PFAS get from one place to another.

Water and gardens

Areas that are near environmental contamination will most likely end up having PFAS[19]. For instance, those who live in an area where there are many factories and/or waste siteshave a higher chance of getting exposed to PFAS, specifically through water and gardenprocessing. However, regardless of that, there are some techniques and products that we do and use that also increase the amount of PFAS in our water and gardensoil.

First, the method of "roof-harvesting rainwater" which is the process of collecting rainwater using structures like pipes and/or tanks to store and use it for later[20]. In this method, the rainwater gets contaminated by many sources. For example, if one does live in an area with environmental contamination, the contaminants in theair could contaminate the rainwater. Another way that it gets contaminated is through roofing materials, pipes, and tanks because some of them are made from PFAS. Now, if we use thiscontaminated roof-harvesting rainwater to water gardens, then the soil and finally the fruits and vegetables could also be contaminated with these chemicals. Second, the use of biosolids for gardening, also known as fertilizers[12].Some fertilizers also contain PFAS which can affect soil, the water given to the garden, the fruits and vegetables that are grown, and eventually our health. Therefore, this is how PFAS are transferred to rainwater and soil which is taken up by the plant roots and spread to the fruits and vegetables that we eat[19].

Regarding PFAS in garden plants, there are still many things that are unknown[19]. So far, current research has found two things[19]. The first thing is that longer-chain PFAS stay in the roots of plants, and shorter-chain PFAS go to other parts of plants[19]. The second thing is that if there are higher concentrations of PFAS in the water, then there are higher levels of them inplants[19]. However, it is said that eating fruits and vegetables that have low levels of PFAS isn't as harmful as drinking water that has a high level of PFAS on a daily basis[19]. Either way, it is still dangerous if we drink water and eat fruits and vegetables that contain a high concentration of PFAS. All in all, this is why drinking water is the major source of exposure for PFAS, especially in areas with environmental contamination[19].

Health Effects of PFAS

Because of the widespread production and use of PFAS, it was found that many Americans have these contaminants in their body[12]. People can be exposed to these chemicals by working in occupations such as firefighting or chemicals manufacturing and processing, drinking water contaminated with PFAS, eating certain foods that may contain PFAS, including fish, swallowing contaminated soil or dust, breathing air containing PFAS, and using products made with PFAS or that are packaged in materials containing PFAS[12]. Based on current research, PFAS have been linked to many health issues like immune function, thyroid function, liver disease, cancer, reproductive and developmental outcomes, etc[21].

Regarding immune function, it is found that PFAS affect the immunity of a person which raises the question if these chemicals change how well a vaccine works[22]. According to a study that was done in the United States in 2016, it was discovered that children between the ages 12 and 19 with high levels of PFOS had low levels of antibodies to rubella and mumps[22].

As for thyroid function, a study in 2020 states that these chemicals can interrupt the thyroid hormone which can affect the outcome of pregnancy and fetal development[23].

Between liver disease and PFAS, it was found that serums with high levels of PFAS are related to the risk of a higher fatty liver and overall liver function, especially for people who have a high alcohol consumption, are obese, or have diets that are high in fat[24].

According to many research studies, there is a link between these chemicals and cancer[25]. For example, a study in Greenland found that blood serums with high levels of PFAS had a positive correlation with breast cancer[25].

Finally, regarding reproductive and developmental outcomes, many peer-reviewed studies found that specific levels of PFAS can cause reproductive effects like lower fertility or increased high blood pressure in pregnant women[12]. It was also discovered that PFAS can also cause developmental effects like low birth weight, behavioral changes, etc[12].

In general, PFAS are associated with many health effects, but there are specific things like the circumstance of exposure (route of exposure, duration, etc.) and factors related to individuals (sex, health status, age, etc.) that are also considered when identifying the ones that are of greatest concerns[21]. Therefore, these are some health issues that have been found to be associated with PFAS.

Discussion

As we can see, many things can be contaminated with PFAS. There are three main things that influence PFAS contamination which are environmental sources, industrial sources, and infrastructural materials.

