Town of Arlington
Department of Health and Human Services
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Artificial Turf Study Committee Agenda
02/27/24

Meeting Date: February 27, 2024
Meeting Time: 5PM-6:30PM
Location: Zoom

Objectives:

1) To hear from subject matter experts on various topics concerning the Health, Safety, and Environmental concerns associated with natural grass and artificial turf fields.
2) To discuss the draft bullet reports submitted by each working group

Agenda

I. Correspondence Received
II. Discussion: Draft Working Group Reports- continuation from 02/20/2024 Meeting
   a. Environmental
   b. Safety
   c. Health
III. Discussion: Project Timeline, Deliverables, Reports
IV. New Business
V. Adjourn

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ARTIFICIAL TURF COMMITTEE MEETING COMMENTS FROM THE CHAT

Date: February 20, 2024
Time: 5PM
Location: Remote Participation

Larry Slotnick

58:48
LS

Best practices in 2023 and forward are downcycling of the synthetic carpet into shock pad, which is the underlayment of a new turf field. Many downcycled materials are utilized to cap landfills, such as glass cullet.

Larry Slotnick

01:01:07
LS

Shaw Industries, in Georgia, will accept any Shaw-produced turf carpet and will store and then downcycle the material, as they need it, to create Shaw shock pad. It's called "Next"

Larry Slotnick

01:07:13
LS

As Ian is commenting on now, and as we all know, every sport is different and has different high-use areas where the fibers will wear out more quickly. This happens, of course, whether the field is natural or synthetic. Field maintenance staff need to do a much better job of managing sectional replacement. Striping often has its seams wear out and come apart, and maintenance staff pays attention to that. With more flexible management of turf condition, an uncovered field can probably give you 15 years of useful life in New England weather conditions.

Larry Slotnick

01:13:47
LS

Crumb rubber infill has a practically infinite useful life. The primary challenge is containing it to the field site. That is THE primary challenge. It has the best playability and lowest cost, and is made from downcycled car and truck tires. Crumb rubber does not absorb moisture. This is an advantage in cold-weather climates because it will not freeze and will not turn a turf field into a rock-hard surface. Given a long cold winter in New England, this could allow organized sports to begin in late March or early April, instead of having to wait for a Spring thaw. But, we now have very functional alternatives to crumb rubber. These should be evaluated.

Larry Slotnick

01:20:03
LS

Robbins Farm baseball-soccer field.... heavy usage

Larry Slotnick

01:32:04

LS

Please remember that natural grass fields are very difficult to set up for multiple sports. And there are unforeseen consequences. Different sports will be striped in different colors, of course. Every time the grass is cut, the field will need to be restriped for every sport. That amounts to a lot of paint purchased and applied, grass clipping that are contaminated with paint, and very high maintenance costs. Synthetic fields are the ideal application for multi-sport utilization for 10-12 months of the year in New England.

Susan Stamps

01:38:26

SS

Appreciate Ian's presentation, thank you!

Susan Stamps

01:39:35

SS

Good to know there's an expect who can help us with our natural turf fields, whatever we decide to do.

expert

Susan Stamps

01:48:02

SS

My group, Green Streets Arlington, has filed a shaded parking lots warrant article for town meeting

Larry Slotnick

01:50:20

LS

At the artificial turf public meeting that was held at Town Hall in May 2023, Arlington Rec staff were asked directly if they were aware of any heat-stress induced illnesses at Arlington High School's Pierce Field. The response was "no." I suppose that question would be better directed to Arlington Public Schools or the AHS athletic director.

Joe Connelly

01:51:32

JC

Hi Larry,

we actually had the AHS athletic trainer in last week and she did not report any issues. They do train their coaches and athletes to look for early signs to prevent incident.

Larry Slotnick

01:53:49

LS

Hi Joe and everyone else. As you saw above, I've chimed in with running commentary on Ian's presentation based on research I conducted leading up to the debate at Town Meeting 2023.

Larry Slotnick

02:00:48

LS

Please keep in mind that a natural grass field that's designed for optimal drainage with major excavation, 12" thick gravel underlayment, is managed with soil amendment products multiple times per year, cut and re-striped dozens of times per year, etc. is never going to be considered a natural habitat for insects, worms or much, if any, natural life.

Susan Stamps

02:03:45

SS

I think wetlands protection generally comes up vis a vis construction projects but PFAS outside of projects, could leach into wetlands, Mill Brook, Mystic Lakes, Spy Pond, the Res and it might not be known,. perhaps

Fwd: Tiny Particles of Plastic Now Pollute Our Food, Water and Even the Clouds | Truthout

Robin Bergman <robinorig@gmail.com>
Wed 2/21/2024 12:46 PM
To:Natasha Waden <nwaden@town.arlington.ma.us>

Hi Natasha,
Please add this to your minutes as correspondence for the Artificial Turf study committee.
Best,
Robin Bergman
Town Meeting Member,
Precinct 12

---------- Forwarded message ---------
From: **Robin Bergman** <robinorig@gmail.com>
Date: Tue, Feb 20, 2024, 12:22 PM
Subject: Tiny Particles of Plastic Now Pollute Our Food, Water and Even the Clouds | Truthout
To: Jim DiTullio <james_ditullio@hotmail.com>

https://truthout.org/articles/tiny-particles-of-plastic-now-pollute-our-food-water-and-even-the-clouds/

Good, comprehensive, latest article on this. Please add it to your correspondence for the artificial turf study group.

Best,
Robin Bergman
Town Meeting Member, Precinct 12

truthout

Bergman Email1_ link 1

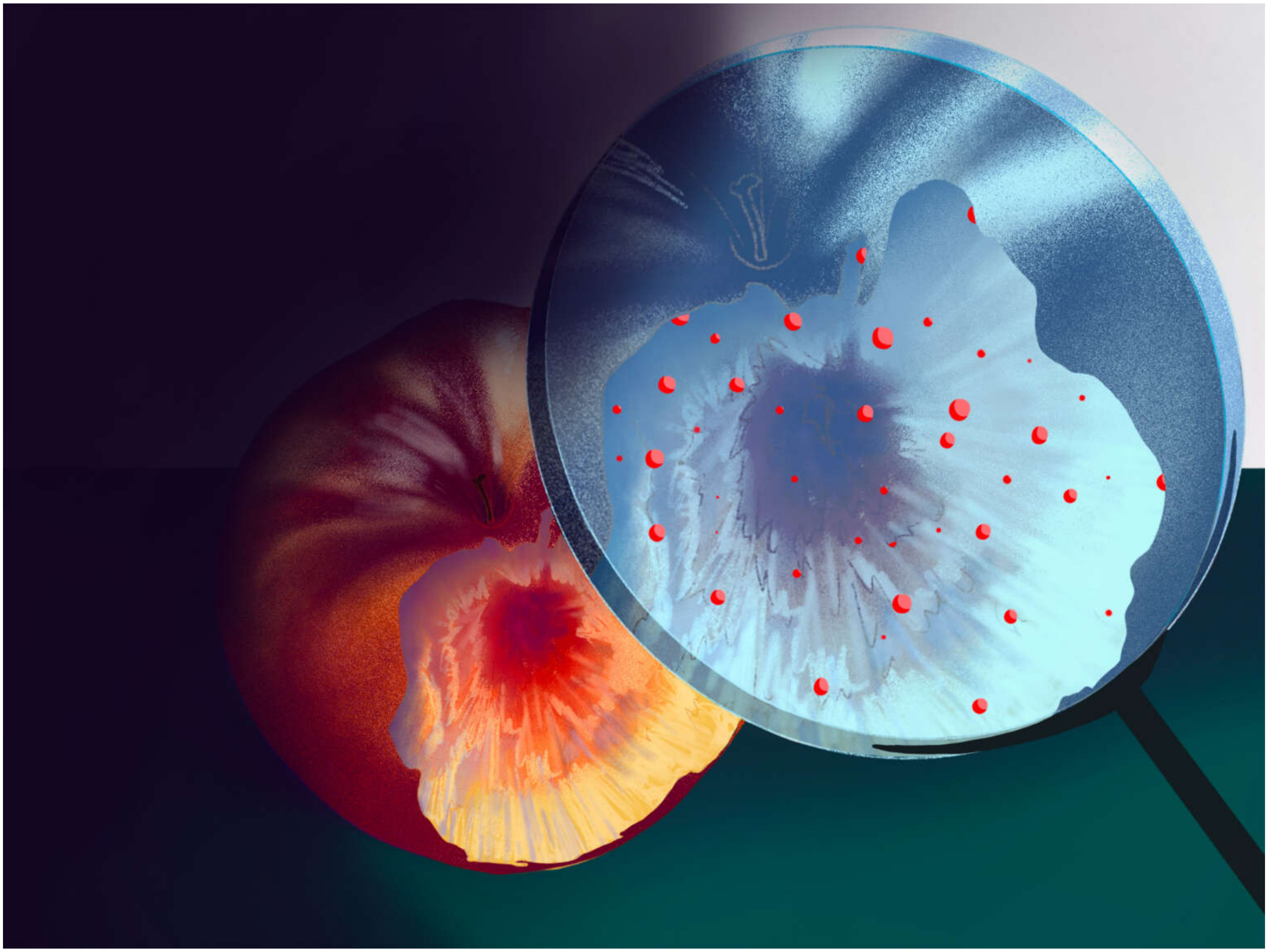
NEWS ANALYSIS | ENVIRONMENT & HEALTH

Tiny Particles of Plastic Now Pollute Our Food, Water and Even the Clouds

From the deep ocean to the sky, microplastics are now everywhere, and fossil fuel firms are still ramping up production.

By JP Sottile, TRUTHOUT

February 19, 2024



AYO WALKER / TRUTHOUT

The bad news about the plastic crisis often seems as ubiquitous as plastic itself. But, like many pressing issues, it also seems to come and go with a breeziness that belies its urgency. That couldn't be truer than it is in the case of three recent reports on the penetration of microplastics, nanoplastics and plasticizers into our food and water and, therefore, into our bodies.

The first story came from the intrepid investigators at *Consumer Reports* (*CR*). They tested a variety of foods in a variety of packaging and the results were shocking. Plasticizers, the chemical components that make plastic so malleable and, therefore, so ubiquitous, are infused throughout our food supply, from Annie's Organic Cheesy Ravioli to Wendy's Crispy Chicken Nuggets, from General Mills Cheerios to Del Monte Sliced Peaches in 100% Fruit Juice, from Hormel Chili With Beans to Chicken of the Sea Pink Salmon in Water. Those products all topped their respective categories for "total phthalates per serving."

Amazingly, a full 99 percent of the well-known, widely consumed products tested by *CR* conclusively showed we regularly eat a hearty helping of phthalates and bisphenols when we chow down a variety of foods. These chemicals can mimic estrogen and disrupt the endocrine system. In the case of a "well-studied," widely used phthalate called "DEHP," *CR* noted its links to "insulin resistance, high blood pressure, reproductive issues, early menopause, and other concerns at levels well below the limits set by American and European regulators."

Another study, this time by Ocean Conservancy and the University of Toronto, found microplastics in 88 percent of the 16 types of protein they tested, "including seafood, pork, beef, chicken, tofu, and three different plant-based meat alternatives." Based on these findings and those from a related study, scientists estimated the average American consumes 11,500 microplastics every year. Depending upon the variety of proteins a given American eats, that figure could rise as high as 3.8 million microplastics consumed annually. "Beef" may be "what's for dinner," but it comes with a heaping side of microplastics.

Finally, researchers at Columbia University used a technique called "stimulated Raman scattering microscopy" to reveal heretofore unseen nanoplastics hiding in bottled water. What they found was a staggering 110,000 to 370,000 plastic particles in each liter of water tested, with 90 percent of those being nanoplastics. Nanoplastics range between one nanometer and one micrometer in size. Compare that to microplastics, which range from one micrometer up to five millimeters. By further comparison, a human hair can range between 17 and 181 micrometers.

RELATED STORY

Plastics Are Fossil Fuel Industry's Plan B. Fenceline Communities Pay the Price.

In other words, nanoplastics are really, really small.

So small, in fact, that a 2022 paper on the "biointerface" between humans and nanoplastics highlighted a number of studies all pointing to the penetrating power of these stray substances, produced so prolifically by the petrochemical industry. The authors cited, among other things, an animal-based study that found nanoplastics "penetrate the intestinal barrier" and "can be further translocated into blood vessels." Additionally, nanoplastics were found to "cross the blood-brain barrier after intravascular injection and accumulate in the brain." Yet another study found nanoplastics crossing the "placental barrier through passive diffusion," and the authors went on to postulate that all of this indicates the likelihood that nanoplastics are respirable, meaning those tiny particles "may penetrate the blood-air barrier and may be transported into the blood-circulating system."

It's unnerving to think we might be breathing in tiny particles of plastic that can enter our bloodstreams through our lungs. It's even more unnerving given recent revelation that we are quite literally "uploading" these nettlesome plastic particles into the clouds.

Cloudy, With a Chance of Plastic

A recent *Nautilus* roundup on the omnipresence of plastics cited a November 2023 paper published in the journal Environmental Science & Technology Letters. In it, the researchers reported finding microplastic fibers in liquid samples from "clouds at the top of Mount Tai in eastern China." Those samples included microplastic fibers "from clothing, packaging, or tires." The lower the altitude of the clouds they sampled, the more particles they found. The paper's authors speculate on the climate-altering synergy of these plastic-infused clouds because some older particles that "attract elements like lead, oxygen, and mercury, could lead to more cloud development."

As if on cue, a team of researchers in Newfoundland, Canada, deployed a simple glass cylinder to record possible changes in the amount of microplastic particles that might've rained down when "pristine" Hurricane Larry hit the province in 2021. Larry was deemed "pristine" because it hadn't yet made landfall after forming over the Atlantic. Even better, according to a detailed report in *Wired*, it passed over the "North Atlantic gyre," a swirling mass of floating plastic refuse created by ocean currents. By simply gathering samples at intervals before, during and after Larry's landfall, researchers saw a "spike" in microplastic particles from "tens of thousands" to as high as "113,000." By tracing those particles with "back trajectory modeling," researchers "confirmed that Larry had picked up the microplastics at sea, lofted them into the air, and dumped them on Newfoundland."

Of course, Hurricane Larry brought a smorgasbord of microplastics with it. The lead author of the paper, Anna Ryan of Dalhousie University in Nova Scotia, told *Wired* the team didn't see "an overwhelming amount of one certain polymer — there's a real variety." While variety might be "the spice of life," we'd probably prefer our hurricanes remain unseasoned.

Denial Is Not Just a River in Egypt

Sadly, the problem of plastic entering the atmosphere is echoed in the food chain. That was confirmed by research scientist Oladimeji Ayo Iwalaye's study of zooplankton. Based at the University of British Columbia, she discovered that "tiny shrimp-like creatures called *Cyphocaris challengeri* — a key food for herring, juvenile salmon and rockfish — are eating the microplastic fibres less than five millimetres in length." This creates a "junk food effect" as the "empty calories" of microplastics "accumulate up the food chain." Even worse, Iwalaye told *Sea West News*, the microplastic fibers generate heavier poop that falls quickly in the deep sea where it is "likely consumed by bottom-dwelling sea life like crabs, sea stars, worms or sea cucumbers."

Another researcher, Dalia Saad of the University of the Witwatersrand, studied freshwater Nile tilapia, a species widely sold in fish markets along one of Earth's most famous, lifegiving rivers. Her team found microplastic particles contaminating all 30 of the freshly caught fish purchased at an open-air market alongside the river. As one report noted, the Nile is "the lifeblood of 300 million people across 11 nations." But, like the food tested in the United States, a key source of protein for millions of Africans carries with it the sad signature of this plastic age. Sadder still, plastic's hydrocarbon-generated cousin — climate pollution — is also taking a toll on the Nile's fish, as the river's stocks "plummet" in part due to rising temperatures.

The oil industry's far-reaching impact was also felt last November in the Nile River Basin, when Kenya hosted the third of five rounds of the United Nations-mandated Intergovernmental Negotiating Committee on Plastic Pollution. Known colloquially as the "Global Plastics Treaty," negotiators from 175 nations tried but failed to reach a long sought-after global agreement on plastic. Environmental activists cited by *Associated Press* said rules governing the entire lifecycle of plastic were scuttled by oil producing nations. Those petrostates prefer to shift the focus to waste management, thus preserving plastic production and "managing" the ensuing pollution on the back end. That's instead of making less plastic in the first place.

It's a well-worn tactic.

Before the preceding round of treaty negotiations in 2022, *Reuters* uncovered the duplicitous strategy of "plastic industry groups representing … ExxonMobil Corp, Royal Dutch Shell Plc and Dow Inc." Publicly, these companies express support for a global agreement to "tackle" plastic pollution. Privately, they fund and deploy trade organizations like the American Chemistry Council (ACC) to "help steer treaty discussions away from production restrictions." *Reuters* knows that because they saw a copy of an email in which the ACC proposed an Orwellian-named alliance called "Business for Plastic Pollution Action."

The alliance's stated goal was to devise "strategies to persuade conference participants to reject any deal that would limit plastic manufacturing." They seek to "shift the debate," *Reuters* wrote, by "focusing governments' attention on the benefits of plastic." They also planned to "hold monthly meetings and share policy recommendations with governments," aka lobbying. And lobby they have. According to the Center for International Environmental Law, the fossil fuel and chemical industries sent 143 registered lobbyists to press their case at the recently failed round of negotiations. That amounted to a 36 percent increase in lobbyists over the previous round of negotiations. It turns out that plastic-pushing lobbyists are almost as plentiful as the petrochemical garbage now accumulating in every corner of the globe.

The ACC has also led the charge against legislative action here in the U.S. They predictably opposed the thrice-proposed "Break Free From Plastic Pollution Act." Immediately after it was reintroduced by Democratic Oregon Sen. Jeff Merkley and Democratic California Rep. Jared Huffman in October of 2023, the ACC responded by agreeing "that plastic waste should never be in our environment," but attacked the bill for doing "little to eliminate plastic pollution while doing a lot to damage the U.S. economy." Instead, they promoted their "5 Actions for Sustainable Change," which requires "U.S. packaging to have at least 30% recycled plastic by 2030, would appropriately regulate innovative recycling technologies, and develop minimum requirements and standards for recycling around the country." The ACC's criticisms were echoed by the Plastics Industry Association, which "slammed" the bill and instead proposed "investments in recycling infrastructure and greater demand for recycled content through minimum requirements and stronger end-markets."

What they really object to is anything that curtails the amount of plastic produced by their petrochemical benefactors. Like their petrostate partners in the global treaty negotiations, they shift the focus from lifecycle management (and interruption) to recycling. The ACC specifically pitches so-called "advanced recycling," tempting pliable legislators with the tantalizing prospect that we can "implement emerging recycling technologies" to keep on producing plastic, break it down chemically and then reuse it again and again.

But the promise of a circular future belies a barrage of reporting all pointing out the abject failure of recycling. In the U.S., only about 5 percent to 6 percent of plastics are recycled each year, and only about 9 percent of *all the plastic ever produced* has been recycled, according to *MIT Technology Review*. These stark facts lead critics of plastic recycling to call it a "myth" and a "lie." At the very least, it is greenwashing at its most alluring and, given the scope of the crisis, at its most pernicious. It also betrays new evidence in favor of interrupting plastic's lifecycle.

A report produced by the U.S. Public Interest Research Group's Environment America Research & Policy Center looked at the impact of plastic bag bans in "five states and cities that cover more than 12 million people combined."

Those bans collectively cut "single-use plastic bag consumption by about 6 billion bags per year." As the authors point out, "that's enough bags to circle the earth 42 times." After enacting a ban in 2022, the state of New Jersey alone eliminated "more than 5.5 billion plastic bags annually," therefore reducing the number of single use plastic bags destined to degrade and disperse for decades to come. Those are future particles that will not get uploaded to the clouds or ingested by aquatic organisms. That's because, quite unlike industry-promoted recycling boondoggles, plastic bag bans actually work.

As *Grist* pointed out, there are now "more than 500 citywide ordinances banning plastic bags in the U.S., as well as 12 statewide bans." But *Grist* also noted a backlash to bans on single-use plastics, often on the grounds that restrictions are hypocritical, "bad for businesses" or curtail a consumer's "freedom" to "choose plastic." As a result of this backlash, some 18 states have passed "so-called preemption laws, preventing local governments from adopting their own bag bans." Among the glaring problems with those arguments is the plain fact that the omnipresence of plastic has eliminated our freedom "to choose" its presence in our lives… so much so that the inescapability of plastic pollution has parents asking if breast milk "will hurt my baby?"

As *The Washington Post* reported, "tiny microplastic particles" have joined pesticides and flame retardants in human milk. The *Post* cited a 2022 study which found "tiny plastic particles" in "75 percent of 34 breast milk samples studied." The lead researcher of the 2022 study told The *Post* the problem comes from the chemicals used to make the plastic — like the phthalates cited in the *CR* report — which "mimic or interfere with human hormones." Because those hormones are "fundamental for everything from sleep to hunger to sex," the "chemicals that disrupt those messages can lead to a wide variety of issues — including fetal development, neurological disorders and even fat storage, leading to obesity."

For prospective parents, some of whom express concerns about bringing children into an evermore climate-altered world, the prospect of hydrocarbons extending their reach into the endocrine systems of their newborn children only exacerbates their plight. At the same time, fossil fuel corporations now see profitable growth in plastic production as their "Plan B" in a world transitioning away, however slowly, from hydrocarbon energy. But there is no "Plan B" for those of us who prefer to not eat, drink or breathe in the byproduct of their cunning plan for continued profitability. For us, and every living creature on this planet, we can't even put our heads in the clouds to avoid the plastic dystopia they're cooking up.

JP SOTTILE

JP Sottile is a freelance journalist, published historian and former news producer. His credits include a stint on the "NewsHour" news desk, *C-SPAN* and as newsmagazine producer for *ABC* affiliate *WJLA* in Washington. He curates a daily newsletter at newsvandal.com.

