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Technical Memorandum

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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.

The Manufacturing Processes

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.

PFAS Analytical Methods and Artificial Turf

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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