Environmental Sources of PFAS. There are many environmental sources that can cause PFAS contamination. One of the main ones is pollution. According to the World Health Organization (WHO), air pollution is contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere[26]. Some common sources of air pollution are from household combustion devices, motor vehicles, industrial facilities, and forest fires[26]. Based on the response of the Michigan PFAS Action Response Team (MPART), there are PFAS in outdoor and indoor air[27]. With that said, we breathe inthis air that is contaminated with PFAS, but the level of PFAS contamination that we inhale will depend on the types of consumers products[27] in a specific location. In addition, according to MPART, inhaling will contribute less PFAS in our body in comparison to eating and drinking contaminated food and water[27]. This does not mean that it is completely safe, but over time, it might become an issue to our health. However, there is limited information on the health risks of inhaling PFAS from the air[27].

Industrial Sources PFAS. Like environmental sources, there are many industrial sources that can contribute to contamination of PFAS. One of the main ones is industrial piping which is used to transfer substances. However, the coatings of these pipes tend to be made up of PFAS[28] which is not a good thing because the substances that go through the pipes also get contaminated with PFAS. For example, every state in the United States has a main water sourcethat is used for domestic purposes like drinking, bathing, gardening, etc. In many places, they use the method of "roof-harvesting rainwater" which uses pipes to collect rainwater. This means that sometimes the roof-harvested rainwater gets contaminated with PFAS through the roof and pipe materials.

InfrastructuralSources of PFAS. Like the other two types of sources mentioned above, there are many infrastructural materials that can cause PFAS contamination too. In the case of "roof-harvesting rainwater", the roofing material is a major factor because the rainwater is collected through roofs. According to the Green Science Policy Institute, PFAS are also used as coatings on roofs[29]. Like pipes, the PFAS from the coatings of the roof will transfer to the rainwater, causing it to have PFAS.

Why did I choose roof-harvested rainwater in my research? Since drinking water is the major source for PFAS, I did a project on PFAS contamination in roof-harvested rainwater[31], which is shown in Figure 1. Basically, I collected samples of roof-harvested rainwater from a reservoir and a filteredsample from the sink. Then, I compared the contamination levels and found that there are higher levels of PFAS in the roof-harvested rainwater samples than in the filtered sample[31].In addition, there is another similar experiment that was conducted by the Department of Environmental Science at the University of Arizona in which they also tested roof-harvested rainwater around rural and urban areas of Tucson and found that there were PFAS in it[32]. Therefore, based on these two experiments, it is important to check the PFAS status of drinking water by getting it tested occasionally or buying a filtering system to prevent any health issues.

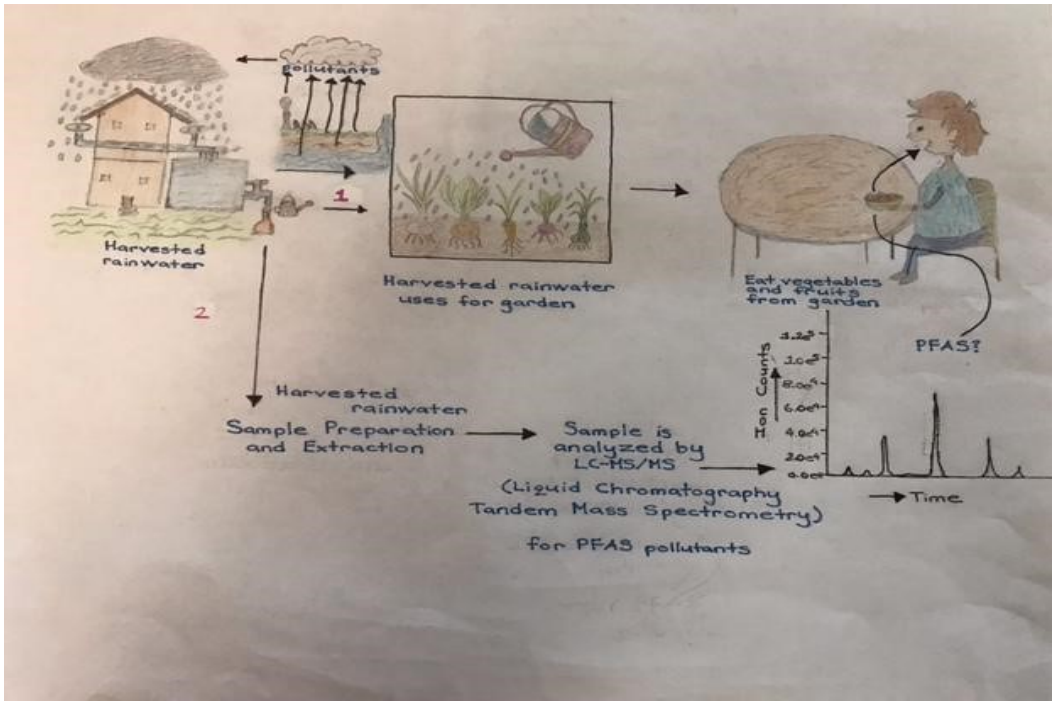

Fig. 1: A diagram that depicts **1.** how PFAS spread from air to gardens and finally to our body and **2.** how they are analyzed