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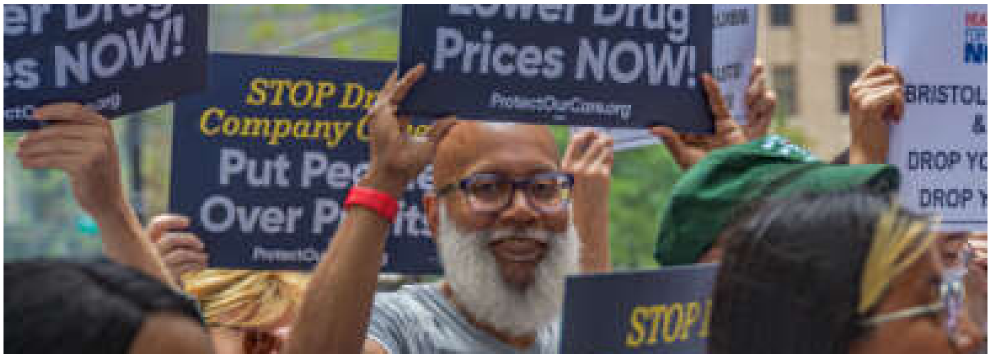

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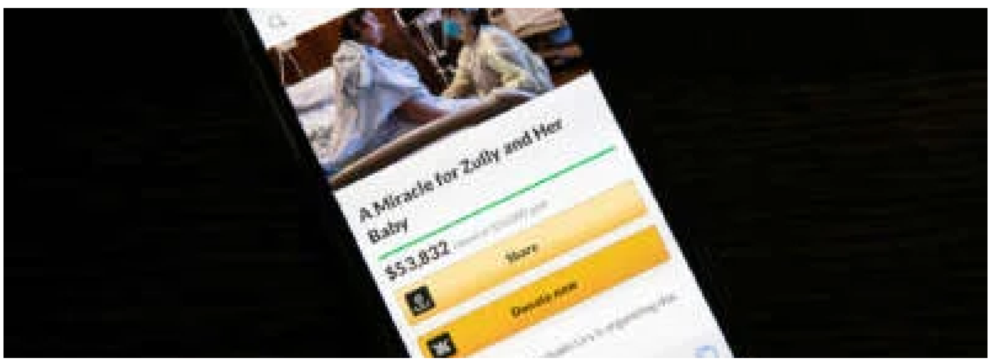

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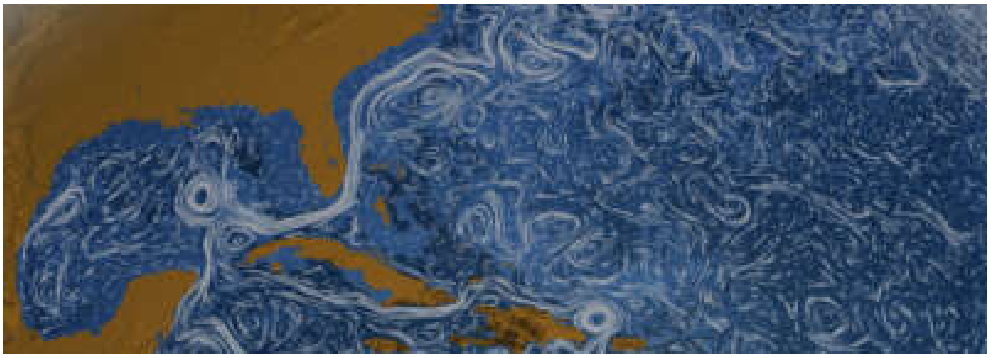

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Wynelle Evans <evco7@rcn.com>
Wed 2/21/2024 1:02 PM
To:Natasha Waden <nwaden@town.arlington.ma.us>;james_ditullio@hotmail.com <james_ditullio@hotmail.com>

Hello Natasha and Jim:

I'm sending along some links to be added to the agenda/minutes for next week's meeting, please.

Artificial turf use presents (at least) two different issues: PFAS and other toxic chemicals, and microplastics—all released into our bodies and our environment. While both have been discussed by the Study Group, I haven't yet heard a discussion about the fact that AT exposure is only one of the hundreds of exposures to plastics and various chemicals, both in isolation and in combination, that we face every day. We need to consider the cumulative effects of these exposures, especially on children, with their not-yet fully developed immune sustems, and the many years ahead of them for adverse effects to develop in their bodies.

MICRO-PLASTICS
— These two studies investigate microplastics and their effects on human and environmental health. Both note the enormous spread of microplastics, and the hazards in plastic production, use, and disposal. As AT fields age, the blades break down and release these particles into the environment. Manufacture of this material has its own hazards for workers and the communities where the plants are located; and as noted in the minutes from last week, there is as yet no option for recycling these fields.

https://www.mdpi.com/1422-0067/24/15/12308

https://pubmed.ncbi.nlm.nih.gov/36969097/

PFAS
— This CDC health advisory notes that PFAS are toxic, bio-accumulative, and persistent. In other words, they build up in the environament and in living organisms, and are not eventually broken down.

https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html

— In addition, there are examples of field materials that claimed to be PFAS-free and were later found to contain PFAS. Again, as these fields age, the release of these chemicals increases. Here are a few examples of communities that installed supposedly PFAS-free fields and then later discovered that they did indeed contain PFAS:

https://www.eenews.net/articles/our-community-has-been-deceived-turf-wars-mount-over-pfas/

— Testing methods are also not sufficient to detect all of the 12,000+ chemicals in the PFAS class. The EPA has continually lowered the safe exposure limits, in some cases to zero, and last year . A few of the testing challenges and deficiencies are discussed here:

https://www.oakbluffsma.gov/DocumentCenter/View/5292/Ecology-Center-Jeff-Gearhart-email-Nov-16-2020?bidId=

https://dep.nj.gov/wp-content/uploads/dsr/pfas-artificial-turf-memo-2023.pdf

— And finally, a brief article detailing the growth of PFAS-related litigation, with potential impacts for communities in terms of personal injury class action suits, and liability for clean-up costs.

https://www.reuters.com/legal/litigation/forever-chemicals-were-everywhere-2023-expect-more-litigation-2024-2023-12-28/

Thank you to all for your painstaking work!

Best,
Wynelle

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International Journal of
Molecular Sciences

MDPI

Article

Acute Exposure to Microplastics Induced Changes in Behavior and Inflammation in Young and Old Mice

Lauren Gaspar [1,2], Sydney Bartman [1,2], Giuseppe Coppotelli [1,2,*] and Jaime M. Ross [1,2,*]

1 George and Anne Ryan Institute for Neuroscience, University of Rhode Island, Kingston, RI 02881, USA
2 Department of Biomedical and Pharmaceutical Sciences, College of Pharmacy, University of Rhode Island, Kingston, RI 02881, USA
* Correspondence: gcoppotelli@uri.edu (G.C.); jaime_ross@uri.edu (J.M.R.)

Abstract: Environmental pollutants have become quite ubiquitous over the past two centuries; of those, plastics, and in particular, microplastics (<5 mm), are among the most pervasive pollutants. Microplastics (MPs) have found their way into the air, water system, and food chain and are either purposely produced or are derived from the breakdown of larger plastic materials. Despite the societal advancements that plastics have allowed, the mismanagement of plastic waste has become a pressing global issue. Pioneering studies on MPs toxicity have shown that exposure to MPs induces oxidative stress, inflammation, and decreased cell viability in marine organisms. Current research suggests that these MPs are transported throughout the environment and can accumulate in human tissues; however, research on the health effects of MPs, especially in mammals, is still very limited. This has led our group to explore the biological and cognitive consequences of exposure to MPs in a rodent model. Following a three-week exposure to water treated with fluorescently-labeled pristine polystyrene MPs, young and old C57BL/6J mice were assessed using behavioral assays, such as open-field and light–dark preference, followed by tissue analyses using fluorescent immunohistochemistry, Western blot, and qPCR. Data from these assays suggest that short-term exposure to MPs induces both behavioral changes as well as alterations in immune markers in liver and brain tissues. Additionally, we noted that these changes differed depending on age, indicating a possible age-dependent effect. These findings suggest the need for further research to better understand the mechanisms by which microplastics may induce physiological and cognitive changes.

Keywords: microplastics; aging; mice; behavior; cognition; inflammation

Citation: Gaspar, L.; Bartman, S.; Coppotelli, G.; Ross, J.M. Acute Exposure to Microplastics Induced Changes in Behavior and Inflammation in Young and Old Mice. *Int. J. Mol. Sci.* **2023**, *24*, 12308. https://doi.org/10.3390/ijms241512308

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1. Introduction

Plastics, which are durable, low-cost, and rapidly produced [1], have contributed to some of the greatest recent advancements in society, including modern technology and medical advancements, such as single-use syringes and modern prosthetics [2,3]. These breakthroughs, in combination with many other daily uses for plastics, have led to an almost exponential increase in global plastic production over the past century that has now surpassed 400 million tons per year, with a projected increase to over 1 billion tons within the next ~30 years [4]. This booming plastic production, however, has also led to a significant pollution problem as up to ~70% of the world's plastic ends up in landfills or is mismanaged in the environment [4]. Plastics in the environment have been shown to leach harmful chemicals [5,6], can be ingested by marine organisms [7], and potentially serve as a transport method for invasive species such as viruses.

In addition to these direct harmful impacts, plastics exposed to environmental factors, such as UV radiation, oxidation, and physical abrasion, have been shown to result in the formation of microplastics (MPs) [8]. Microplastics (MPs) are also purposely produced for use in paints, detergents, and personal care products, such as toothpaste, sunscreen, and cosmetics [9,10]. Microplastics are defined as plastic particles less than 5 mm in diameter and have been shown to have adverse health effects in vitro [11,12] and in vivo [8,13]. Humans are exposed to MPs through the consumption of water, seafood, consumer products (clothes, toothpaste, salt, sugar, honey, beer, anything stored in plastic bottles, plastic wrap, or cans/cartons lined with plastic), and via inhalation from textiles, synthetic rubber tires, and plastic covers [14–16]. MPs have been reported to induce oxidative stress [17–19], upregulate pro-inflammatory cytokines [20–22], decrease cell viability [21,23], and alter energy metabolism [24–26], amongst other negative outcomes.

More recently, MPs have been detected in human feces [27,28], cirrhotic liver tissues [29], lungs [30,31], blood [32,33], and even breastmilk [34]. With these discoveries and given that a large portion of research into MPs is still performed in marine models, it has become increasingly important to understand the health outcomes of microplastics exposure in mammals. Currently, there are limited studies that address the potential adverse effects of exposure to MPs on brain health in mammals and even fewer studies that consider age as an additional factor that may impact the outcome of exposure to MPs. Thus, we proposed to investigate the effect that exposure to MPs has on young and old C57BL/6J mice, focusing on neurobehavioral effects, inflammatory response, as well as translocation and accumulation of MPs in tissues, including the brain.

2. Results

2.1. Cell Viability and Cellular Uptake

In order to study the effect that MPs have in vivo, we first tested cellular uptake and viability in vitro after exposure to commercially available pristine fluorescent polystyrene particles (PS-MPs). U-2 OS cells were cultured and subsequently treated with 0.1 and 2 µm PS-MPs at concentrations ranging from 0.01 to 1000 µg/mL. Following exposure times of 24, 48, and 72 h, cell viability was assessed via MTT assay. After 48 and 72 h, PS-MPs of both sizes induced a dramatic decrease in cell viability, which became more exaggerated with increased concentrations (Figure 1A). Microscopic analysis revealed internalization of PS-MPs in U-2 OS cells as early as after 24 h of exposure (Figure 1B).

2.2. In Vivo Exposure and Behavioral Studies

Next, we tested the effect of exposure to MPs in young (4-month-old, n = 40) and old (21-month-old, n = 40) C57BL/6J female mice. Animals were divided into four exposure groups (n = 10 per group): normal drinking water (control), 0.0025 mg/mL (low-dose), 0.025 mg/mL (medium-dose), and 0.125 mg/mL (high-dose) water treated with a 1:1 mixture of 0.1 and 2 µm PS-MPs (Figure 2A). All mice were exposed to the appropriate dose of PS-MPs for 3 weeks via water delivery. To ensure that sedimentation of the PS-MPs would not drastically alter concentration throughout the day, each dosage was tested hourly for 10 h, followed by a measurement at 24 h. No significant changes in concentration were found throughout the 24 h period (Figure 2B). We also monitored water consumption and body weights and did not find any alterations in either parameter (Supplementary Figure S1A–D).

At the end of the 3-week-long exposure, behavioral testing began. During the open-field test, mice were allowed to explore a low-lit chamber for 90 min with spontaneous movements monitored in the x-, y-, and z-directions. Several parameters to measure behavioral performance were recorded, including distance traveled, rearing activity, and duration in the center. Surprisingly, we found that acute exposure to PS-MPs induced an increase in distance traveled, which was more pronounced in older animals (Figure 3A–D). Similarly, both young and old PS-MP-exposed mice reared significantly more in the open-field, as compared to age-matched controls (Figure 3E–H). Young PS-MP-exposed mice did not spend more time in the center of the chamber overall (Figure 3J), but both low- and high-dose groups spent more time in the center when analyzed as a function of time (Figure 3I). Low- and medium-dose older animals also showed an increased duration in the center (Figure 3K,L).

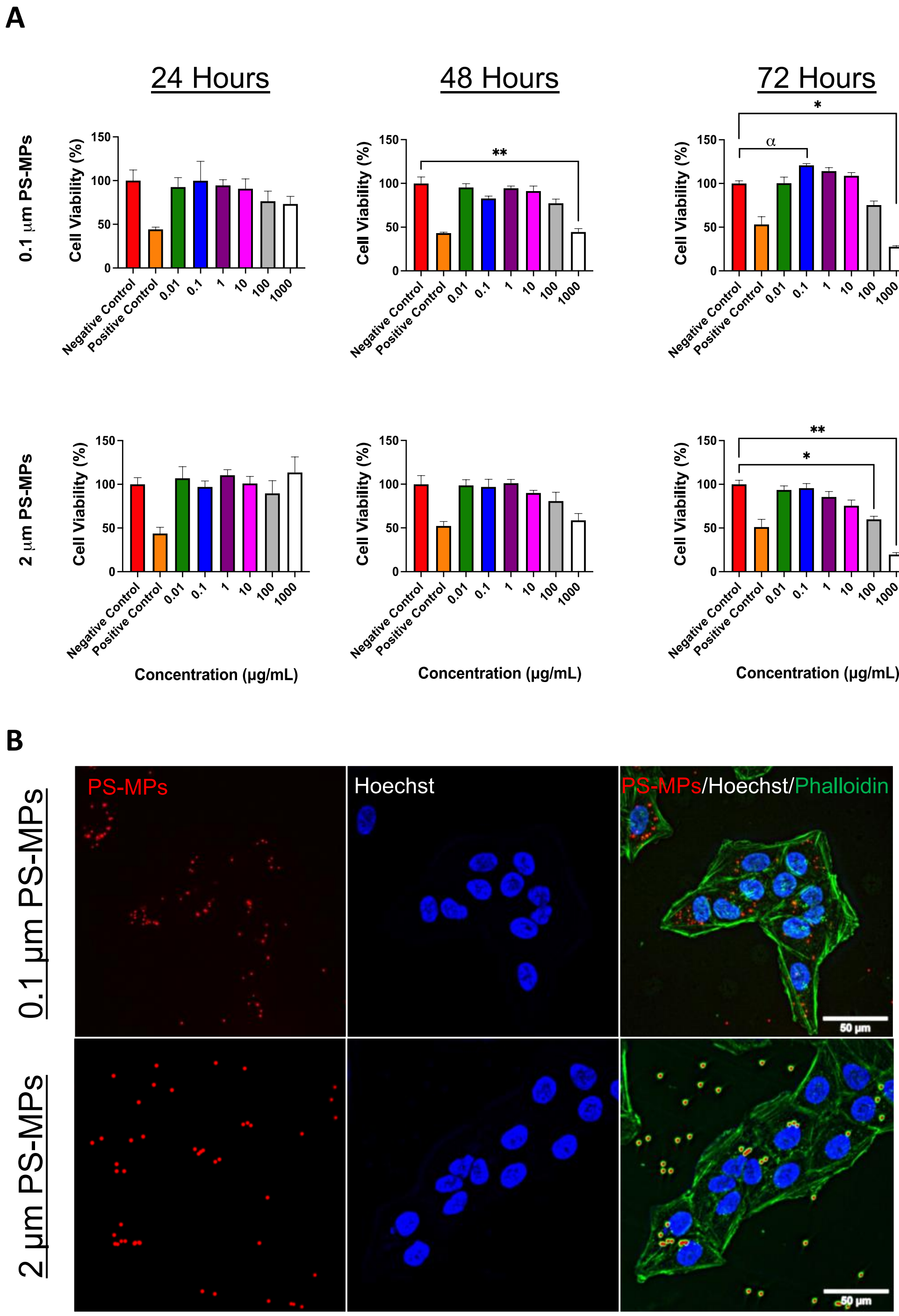

Figure 1. MTT assay and localization of PS-MPs in cells. (**A**) MTT assay to assess cell viability in U-2 OS cells following exposure to PS-MPs. Data shown for 0.1 and 2 µm PS-MPs at concentrations ranging from 0.01 to 1000 µg/mL and exposure times of 24, 48, and 72 h. Significances were determined by one-way ANOVA with post hoc analysis and * $p < 0.05$, ** $p < 0.01$, and α $p < 0.10$ as trending. Data shown are from two or more experiments. (**B**) Representative images of 0.1 and 2 µm PS-MPs (left panel, red) localized in U-2 OS cells counterstained with Hoechst (middle panel, blue) and phalloidin (right panel, green). Scale bar = 50 µm.

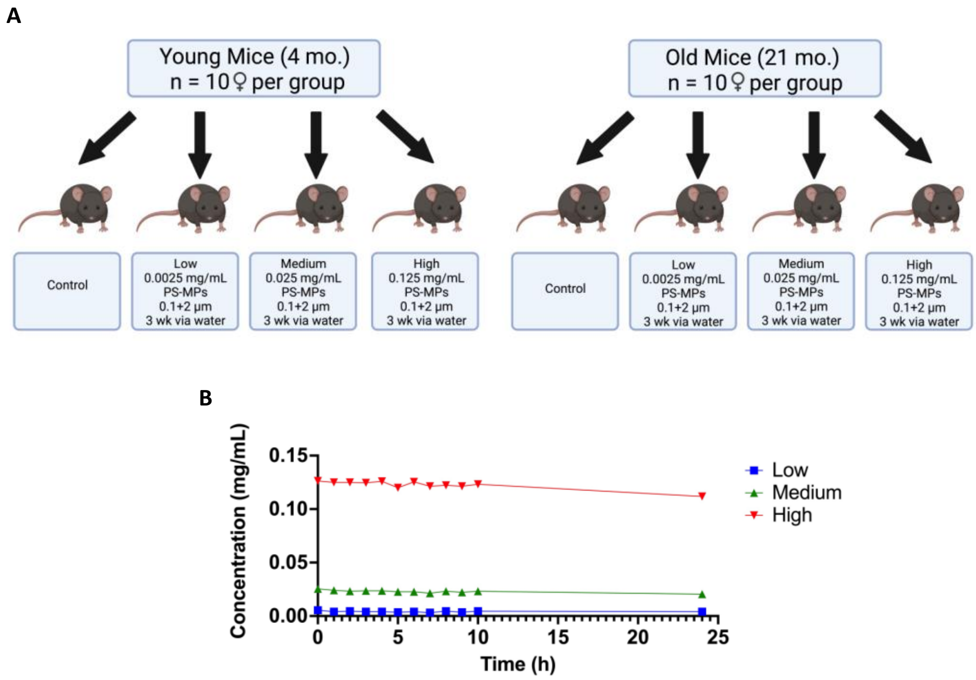

Figure 2. In vivo study design and PS-MPs delivery system concentration curve. (**A**) In vivo study design for short-term (3 weeks) exposure to PS-MPs in young (4 month-old) and old (21 month-old) female C57BL/6J mice (n = 10 per group). Schematic was created with BioRender.com (accessed on 2 December 2021). (**B**) Concentration of each dose (low, medium, high) of PS-MPs was measured hourly for 10 h without resuspension and again at 24 h without any resuspension.

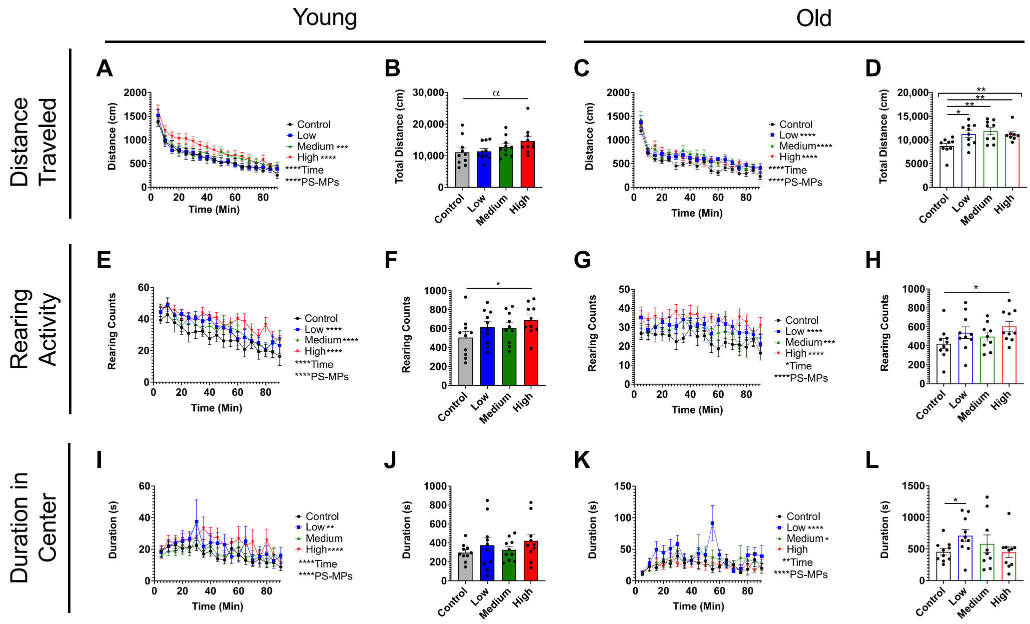

Figure 3. Effects of exposure to PS-MPs on locomotion in young and old mice. Spontaneous locomotor activity of 4- and 21-month-old female C57BL/6J mice (n = 10 per group) exposed to low (blue), medium (green), and high (red) doses of PS-MPs, as compared to control mice (gray). Both young and old mice exposed to PS-MPs showed marked increases in (**A**–**D**) distance traveled, (**E**–**H**) rearing activity, and (**I**–**L**) duration in center. Significances were determined by unpaired t-test, one-way ANOVA (**B**,**D**,**F**,**H**,**J**,**L**), or two-way ANOVA with post hoc analysis (**A**,**C**,**E**,**G**,**I**,**K**) and * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$ and α $p < 0.10$ as trending.

In the light/dark preference test, mice were again placed in a chamber, now divided into light and dark zones, with movements monitored in the x-, y-, and z- directions. Parameters recorded for this assay included duration in zone, distance traveled, and rearing activity. PS-MP-exposure did not affect the duration spent in light and dark zones in either age group (Figure 4A,B). This assay did, however, confirm the increased distance traveled (Figure 4C,D) and rearing activity (Figure 4E,F) revealed in the open-field test (Figure 3A–H). These findings are again more pronounced in older animals.

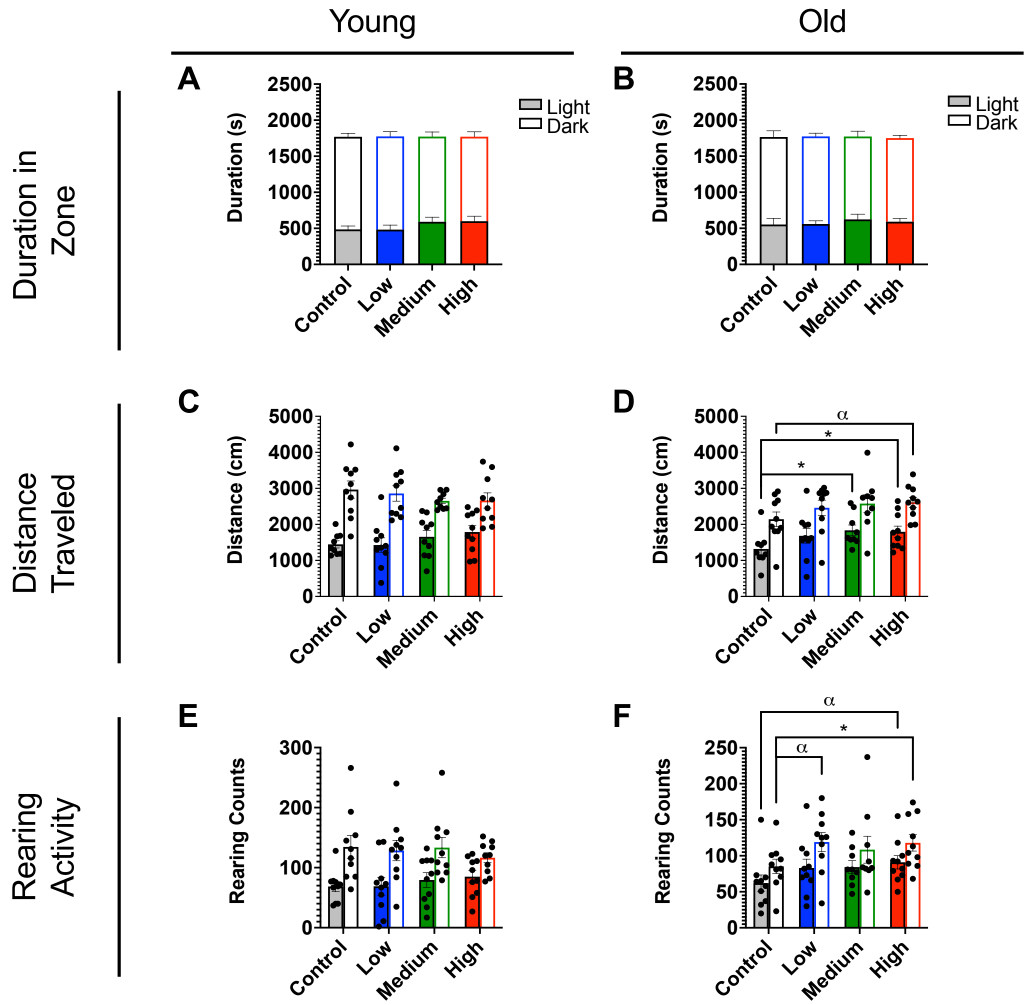

Figure 4. Effects of exposure to PS-MPs on light–dark preference in young and old mice. Exploratory behavior during the light-dark (solid and transparent bars, respectively) preference assay of 4- and 21-month-old female C57BL/6J mice (*n* = 10 per group) exposed to low (blue), medium (green), and high (red) doses of PS-MPs, as compared to control mice (gray). Both young and old mice exposed to PS-MPs showed striking increases in (**C**,**D**) distance traveled and (**E**,**F**) rearing activity. (**A**,**B**) No alterations were found for duration in light/dark zone. Significances were determined by unpaired *t*-test with * $p < 0.05$, and α $p < 0.10$ as trending.

2.3. Bioaccumulation of MPs

To determine if MPs in drinking water are absorbed and are able to translocate and accumulate in tissues after exposure, samples of liver, kidney, gastrointestinal tract, lung, spleen, heart, and brain tissues from both young and old exposed mice were cryosectioned and counterstained with DAPI. Unexpectedly, we detected PS-MPs within intracellular compartments of every tissue examined (Figures 5 and 6). We also observed PS-MPs in urine and fecal matter.

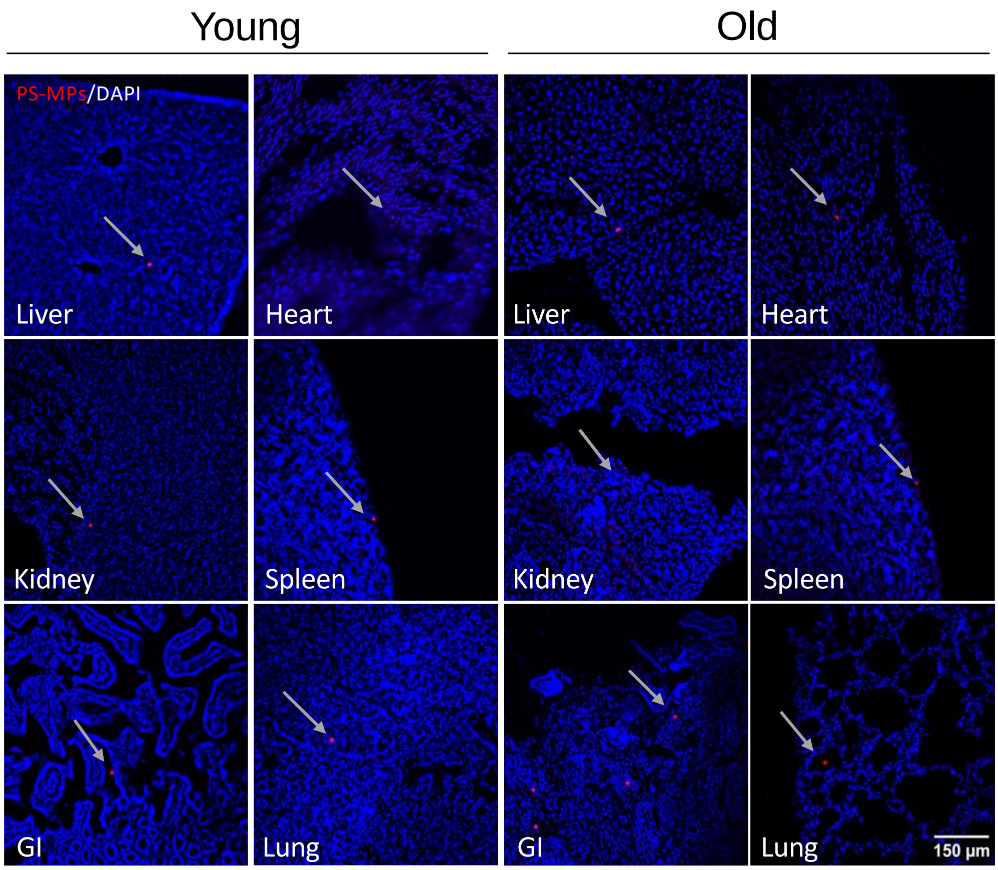

Figure 5. Accumulation of PS-MPs in peripheral tissues from young and old mice. Representative images of liver, kidney, gastrointestinal tract (GI), lung, spleen, and heart from young (4-month-old) and old (21-month-old) C57BL/6J mice showed presence of red fluorescent PS-MPs (red, indicted by arrows) in DAPI (blue)-stained tissues after acute (3 weeks) exposure to MPs. Scale bar = 150 µm.

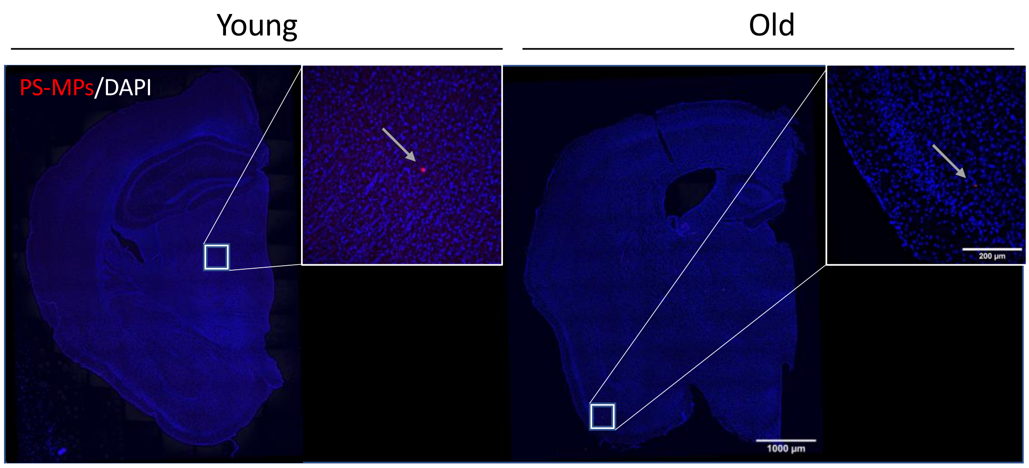

Figure 6. Accumulation of PS-MPs in brains from young and old mice. Representative images from young (4-month-old) and old (21-month-old) C57BL/6J mice showed presence of red fluorescent PS-MPs (red, indicated by arrows) in DAPI (blue)-stained brain tissue after acute (3 weeks) exposure to MPs. Scale bar = 1000 µm, 200 µm.

2.4. Assessing Impact of MPs on Immune Markers

Upon observing entry of PS-MPs into the brain, we performed fluorescent immunohistochemistry of GFAP (glial fibrillary acidic protein), a marker of glial cells, which include activated astrocytes. We found decreased GFAP expression in brains from both young and old mice exposed to PS-MPs, as compared to age-matched controls (Figure 7A). A Western blot of brain lysates confirmed decreased GFAP expression (Figure 7B), and quantification revealed that this reduction was significant in young mice exposed to PS-MPs, as compared with age-matched controls (Figure 7C).

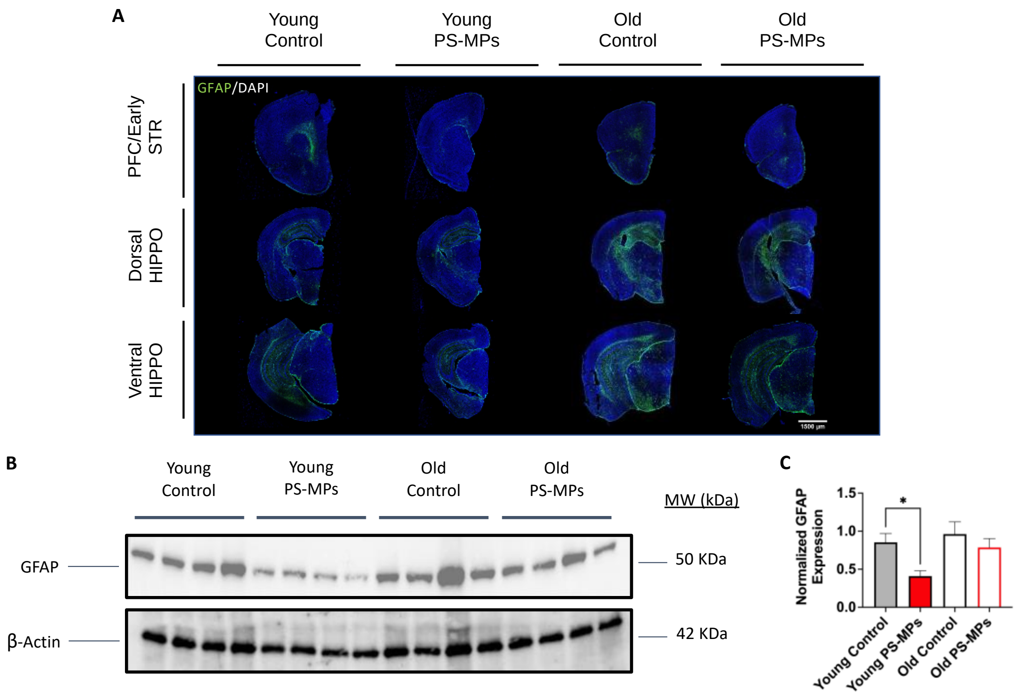

Figure 7. PS-MPs reduced GFAP expression in brains from young and old mice. (**A**) Representative images of GFAP (green)/DAPI (blue) fluorescent immunohistochemistry showed decreased expression throughout the brain including prefrontal cortex (PFC)/early striatum (STR) and dorsal/ventral hippocampus (HIPPO). (**B**,**C**) Decreased GFAP expression was confirmed using Western blot, with quantifications shown. Significances were determined by unpaired *t*-test with * $p < 0.05$. Scale bar = 1500 µm.

Alterations of immune markers in liver tissues from PS-MP-exposed mice were also examined. qPCR analysis revealed a ~2-fold increase in mRNA expression of inflammatory cytokine *TNF-α* (tumor necrosis factor) in liver from young and old mice exposed to PS-MPs (Figure 8A). Calcium-binding proteins S100a8 and S100a9 (calgranulins), which mediate inflammatory responses, were also assessed. Young PS-MP-exposed mice showed little change in *S100a8* and moderate increases in *S100a9* mRNA expression. Old mice, however, exhibited higher levels of both calgranulins, as compared to young controls, and a ~3-fold increase in *S100a8* and a ~4.5-fold increase in *S100a9* mRNA expression in old mice exposed to PS-MPs, as compared to age-matched controls (Figure 8B,C).

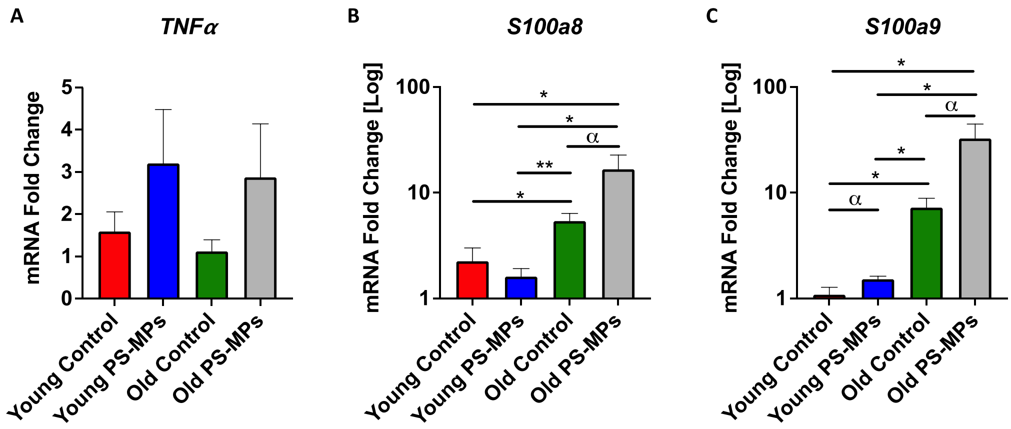

Figure 8. PS-MPs altered mRNA expression of inflammatory cytokine *TNF-alpha* and inflammatory-mediators *S100a8* and *S100a9* in liver tissue. (**A**) qPCR analysis showed approximately 2-fold increases in mRNA expression of *TNF-alpha* in both young and old PS-MP-exposed mice, as compared to age-matched controls. (**B**,**C**) Further analyses also showed significant increases in *S100a8* and *S100a9* mRNA expression in old mice exposed to PS-MPs, as compared to controls. Significances were determined by unpaired *t*-test with α $p < 0.10$, * $p < 0.05$, and ** $p < 0.01$.

3. Discussion

As global plastic production continues to rapidly grow, leading to the ubiquitous presence of microplastics, we set out to understand the potential harmful impacts of MPs in mammalian systems with a particular focus on age as a potential co-factor in adverse exposure outcomes. To first establish in vitro toxicity of 0.1 and 2 µm PS-MPs, U-2 OS cells were exposed at concentrations ranging from 0.01 to 1000 µg/mL for exposure times of 24, 48, and 72 h. Following these exposures, cell viability was assessed via an MTT assay (Figure 1A). Data collected from this assay showed that for both sizes of PS-MPs, cell viability was significantly reduced, especially as concentration and exposure time increased. Thus, suggesting that PS-MPs in this size range exhibit cytotoxicity. Additionally, PS-MPs were found to enter cells within 24 h of exposure and accumulated perinuclearly (Figure 1B).

With this in mind, an in vivo study was designed to determine the effects of these MPs in a rodent model (Figure 2A). Following a 3-week exposure to PS-MPs, C57BL/6J mice were tested in a series of behavioral assays including the open-field and light–dark preference tests. Both assays showed significant changes in parameters such as distance traveled, rearing activity, and duration in the center between the control and the exposed groups for both old and young mice (Figures 3 and 4). Overall, these changes seemed to be more pronounced in older animals, which may be due to age-related dysfunction exasperating the effects of the PS-MPs on behavioral performance (Figure 3D,H,L and Figure 4D,F). The behavioral changes exhibited by the young mice, however, suggest that even without increased age as a co-variable, PS-MPs can induce altered behavior in rodents after just 3 weeks of exposure (Figures 3B,F,J and 4C,E).

To understand the physiological systems that may be contributing to these changes in behavior, we began by sectioning several major tissues including the brain, liver, kidney, gastrointestinal tract, heart, spleen, and lungs to determine where these MPs may be accumulating. Surprisingly, we detected the presence of PS-MPs in every tissue examined (Figures 5 and 6), as well as in urine and feces. Given that in this study the MPs were delivered orally via drinking water, detection in tissues such as the gastrointestinal tract (Figure 5), which is a major part of the digestive system, or in the liver and kidneys (Figure 5), which contribute to the detoxification of xenobiotics [35,36], was always probable. The detection of MPs in tissues such as the heart and lungs (Figure 5), however, suggests that the PS-MPs are going beyond the digestive system and likely undergoing systemic circulation. This is further supported by the detection of MPs in urine and in the brain

(Figure 6), which additionally demonstrates that the PS-MPs can pass the blood–brain barrier (BBB).

Given the ability of MPs to pass the BBB, an immediate concern was the potential for these xenobiotics to trigger neuroinflammation. GFAP (glial fibrillary acidic protein), a major intermediate filament protein found in mature astrocytes that is involved in many cell processes such as autophagy, neurotransmitter uptake, and astrocyte development [37], can be used to measure the expression of activated astrocytes and is a commonly used marker in neuroinflammatory studies [38]. Astrocytes are typically activated in response to neural stress or injury [39], and because of this, an increase in GFAP expression is often associated with an increase in neuroinflammation. Fluorescent immunohistochemical staining for GFAP in PS-MP-exposed mouse brain, however, showed a slight decrease in expression for older animals and a more pronounced decrease in young mice exposed to PS-MPs, as compared to age-matched controls (Figure 7A). These results were confirmed with a Western blot analysis (Figure 7B,C). Although these results are not typical of an inflammatory response, they are consistent with previous studies that suggest that GFAP expression might decrease in early stages of certain diseases, such as Alzheimer's disease (AD) [40,41], or in younger patients with disorders such as Major Depressive Disorder (MDD) [42]. These studies indicate that early pathology/early onset of disease may be characterized by astrocyte atrophy (as opposed to astrocyte hypertrophy later on), which may result in decreased GFAP expression. Although these mechanisms are still not well understood, our results suggest that exposure to PS-MPs results in a comparable age-dependent pattern.

Similar to our findings, results from Lee and colleagues [43] found that following either a 4- or 8-week exposure to 2 µm carboxyl-modified PS-MPs via an oral gavage, 6-week-old C57BL/6J mice exhibited accumulation of MPs in both liver and brain tissues, alterations in cognitive behavior, and modifications in immune markers in the brain. However, Lee et al. did not find any alterations in the open-field test in mice exposed to PS-MPs, in contrast to our study. This could be due to several differences between the setup of the two studies, such as age of the animals, method and length of delivery of MPs, PS-MPs having different surface chemistries, as well as Lee's study only using one size of MPs. Despite some discrepancies between the studies, it is evident that PS-MPs can travel to and exert detrimental effects on the brain after absorption. Further studies are needed to dissect the underlining molecular mechanisms of such an effect. One possibility proposed by Lee et al. is that neurotoxic effects of PS-MPs may depend on the vagal-pathway-dependent gut–brain axis; however, other mechanisms including the impairment of blood detoxification pathways in the liver cannot be excluded. Several studies have indeed suggested that the ability of a toxin to reach the brain may be in part due to liver dysfunction, since the liver is a major site of blood detoxification. If the liver is unable to properly function, this can lead to toxin build-up in the blood [44], which may ultimately reach the brain. Similarly, hepatic failure or injury may result in increased BBB permeability [45,46]. Thus, we investigated whether PS-MPs induced an inflammatory response in the liver from young and old mice in our study and found an approximately two-fold increase in the mRNA expression of inflammatory cytokine *TNF-α* in both young and old PS-MP-exposed mice, as compared to controls (Figure 8A). Additionally, in older PS-MP-exposed mice, there was a 3-fold increase in *S100a8* mRNA expression and a 4.5-fold increase in *S100a9* mRNA expression (Figure 8B,C). S100a8 and S100a9 are Ca^{2+}-binding proteins that help mediate inflammatory responses. Increased expression of these genes indicate inflammation of the liver, which may play a role in allowing the MPs to enter the bloodstream and ultimately reach the brain and other major organs.

Overall, since human exposure to MPs is inevitable due to their persistence and pervasiveness in the environment, it is essential to better understand their toxicity to limit their impact on human health. In the present study, we have shown that 0.1 and 2 µm PS-MPs can reduce cell viability, translocate throughout the body, accumulate in tissues including brain tissue, markedly modify behavior in C57BL/6J mice after only

3 weeks of exposure, and significantly alter immune markers in both the liver and the brain. Additionally, the effects of exposure seem to be age-dependent. Research into the effects of exposure to MPs in mammals is still a very broad field with many variables worth pursuing. In this study, we chose to focus specifically on the effects of exposure to pristine polystyrene microplastics (PS-MPs) via drinking water in female C57BL/6J mice. There are still many questions that remain, including but not limited to how sex, MP delivery method, length of exposure to MPs, and MP surface chemistry impact exposure outcome. While these variations were not explored in this study, future work should examine these factors in order to understand the mechanisms by which MPs exert these effects and how these mechanisms are altered with age.