How do we minimize PFAS? PFAS can be found everywhere, and we can be exposed to them very easily which brings up the question of whether there is a way that we can limit these chemicals. Yes, there are ways that we can do that:

First, we need to reduce the use of products that have PFAS in them[33]. Some ways that we can do that is by making sure that the ingredients in product labels don't have words like "fluoro" or "perfluoro," being aware of packaging for foods that contain grease-repellent coatings, avoiding stain-resistance treatments, and limiting the use of non-stick cookware[33].

Second, we need to limit levels of PFAS in drinking water[33]. To do that, we need to use alternate sources of drinking water that have been tested to have low levels of PFAS, a treatment system that reduces PFAS, and bottled water that has a NSF and/or IBWA seal[33]. It is also recommended to use a filtering system when drinking, cooking, washing fruits or vegetables, etc[33].

Third, we need to protect our health after being in or around lakes and streams[33]. Some ways to do that areto not use the water in lakes and streams for any purpose like drinking, washing our hands, and touching foam on the water that might be contaminated with PFAS[33]. Usually, the foam that has PFAS is a bright white coloring, gathers on land, and is lightweight[33]. Natural foam is off-white and/or brown, builds up in bays, and smells like soil[33]. If you do end up doing one of the things that are mentioned above, then you should wash your hands[33].

Finally, we can practice safe gardening habits to lower the chance of exposing ourselves to PFAS[19]. We can do that by washing fruits and vegetables to get rid of any soil and dust particles, using natural matter in your soil, putting on gloves and washing hands after gardening and before consuming anything, avoiding things like smoking, making sure not to trace dirt from the garden into the house, and teaching kids to clean fruits, vegetables, and their hands before touching or ingesting food[19]. Regarding the use of irrigation water, it is best to use a filter that removes PFAS and confirmthrough lab testbefore using it to water plants[34].

All in all, these are some ways that we can minimize PFAS in our daily lives.

Government Action on PFAS. In the past few years, the federal government has acted on PFAS. In 2016, the Environmental Protection Agency (EPA) established a "safe level" of the chemicals PFOA and PFOS in drinking water which is 70 parts per trillion (70 ppt or 70 ng/L)[35]. If it exceeds this level, then the drinking water is not safe. In 2019, the EPA created an action plan on PFAS[35] which describes how they will approach these chemicals by identifying and understanding them, explaining the status of PFAS contamination, limiting future contamination, and making the public aware of PFAS[36]. In 2020, the EPA updated the 2019 action plan[35] for PFAS which outlines a few key areas[36]. In 2022, the EPA stated PFOA and PFOS as dangerous chemicals[35]. In the beginning of 2023, the EPA made a proposal to develop a "safe level" for six PFAS (PFOA, PFOS, PFNA, PFBS, HFPO-DA, and PFHxS) which are 4 ng/L, 4 ng/L, 10 ng/L, 2000 ng/L, 10 ng/L, and 9 ng/L,

respectively, in drinking water[37]. Regarding state governments, there have been several states that created laws and/or banned the use of PFAS[38]. These are some actions taken by the federal and state governments against PFAS.

Conclusion

Since the 1940s, PFAS have been used in many products like grease-resistant paper, fast food containers/wrappers, microwave popcorn bags, pizza boxes, cosmetics, shampoos, etc[11]. A recent study (2019) by the CDC indicates that 97% of Americans have PFAS in their blood[10]. However, many studies have found that these chemicals are linked to many health issues like immune function, thyroid function, liver disease, cancer, reproductive and developmental outcomes, etc[21]. This is why it is important to minimize PFAS by reducing the use of products that have PFAS in them[33], limiting levels of PFAS in drinking water by getting it tested once in a while and/or using a filtration system[18], protecting our health after being in or around lakes and streams[33], continuing the habit of breastfeeding[33], and using safe gardening habits[19]. In conclusion, as an "emerging contaminant", it is important for us to regulate PFAS to avoid any future consequencesof damaging our health and the environment.