4. Materials and Methods

4.1. Microplastic Particles

Dyed red aqueous pristine fluorescent polystyrene particles (PS-MPs; Thermo Scientific, Fremont, CA, USA) were obtained at diameters of 0.1 and 2 μm. MPs in this size range were selected because 0.1 μm represents the smallest end of the microplastics spectrum, bordering on nanoplastics, and 2 μm nears the upper limit of what may enter into cells [47,48]. MPs within this size range have recently been detected in human breastmilk [34], placentas [49], lungs [31], and on human hands and hair [50]. Prior to use, PS-MPs were centrifuged (Eppendorf 5424R, Hamburg, Germany) at 21,000× *g* at 4 °C for 1 h 45 min, and the supernatant was discarded. The PS-MPs were resuspended using sterile distilled water. This process was repeated 3 times to remove trace amounts of DMSO and sodium azide.

4.2. MTT Assay

Cell viability was assessed in vitro using an MTT assay. U-2 OS cells were seeded (Gibco, Waltham, MA, USA) in 24-well plates (Celltreat, Pepperell, MA, USA) and allowed 24 h to attach. Following this, cells were exposed to 0.01, 0.1, 1, 10, 100, and 1000 μg/mL concentrations of 0.1 and 2 μm PS-MPs for exposure times of 24, 48, and 72 h. At the end of exposure, 200 μL of MTT solution (5 mg/mL 3-(4,5-Dimethylthiazol-2-yl)-2,5-Diphenyltetrazolium Bromide (Alfa Aesar, Ward Hill, MA, USA)) in 0.01 M sterile PBS (Corning, Corning, NY, USA) diluted 1:6 in Dulbecco's Modified Eagle Medium (DMEM; Gibco, Waltham, MA, USA) was added to each treated well. Negative controls received 200 μL of MTT solution, and positive controls received 180 μL of MTT solution and 20 μL of DMSO (MilliporeSigma, Burlington, MA, USA). Following this, plates were incubated at 37 °C for 2.5 h. After completion of the MTT reaction, cells were washed with 0.01 M PBS, and 200 μL of DMSO was added to each well. The plates were placed back in the incubator for 15 min before being placed on an orbital shaker at RT for 15 min. A total of 150 μL from each well was transferred to a 96-well plate, and absorbance was measured at 485 nm.

4.3. Visualization of Red Fluorescent MPs in Cells

U-2 OS cells were cultured and plated in a 6-well plate (Celltreat, Pepperell, MA, USA). Once adherent, cells were treated with 5 μg/mL of 0.1 μm PS-MPs or 20 μg/mL of 2 μm PS-MPs for 24 h. After exposure, the cells were washed with sterile PBS (Gibco, Waltham, MA, USA), detached, centrifuged in DMEM (Gibco, Waltham, MA, USA) at 1000× *g* at 4 °C for 5 min to remove excess PS-MPs, and re-plated on 13 mm coverslips in a 6-well plate. After 24 h, the cells were washed 3 times with PBS, fixed for 10 min with 4% formaldehyde at RT in PBS, permeabilized with 0.1% Triton X-100 (Sigma, St. Louis, MO, USA) in PBS at RT for 15 min, stained with Hoescht (1:2000, H1399, Invitrogen, Waltham, MA, USA) and Phalloidin (1:500, PF7501, EPM Scientific, New York, NY, USA) for 5 min at RT, washed 3 times in PBS, and mounted onto glass slides with an aqueous mounting medium. Fluorescence imaging (Leica THUNDER DMi8 3D Fluorescence Imaging System, Leica Biosystems, Wetzlar, Germany and LAS X 3D Analysis Software v. 2018.7.3, Leica

Biosystems, Wetzlar, Germany) was used to identify the dyed red fluorescent polystyrene particles using a TRITC (550 nm) filter.

4.4. Animals and Exposure

Both young (4-month-old, n = 40) and old (21-month-old, n = 40) female C57BL/6J mice were obtained from the National Institute of Aging (NIA) aged rodent colony (Charles River Laboratories, Kingston, NY or Raleigh, NC, USA). Female mice were selected based on their ability to be re-housed after the mice were delivered and acclimated in our animal facility in order to minimize weight discrepancies between treatment groups. All mice were acclimated for at least 2 weeks in our animal facility prior to testing. Within each age cohort, four exposure groups (n = 10 per group) were established to receive 1:1 ratios of 0.1 and 2 µm PS-MPs via drinking water: normal drinking water (control group), 0.0025 mg/mL (low-dose group), 0.025 mg/mL (medium-dose group), and 0.125 mg/mL (high-dose group). Drinking water was selected as the delivery vehicle over oral gavage in order to allow for continuous exposure as opposed to timed bursts, as well as to minimize external stress that may impact behavior performance. Water consumption and body weights were monitored throughout exposure to ensure comparable exposure between groups (Figure S1). Water bottles were mixed every 10–12 h; mice were exposed for three weeks, during which time the drinking water was replaced as needed, i.e., every ~10–12 days. Exposure dosages were selected according to previous studies [18]. All mice received a standard diet (Teklad Global Soy Protein-Free [Irradiated] type 2920X, Envigo, Indianapolis, IN, USA) and water ad libitum; they were group-housed based on how the mice were received from the source institution with up to 5 mice per ventilated cage with access to a small house and tissues for nesting. The mice were kept on a 12:12 light: dark cycle at 22 °C ± 1 and 30–70% humidity. Adequate measures were taken to minimize animal pain and discomfort. The investigation was conducted in accordance with the ethical standards and according to the Declaration of Helsinki and national and international guidelines and has been approved by the authors' institutional review board.

4.5. Behavior Experiments

The mice were acclimated in their home cage for 1 h in the testing room and were kept at 22 °C ± 1, 30–70% humidity, and ~100 lux prior to testing. The testing room was in a neutral, quiet environment, and mice were tested between 9:00 and 17:00 (light phase) by the same researcher, with care taken to stagger the testing of mice from the different exposure and age cohorts. The mice were transported to and from the apparatus in a non-transparent plastic container cleaned with 70% ethanol after each use.

4.6. Open-Field Test (OF)

A multi-cage infrared-sensitive motion detection system (Fusion v6.5 SuperFlex, Omnitech Electronics, Columbus, OH, USA) was used to assess exploratory behavior and spontaneous locomotion. During this assay, the mice were placed in darkened transparent locomotor chambers (40 × 40 × 30 cm) equipped with a grid of infrared beams at floor level and 7.5 cm above floor level for 90 min while their movements were monitored in 5 min intervals in the x-, y-, and z-planes. All horizontal and vertical movements were recorded, and data were analyzed using the Fusion v6.5 software system. Locomotor boxes were cleaned with 70% ethanol after each test period.

4.7. Light–Dark Preference Test (LD)

To assess exploratory and anxiety-related behaviors, all mice were placed in locomotor chambers (40 × 40 × 30 cm) divided into light and dark zones that were equipped with a grid of infrared beams at floor level and 7.5 cm above floor level. All mice were tested for 30 min with their movements being monitored in the x-, y-, and z-planes using an infrared-sensitive activity-monitoring cage system (Fusion v6.5 SuperFlex, Omnitech Electronics, Columbus, OH, USA). All movements were recorded, and data were analyzed using the

Fusion v6.5 software system. Locomotor boxes and inserts were cleaned with 70% ethanol after each test period.

4.8. Tissue Preparation

All mice were anesthetized with sodium pentobarbital (200 mg/kg) intraperitoneally and were killed by cervical dislocation; brain, lungs, heart, liver, kidneys, gastrointestinal tract (GI), spleen, and gastrocnemius muscle tissues were either post-fixed in 10% formalin (Epredia, Portsmouth, NH, USA) for 24 h at 4 °C, followed by 30% sucrose (*w*/*v*) in 1X PBS, or rapidly frozen on dry ice, embedded (Tissue-Plus® OCT compound, Fisher Scientific, Waltham, MA, USA), and stored at −80 °C.

4.9. Visualization of Red Fluorescent MPs in Tissues

For detection of MPs, representative post-fixed brain, lung, heart, liver, kidney, GI, and spleen samples from control and high-dose groups from both young and old cohorts were examined. Frozen embedded tissues were sectioned at 20 μm using a cryostat (Leica BioSystems, CM1950, Wetzlar, Germany) taken at −21 °C and collected onto glass slides (VWR Colorfrost® Plus, Radnor, PA, USA). The sections were allowed to dry at 30 °C for 5–10 min before being circled using a wax pen. The sections were washed for 5 min in TBS, permeabilized with 0.3% Triton X-100 (Sigma, St. Louis, MO, USA) in TBS for 30 min, and stained with DAPI (1:5000, 5.08741.0001, MilliporeSigma, Burlington, MA, USA) for 10 min. Sections were washed again in TBS for 5 min and coverslipped (VWR, Radnor, PA, USA) with aqueous anti-fading mounting medium (20 mM Tris pH 8.0, 0.5% N-propyl gallate, 50% glycerol). Fluorescence imaging (Leica THUNDER DMi8 3D Fluorescence Imaging System, Leica Biosystems, Wetzlar, Germany and LAS X 3D Analysis Software v. 2018.7.3, Leica Biosystems, Wetzlar, Germany) was used to identify the dyed red fluorescent polystyrene particles using a TRITC (550 nm) filter.

4.10. Fluorescent Immunohistochemistry (IHC)

For determining GFAP expression, frozen and embedded post-fixed brain samples from control and high-dose groups from both the young and old cohorts were cryosectioned (Leica BioSystems, CM1950, Wetzlar, Germany) at 30 μm taken at −21 °C; free-floating sections were collected into 12-well plate netwells (3477, Corning, Corning, NY, USA) filled with PBS using previously reported methodology [51]. Briefly, sections were blocked in TBS with 3% horse serum and 0.3% Triton X-100 at RT for 30 min on an orbital shaker and incubated overnight at 4 °C on a rotator with rabbit anti-GFAP primary antibody (1:2000, PA1-10019, Invitrogen, Waltham, MA, USA) in TBS with 1% horse serum and 0.3% Triton X-100. Sections were incubated the following day with donkey anti-rabbit Alexa 488 (1:500, A21202, Invitrogen, Waltham, MA, USA) secondary antibody in TBS with 1% horse serum and 0.3% Triton X-100 at RT for 2 h on an orbital shaker, while being protected from light. This was followed by DAPI (1:5000, 5.08741.0001, MilliporeSigma, Burlington, MA, USA) staining. Sections were mounted onto slides (VWR Colorfrost® Plus, Radnor, PA, USA), coverslipped with aqueous mounting medium, and dried at RT for 15–20 min protected from light. Fluorescence imaging (Leica THUNDER DMi8 3D Fluorescence Imaging System, Leica Biosystems, Wetzlar, Germany and LAS X 3D Analysis Software v. 2018.7.3, Leica Biosystems, Wetzlar, Germany) was used to evaluate GFAP expression.

4.11. Western Blot (WB)

Brain samples from young and old control and high-dose cohorts were lysed in RIPA buffer (50 mM Tris-HCl pH 7.4, 150 mM NaCl, 0.5% deoxycholic acid, 0.1% sodium dodecyl sulfate, 2 mM EDTA, 1% Triton X-100) containing a proteinase (1:100, 78,438, Halt, Thermo Scientific, Fremont, CA, USA) and phosphatase (1:100, P0044, Sigma Aldrich) inhibitor cocktail. Samples were incubated on ice for 30 min and then sonicated (QSonica, Newtown, CT, USA) for 3 min (30–30 pulse) at 4 °C with 30% amplitude and centrifuged at 10,000× *g* for 10 min. Protein concentration was determined using a BCA protein assay kit (23,225, Thermo Scientific, Fremont, CA, USA) according to the manufacturer's instructions. Lysates were mixed with loading buffer (1610747, Bio-Rad, Hercules, CA, USA) plus 100 mM DTT and incubated at 98 °C for 10 min. Samples were fractionated in an SDS-PAGE precast 8–16% gradient gel (5671104, Bio-Rad, Hercules, CA, USA) and blotted on a 0.2 µm nitrocellulose membrane (1620112, Bio-Rad, Hercules, CA, USA) using transfer buffer (25 mM Tris-HCl pH 8.3, 190 mM glycine 20% methanol). The membrane was blocked (0.1% TBS-Tween with 5% skim milk) and probed with rabbit anti-GFAP primary (1:10,000, PA1-10019, Invitrogen, Waltham, MA, USA) and goat anti-rabbit-HRP secondary antibodies in 0.1% TBS-Tween (1:3000, 1706515, Bio-Rad, Hercules, CA, USA); then, immunocomplexes were detected by chemiluminescence (Clarity ECL, Bio-Rad, Hercules, CA, USA) and visualized (ChemiDoc, BioRad, Hercules, CA, USA). Images were processed and quantified using appropriate software (FIJI v2.1.0/1.53c, Madison, WI, USA) [52].

4.12. Quantitative Real-Time PCR (qPCR)

Samples of liver tissue (30–50 mg) from young and old control and high-dose groups were lysed, and RNA was extracted and purified (Zymo Direct-zol RNA MiniPrep Plus Kit R2070, Zymo Research, Irvine, CA, USA) according to the manufacturer's instructions. RNA concentration was determined using a spectrophotometer (NanoDrop, ND-2000, Thermo Scientific, Fremont, CA, USA), and reverse transcription was run (Lunascript® RT Supermix Kit E3010, New England BioLabs Inc., Ipswich, MA, USA) according to the manufacturer's protocol. Once the cDNA was synthesized, qPCR reactions were run using a SYBR green-based master mix (Luna® qPCR Mastermix M3003, New England BioLabs Inc.) according to the manufacturer's instructions using appropriate instrumentation (Viia7 Real-Time PCR System, Applied Biosystems, Waltham, MA, USA) and the following conditions: 95 °C for 15 s, 95 °C for 15 s with optimal annealing temperature for each gene of interest (varied by gene) for 30 s × 40, and melt curve of 65–90 °C. The results were analyzed using the appropriate software (GraphPad Prism v. 9, San Diego, CA, USA). The primer sequences were as follows: $TNF\alpha_{For}$: GGTGCCTATGTCTCAGCCTCTT, $TNF\alpha_{Rev}$: GCCATAGAACTGATGAGAGGGAG; $s100a8_{For}$: CCTTTGTCAGCTCCGTCTTCA, $s100a8_{Rev}$: TCCAGTTCAGACGGCATTGT; $s100a9_{For}$: AATGGTGGAAGCACAGTTGG, $s100a9_{Rev}$: CTGGTTTGTGTCCAGGTCCTC.

4.13. Microscopy

Fluorescence imaging was used to evaluate and document MPs and the immunolabeling results (Leica THUNDER DMi8 3D Fluorescence Imaging System, Leica Biosystems, Wetzlar, Germany, and LAS X 3D Analysis Software v. 2018.7.3, Leica Biosystems, Wetzlar, Germany). Images were processed using the appropriate software (FIJI v2.1.0/1.53c, Madison, WI, USA) [52].

4.14. Statistical Analysis

Data are presented to three significant digits as mean values (Ms) with SEM and are indicated in the figure legend together with sample size (N). Statistical analyses, unpaired t-tests, one-way ANOVAs, or two-way ANOVAs with Tukey posthoc multiple comparisons were performed with an α level of 0.05 using the appropriate software (GraphPad Prism v. 9, San Diego, CA, USA). Significances are denoted in figures with * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$, and trending with α $p < 0.10$.

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Data Availability Statement: Data generated from this study are available upon request.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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The Minderoo-Monaco Commission on Plastics and Human Health

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Abstract

Background: Plastics have conveyed great benefits to humanity and made possible some of the most significant advances of modern civilization in fields as diverse as medicine, electronics, aerospace, construction, food packaging, and sports. It is now clear, however, that plastics are also responsible for significant harms to human health, the economy, and the earth's environment. These harms occur at every stage of the plastic life cycle, from extraction of the coal, oil, and gas that are its main feedstocks through to ultimate disposal into the environment. The extent of these harms not been systematically assessed, their magnitude not fully quantified, and their economic costs not comprehensively counted.

Goals: The goals of this Minderoo-Monaco Commission on Plastics and Human Health are to comprehensively examine plastics' impacts across their life cycle on: (1) human health and well-being; (2) the global environment, especially the ocean; (3) the economy; and (4) vulnerable populations-the

poor, minorities, and the world's children. On the basis of this examination, the Commission offers science-based recommendations designed to support development of a Global Plastics Treaty, protect human health, and save lives.

Report structure: This Commission report contains seven Sections. Following an Introduction, Section 2 presents a narrative review of the processes involved in plastic production, use, and disposal and notes the hazards to human health and the environment associated with each of these stages. Section 3 describes plastics' impacts on the ocean and notes the potential for plastic in the ocean to enter the marine food web and result in human exposure. Section 4 details plastics' impacts on human health. Section 5 presents a first-order estimate of plastics' health-related economic costs. Section 6 examines the intersection between plastic, social inequity, and environmental injustice. Section 7 presents the Commission's findings and recommendations.

Plastics: Plastics are complex, highly heterogeneous, synthetic chemical materials. Over 98% of plastics are produced from fossil carbon- coal, oil and gas. Plastics are comprised of a carbon-based polymer backbone and thousands of additional chemicals that are incorporated into polymers to convey specific properties such as color, flexibility, stability, water repellence, flame retardation, and ultraviolet resistance. Many of these added chemicals are highly toxic. They include carcinogens, neurotoxicants and endocrine disruptors such as phthalates, bisphenols, per- and poly-fluoroalkyl substances (PFAS), brominated flame retardants, and organophosphate flame retardants. They are integral components of plastic and are responsible for many of plastics' harms to human health and the environment.Global plastic production has increased almost exponentially since World War II, and in this time more than 8,300 megatons (Mt) of plastic have been manufactured. Annual production volume has grown from under 2 Mt in 1950 to 460 Mt in 2019, a 230-fold increase, and is on track to triple by 2060. More than half of all plastic ever made has been produced since 2002. Single-use plastics account for 35-40% of current plastic production and represent the most rapidly growing segment of plastic manufacture.Explosive recent growth in plastics production reflects a deliberate pivot by the integrated multinational fossil-carbon corporations that produce coal, oil and gas and that also manufacture plastics. These corporations are reducing their production of fossil fuels and increasing plastics manufacture. The two principal factors responsible for this pivot are decreasing global demand for carbon-based fuels due to increases in 'green' energy, and massive expansion of oil and gas production due to fracking.Plastic manufacture is energy-intensive and contributes significantly to climate change. At present, plastic production is responsible for an estimated 3.7% of global greenhouse gas emissions, more than the contribution of Brazil. This fraction is projected to increase to 4.5% by 2060 if current trends continue unchecked.

Plastic life cycle: The plastic life cycle has three phases: production, use, and disposal. In production, carbon feedstocks-coal, gas, and oil-are transformed through energy-intensive, catalytic processes into a vast array of products. Plastic use occurs in every aspect of modern life and results in widespread human exposure to the chemicals contained in plastic. Single-use plastics constitute the largest portion of current use, followed by synthetic fibers and construction.Plastic disposal is highly inefficient, with recovery and recycling rates below 10% globally. The result is that an estimated 22 Mt of plastic waste enters the environment each year, much of it single-use plastic and are added to the more than 6 gigatons of plastic waste that have accumulated since 1950. Strategies for disposal of plastic waste include controlled and uncontrolled landfilling, open burning, thermal conversion, and export. Vast quantities of plastic waste are exported each year from high-income to low-income countries, where it accumulates in landfills, pollutes air and water, degrades vital ecosystems, befouls beaches and estuaries, and harms human health-environmental injustice on a global scale. Plastic-laden e-waste is particularly problematic.

Environmental findings: Plastics and plastic-associated chemicals are responsible for widespread pollution. They contaminate aquatic (marine and freshwater), terrestrial, and atmospheric environments globally. The ocean is the ultimate destination for much plastic, and plastics are found throughout the ocean, including coastal regions, the sea surface, the deep sea, and polar sea ice. Many plastics appear to resist breakdown in the ocean and could persist in the global environment for decades. Macro- and micro-plastic particles have been identified in hundreds of marine species in all major taxa, including species consumed by humans. Trophic transfer of microplastic particles and the chemicals within them has been demonstrated. Although microplastic particles themselves (>10 µm) appear not to undergo biomagnification, hydrophobic plastic-associated chemicals bioaccumulate in marine animals and biomagnify in marine food webs. The amounts and fates of smaller microplastic and nanoplastic particles (MNPs <10 µm) in aquatic environments are poorly understood, but the potential for harm is worrying given their mobility in biological systems. Adverse environmental impacts of plastic pollution occur at multiple levels from molecular and biochemical to population and ecosystem. MNP contamination of seafood results in direct, though not well quantified, human exposure to plastics and plastic-associated chemicals. Marine plastic pollution endangers the ocean ecosystems upon which all humanity depends for food, oxygen, livelihood, and well-being.

Human health findings: Coal miners, oil workers and gas field workers who extract fossil carbon feedstocks for plastic production suffer increased mortality from traumatic injury, coal workers' pneumoconiosis, silicosis, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer. Plastic production workers are at increased risk of leukemia, lymphoma, hepatic angiosarcoma, brain cancer, breast cancer, mesothelioma, neurotoxic injury, and decreased fertility. Workers producing plastic textiles die of bladder cancer, lung cancer, mesothelioma, and interstitial lung disease at increased rates. Plastic recycling workers have increased rates of cardiovascular disease, toxic metal poisoning, neuropathy, and lung cancer. Residents of "fenceline" communities adjacent to plastic production and waste disposal sites experience increased risks of premature birth, low birth weight, asthma, childhood leukemia, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer.During use and also in disposal, plastics release toxic chemicals including additives and residual monomers into the environment and into people. National biomonitoring surveys in the USA document population-wide exposures to these chemicals. Plastic additives disrupt endocrine function and increase risk for premature births, neurodevelopmental disorders, male reproductive birth defects, infertility, obesity, cardiovascular disease, renal disease, and cancers. Chemical-laden MNPs formed through the environmental degradation of plastic waste can enter living organisms, including humans. Emerging, albeit still incomplete evidence indicates that MNPs may cause toxicity due to their physical and toxicological effects as well as by acting as vectors that transport toxic chemicals and bacterial pathogens into tissues and cells.Infants in the womb and young children are two populations at particularly high risk of plastic-related health effects. Because of the exquisite sensitivity of early development to hazardous chemicals and children's unique patterns of exposure, plastic-associated exposures are linked to increased risks of prematurity, stillbirth, low birth weight, birth defects of the reproductive organs, neurodevelopmental impairment, impaired lung growth, and childhood cancer. Early-life exposures to plastic-associated chemicals also increase the risk of multiple non-communicable diseases later in life.