Acknowledgements

I would like to thank Dr. Leif Abrell,Ms. Mary Kay Amistadi, and Ms. Danielle Barrientes of Arizona Laboratory for Emerging Contaminants (ALEC), for allowing me to do my senior high school research project in ALEC and guiding me throughout the entire process of collecting and measuringPFAS inroof-harvested rainwater samples. I would also like to thank Dr. John Chorover, Director of ALEC, for his support.

I would also like to thank David Stropka and Elayna Direnfeld of BASIS Oro Valley High School, Oro Valley, AZ for always giving me feedback throughoutthis entire senior project.

Finally, I am thankful to Dr. Uttam K. Chowdhury, my father, for helping me throughout the senior project andreviewing and suggestingfor the preparation of this manuscript.

References

1. Dyjak, A. (2020). "Yale University: PFAS Linked With Increased Risk of Miscarriage." Hydroviv, 28 Apr. 2020, https://www.hydroviv.com/blogs/water-smarts/yale-university-pfas-linked-with-increase-risk-of-miscarriage.
2. Wikström, S., et al., (2019). "Maternal serum levels of perfluoroalkyl substances in early pregnancy and offspring birth weight." Pediatric Research, 13 Dec. 2019, https://www.nature.com/articles/s41390-019-0720-1.
3. Goodrich, J. A., et al (2022). "Exposure to perfluoroalkyl substances and risk of hepatocellular carcinoma in a multiethnic cohort." JHEP Reports Innovation in Hepatology, 8 Aug. 2022, https://www.jhep-reports.eu/article/S2589-5559(22)00122-7/fulltext.
4. Bartell, S. M. and Vieira, V. M (2021). "Critical review on PFOA, kidney cancer, and testicular cancer." Taylor & Francis Online, 24 May 2021, https://www.tandfonline.com/doi/full/10.1080/10962247.2021.1909668.
5. Li, Y., et al., (2020). "Associations between perfluoroalkyl substances and serum lipids in a Swedish adult population with contaminated drinking water." Environmental Health, 14 Mar. 2020, https://ehjournal.biomedcentral.com/articles/10.1186/s12940-020-00588-9.
6. Averina, M., et al (2019). "Serum perfluoroalkyl substances (PFAS) and risk of asthma and various allergies in adolescents. The Tromsø study Fit Futures in Northern Norway." ScienceDirect, Feb 2019, https://www.sciencedirect.com/science/article/abs/pii/S0013935118305760?via%3Dihub.
7. Gui, S. Y., et al (2022). "Association between per- and polyfluoroalkyl substances exposure and risk of diabetes: a systematic review and meta-analysis." National Library of Medicine, 15 Aug. 2022, https://pubmed.ncbi.nlm.nih.gov/35970987/.
8. Dyjak, A. (2022). "What Are Per and Polyfluoroalkyl Substances (PFAS)?" Hydroviv, 12 Sept. 2022, https://www.hydroviv.com/blogs/water-smarts/what-are-per-and-polyfluoroalkyl-substances-pfas?nbt=nb%3Aadwords%3Ag%3A18357042197%3A142778256673%3A593775621088&nb_adtype=&nb_kwd=&nb_ti=dsa-40129889513&nb_mi=&nb_pc=&nb_pi=&nb_ppi=&nb_placement=&nb_si=%7Bsourceid%7D&nb_li_ms=&nb_lp_ms=&nb_fii=&nb_ap=&nb_mt=&utm_term=&utm_medium=ppc&utm_source=adwords&utm_campaign=General%2BTerms%2B%257C%2BSearch&hsa_net=adwords&hsa_mt=&hsa_tgt=dsa-40129889513&hsa_grp=142778256673&hsa_acc=6208013034&hsa_kw=&hsa_ad=593775621088&hsa_src=g&hsa_cam=1775518925&hsa_ver=3&gclid=EAIaIQobChMIr4fb_qz1-gIV4hZ9Ch2x6Qd8EAAYAiAAEgJIl_D_BwE.
9. "What are PFAS?" Agency for Toxic Substances and Disease Registry, 1 Nov. 2022, https://www.atsdr.cdc.gov/pfas/health-effects/overview.html#:~:text=PFAS%20are%20man%2Dmade%20chemicals,grease%2C%20water%2C%20and%20oil
10. "Fourth National Report on Human Exposure to Environmental Chemicals Updated Tables, January 2019, Volume One." CDC, Jan. 2019, file:///home/chronos/u-1244f0d333d54d74918ed61cec74254f90a18d18/MyFiles/Downloads/cdc_75822_DS1%20(1).pdf.