Economic findings: Plastic's harms to human health result in significant economic costs. We estimate that in 2015 the health-related costs of plastic production exceeded $250 billion (2015 Int$) globally, and that in the USA alone the health costs of disease and disability caused by the plastic-associated chemicals PBDE, BPA and DEHP exceeded $920 billion (2015 Int$). Plastic production results in greenhouse gas (GHG) emissions equivalent to 1.96 gigatons of carbon dioxide (CO_2e) annually. Using the US Environmental Protection Agency's (EPA) social cost of carbon metric, we estimate the annual costs of these GHG emissions to be $341 billion (2015 Int$).These costs, large as they are, almost certainly underestimate the full economic losses resulting from plastics' negative impacts on human health and the global environment. All of plastics' economic costs-and also its social costs-are externalized by the petrochemical and plastic manufacturing industry and are borne by citizens, taxpayers, and governments in countries around the world without compensation.

Social justice findings: The adverse effects of plastics and plastic pollution on human health, the economy and the environment are not evenly distributed. They disproportionately affect poor, disempowered, and marginalized populations such as workers, racial and ethnic minorities, "fenceline" communities, Indigenous groups, women, and children, all of whom had little to do with creating the current plastics crisis and lack the political influence or the resources to address it. Plastics' harmful impacts across its life cycle are most keenly felt in the Global South, in small island states, and in disenfranchised areas in the Global North. Social and environmental justice (SEJ) principles require reversal of these inequitable burdens to ensure that no group bears a disproportionate share of

plastics' negative impacts and that those who benefit economically from plastic bear their fair share of its currently externalized costs.

Conclusions: It is now clear that current patterns of plastic production, use, and disposal are not sustainable and are responsible for significant harms to human health, the environment, and the economy as well as for deep societal injustices.The main driver of these worsening harms is an almost exponential and still accelerating increase in global plastic production. Plastics' harms are further magnified by low rates of recovery and recycling and by the long persistence of plastic waste in the environment.The thousands of chemicals in plastics-monomers, additives, processing agents, and non-intentionally added substances-include amongst their number known human carcinogens, endocrine disruptors, neurotoxicants, and persistent organic pollutants. These chemicals are responsible for many of plastics' known harms to human and planetary health. The chemicals leach out of plastics, enter the environment, cause pollution, and result in human exposure and disease. All efforts to reduce plastics' hazards must address the hazards of plastic-associated chemicals.

Recommendations: To protect human and planetary health, especially the health of vulnerable and at-risk populations, and put the world on track to end plastic pollution by 2040, this Commission supports urgent adoption by the world's nations of a strong and comprehensive Global Plastics Treaty in accord with the mandate set forth in the March 2022 resolution of the United Nations Environment Assembly (UNEA).International measures such as a Global Plastics Treaty are needed to curb plastic production and pollution, because the harms to human health and the environment caused by plastics, plastic-associated chemicals and plastic waste transcend national boundaries, are planetary in their scale, and have disproportionate impacts on the health and well-being of people in the world's poorest nations. Effective implementation of the Global Plastics Treaty will require that international action be coordinated and complemented by interventions at the national, regional, and local levels.This Commission urges that a cap on global plastic production with targets, timetables, and national contributions be a central provision of the Global Plastics Treaty. We recommend inclusion of the following additional provisions:The Treaty needs to extend beyond microplastics and marine litter to include all of the many thousands of chemicals incorporated into plastics.The Treaty needs to include a provision banning or severely restricting manufacture and use of unnecessary, avoidable, and problematic plastic items, especially single-use items such as manufactured plastic microbeads.The Treaty needs to include requirements on extended producer responsibility (EPR) that make fossil carbon producers, plastic producers, and the manufacturers of plastic products legally and financially responsible for the safety and end-of-life management of all the materials they produce and sell.The Treaty needs to mandate reductions in the chemical complexity of plastic products; health-protective standards for plastics and plastic additives; a requirement for use of sustainable non-toxic materials; full disclosure of all components; and traceability of components. International cooperation will be essential to implementing and enforcing these standards.The Treaty needs to include SEJ remedies at each stage of the plastic life cycle designed to fill gaps in community knowledge and advance both distributional and procedural equity.This Commission encourages inclusion in the Global Plastic Treaty of a provision calling for exploration of listing at least some plastic polymers as persistent organic pollutants (POPs) under the Stockholm Convention.This Commission encourages a strong interface between the Global Plastics Treaty and the Basel and London Conventions to enhance management of hazardous plastic waste and slow current massive exports of plastic waste into the world's least-developed countries.This Commission recommends the creation of a Permanent Science Policy Advisory Body to guide the Treaty's implementation. The main priorities of this Body would be to guide Member States and other stakeholders in evaluating which solutions are most effective in reducing plastic consumption, enhancing plastic waste recovery and recycling, and curbing the generation of plastic waste. This Body could also assess trade-offs among these solutions and evaluate safer alternatives to current plastics. It could monitor the transnational export of plastic waste. It could coordinate robust oceanic-, land-, and air-based MNP monitoring programs.This Commission recommends urgent investment by national governments in research into solutions to the global plastic crisis. This research will need to determine which solutions are most effective and cost-effective in the context of particular countries and assess the risks and benefits of proposed solutions. Oceanographic and environmental research is needed to better measure concentrations and impacts of plastics <10 µm and understand their distribution and fate in the global environment. Biomedical research is needed to elucidate the human health impacts of plastics, especially MNPs.

Summary: This Commission finds that plastics are both a boon to humanity and a stealth threat to human and planetary health. Plastics convey enormous benefits, but current linear patterns of plastic production, use, and disposal that pay little attention to sustainable design or safe materials and a near absence of recovery, reuse, and recycling are responsible for grave harms to health, widespread environmental damage, great economic costs, and deep societal injustices. These harms are rapidly worsening.While there remain gaps in knowledge about plastics' harms and uncertainties about their full magnitude, the evidence available today demonstrates unequivocally that these impacts are great and that they will increase in severity in the absence of urgent and effective intervention at global scale. Manufacture and use of essential plastics may continue. However, reckless increases in plastic production, and especially increases in the manufacture of an ever-increasing array of unnecessary single-use plastic products, need to be curbed.Global intervention against the plastic crisis is needed now because the costs of failure to act will be immense.

Keywords: environmental health; human health; microplastics; ocean health; plastic additives; plastic life cycle.

Figures

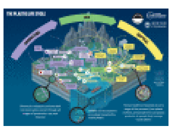

Figure 2.1 The plastic life cycle. The...

Figure 2.2 Throwaway Living – Disposable items...

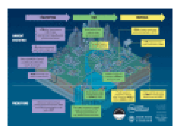

Figure 2.3 Plastic life cycle: Production and...

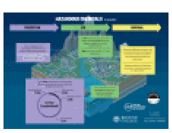

Figure 2.4 A multitude of hazardous chemicals...

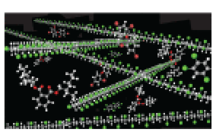

Figure 2.5 Plastic is a complex chemical...

Figure 2.6 Plastic life cycle: Plastic leakage....

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Related information

MedGen
PubChem Compound (MeSH Keyword)

LinkOut - more resources

Full Text Sources

Europe PubMed Central

PubMed Central

Ubiquity Press

Medical

MedlinePlus Health Information

Research Materials

NCI CPTC Antibody Characterization Program

Miscellaneous

NCI CPTAC Assay Portal

Centers for Disease Control and Prevention

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National Biomonitoring Program

Per- and Polyfluorinated Substances (PFAS) Factsheet

The per-and polyfluoroalkyl substances (PFAS) are a group of chemicals used to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water. Fluoropolymer coatings can be in a variety of products. These include clothing, furniture, adhesives, food packaging, heat-resistant non-stick cooking surfaces, and the insulation of electrical wire. Many PFAS, including perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), are a concern because they:

- do not break down in the environment,
- can move through soils and contaminate drinking water sources,
- build up (bioaccumulate) in fish and wildlife.

PFAS are found in rivers and lakes and in many types of animals on land and in the water.

PFAS Exposure in People

PFAS persist in the environment and exposure in people can occur by consuming PFAS-contaminated water or food. Exposure may happen by using products that contain PFAS.

How PFAS Affect People's Health

Human health effects from exposure to low environmental levels of PFAS are uncertain. Studies of laboratory animals given large amounts of PFAS indicate that some PFAS may affect growth and development. In addition, these animal studies indicate PFAS may affect reproduction, thyroid function, the immune system, and injure the liver. Epidemiologic studies on PFAS exposure evaluated several health effects. Descriptions of these studies are available at: https://www.atsdr.cdc.gov/pfas/. More research is necessary to assess the human health effects of exposure to PFAS.

Levels of PFAS in the U.S. Population

Since 1999, CDC scientists have measured at least 12 PFAS in blood serum (the clear portion of blood). Blood serum is obtained from participants, aged 12 years and older, who have taken part in the National Health and Nutrition Examination Survey (NHANES) (Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables). By measuring PFAS in serum, scientists can estimate the amount of PFAS in people's bodies.

CDC scientists found four PFAS (PFOS, PFOA, PFHxS or perfluorohexane sulfonic acid, and PFNA or perfluorononanoic acid) in the serum of nearly all of the people tested. This indicates widespread exposure to these PFAS in the U.S. population. The data tables showing results since 1999 are available here: https://www.cdc.gov/exposurereport/.

Finding a measurable amount of PFAS in serum does not imply that the levels of PFAS cause an adverse health effect. Biomonitoring studies on levels of PFAS provide physicians and public health officials with reference values. These reference values can determine whether people have been exposed to higher levels of PFAS than the general population. Biomonitoring data also help scientists plan and conduct research on exposure and health effects.

Additional Resources

Agency for Toxic Substances and Disease Registry

- Toxicological Profile for Perfluoroalkyls
- Information about Per- and Polyfluoroalkyl Substances and Your Health

Environmental Protection Agency

- https://www.epa.gov/pfas

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'Our community has been deceived': Turf wars mount over PFAS

By E.A. Crunden, Ariel Wittenberg | 08/03/2022 01:24 PM EDT

Across the country, bitter fights are playing out over synthetic grass surfaces. Some towns already have buyer's remorse after finding PFAS in their turf, while others have put plans to install their own on hold.

Deep divisions have emerged across the country as communities have battled over artificial turf known to contain so-called forever chemicals. The issue has spiraled in areas like Portsmouth, N.H., where a turf installation has spurred fiery back-and-forth. Claudine Hellmuth/E&E News (illustration); Researchgate (chemical compound); Clean and Healthy New York and Environmental Working Group (text); Satakorn/istock (turf photo); Валентин Игнаткин/iStock (soccer ball); SnazzyMaps (map)

In need of a new athletic field and already concerned about "forever chemicals" in its drinking water, the city council of Portsmouth, N.H., voted two years ago to install a new synthetic turf field only if it was "PFAS-free."

PFAS, or per-and polyfluoroalkyl substances, are a family of thousands of compounds that do not break down in the environment. Some have been linked to health problems including kidney and liver issues, along with various cancers. The City Council did not want to take a chance that the field could create more contamination.

But once installed, testing performed by a local advocacy group found organic fluorine in the field, an indicator that it might contain PFAS. City-ordered tests for specific compounds confirmed there were indeed some PFAS in the turf. Now, the City Council appears poised to accept potential athlete and environmental exposure, angering concerned residents who want the city to sue manufacturers.

"Where is the accountability from the city [when] we did not get the turf the City Council approved? You should be upset about that," asked Portsmouth resident Andrea Amico at a June council meeting. "You should not be setting a precedent that a manufacturer can lie to you in writing without any consequences."

The city's experience has emerged as a cautionary tale for many other communities across the country grappling with whether to replace degrading natural athletic fields with artificial turf.

"Portsmouth is a really good example of [how] it's really hard to put the horse back in the barn after the doors are open," said Kyla Bennett, director of science policy at Public Employees for Environmental Responsibility, who has worked with a number of environmental groups battling turf fields in their communities. "The moral of the story in Portsmouth is it is much easier to investigate this stuff first, before you put it in, than it is to deal with the fallout."

Three years ago, when Portsmouth was considering how to restore its athletic field complex, *The Boston Globe* (https://www.bostonglobe.com/metro/2019/10/09/toxic-chemicals-found-blades-artificial-turf/1mlVxXjzCAqRahwgXtfy6K/story.html) reported that tests of athletic turf in Franklin, Mass., contained organic fluorine. Portsmouth is no stranger to PFAS, which contaminate part of the city's water supply due to the use of aqueous firefighting foam at a former Air Force base there.

The city was considering a turf field because soggy New England springs mean natural grass fields are out of commission for much of the season. But Portsmouth did not want to further imperil its drinking water.

Aware of the Massachusetts findings, the city's consultants — Weston & Sampson — promised in a February 2020 public meeting that the chemicals would not be an issue. In a PowerPoint slide, they said they would "require PFAS-free materials in the bid specifications," and pledged that they already had documentation from two manufacturers to that end. That included a promise (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b524-daca-a1ab-bde62f420000) from the company FieldTurf that "Our supplier has confirmed that their products are free of PFAS, PFOS and fluorine."

Portsmouth ultimately contracted with that company and approved the $3.5 million artificial athletic field.

The conditions comforted Amico, whose family already had elevated levels of PFAS in their blood due to the Air Force base. "I signed my kids up for soccer. I'm thinking, 'Oh, it's PFAS-free, it's great,'" she said. "The city made us feel safe."

But local advocacy group Non Toxic Portsmouth argued that PFAS-free turf does not exist. On the day the field was being installed, member Ted Jankowski cut samples from rolls of the artificial turf before it could even be put in the ground. Those samples were sent to a lab in Michigan, which found high levels of organic fluorine.

Additional tests ordered by the City Council found multiple compounds (https://www.cityofportsmouth.com/sites/default/files/2022-06/Technical%20Memorandum_Portsmouth_Final.pdf), including 135 parts per trillion of PFOS. EPA released a health advisory in June saying just 20 parts per quadrillion was the maximum safe level for that chemical in drinking water (*Greenwire* (https://subscriber.politicopro.com/article/eenews/2022/06/15/epa-sets-targets-for-slashing-pfas-in-drinking-water-00039819), June 15).

Weston & Sampson then asserted that city officials had simply misunderstood their agreement. The bid documents (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b524-d590-abb9-fd24ed5a0000) only specify that levels of 30 compounds should be so low they cannot be detected by a particular EPA-approved laboratory method.

That list of 30 compounds includes PFOS, but the EPA-approved laboratory method mentioned in the contract bid is not the same city-ordered test that ultimately uncovered the compound in the turf. So, while advocates want the city to sue Weston & Sampson and the turf manufacturer, city officials say no agreement has been breached.

"We felt and continue to feel, based on the recent testing and results, that the testing performed in the original bid specification was sufficient to determine safety of the product," Deputy City Manager and Deputy City Attorney Suzanne Woodland said.

Weston & Sampson did not respond to a request for comment. But consultants at the group TRC, which conducted the testing for the city, also told a City Council meeting that the fields pose no risk to players whose skin might come into contact with them. Iannick Di Sanza, director of marketing for FieldTurf, said the company "complied with all of the specification requests and even voluntarily submitted our product for additional testing that was outside of the initial requirements."

FieldTurf cited the TRC testing and emphasized their conclusion that "a limited number of PFAS in the synthetic turf components does not represent a human health risk."

That has left local advocates enraged.

"That's lying, we call that lying," Diana Carpinone, president of Non Toxic Portsmouth, said of the consultants' promises. "We want [the council] to sue and go after Weston & Sampson, and go after the manufacturers, and say, 'This is fraud, we bought a product you told us was PFAS-free and it's not.'"

Amico agreed that the broader process felt dishonest.

"I feel like our community has been deceived," she said.

To Woodland, the entire issue boils down to multiple miscommunications. She does not think FieldTurf or Weston & Sampson had any ill intentions when they promised a PFAS-free field — they only meant that they were not purposely adding PFAS coatings to the turf.

She does not believe the city would opt against installing turf knowing what they know now. But Woodland added that officials wish they could have avoided "overgeneralizations" and communicated more precisely which compounds they were focused on.

"The city staff and its engineering consultants could have done a better job in 2020 discussing what could and what could not be expected, with regard to PFAS in an artificial turf field," Woodland said. "The manufacturers could have done a better job at identifying elements of their manufacturing process that might generate PFAS compounds in the product."

'We need to ... restrict exposure'

Portsmouth's problems are illustrative of the turmoil surrounding artificial turf projects.

Often scrutinized for the use of crumb rubber infill, which can contain neurotoxic metals like lead, plastic fields are drawing new fire due to PFAS even as manufacturers move away from crumb rubber.

Prized for their ability to repel moisture, PFAS prevent plastic blades of fake grass from sticking to manufacturing equipment. Documents (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b523-d010-a3cb-b5ab460f0000) from PFAS manufacturer 3M Co. show the company recommends up to 1,000 parts per million of certain compounds to aid in such processing. A consultant for the synthetic turf industry said last year that the chemicals PVDF and PVDF-HFP are used in manufacturing, before later telling E&E News that PVDF-HFP was the only compound used and that it would not break down (*Greenwire* (https://subscriber.politicopro.com/article/eenews/2021/12/08/epa-linked-consultant-undercuts-agencys-pfas-concerns-284027), Dec. 8, 2021).

But the actual research underpinning the health effects of chemicals like PVDF and PVDF-HFP is scant. An October 2020 study (https://pubs.acs.org/doi/10.1021/acs.est.0c03244) raised questions about the environmental and health implications of PVDF, with additional research (https://www.mdpi.com/2073-4360/13/9/1354) indicating that chemical can break down in the presence of ultraviolet light.

Whether PVDF-HFP poses similar concerns is unknown.

In a statement, the Synthetic Turf Council said it did not have information on which specific fluoropolymers might be used as processing aids.

"With the widespread use and availability of PFAS in the environment from many other sources, there is always the possibility of PFAS contamination when testing synthetic turf products," the group said, emphasizing that the compounds used in the extrusion process are "not the PFAS compounds of concern associated with groundwater and soil contamination."

Despite expressing confidence in turf safety, however, STC said that some members are working on PFAS alternatives in order to meet market demand.

Turf proponents have cited the presence of PVDF-HFP in surgical sutures and medical devices as evidence that its use in artificial fields should be acceptable. Some toxicologists and other scientists have pushed back, noting that the conditions present on a turf field are very different. Testing meant to imitate the impact of decades of use on turf has shown other PFAS compounds present, which some scientists say could mean that PVDF-HFP can break down into more concerning compounds, like the PFOS found in Portsmouth's field.

That reality has raised red flags for the Icahn School of Medicine Children's Environmental Health Center. The team has written letters (https://villagegreennj.com/wp-content/uploads/2021/07/Mount-Sinai-Letter-to-Maplewood-Township-June-2021.pdf) to municipalities weighing whether to invest in turf, discouraging the decision over concerns about exposure risks for children.

Sarah Evans, a faculty member at Mount Sinai Children's Environmental Health Center, also highlighted the many unknowns that surround most PFAS. "[It's] a very stable bond that persists in the environment and builds up in the body," she said. "We suspect most of the chemicals in that class are going to have similar effects. The absence of evidence of harm is not evidence of absence of harm."

Chemical exposure can be particularly concerning for children. Evans expressed concern about “additive and multiplicative avenues of exposure” from children who might be exposed to PFAS from turf and other sources, like drinking water, that could ultimately harm small bodies.

Skin contact is not the only way that athletes or kids could be exposed to chemicals in the turf. They could also accidentally ingest the compounds if they touch their mouths after touching the turf.

“I would say we need to, to the greatest degree possible, restrict exposure to these chemicals,” she said.

Environmental concerns

Turf wars are also raging in other parts of the country.

In Los Gatos, Calif., some parents have become embroiled in a fight over plans to put in artificial plastic grass at local elementary schools. Similar battles are playing out in states like Connecticut and Vermont with a focus on high schools.

All have involved some level of concern around PFAS, with water contamination in the backdrop. In Woodbridge, Conn., for example, testing has shown PFAS levels rose (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b526-d010-a3cb-b5aed1070000) in surface water yards away from the Amity High School field after (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b527-daca-a1ab-bde7b1df0000) its construction, an uptick local advocates attribute to the turf. PFOA and PFOS levels in that water are above the threshold now considered safe by EPA. FieldTurf installed that field and said (https://subscriber.politicopro.com/eenews/f/eenews/?id=00000181-b526-d590-abb9-fd2626ee0000) it would be free of total PFAS measured under EPA’s testing method.

Tracy Stewart has been fighting turf across Massachusetts for nearly a decade, including in the town of Franklin, where she connected used turf discarded near wetlands to increased PFAS contamination. In 2019, she and PEER’s Bennett confirmed through testing that the turf contained elevated levels of Total Organic Fluorine. But the town has yet to address questions around turf, even as concerns over PFAS in drinking water have cropped up (https://www.milforddailynews.com/story/country-gazette/2022/02/09/franklin-investigating-elevated-pfas-readings-town-well/9317181002/).

Advocates concerned about turf say industry’s focus on whether it could harm athletes ignores a bigger fear: that the material could contaminate the surrounding environment. Years in the sun and rain could cause chemicals to enter local drinking water and waterways.

One of the most heated debates over turf is playing out on a Massachusetts island.

Martha’s Vineyard has preexisting PFAS contamination and relies on a single aquifer for drinking water. But school officials have vehemently pushed for a multimillion-dollar turf project, arguing it will bolster the performance of student athletes.

That dispute took on a violent tone earlier this year. Oak Bluffs’ health agent, Meegan Lancaster, had been advising the town’s health board on the potential for PFAS contamination from a synthetic field when she found 10-millimeter shell casings in her personal tote bag. She left the job not long afterward, according to the *Martha’s Vineyard Times.* (https://www.mvtimes.com/2022/03/18/shell-casing-case-closed/)

Ultimately, the Oak Bluffs Planning Board voted to deny a permit for the field, citing concern that PFAS could ultimately leach into the water supply. They pointed to calculations conducted by a regional regulatory body finding the field could leach up to 12 ppt of the six PFAS regulated in Massachusetts into the island’s drinking water annually, including PFOS.

Now, the Martha’s Vineyard Regional School District is challenging the decision with a lawsuit, arguing the board should have listened to town-hired consultants, including Weston & Sampson, who said contamination from the field is “likely insignificant.” Opponents say they are unfazed and will continue fighting. Rebekah Thompson, who works with the nonprofit Field Fund in support of natural fields, said the group was surprised by the extent to which the school system would fight for turf.

“It is shocking to see Martha’s Vineyard school officials challenge the authority of the town to take steps to protect a predefined, environmentally sensitive area,” Thompson said.

A decision to delay

At least one town has opted to put a turf project on hold over health and environmental concerns. In Sharon, Mass., officials imposed a three-year moratorium (https://ecode360.com/37379890) on the installation of artificial turf.

Like other towns, Sharon has faced pressure to repair crumbling athletic fields. In 2019, the town’s school committee requested the installation of a synthetic football field at Sharon High School, but local advocates pushed back and were successful. In May 2020, the Sharon Conservation Commission rejected the field, and the moratorium followed several months later.

“We went on the warpath,” said Paul Lauenstein, a local advocate who works on water issues.

Residents said that decision was reached due to a range of concerns, like microplastics, crumb rubber and other pollutants associated with such fields. But PFAS were a major factor.

Then, Sharon opted to try something different: experiment with reviving grass fields.

Sharon is working with Ian Lacy, a consultant with an extensive background in both natural and synthetic turf fields. Lacy said the town's grass fields could be improved through a number of steps, like properly managing drainage and soils. Two fields were ultimately selected as pilot projects to test whether more intensive upkeep would make them more resilient.

"Suffice to say, the fields have improved," said Lacy, who feels that both synthetic and natural surfaces can have different advantages for athletes. While Lacey has clients on "both sides of the argument," he emphasized that success has more to do with a commitment to upkeep.

"This is an investment, and you have to sustain that investment," he said.

With the moratorium lifting next year, Sharon will once again have to decide if it wants to stick to natural grass for good. Lauenstein and other advocates are hopeful that the pilot projects prove it can work for their community.

"The idea is to demonstrate that natural grass can be serviceable," said Lauenstein. "We don't have to buy a million-dollar field with 40 tons of plastic."

Correction: *The story has been updated to reflect the correct name of Non Toxic Portsmouth.*

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Memo on PFAS-free Synthetic Turf Standards and Testing

Jeff Gearhart <jeffg@ecocenter.org>

Mon 11/16/2020 4:45 PM

To: elvin@mvcommission.org <elvin@mvcommission.org>; turner@mvcommission.org <turner@mvcommission.org>; Oak Bluffs Planning Board <planningboard@oakbluffsma.gov>

3 attachments (2 MB)

TURI-fact-sheet-PFAS-in-artificial-turf.pdf; CFE_PFAS_Testing_FactSheet_Final.pdf; EcologyCenterPFASTesting.pdf;

The Martha's Vineyard Commission and Oak Bluffs Planning Board,

Please see attached memo which summarizes our experience testing systhetic turf fibers for PFAS. I have included some guidance on best practices for assessing these products.

I look forward to wokring with you on this issue.

Jeff Gearhart
Research Director
Ecolog Center

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734-945-7738
skype: jeff.gearhart1442

ECOLOGYCENTER
Healthy People, Healthy Planet

November 16, 2020

The Martha's Vineyard Commission and Oak Bluffs Planning Board,

I have been made aware of the Martha's Vineyard Commission and Oak Bluffs Planning Board pending review for a synthetic turf project. Our organization has been conducting research on PFAS content in commercial and residential indoor carpet, as well as synthetic artificial turf, for the last two years. We have analyzed 100's of residential carpet samples and dozens of synthetic artificial turf samples. This work, carried out with external contract labs and university-based scientists, includes testing carpet and synthetic turf fiber for individual PFAS chemicals, total oxidizable precursors and for total fluorine, an indicator of PFAS. My understanding is that the applicant, Martha's Vineyard Regional High School, is objecting to the testing methods recommended by your hired third party consultant, Horsley Whitten.

The turf industry (or in your case, a third party hired to test the proposed products) should conduct elemental fluorine testing for all products. Total fluorine testing is now required for certification systems for PFAS-free firefighting foams and PFAS-free food packaging, and should be the standard for polymers like turf as well.

Of the nine synthetic turf fibers we tested last year, fluorine was detected in 100%. Fluorine levels ranged from 44 to 255 parts per million. Additional tests not detailed here on two of the samples found evidence of organic fluorine, supporting the likelihood that PFAS is present. These turf samples included both new and installed product. This sampling is limited and does not represent the entire market. However, we continue to conduct ongoing testing of samples and testing of additional samples had similar findings. And it highlights the need for companies to provide clear test results if they are claiming PFAS-free.

Total fluorine tests do not tell us exactly which PFAS chemicals are present, but based on industry literature, we believe a likely source of the detected fluorine is processing aids used in the production of synthetic turf fibers. PFAS-based processing aids are not included in commonly used test methods and thus can be missed.

For this reason, it is critical for companies to conduct testing of fibers using an appropriate method. Most manufacturer-provided test results we have reviewed used a method designed for water testing. While this method is not designed specifically for solid polymer samples, it has been widely, and appropriately used to look at PFAS in variety of matrices. However, these tests are limited due to the fact they can detect only a portion (typically 24 – 40 compounds, depending on the lab) of the hundreds of possible PFAS chemicals which may be present.

The testing method that has typically been used by companies attempting to demonstrate PFAS-free composition is EPA Method 537.1, "Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry." I see that is the method being recommended to you by Huntress Associates and Cooperstown Environmental LLC.

As your third party consultant Horsley Whitten correctly states, due to the limited number of chemicals it can detect, this US EPA method is likely not sufficient to demonstrate a carpet or turf fiber is PFAS-free. We routinely request contract labs run both EPA Method 537.1 and one of the total fluorine methods to document . We often see that the targeted analysis for inidviudual PFAS chemicals significantly underreport the actual PFAS content of products in which PFAS is used. In addition to the two methods that measure total fluorine, other techniques can measure total organic fluorine, thus ensuring results are not skewed by the possible presence of inorganic fluorine (which is distinct from PFAS).

A company claiming PFAS-free turf fiber should thus be able to produce testing results showing less than 1 part per million of total organic fluorine or total fluorine. In the case of Martha's Vineyard Regional High School, it seems they may not be aiming for a PFAS-free synthetic turf system. While they state they "should guarantee the safety of our groundwater," according to the project specifications, Section 38 13 23.29 Synthetic Field Sports Surfacing (July 28, 2020), the requirement only states that the synthetic turf should "not use any PFAS chemicals currently listed as part of California's Proposition 65 regulations or identified as part of US EPA's Method 537 to manufacture the components of its turf field products, including the fibers, backing and any coating materials."

The California Proposition 65 and US EPA's Method 537 are not relevant standards for asserting a product is PFAS-free. California Proposition 65 only regulates few PFAS chemicals. US EPA's Method 537 is a test method not even a definitive list of chemicals. The list of chemicals that can be analyzed by US EPA's Method 537 is limited by the availability of laboratory reference standards for the many hundreds of PFAS chemicals that should be analyzed for. Labs routinely use US EPA's Method 537 (with modifications) to analyze 11 to 40 PFAS chemicals, depending on the lab. As I stated earlier, recent PFAS-free certification standards (*GreenScreen Certified*) for both firefighting foams and food packaging have specified total elemental fluorine testing.

Given the concerns around groundwater contamination (something Martha's Vineyard has already experienced due to the use of AFFF at the Martha's Vineyard Airport), as well as athlete health, your boards should require reliable third-party testing using both one of the total fluorine methods and one of the targeted methods:

To certify a product to be PFAS -free, we would recommend the following tests:

1. Combustion Ion Chromatography OR Oxygen Flask Combustion and Ion-Selective Electrode to identify elemental fluorine content;
2. It is also helpful to run EPA Method 537.1 modified for polymers with the ability to detect 40 PFAS compounds; AND a TOP Assay to identify the presence of some PFAS precursors.

In addition to our academic collaborators, we have found a range of third-party labs capable of conducting this type of analysis. These include, but are not limited to: Eurofins Australia or Test America (Sacramento); Galbraith Labs; ALS Environmental; and SGS.

I have also included a fact sheet from University of Massachusetts Toxics Use Reduction Institute; and the Cancer Free Economy Network (CFEN) guide entitled “A Short Guide to Common testing methods for Per- and Polyfluoroalkyl Substances (PFAS)” which discusses these issues. The CFEN guide discusses in more detail the range methods and references which test methods are commercially available

Please feel free to contact me directly if you have further questions.

Sincerely,

Jeff Gearhart
Research Director

Ecology Center
jeffg@ecocenter.org

FACT SHEET: AUGUST 2020

A SHORT GUIDE TO COMMON TESTING METHODS

FOR PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

A challenge to eliminating the use and exposure to per- and polyfluoroalkyl substances (PFAS) is knowing where these chemicals are used and found. Testing, be it of products, water, or food, is critical to ascertain whether PFAS are present and at what levels. But what test methods are appropriate in which application? This guide to PFAS test methods is to help manufacturers, researchers, government agencies, and NGOs understand the different types of PFAS testing techniques available to support their work in knowing where PFAS are found and at what level.

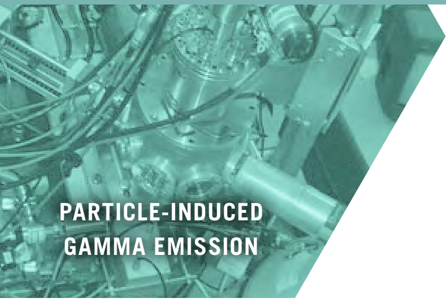
PFAS BACKGROUND

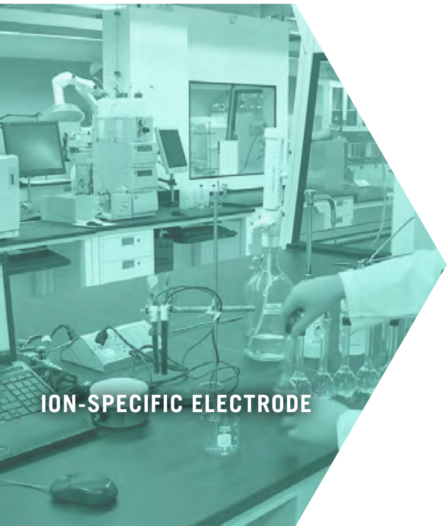
Per- and polyfluoroalkyl substances (PFAS) are a class of fluorinated organic chemicals that contain at least one fully fluorinated carbon atom, with over 5,000 chemicals identified in the class. PFAS are used in a wide variety of products, from non-stick cookware and textiles to firefighting foams and food packaging. One of the main concerns surrounding PFAS is their high potential to persist in the environment. Given their ubiquitous use and persistence, testing for PFAS is an important part of monitoring and limiting their continued use in supply chains.

This fact sheet focuses on testing techniques and methods that can be used to identify PFAS in food packaging, firefighting foams, and drinking water. While some test methods apply to multiple products and drinking water, there are few standardized PFAS test methods, which makes comparing results between different laboratories and studies difficult.

TESTING TECHNIQUES

PFAS analytical testing techniques can be divided into two categories: (1) targeted testing, and (2) total fluorine test methods. Targeted testing techniques measure a subset of PFAS (e.g., 30 of the 5,000 PFAS chemicals), while total fluorine tests are indirect methods designed to measure a representative element indicative of PFAS.





TOTAL FLUORINE METHODS

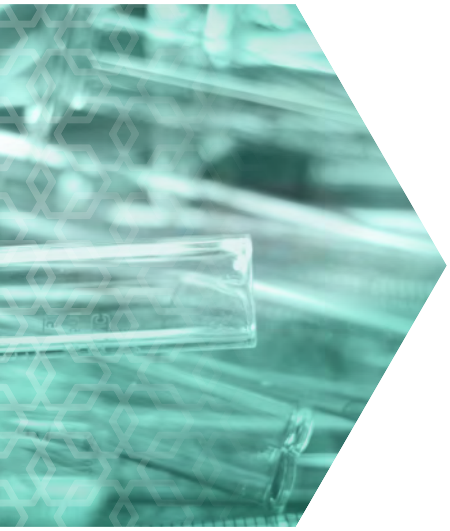
Total fluorine techniques measure either total organic fluorine or total fluorine. These techniques are efficient ways to identify whether PFAS are likely present. They can be used for screening as well as in a tiered approach to quantify PFAS in a product.

Total fluorine methods include: (1) particle-induced gamma emission (PIGE), (2) combustion ion chromatography (CIC), (3) instrumental neutron activation analysis (INAA), (4) ion-specific electrode (ISE), and (5) x-ray photoelectron spectroscopy (XPS). CIC can be used to quantify total organic fluorine or total fluorine. PIGE can be used to quantify total fluorine. PIGE, XPS, and INAA are non-destructive, meaning a single sample can be analyzed multiple times, which is beneficial when using more than one technique. PIGE and XPS are surface measurements, providing information on fluorine present on the surface rather than the concentration in the entire sample. CIC and ISE are both destructive, requiring combustion of the product sample, and measure fluorine in the entire sample. Table A includes more specific information on these methods.

TARGETED TESTING

Targeted testing techniques identify and quantify the presence of a specific set of PFAS. The chemicals of interest being identified and quantified are called analytes. The majority of targeted test methods use chromatography, with most relying on a combination of gas or liquid chromatography (GC or LC) and mass spectrometry (MS) analysis. GC/MS and LC/MS methods are used to both identify and quantify different types of specific chemical analytes.

Standards are required to identify and quantify an analyte and, to date, less than 100 of the 5,000 PFAS can be identified and quantified using targeted testing. Targeted testing techniques have the advantage of positively identifying the specific chemical as well as the concentration of that chemical in the sample. In addition, there are standardized and validated test methods in this category, such as those for drinking water. The primary disadvantage is that in most cases these methods measure only a small fraction of the PFAS that may be present in the



sample, missing those present in polymers and others not on the list of target analytes. The table includes more specific information on these techniques.

Two other methods incorporate LC/MS, namely quadrupole time-of-flight mass spec (QTOF-MS) and total oxidizable precursors (TOP) assay. QTOF-MS can determine a wide range of compounds in the PFAS family. TOP assay is used to convert precursors to PFAS that can be quantified using standard methods.

STANDARDIZED AND VALIDATED TEST METHODS

Most of the standardized and validated test methods are written for drinking water, groundwater, and open waterways. They are all chromatography-based methods, with differences mainly appearing in the sample preparation step. The complex nature of samples containing multiple materials, such as packaging, require significantly more sample preparation and clean-up when compared to drinking water. The number of analytes that can be determined varies depending on which method is employed and ranges from 11 to 40. The US Environmental Protection Agency (EPA) test method 537.1 is commonly referenced as it is a multi-laboratory validated test method.

PFAS testing is an evolving science that will benefit from standardized test methods for a wider variety of matrices and analytical techniques. Standardization allows for better reproducibility and comparison of PFAS determination, which will become more important as governments, agencies, and supply chains aim to reduce and eliminate the use of PFAS.

ANALYTICAL TECHNIQUES	APPLICATIONS	TARGET SUBSTANCE(S)	ADDITIONAL INFORMATION
COMBUSTION ION CHROMATOGRAPHY (CIC)	Food packaging Firefighting foams Water samples	Total fluorine or total organic fluorine	• Offers possibility of fast, accurate analysis • Destructive to sample • Direct combustion of the sample measures the total fluorine of the entire sample, independent of thickness. Direct combustion can be combined with a separate measurement of total inorganic fluorine through water extraction of the sample followed by combustion to determine total, inorganic, and organic fluorine. • Instead of directly combusting the sample, the organic fluorine can be either extracted or adsorbed and then combusted to measure total organic fluorine (either extractable or adsorbable). These techniques result in lower limits of reporting than direct combustion. These techniques are known as Extractable Organic Fluorine (EOF) and Adsorbable Organic Fluorine (used for waters/ wastewater) methods. • Technique referenced in Clean Production Action's firefighting foam standard - 1 ppm total organic fluorine threshold requirement for certification • Commercially available
INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA)	Food packaging Textiles Other organic materials	Total fluorine	• Measures total of entire sample, independent of thickness • Non-destructive and rapid • Since technique relies on nuclear, rather than chemical reaction, samples may be analyzed without dissolution or decomposition • No chemical prep needed • Samples are irradiated followed by a decay period, emitting gamma rays, and target nuclide identified via gamma ray spectroscopy. Quantification accomplished by comparison with standards. • Not commercially available
ION-SPECIFIC ELECTRODE (ISE)	Food packaging	Total fluorine	• Combustion with known amount of buffer solution, then analyzed with fluoride-specific electrode • Destructive method, low-cost • Commercially available
PARTICLE-INDUCED GAMMA EMISSION (PIGE)	Food packaging Firefighting foam	Total fluorine	• Surface measurement, so results dependent on sample thickness • Good result accuracy, well-used, cost-effective • Not commercially available
QUADRUPOLE TIME-OF-FLIGHT-MASS SPEC (QTOF-MS)	Water samples Materials	Full range of potential compounds in the PFAS family	• QTOF-MS combines TOF and quadrupole instruments, a pairing that results in high mass accuracy; speed and sensitivity are benefits of the QTOF • Coupled with LC or GC for analyte determination • Expensive and time consuming
TOTAL OXIDIZABLE PRECURSORS (TOP) ASSAY	Foam products Textiles Water samples	Quantifies total amount of chemical precursors to perfluoroalkyl acids (PFAAs)	• Selective PFAS method (only those that can be oxidized to form targeted PFAAs) • Destructive, relatively rapid, low cost • Sample treated so precursor substances contained within the sample are oxidized, then PFAS determination done using methods like LC-MS/MS

STANDARDIZED TEST METHODS	APPLICATIONS	TARGET SUBSTANCE(S)	ADDITIONAL INFORMATION
DIN EN ISO 10304-1	Water samples	Total organic fluorine	• Validated standardized test method is for water samples
ASTM D7979	Water samples	Individual PFAS (39 analytes)	• Direct injection method, LC-MS/MS analysis • Performance-based method (i.e., can adjust measurement sensitivity), wider range of analytes
ISO METHOD 25101	Unfiltered drinking water	Determination of linear isomers of PFOS and PFOA	• Solid phase extraction (SPE), high performance mass spec (HPLC-MS/MS) technique
USEPA METHOD 533	Drinking water	Individual PFAS (25 analytes)	• Isotope dilution anion exchange, solid phase extraction (SPE), and liquid chromatography/ mass spectrometry (LCMS/MS) techniques
USEPA METHOD 537	Drinking water	Selected PFAAs	• Solid phase extraction (SPE) liquid chromatography/tandem mass spectrometry (LCMS/MS) techniques utilized
USEPA METHOD 537.1	Drinking water	Individual PFAS (18 analytes)	• Multi-laboratory validated • Solid phase extraction (SPE), liquid chromatography/tandem mass spectrometry (LCMS/MS) techniques utilized

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SPECIAL THANKS TO

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Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet

Introduction

The Massachusetts Toxics Use Reduction Institute (TURI) has received inquiries from municipalities and community members regarding the presence of per- and poly-fluoroalkyl substances (PFAS) in artificial turf carpet. This brief fact sheet provides some basic background information on PFAS and on recent testing for these chemicals in artificial turf as reported by nonprofit organizations. This information is provided under TURI's mandate to provide information on toxic chemicals and safer alternatives to businesses, municipalities, community members and others.

TURI has conducted background research on health and environmental effects of PFAS in its work with the Toxics Use Reduction Act (TURA) program's Science Advisory Board. TURI has neither conducted nor sponsored any laboratory testing of PFAS in turf or other products.

What are PFAS?

PFAS are a category of chemicals that contain multiple fluorine atoms bonded to a chain of carbon atoms. Thousands of such chemicals exist. A study by the Organization for Economic Cooperation and Development (OECD) identified over 4,700 PFAS-related Chemical Abstract Service (CAS) numbers.[1] PFAS chemicals have properties that can be useful in a variety of settings, such as water and stain resistance. They also pose concerns, including persistence, bioaccumulation, and adverse health effects, as summarized below.

PFAS Nomenclature and Vocabulary

PFAS are sometimes described as "long-chain" or "short-chain" based on the length of the fluorinated carbon chain. They can also be categorized and described based on the number of carbons; for example, a PFAS chemical with an 8-carbon chain may be referred to as "C8." For more information, see the ITRC fact sheet "Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS)."[2]

PFAS "precursors" are complex chemicals that break down into other simpler PFAS compounds ("degradation products"). In addition, some PFAS are fluoropolymers (longer chains of molecules containing carbon and fluorine).

February 2020

TURI
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Persistence

Although there are thousands of PFAS, most of them break down into a common set of degradation products. These degradation products are characterized by very high persistence in the environment.[3] Persistent chemicals do not break down under normal environmental conditions, and some can last in the environment for hundreds of years or longer. As a result, introducing these chemicals into the environment has lasting consequences.

Bioaccumulation

All PFAS pose some degree of bioaccumulation concern, especially in air-breathing organisms.[3] In other words, they can accumulate in plants, animals, and humans.

Health Effects

Due to widespread contamination of drinking water in some areas of the US, the human health effects of certain PFAS have been studied in depth. Other PFAS have been studied in laboratory animals. Because the class of PFAS is so large, many individual PFAS have not been studied in depth. Researchers have emphasized the need to address PFAS as a group rather than one by one. Health effects documented for some PFAS include effects on the endocrine system, including liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity.[3]

PFAS have been studied by a number of government entities. For example, OECD has done the most comprehensive work on PFAS as a class; the US Environmental Protection Agency (US EPA) has done extensive research on several PFAS compounds; and certain states have researched individual PFAS chemicals in depth.

Drinking Water Contamination

PFAS have been found as drinking water contaminants in many states. For example, the Massachusetts Department of Environmental Protection (MassDEP) has worked with municipalities to gather data on levels of six PFAS in groundwater and drinking water. According to MassDEP, "since 2013, the sum of the concentrations of the six PFAS compounds above 20 ppt [parts per trillion] have been detected at over 20 PWSs [public water systems] in Massachusetts." MassDEP has issued a proposed regulation that would set a Maximum Contaminant Level (MCL) in drinking water of 20 ppt for the sum of the concentrations of these six PFAS. MassDEP has also finalized and adopted standards for groundwater cleanup.[4]

PFAS Testing

PFAS testing is difficult due to the large number of individual chemicals in the class, as well as the very low concentrations at which adverse effects may occur. Additional difficulties result from the fact that while methods have been developed for testing drinking water and wastewater, there are no consistent guidelines for testing solid materials. Some of these difficulties have been addressed through the development of methods for testing the total presence of fluorine-containing organic (carbon-containing) compounds.