11. "How can I be exposed?" Agency for Toxic Substances and Disease Registry, 1 Nov. 2022, https://www.atsdr.cdc.gov/pfas/health-effects/exposure.html.
12. "Our Current Understanding of the Human Health and Environmental Risks of PFAS." EPA, 7 June 2023, www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.
13. Davis, T. (2022). "Soaring Contamination Causes Shutdown of Tucson Water Treatment Plant." Arizona Daily Star, 14 July 2022, tucson.com/news/local/soaring-contamination-causes-shutdown-of-tucson-water-treatment-plant/article_cbdc8044-c7f1-11eb-a3b5-e7261bcdd359.html.
14. Migoya, C. Zayna, S. (2023). "PFAS Contamination in South Tucson Challenges Historic Cleanup, Revives Health Concerns." Azcentral, 17 Jan. 2023, www.azcentral.com/story/news/local/arizona-environment/2023/01/16/tucson-water-contaminated-by-pfas-health-concerns-amplified/69807318007/.
15. Davis, T. (2022). "Why PFAS chemical levels are rapidly rising in Tucson groundwater." Arizona Daily Star, 18 July 2022, https://tucson.com/news/local/why-pfas-chemical-levels-are-rapidly-rising-in-tucson-groundwater/article_44728cfe-caec-11eb-bfe8-3b727410191d.html.
16. House, K. (2023). "Lakes Michigan and Huron join list of lakes with PFAS-tainted smelt." Great Lakes Now, 2 Feb. 2023, https://www.greatlakesnow.org/2023/02/lakes-michigan-huron-pfas-tainted-smelt/#:~:text=While%20that%20research%20is%20ongoing,foam%20factory%20in%20Marinette%2C%20Wisconsin.
17. Kelly, J. (2021). "Wisconsin city sues makers of firefighting foam over "Forever chemicals" pollution." Courthouse News Service, 4 March 2021, https://www.courthousenews.com/wisconsin-city-sues-makers-of-firefighting-foam-over-forever-chemicals-pollution/.
18. Jha, G., et al (2021). "Per- and polyfluoroalkyl substances (PFAS) in integrated crop-livestock systems: Environmental exposure and human health risks." U.S. National Library of Medicine, 28 Nov. 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8657007/.
19. "PFAS and Backyard Gardening." Wisconsin Department of Health Services, Jan. 2023, https://www.dhs.wisconsin.gov/publications/p03111.pdf.
20. "Rainwater harvesting 101: Your how-to collect rainwater guide." Innovative Water Solutions LLC, n.d., https://www.watercache.com/education/rainwater-harvesting-101#:~:text=Rainwater%20harvesting%20is%20collecting%20the,some%20sort%20of%20storage%20vessel.
21. Fenton, S. E., et al (2021). "Per- and polyfluoroalkyl substance toxicity and human health review: Current state of knowledge and strategies for informing future research." U.S. National Library of Medicine, March 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7906952/#R101.
22. "PFAS and the Immune System: What Do We Know? - PFAS exchange." Silent Spring Institute, n.d., https://pfas-exchange.org/resources/pfas-and-the-immune-system-what-do-we-know/#:~:text=Because%20PFAS%20can%20interfere%20with,the%20effectiveness%20of%20routine%20vaccinations.
23. Coperchini, F., et al (2021). "Thyroid Disrupting Effects of Old and New Generation PFAS." U.S. National Library of Medicine, 19 Jan. 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7851056/#:~:text=In%20vitro%2C%20ex%20vivo%20data,pregnancy%20and%20fetal%2Dchild%20development.
24. Zhang, X., et al (2023). "Association of per- and polyfluoroalkyl substance exposure with fatty liver disease risk in US adults." JHEP Reports, 2 Feb. 2023, https://www.jhep-reports.eu/article/S2589-5559(23)00025-3/fulltext.
25. "PFAS Forever Chemicals (also PFOA, PFOS)." Breast Cancer Prevention Partners, n.d., https://www.bcpp.org/resource/pfas-forever-chemicals-pfoa-pfos/#:~:text=PFOA%20is%20a%20suspected%20endocrine,increased%20risk%20for%20breast%20cancer.
26. "Air Pollution." WHO, n.d., https://www.who.int/"The Emerging Contaminants, PFAS, in Roof-Harvested Rainwater." 5 May 2023, https://docs.google.com/document/d/14EMEgsiEsfKxVfcEv3TBvHPXM9u8Ax9Sk6R7FIeS06Y/edit?usp=sharing.
27. "Frequently Asked Questions on Air Quality Related Issues Air Quality Workgroup – Michigan PFAS Action Response Team (MPART)." Michigan Department of Environment, Great Lakes, and Energy, Aug. 2019, https://www.michigan.gov/-/media/Project/Websites/PFAS-Response/Workgroups/Air-Quality/FAQ-Air-Quality-Related-Issues.pdf?rev=cbd9c3f0d4f04a9699d288ab5b38f056#:~:text=Can%20PFAS%20be%20found%20in%20indoor%20air%3F,been%20detected%20in%20household%20dust.
28. "Does PVC Pipe Contain PFAS?" Pintas& Mullins, n.d., https://www.pintas.com/pfas-class-action-lawsuit/does-pvc-pipe-contain-pfas/#:~:text=PVC%20piping%20is%20commonly%20used,Environmental%20Protection%20Agency%20(EPA).