In many cases, testing may be conducted for a small group of PFAS that have been a particular focus of regulatory activity. The absence of these chemicals does not indicate that all PFAS are absent. For example, US EPA has published methods for testing just 29 PFAS in water.[5]

Difficulty of Testing Products

Difficulties may be encountered in choosing appropriate test methods for a given material. For example, guidance that has been developed for drinking water is not necessarily applicable to a solid material. In addition, some laboratories use a modified version of a US EPA method; US EPA has not validated these approaches.[5]

In any testing effort, it is important to adopt an appropriate study design. For example, US EPA has provided guidance on approaches to understanding potential leaching of chemicals from liquids, soils and wastes into rainwater. This includes consideration of the acidity of rainwater in certain areas of the US. US EPA recommends choosing an appropriate extraction fluid depending on the relevant environmental conditions in the region.[6]

Total Fluorine Analysis

In addition to testing for individual compounds, it can also be useful to conduct a Total Fluorine Analysis. This can be carried out using Particle-Induced Gamma Ray Emission (PIGE) spectroscopy, and other techniques such as Combustion Ion Chromatography (CIC).

These tests do not look for specific PFAS chemicals. Rather, they look for fluorine atoms as an indicator of the presence of PFAS chemicals. This kind of test can be useful because testing standards have not been developed for all the types of PFAS that are available on the market. These measurements can also be performed on solid samples.

TOP Assay

Another test used to gather information about PFAS present in a sample is a Total Oxidizable Precursor (TOP) assay. This test creates the conditions in which precursors are broken down into degradation products. These degradation products are among the PFAS that can be measured by EPA methods in water. TOP assay enables researchers to detect the presence of precursors, even if they do not know which specific precursors are present.[7]

Understanding Test Results

When interpreting results of testing conducted on products, including turf carpet samples, it is important to understand what test was conducted and what that test has the ability to detect. For example, if a fluoropolymer is present in the product, an appropriate test must be selected to detect its presence.

In summary, lack of detection of one or more specific PFAS does not mean that a material is free of PFAS. To determine whether PFAS are likely to be present, a total fluorine test and/or a TOP assay may be helpful.

Another factor to consider is that in some cases, a test may be carried out only for long-chain chemicals that were used more frequently in the past, or that appear primarily as degradation products in the environment. Knowing the presence of these chemicals is important, but they are not the most likely chemicals to appear in a new product.

PFAS Testing in Artificial Turf Carpet

Determining what chemicals are present in a product can be challenging because chemical contents are frequently not disclosed by the manufacturer. Two nonprofit organizations recently tested artificial turf carpet and found evidence of the presence of PFAS in the material.[8] The nonprofit organizations tested backing of both new turf and older, discarded turf. They also tested a number of samples of artificial grass blades (carpet fibers).

They detected one PFAS chemical in the backing of the new turf sample. Specifically, they detected 6:2-fluorotelomer sulfonic acid (known by the abbreviation 6:2 FTSA). 6:2 FTSA has a 6-carbon chain, and is considered a short-chain PFAS because of the way in which it breaks down. In many cases, short-chain PFAS have been adopted as substitutes for longer-chain PFAS.

They detected perfluorooctane sulfonate (PFOS) in the backing of the discarded, older turf sample. PFOS is a long-chain PFAS that is no longer manufactured in the US due to concerns about health and environmental effects.

They also tested a number of synthetic turf fiber samples and found that all of them contained quantities of fluorine that suggest the presence of PFAS.[8] These quantities were in the parts per million range, but given the large surface areas of a typical turf carpet, researchers note these may represent a source of PFAS in the environment.[9] Research on this topic is still in process and it will be important to review new scientific publications as the work continues.

One possible reason for the use of PFAS in the artificial turf grass blades is to serve as an extrusion aid.[10] That is, PFAS is added to the polymer mixture (which is a non-fluorinated plastic) before it is passed through an extruder. An extruder is manufacturing equipment that melts and forms the polymer mixture into its desired shape. The PFAS helps to prevent the polymer from sticking to the extruder. According to a researcher, artificial turf grass blades were previously made from low-density polyethylene, but the material had poor durability. Newer polymer mixtures have greater durability, but were not compatible with existing extrusion equipment. Therefore, PFAS were added in order to facilitate use of the new polymer mixture with existing equipment.[8,9]

The researchers who conducted this work do not know exactly what types of PFAS may be used as processing aids in this application. They are not present in US EPA's Method 537.1 ("Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry"). Thus, using this US EPA method would not be informative in this application. However, the TOP assay allows researchers to confirm the presence of some type of PFAS. According to researchers, preliminary results on two samples indicated the presence of PFBA, PFBS, FPHxA, PFHpA, PFOA and PFOS in turf carpet fibers that had undergone TOP assay.[9]

Questions about Athletes' Exposure to PFAS

TURI has received questions about the possibility of PFAS exposure associated with playing on artificial turf. PFAS exposure has not been assessed specifically in relation to playing on artificial turf, and studying children's exposures often presents methodological and ethical challenges. More generally, the approach of the Toxics Use Reduction Institute is to identify opportunities to reduce or eliminate the use of toxic chemicals as a means to protect human health and the environment. Eliminating the use of a toxic chemical also makes it unnecessary to assess exposure.

The vast majority of PFAS research to date has focused on the results of ingestion exposure. There is also some emerging information on health effects of dermal exposure to PFAS. Some researchers have suggested that dermal exposure to consumer products treated with PFAS may contribute to over-all PFAS exposure.[11,12] In the absence of more specific information, it may be helpful to follow general guidelines provided by the Icahn School of Medicine at Mt. Sinai and others for helping to minimize exposure to chemicals that may be present in artificial turf.[13]

Learn more about PFAS

Technical fact sheets from the Interstate Technology Regulatory Council (ITRC) are available at: https://pfas-1.itrcweb.org/

Acknowledgements

Dr. Graham Peaslee (University of Notre Dame) provided comments on a draft of this fact sheet. Support for TURI's background research on this topic was provided by The Heinz Endowments.

References

Note: For several points covered in this overview, we have provided the TURA Science Advisory Board's summaries of scientific information as a reference. These summaries draw upon a large set of authoritative government documents and peer reviewed studies.

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Technical Memorandum

To: Martha Sapp, Director, Green Acres Program
Cecile Murphy, Program Specialist, Green Acres; Local and Nonprofit Assistance

Through: Nicholas A. Procopio, Ph.D., Director, Division of Science and Research

From: Sandra Goodrow, Ph.D., Research Scientist I, Division of Science and Research

Date: February 8th, 2023

Subject: PFAS in Artificial Turf

There is growing concern about sources of PFAS to the environment as reports have shown widespread levels of PFAS in soils, surface water, and groundwater at levels that could impact human health. It is with this in mind that the Division of Science and Research has reviewed current literature and related reports that may provide some information on the potential contribution of PFAS to the environment from the placement of artificial turf (AT). Initial considerations for this inquiry into the PFAS content of artificial turf are focused on the site where the turf field is placed for a period of use, but future considerations on the contribution of PFAS to the environment from the artificial turf should include both the initial manufacturing process of the AT (including petrochemicals used and contaminants released from manufacturing facility) and the method of waste management (including potential contribution of PFAS from the degradation of the AT in the final waste stream).

This memo follows an earlier memo on the human health impacts, specifically heat exposure, and stormwater management concerns related to artificial turf, provided by DSR to the program on June 23, 2022.

This memo will address only the PFAS that are contained in and potentially leached from the AT while in its place of use, it will include a review of what is currently known about PFAS in the components of the AT- the plastic backing, the blades, and the infill. At this point in time, it is only possible to provide a preliminary assessment of PFAS in AT since the available analytical data and formal studies are limited. A full evaluation is also bounded by limitations in the analytical techniques necessary to quantify all PFAS. In addition, it is not appropriate to generalize about all AT, as variability in manufacturing processes and materials would likely impact PFAS content and leachability.

<u>The Manufacturing Processes</u>

PFAS have been reported as being widely used to aid the molding and extrusion of plastic, such as is used in the manufacturing of artificial turf (Kulikov, 2005). Patent literature includes the use of polytetrafluoroethylene (PTFE) and fluoroelastomers as production processing aids as well as being used after treatment for polyethylene blades (Lambert, 2008). Patents related to artificial turf filling shows where PTFE and polyvinylidene fluoride (PVDF) are used as a coating treatment (Reddick, 2012) and a binding matrix (Wu, 2020). The filling material has also been reported to include fire retardants composed of unspecified organofluorine chemicals (Wu, 2020). Since PFAS are included in the chemical makeup of fluoropolymers that are added as polymer processing aids to improve plastic extrusion, there is also the potential of leaving a low-level fluoropolymer residual on the product following processing.

The manufacturing of newer artificial turf often incorporates the use of recycled materials. This may serve some purpose, but it also could serve to incorporate the older, long-chain PFAS into newer AT materials. Infill made of recycled materials could potentially contain contaminants originally found in automotive foam, acrylic coated sand, and shredded automotive tires. This variation in recycled materials, and potential ranges in contaminant concentrations, also introduce uncertainty.

<u>PFAS Analytical Methods and Artificial Turf</u>

There are thousands of PFAS in circulation today, but only a small subset of PFAS can be accurately quantified by existing analytical methods. The methods to characterize certain PFAS in water have been well established, but generally can only identify and quantify anywhere from eighteen (USEPA, 2020) to seventy-five (Eurofins, 2023) PFAS. The limited number of PFAS is driven by the availability of validated reference standards for the individual chemical compound, and a method that is proven to be able to quantify that chemical compound. The analytical methods to evaluate PFAS in solids are still evolving and using the results from these analyses require an understanding of the processes.

Four types of analyses were used to evaluate AT in a paper from Stockholm University by Lauria et al., 2022. The four methods used included total fluorine (TF), extractable organic fluorine (EOF), target PFAS analysis, and total oxidizable precursor assay (TOPA). The analytical method used to measure TF allows for some measure of the potential for the upper limit of PFAS that may be present in a sample. The EOF could be used as a surrogate for the concentration of PFAS as an organic compound that could be a portion of the TF. Target PFAS analysis uses reference standards and validated methods to quantify a small number of PFAS and is used to evaluate compliance with regulatory standards for PFAS including PFOA, PFOS, and PFNA. The total oxidizable precursor assay (TOPA) creates conditions that oxidize chemical compounds known as precursors to their final form of being a perfluoroalkyl acid (PFAA). PFAAs are a subgroup of PFAS that are the most recalcitrant due to the strong fluorine-carbon bonds and have been often found to be among the most toxic and bioaccumulative of PFAS.

A lack of detection in most analytical methods does not mean that the product is PFAS free. Non-detection using methods such as TF and TOPA can provide some assurance that presence of PFAS or PFAAs, respectively, is unlikely. A result of non-detect using the EOF could be used as an indicator that the fluorine detected by the TF method is unlikely to be PFAS.

<u>PFAS Data Reported in Artificial Turf</u>

In July of 2019, the US EPA, in cooperation with ATSDR, DHHS, and the CDC, published the first of two volumes evaluating the chemical content of recycled tire crumb in the fill of the synthetic turf field (US EPA, 2019). The characterization of PFAS in this fill was not included in the discussion. In October of 2019, an article published in the Intercept (Lerner, 2019), concerned that the EPA report did not evaluate PFAS in the infill, or evaluate the blades and backing of the artificial turf, reported on results of analysis performed by non-profits in the United States. The group, Public Employees for Environmental Responsibility (PEER), collected two samples from a new sports field being installed in Massachusetts. The samples were sent to two labs- one lab appeared to perform a target analysis that found detectable levels of 6:2 FTSA, a six-carbon sulfonic acid, at 300 ppt, and the other lab, the Ecology Center, performed a total fluorine analysis on the blades of the grass to show presence in the fibers, at a concentration of 44-255 ppm (44,000,000 – 255,000,000 ppt). An additional sample was collected from the older discarded turf field, placed nearby since it was removed in 2017, and was found to contain PFOS at 190 ppt. PFOS is a known toxic PFAS that has been phased out since the early 2000's, but is widely found due to previous use and persistence in the environment. Nearby surface water also contained levels of PFAS, leading to a supposition that the artificial turf may have contributed PFAS to the adjacent environment.

In another small study reported out of the University of Connecticut, an undergraduate group performed a Senior Design Project where they exposed samples of AT to conditions intended to mimic some level of acid rain and UV light exposure. They then sent the leachate for target analysis that quantified 18 PFAS, and they did recover a detectable amount of PFHpA, albeit below the reporting limits of 0.2 ppt and 0.25 ppt. (UConn, 2021) The samples they tested were from a new turf sample collected directly from a manufacturer. The results of this limited study are reported only in an aural presentation provided on the website, so a true evaluation of methods used to create the leachate is not possible. Similar results depicting artificial turf as having negligible PFAS leaching was reported from a consultant report requested by the Martha's Vineyard Commission. While results appear to suggest negligible PFAS leaching, the report does not assess lifetime leaching from the total mass of artificial turf to be placed (Tetra Tech, 2021).

In 2022, researchers from Stockholm University, designed a study to evaluate PFAS in a representative sample of the blades, infill, and backing of AT (Lauria, 2022). As discussed previously, this study, used all four methods including total fluorine (TF), extractable organic fluorine (EOF), target PFAS analysis, and total oxidizable precursor assay (TOPA). This study collected fifty-one samples of artificial turf, and separated them into backing, filling, and blades for analysis. Total fluorine was detected in 100% of samples, with concentrations ranging from 16-313 ppm (16,000,000- 313,000,000 ppt) in backing, 12-310 ppm (12,000,000-310,000,000 ppt) in filling, and 24-661 ppm (24,000,000-661,000,000 ppt) in blades. Analysis using EOF and target analysis showed detectable levels of PFAS in 42% of samples, albeit at levels more than an order of magnitude lower. The lower boundary of the EOF results were below the limit of detection, while the upper boundaries were 145 ppb (145,000 ppt), 179 ppb (179,000 ppt), and 192 ppb (192,000 ppt) for backing, filling, and blades, respectively. Tests using extraction with water only did not show detectable levels in the water. The target analysis results were summed and reported in ng F/g (ppb) and ranged from non-detect to 0.63 ppb (630,000 ppt) in backing, and non-detect to 0.15 ppb (150,000 ppt) in filling. Targeted analytes were not detected in the blades. Results of the TOPA indicated negligible PFAA formation in all three sample types. PFOS and PFOA were detected in five of the fields evaluated, ranging from 84-118 ppt PFOS, and 47-96 ppt of PFOA.

The results of the Lauria study suggest that PFAS is contained within the artificial turf (100% detection in total fluorine). The levels of TF are similar to the samples collected and sent to the Ecology lab by PEER. These results quantifying the TF within the product suggests PFAS are present within the matrix of the artificial turf. The addition of the EOF provides further information on what portion of the TF might be organic in nature, and more likely to be under the PFAS family. The results of the targeted methods identify known PFAS to also be present. Less than 42% of all samples had detectable levels of EOF and targeted PFAS. The results of the EOF were more than one order of magnitude lower indicating that most PFAS in AT is not extractable[1].

Review of Results

The extraction process used in the EOF method is intended to maximize the partitioning of the organic fluorine for analysis. The Stockholm study also included a small subset of samples extracted only by water and found no detectable fluorine. Neither method could be considered fully representative of the impact of environmental conditions experienced over a long period of time and therefore, conclusions regarding leachability cannot definitively be made based on these results, but these results could suggest that leachability is low.

Additional tests with conditions replicating all environmental impacts experienced by the area where the artificial turf is applied, including exposure to ultraviolet light and acidic precipitation, would be necessary to provide a more accurate assessment.

Notably, the Lauria study showed that PFAS concentrations were higher in the newer fields that used recycled materials such as ethylene propylene diene monomer rubber (EPDM) or styrene-butadiene rubber (SBR) when compared to the concentrations in the older fields. This finding should be considered when evaluating various options to procure, but also to guide future manufacturing guidance that could reduce resource consumption while reducing contaminant concentrations present in the product.

The Lauria study out of Stockholm is a well-defined study and confirms that PFAS are present in artificial turf material and can be significant components. However, the identification of what type of PFAS is present remains largely unknown and is not likely to be of similar make up across different manufactured turfs. In addition, this Stockholm study, as well as the smaller, less rigorous studies from PEER and UConn, suggest that any PFAS contained in the turf appears unable to migrate from the material. This may be in fact true, or it may be an artifact of the testing process which may not accurately represent all environmental conditions that impact the turf (including exposure to UV light) over time.

Conclusion

While the Stockholm study compiled a larger representative sample, it is unclear if this sample is representative of the types of AT available in the United States. If the samples are representative of AT placed in the U.S., the study appears to suggest that low levels of PFAS may be released from the product and the larger portion of PFAS detected is within the structure of the material. However, the lack of analytical methods that identify and quantify all potential PFAS limits the ability to make absolute conclusions that PFAS release is not a problem.

Manufacturers of artificial turf claim environmental benefits based on the elimination of the need for watering, mowing, and pesticides. However, the 2019 EPA report indicates the crumb rubber can contain many chemical compounds such as cadmium, chromium, and arsenic, although they do not characterize the infill for PFAS, and they do not assign risk to the chemical compounds detected. These concerns continue to be investigated and

[1] *"Extractable" is terminology used to define laboratory methods that are intended to separate the analyte from the surrounding material for analysis. Laboratory methods used for extraction to provide "total" analyte concentration are generally more aggressive than conditions experienced through aging or weathering of a material. If an analyte is not extractable, there may be an assumption that it would not leach under typical environmental conditions. This assumption might be accurate, but true leachability would need to be determined under a different experimental design and is not fully assessed with extractability alone.*

are further discussed in a recent paper by Murphy, et al., 2022, "Health impacts of artificial turf: Toxicity studies, challenges, and future directions" from two investigators out of NJIT.

Recommendations

There is limited data available to make a conclusion about the release of PFAS from AT during its period of active use. The available data shows PFAS as being a component of the material, but the types of PFAS that are present and the potential to have those chemicals released to the environment has not been established.

Given the uncertainties, it is advisable to create a plan to evaluate all available options. Although there appears to be some benefits to using AT, a full assessment of optional alternatives should be performed and endpoints such as toxic releases and carbon footprints should appropriately be compared to evaluate the full impact to environmental and human health. These evaluations should include not only the time where the AT is in active use, it should also include an evaluation of the resources used and contaminants, including PFAS, released during the manufacturing process and the end-of-life recycling/waste management process.

PFAS released in the plastic manufacturing process through wastewater discharges and stack emissions have been one of the largest sources to the environment, having an impact on both humans and natural resources. Due to the limited studies investigating the specific issue of leaching from AT, it is not entirely possible to assess levels of PFAS that may enter the environment during the relatively short use as an artificial turf product. The release of PFAS during the manufacturing of this material together with the release of PFAS during the decomposition in a landfill (or when discarded on a lot not far from the original use location, as occurred in the Massachusetts scenario) should also be considered. Although there is some advocacy for recycling this material at end-of-life, there are currently no known facilities that will perform this process for artificial turf (Horsley Witten, 2020).

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'Forever chemicals' were everywhere in 2023. Expect more litigation in 2024

By **Clark Mindock**

December 28, 2023 10:54 AM EST · Updated 2 months ago

Aa

Signage is seen at the headquarters of the United States Environmental Protection Agency (EPA) in Washington, D.C., U.S., May 10, 2021. REUTERS/Andrew Kelly/File Photo *Purchase Licensing Rights*

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Dec 28 (Reuters) - Lawsuits accusing major chemical companies of polluting U.S. drinking water with toxic PFAS chemicals led to over $11 billion in settlements in 2023, with experts predicting that new federal regulations and a growing awareness of the breadth of PFAS contamination in the U.S. will spur more litigation and settlements in the year ahead.

Dubbed "forever chemicals" because they do not easily break down in the human body or environment, per- and polyfluoroalkyl substances, or PFAS, are a group of roughly 15,000 known chemicals used in hundreds of consumer and commercial products including firefighting foams, non-stick pans, stain resistant clothing and cosmetics.

The U.S. Environmental Protection Agency has taken several steps in recent years to tighten regulations for PFAS, calling the chemicals an "urgent public health and environmental issue."

WHY IT MATTERS

Chemical companies, including 3M (MMM.N), Chemours (CC.N), Corteva (CTVA.N) and DuPont de Nemours (DD.N), have faced thousands of lawsuits in recent years over alleged PFAS contamination.

Many of the cases, which involve claims that PFAS in firefighting foams sprayed at airports and firehouses across the country contaminated water supplies, have been consolidated in multidistrict litigation (MDL) in South Carolina federal court.

The litigation includes lawsuits brought by water utilities seeking to make the companies pay to clean up PFAS contamination and personal injury claims by individual plaintiffs who allege that exposure to PFAS has led to health issues, including cancer, hormonal dysfunction and ulcerative colitis.

A 3M spokesperson said PFAS can be safely made and used, and noted the company plans to discontinue its production of PFAS by 2025. Chemours, DuPont and Corteva declined to comment on the litigation.

Other lawsuits include consumer class actions over PFAS-containing products, lawsuits by states over environmental damage to wildlife and waterways, and lawsuits seeking to force companies to pay to clean up PFAS in waste that has seeped or been dumped into groundwater and rivers from manufacturing and industrial plants.

In June, shortly before a bellwether test trial in the MDL was set to kick off, 3M and water utilities announced they had clinched a $10.3 billion settlement that would help pay to clean up drinking water. A similar settlement involving DuPont, Chemours and Corteva was reached that same month for $1.19 billion.

U.S. District Judge Richard Gergel in Charleston, who is overseeing the MDL, has warned the lawsuits could pose an "existential threat" to companies facing PFAS claims.

Experts say potential liabilities from the litigation could push defendants to settle to avoid massive verdicts or seek bankruptcy protection. In May, Carrier Global subsidiary Kidde-Fenwal Inc filed for bankruptcy citing the weight of its PFAS liabilities.

WHAT IT MEANS FOR 2024

The EPA has said PFAS has been found in the environment all over the world, and the Centers for Disease Control and Prevention has found the chemicals may be in the blood of 97% of Americans, so the possible number of plaintiffs could be huge.

Legal experts predict more PFAS-related lawsuits to be filed outside of the MDL in 2024, including more claims against consumer brands whose products contain PFAS and more personal injury claims.

"The litigation story is just beginning," said Kenneth Rivlin, the head of Allen & Overy's environmental law group.

Experts also expect key developments in the MDL in 2024. At least one trial is scheduled in August, when water utilities will make their case that companies that made firefighting foams but did not settle in June are responsible for PFAS-related cleanup costs.

Meanwhile, the process for selecting bellwethers for thousands of personal injury cases in the MDL is underway, and the first trials for plaintiffs with kidney cancer, testicular cancer, hypothyroidism and ulcerative colitis are expected to be scheduled in 2024.

Cases outside South Carolina may also be scheduled for trial, including a lawsuit brought by a group of 100,000 North Carolina residents claiming Chemours and others are responsible for PFAS dumped into the Cape Fear River and a lawsuit brought by homeowners in Maine who claim a local paper mill contaminated their groundwater wells.

Experts are also watching for more potential settlements between chemical firms and state attorneys general that claim PFAS is damaging their rivers, wildlife and other natural resources, after New Jersey and Ohio signed their own settlements for $393 million and $110 million respectively in 2023. So far, more than two dozen state attorneys general have filed PFAS lawsuits, 14 of which were filed in 2023.

There's also been a growth in recent years in the number of consumer class action lawsuits against companies that produce clothing, personal hygiene products such as dental floss and even food wrappers that contain PFAS and that litigation is likely to continue ramping up, according to David Fusco, an attorney at K&L Gates.

The EPA has meanwhile indicated it is moving forward with regulations in the new year that would set enforceable limits for some PFAS in drinking water, and potentially designate some PFAS as hazardous under the U.S. Superfund law, which establishes liability and cost sharing to clean up polluted sites.

Lauren Brogdon, a partner at Haynes and Boone, said those regulations "will almost undoubtedly spur litigation into 2024 and beyond."

Reporting by Clark Mindock

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Fw: PFAS

Beth Melofchik <tankmadel@yahoo.com>
Wed 2/21/2024 12:21 PM
To:Natasha Waden <nwaden@town.arlington.ma.us>

Natasha,

Please include in correspondence for the AT study committee.

Thank you

Beth Melofchik

----- Forwarded Message -----
From: Beth Melofchik <tankmadel@yahoo.com>
To: James Ditullio <james_ditullio@hotmail.com>
Sent: Wednesday, February 21, 2024 at 09:24:52 AM EST
Subject: PFAS

Jim di Tullio, Study Committee on Artificial Turf Arlington

Dear Jim,

I heard the WBUR story this morning and want to be sure it and the implications for artificial turf are on your radar for the Artificial Turf study committee.

Article from Inquirer came to my attention recently though I am familiar with the concerns with the Phillies and their players.

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Thank you for your work and diligence regarding health, safety and environmental issues for our community.

Kind regards,
Beth Melofchik

Personal injury firms look for people exposed to PFAS from Joint Base Cape Cod

February 20, 2024 By Eve Zuckoff, CAI

Vehicles are stopped by security personnel as they enter a gate at Joint Base Cape Cod. (Steven Senne/AP)

Across the country, more than 10,000 people — many veterans and firefighters — have joined a lawsuit over exposure to toxic PFAS chemicals.

Attorneys estimate that more than 100 who've already joined the case were exposed to the so-called "forever chemicals" linked to cancer, thyroid diseases, fertility issues and more while working with firefighting foam on or around Joint Base Cape Cod.

"If you talk to some of the clients they'll tell you it looks just like bubble bath or dish soap," Yahn Olson, associate attorney at Environmental Litigation Group, said of the foam. "And then 20 years later, you wind up with linkable cancer to these chemicals that you thought were totally, totally harmless."

Olson said his firm gets hundreds of new client inquiries each month as the lawsuit grows, and they're hoping to go to trial in the next two years. PFAS litigation has been compiled into what's called a multidistrict litigation, which is similar to a class action, Olson said. "The main difference being that the claims are individualized. So every single person who submits a complaint, they have their own case."

Claims over the same injuries and causation from all over the country have been put in one federal court. It's a useful strategy, Olson said, for individual plaintiffs who don't have the resources to successfully sue PFAS manufacturers, like 3M and Dupont.

In a statement, a spokesperson for 3M said the company addressed the litigation by saying the company is working on its impact.

"As the science and technology of PFAS, societal and regulatory expectations, and our expectations of ourselves have evolved, so has how we manage PFAS. We have and will continue to deliver on our commitments — including remediating PFAS where appropriate, investing in water treatment, and collaborating with communities," the spokesperson said. "3M will address PFAS litigation by defending itself in court or through negotiated resolutions, all as appropriate."

Olson said many of his clients hope to at least walk away with money for their healthcare bills.

"I have to have the conversations about, 'What happens if I die before this litigation ends?' [I do that] more than I'd like to. I mean, they've got Stage 4 lymphoma or something, and they really want to get some money before they die," he said. "And they want to hold 3M accountable."

This story is a production of the New England News Collaborative. It was originally published by CAI.

New England News Collaborative PFAS chemicals

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Pa. a dumping ground for old turf

A stew of toxic chemicals lurks in artificial turf. Some experts worry they could be linked to cancer in young athletes.

Mike Herman with a photograph of his daughter, Schyler, at Pleasant Valley High School, in the Pocono Mountains, where she played soccer. He wants to know whether artificial turf could be linked to the cancer that killed her at age 15.

Jessica Griffin / Staff Photographer

By Barbara Laker and David Gambacorta

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It was fitting that Schyler Herman's signature jersey was emblazoned with the orange and black stripes of a tiger.

She was an intimidating presence on the soccer field, a 5-foot-10 goalie with eight-pack abs and fast, fluid movements. Able to bench press 160 pounds and run a sub-5-minute mile, she would pop a dislocated finger back in place midgame.

As a 14-year-old freshman, she bumped seniors from the starting spot on the varsity team at Pleasant Valley High School in Brodheadsville, a tiny, close-knit community in the Pocono Mountains. Between her role on the school team, and a spot that she earned in the coveted Players Development Academy in New Jersey, Schyler played soccer year round, day after day, mostly on artificial turf. Division 1 college scouts had already come knocking, assuming she was years older.

Not the hold-back type, Schyler would fly out of the net, often diving hard on plastic grass. Deep cuts and bruises that morphed from black and blue to purple and yellow were the norm, her marks of pride.

Over time, Schyler's parents, Mike and Sherrie Herman, noticed that she seemed to be bruising more easily and more often, and the marks took longer to fade. She started to experience headaches, too, which her parents thought were caused by exhaustive training and dehydration. They said they didn't know she was "popping ibuprofen like Tic Tacs" to lessen the pain.

Schyler Herman, a star soccer player, loved to wear a tiger-striped jersey as she played for years as a goalkeeper, mostly on artificial turf.
Courtesy of Mike Herman

Then, during a game in late September 2017, an opposing player kicked Schyler so fiercely in her calf that she struggled to walk. Her parents took her to a nearby emergency room at St. Luke's Monroe Campus, in Stroudsburg, where doctors put a rush on her blood work.

Afterward, during the drive home, Sherrie's phone rang. A doctor instructed the Hermans to turn around and bring their daughter back to the hospital. He thought there might have been a mistake. But after a retest, he explained that Schyler's white cell count was about 80 times higher than normal.

MORE FROM THIS SERIES

Six former Phillies died from the same brain cancer. We tested the Vet's turf and found dangerous chemicals.

Tests run on two samples of old Vet Stadium turf found it contained 16 different types of PFAS, or per-and polyfluoroalkyl substances — so-called "forever chemicals."

She had leukemia.

An ambulance took the family to the Children's Hospital of Philadelphia.

"And our lives were never the same," Mike Herman said.

Herman felt a pit in his stomach. “Immediately I thought it was because of the turf fields,” he said. He’d known for a while that the turf has “like 90 carcinogens,” so he had instructed Schyler to play in long sleeves and pants. Sometimes she forgot, and wore shorts.

Schyler promised her father that when she got well, she would play in Kevlar, and cover herself from neck to foot.

Across the United States, parents, youth coaches, and medical experts worry that a melange of dangerous chemicals, lurking unseen in an estimated 13,000 artificial turf fields, has made youth athletes sick.

It is a vexing dilemma, particularly in municipalities that still regard turf as a cheap and effective way to create safe outdoor spaces for children. In Philadelphia, a new turf soccer and baseball field is the centerpiece of a $7.5 million overhaul of South Philly’s Lawrence E. Murphy Recreation Center, and city officials are seeking to include more than a dozen turf fields as part of a controversial $250 million renovation of sprawling Franklin Delano Roosevelt Park.

Arlington Artificial Turf Study Committee
Environmental Subgroup
DRAFT outline of report

While there is extensive information available regarding some of the environmental concerns of installing artificial turf versus natural turf fields, other aspects are less studied. The following are topics that we feel are essential and will be dealt with to the extent that time and information allow.

1. Wetland functions and values. What are the impacts of polluted runoff, impervious surface, and heat (also discussed further below) on wildlife and habitat in wetlands and buffer zones, and what are the differences between artificial fields versus natural grass on the ability of the resource areas and resource area buffers to provide for the wetlands functions including wildlife habitat, connectivity, water quality protection, etc.? We will review the Town's Bylaw and implementing Wetland Regulations regarding the protection of specific interests, collectively, "Resource Area Values" or "Interests of the Bylaw". Do artificial turf versus natural fields provide the protections listed in our Bylaw and implement Wetland Regulations? We expect to provide a summary of main concerns and recommendations.
    - The Town Bylaw and Wetlands Regulations protect "public or private water supply, ground water supply, flood control, erosion control and sedimentation control, storm damage prevention, other water damage prevention, prevention of pollution, protection of surrounding land and other homes or buildings, wildlife protection, plant or wildlife habitat, aquatic species and their habitats, and the natural character or recreational values of the wetland resources (collectively, "Resource Area Values" or "Interests of the Bylaw")." Recommend tabulating these Resource Area Values and then check boxes for artificial turf and natural turf in terms of offering protection to these values.
    - Consider also the environmental impact outside of wetland resource areas – where many of the same "values" are still important to the Town.
2. Runoff includes impacts of chemicals and particulates from infill migration including crumb rubber and other infills. We have not seen much, if anything, on the comparative impacts of new infills like processed coconut or walnut or some new combinations but there still remain the issues of plastic grass deterioration and other component and resulting microplastic and chemical impacts on wildlife and habitat health. We plan to look at these issues in comparison with management of natural turf fields. We will also try to consider the extent to which stormwater runoff impacts can be mitigated through stormwater management and treatment techniques. Note that increased pollution loads from runoff could include the following:
    - Chemicals = Metals (Zinc toxicity), Polyaromatic Hydrocarbons (carcinogens) and phthalates which are endocrine disruptors (aquatic toxicity), Volatile Organic Compounds (carcinogens and irritants), PFAS (found in several artificial turf components), 6ppd-quinone found in tire-crumb rubber infill (toxic to freshwater fish), Pesticides/Herbicides, Fertilizers, and disinfectants (used on Artificial fields)
    - Particulates = tire crumb rubber, micro and macroplastics from infill and from plastic grass blades due to wear / weathering)
3. Heat is a question for us as well as the health and safety subgroups. We will include reference to the Arlington climate resilience and hazard mitigation plans, both of which document the areas in Arlington where heat islands are an issue. There is TURI and other information on comparing with real turf.

- Urban Heat / Heat Islands / Hot Spots.
- Artificial Turf surface temp measured ~ 150 degrees F vs. Natural Grass surface temp of ~ 90 degrees F when air temp = 90 degrees F; surface temperature is the applicable measurement for environmental considerations for wildlife (small mammals, birds, reptiles/amphibians, insects, other invertebrates) – note that "wet-bulb" temperature measurements are not applicable to the impacts on wildlife as they are measurements made at ~ 4ft above the surface.
- Consideration of artificial field and natural fields as wildlife corridors in urban environments to connect open spaces for habitat

4. The larger context is <u>climate change resilience and adaptation</u> – do artificial turf or natural turf fields promote climate resilience and adaptation? The Arlington Bylaw and implementing Wetland Regulations require the "consideration of climate change adaptation planning to promote climate change resilience to protect and promote resource area values into the future. These considerations are especially important in Land Subject to Flooding (floodplain) and Riverfront Area and other Resource Areas which protect the interest of Flood Control and Storm Damage Prevention, including Adjacent Upland Resource Areas."
5. There is no verified evidence of any meaningful <u>recycling</u> of plastic turf or its components. Additionally, artificial turf fields must be replaced every 8 – 10 years, creating additive impacts over the expected life of an athletic field. We will explore how artificial fields and natural grass fields are consistent or inconsistent with other Arlington initiatives and goals towards green solutions, less reliance on fossil fuels, plastic reduction, urban heat reduction, and sustainability.
6. We also may be able to look at issues of <u>carbon sequestration</u> and the importance of soil for wildlife etc.

Feb 14, 2024 draft

<u>Safety Working Group</u>

- Artificial turf (or synthetic turf, as it is also known) presents a series of questions about its use as a playing surface for both professional athletes and casual users.

- As part of this Committee's charge, we examined artificial turf's impact on player injuries (head injuries/concussions, tears/breaks/sprains, etc.), heat stress, and skin abrasions and bacteria infections. We have found that artificial turf has taken great leaps with respect to athlete and user safety over the last six decades, though even modern synthetic turf has notable limitations in comparison to professionally maintained natural turf fields, albeit limitations that can be managed or mitigated.

Injury

- Artificial turf has advanced from its early AstroTurf days, and that includes improvements in lowering player injuries.

- Recent studies on player injuries provide a mixed picture. While some studies still see a greater likelihood of sports injuries with artificial turf over grass, other studies see the two playing surfaces as equivalent with respect to injuries, and one recent study even saw an advantage to artificial turf fields.

- With the benefit of first-hand local experience on both natural grass and artificial turf with crumb rubber infill, Arlington High School's head athletic trainer has not seen any measurable difference in the type or number of injuries associated with playing surface. Some more frequent injury types are attributable to factors like differing physiology or player preparedness.

- In light of recent studies and research, it seems hard to definitively say whether modern artificial turf playing fields inherently present more risk of player injury than natural grass fields that are maintained to a professional standard. There seems to be a slightly higher risk of foot and ankle injuries on artificial turf fields versus natural grass fields, but the difference is not dramatic. And there is some indication that, with respect to certain sports injuries, artificial turf playing surfaces might be better than natural grass, including in the area of concussions.

Heat

- One area where there seems to be wide consensus is that artificial turf fields get hotter (and, in some cases, much hotter) in warm temperatures than natural grass fields. But there is nuance and complexity to the issue.

- Most reputable studies or analyses show that artificial turf fields with crumb rubber infill can get considerably hotter (sometimes as much as 80 degrees hotter) than natural turf on hot, sunny days.

- The heat-related concerns are very capable of being mitigated, especially in a community like Arlington that is in the New England climate.

- Heat-related concerns over artificial turf fields in New England would be most acute in the hottest months of the year (June, July, and August).

- For Arlington, installing new (or retaining existing) artificial turf fields of any kind should require closely monitoring of air and surface temperatures at those fields every day of their operation.

- If surface temperatures climb above a certain established level, then those fields should be closed to all uses for that day – much like natural grass fields are closed when rain or snow conditions prevent their use.

- For Arlington's high school level athletic programs, local field conditions are regularly monitored by staff using wet-bulb temperature readings; during warm days in August, artificial turf temperatures tend to be 10 degrees warmer than natural grass.

- Arlington follows existing Massachusetts Interscholastic Athletic Association (MIAA) protocols related to practice and play during heat events and provides related training to coaches and team captains.

- Although there are a variety of alternative, organic infill materials, such as wood chips, coconut husks, cork, and BrockFILL, there is unfortunately very little published research relating to these materials' ability to moderate the heat effects of artificial turf. Industry-reported data indicates that an alternative like BrockFILL, an engineered wood particle infill, may effectively control the worst heat effects associated with artificial turf, although it is debatable how much it can do so.

Skin/Bacteria

- Artificial turf fields raise the prospect of skin injury from high temperatures.

- There are mitigation measures to address those concerns, including signage directing users of the field to wear shoes at all times or limiting/closing the field to use on the hottest days of the year.

- Artificial turf fields also raise questions of bacteria infections, including greater prevalence of turf burns and skin abrasions compared to natural grass fields.

- But the threat of bacteria infections from artificial turf can be mitigated through good hygiene practices, such as washing skin abrasions with soap and water. Based on medical guidance, those who play on artificial turf surfaces should wash their hands before eating, drinking, or adjusting mouth guards, as well as cleaning cuts and abrasions immediately.

Health Working Group Outline

The Health Working Group is composed of the following Artificial Turf Study Committee Members: Marvin Lewiton, Jill Krajewski and Natasha Waden. This group identified the following three topic areas to study as it relates to both natural and artificial turf fields: 1) access to youth sports and its impact on mental and physical health; 2) heat impacts on human health as it pertains to field surfaces; and 3) health impacts associated with exposure to various chemicals associated with all natural and artificial turf playing fields. While our topic areas are listed from macro to micro, this does not indicate an order of importance or priority. We believe that each area should be considered and weighed individually in order to determine an overall decision.

TOPIC 1: ACCESS TO YOUTH SPORTS AND ITS IMPACT ON MENTAL AND PHYSICAL HEALTH

Exercise, and team sports in particular, improve the overall health of young people. Arlington should consider working on how to increase playing spaces to ensure equitable access to team sports for all its young residents. It should be considered that artificial turf may be uniquely positioned to allow for continuous play when adverse weather restricts play on natural grass fields.

- Participation in youth sports impacts many aspects of health.
    - Provides equitable access to youth programs that promote exercise and develop social interactions that occur as a part of a team.
    - Reduces risk of type 2 diabetes, obesity, cancer, depression, anxiety.
    - Lack of field space can limit enrollment and access to practice/playing times.
- Seasonal weather
    - Wet weather conditions limit access to grass fields during the busy season: (March 15- June 15 and August 15 - November 15).
    - Inability for users to utilize field in early months:
        - Artificial turf gives user access earlier, later in season, and potentially winter months depending on snow/ice etc.
        - Artificial turf doesn't require rest periods when rain occurs.

Gaps/limitations in research
- No direct research related to mental/physical health as it relates to access to artificial turf fields. Since this is an access issue and artificial turf might increase the access:
    - Will adding artificial turf fields increase access to playing times?
    - Will adding artificial turf fields increase youth sports enrollment?

Mitigation Measures
- Carefully selecting sites for artificial turf when/if they can increase access to youth town sports programs <u>may</u> be a benefit to the overall health of Arlington's youth.

TOPIC 2: HEAT IMPACTS ON HUMAN HEALTH

This may become an increasingly important issue as we continue to see the warming effects of climate change. The concerns are that artificial turf does have a higher heat load than natural grass. In addition, in all types of playing surfaces exposure to high heat levels has a cumulative effect on the human body. Children are more vulnerable to high temperatures than adults. For these reasons, education and mitigation are essential.

- Heat related illness
    - Cumulative effect - several days of heat exposure can be detrimental.
    - Lack of awareness by coaches and players of signs and symptoms of heat stress, appropriate remedial actions.
    - Need for gradual acclimatization in hot weather.
- Temperature difference between natural grass vs artificial turf fields, both surface and above surface, can lead to difference in heat stress for players, potential for burns; including local data from the High School Athletic trainer.
- Impact of color of infill and fiber on temperature.

Gaps/limitations in research
- Comparison of days lost to rain within spring (March 15 - June 15) and fall (August 15 - Nov 15) season as compared to loss of days for high heat/humidity.
    - Which has a greater impact?
- Challenges in accurately assessing air temperature above field (wet bulb), how is this measurement done by various organizations other than the high school Athletic Department.
- What is currently done for heat impact training for sports coaches that are not governed by the MIAA?

Mitigation Measures
- Implement guidelines/restrictions for use of both grass and Artificial Turf during periods of high heat/humidity. The MIAA may be a good place to reference.
- Ensure acclimatization schedule for players in hot weather.
- Raise awareness of heat related illness for coaches/parents/players:
    - Ensure acclimatization schedule for players in hot weather.
    - Train coaches in recognizing signs and appropriate responses to heat strain.
    - Provide heat-related illness resources to families that participate in youth sport.
    - Could possibly be a requirement through issuance of permits through the Arlington Recreation Department.
- Proposals for artificial turf should have built-in mitigations for heat reduction such as shade structures and reflective infill color; where possible grass fields should include heat mitigations as well.

<u>TOPIC 3:</u> CHEMICAL EXPOSURE

We know that artificial turf and its infills contain a wide variety of hazardous chemicals. What is not known at this point is how much exposure results from playing on these surfaces. In general, reducing exposure to hazardous materials has a positive health effect. One way to do this is to opt for PFAS free turf carpet and to move away from crumb rubber and continue to research safer infills.

- Routes of exposure:
  - Ingestion.
  - Inhalation.
  - Dermal.
  - “Take home” exposures.
- Health Concerns
  - Toxicity risk.
  - Carcinogen risk.
  - Endocrine disruption risk.
  - Reproductive system risk.
- Chemicals of concern:
  - Major route of exposure is ingestion, also inhalation.
  - PAHs - polycyclic aromatic hydrocarbons.
  - PFAS - fluorinated carbon compounds; thousands of types:
    - Major route of exposure is ingestion, also inhalation.
    - Limits are set for drinking water.
    - Arlington’s drinking water comes from MWRA.
    - No limits have been set for inhalation or absorption.
  - Phthalates - plasticizers.
  - Microplastics.
  - Heavy metals.

- Cumulative effects of these chemicals have adverse effects on human health. This is a particular concern for the chemicals that have not been clearly regulated or which exposure levels other than water have not been established.

- Effects of potential exposure on different age groups
  - Toddler - 5yr old.
  - Elementary.
  - Middle School and above.

- Comparison of infill materials
  - Crumb rubber infill.
  - Rubber alternative infills.
  - Acrylic sand infills.

    - Organic infill material.

Gaps/limitations in research

- Limitations in personal sampling methods, analytical methods for exposure.
- Very little research on alternative infill materials.
- Very little research on exposure to turf components (blades, backing).
- Most research is cancer focused:
    - However, no cancer clusters as a result of artificial turf have been identified.
    - No research on the effects of multiple compounds.
    - Little research on non-cancer or other health outcomes (eg. endocrine disruption).

Mitigation Measures

- Discontinue the use of tire crumb rubber in future projects and opt for safer alternatives.
- Conduct pre-installation testing of field materials to ensure they are PFAS free.
- Since the major route of entry of PFAS and phthalates is ingestion, consider which age groups are best suited to be scheduled on turf fields.