29. "PFAS in Building Materials." Green Science Policy Institute, n.d., https://greensciencepolicy.org/our-work/building-materials/pfas-in-building-materials/#:~:text=PFAS%20are%20used%20as%20protective,in%20this%20type%20of%20application.
30. "What are the health effects of PFAS?" *ATSDR*, 1 Nov. 2033, https://www.atsdr.cdc.gov/pfas/health-effects/index.html.
31. Chowdhury, S. (2023). "The Emerging Contaminants, PFAS, in Roof-Harvested Rainwater." Senior Thesis, BASIS Oro Valley High School, Oro Valley, AZ. This research work was done in the Department of Environmental Science at the University of Arizona, Tucson. 5 May 2023, https://drive.google.com/file/d/18izxNiJc6soFKFmEMuHZTlSXH_IuqiIe/view?usp=drive_link.
32. Villagómez-Márquez, N., et al (2023). "Organic micropollutants measured in roof-harvested rainwater from rural and urban environmental justice communities in Arizona." 10 June 2023, https://www.sciencedirect.com/science/article/abs/pii/S0048969723012780?via%3Dihub.
33. "PFAS Health Effects & Ways to Reduce Exposure." Public Health Madison & Dane County. n.d., https://www.publichealthmdc.com/environmental-health/environmental-hazards/pfas/pfas-health-effects-ways-to-reduce-exposure.
34. "PFAS in drinking water: Safety questions about gardening, livestock, pets." Washington State Department of Agriculture, n.d., https://cms.agr.wa.gov/WSDAKentico/Documents/FSCS/Food%20Safety/AGR-PUB-101-016WSDA-DOH-FS-on-Pets-Livestock-and-Gardening-Final-English.pdf.
35. Aguilera, E. (2023). "The federal government aims to crack down on pfas in drinking water. What happens next?" Association of Health Care Journalists, 28 July 2023, https://healthjournalism.org/blog/2023/07/the-federal-government-aims-to-crack-down-on-pfas-in-drinking-water-what-happens-next/#:~:text=The%20federal%20government%20has%20taken,a%20formal%20PFAS%20Action%20Plan.
36. "EPA's Per- and Polyfluoroalkyl Substances (PFAS) Action Plan." *EPA*, Feb. 2019, https://www.epa.gov/sites/default/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf.
37. "2023 EPA PFAS Rule Proposal." Department of Environmental Protection, 24 July 2023, https://dep.nj.gov/pfas/2023-epa-pfas-rule-proposal/#:~:text=On%20March%2014%2C%202023%2C%20EPA,(GenX%20chemicals)%20and%20PFHxS.
38. Kindy, K. (2023). "States take matters into their own hands to ban 'forever chemicals.'" *The Washington Post*, 5 June 2023, https://www.washingtonpost.com/politics/2023/06/05/forever-chemicals-state-bans-pfas/.