A review of recent research and findings on the environmental aspects of artificial turf surfaces

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Introduction

The following review considers all of the key environmental aspects that have been raised as potential concerns due to the proposed construction of an artificial turf, all weather, multi-sport playing surface at Unley High School. These comprise:

- Water pollution
- Waste
- Heat
- Carbon emissions
- Human health
- Soil sterilization
- PFAS

It demonstrates that any environmental impacts from the project are either below acceptable limits, and/or less or no different to the current situation. This is due to the measures taken by the manufacturer of the turf surface and the proposed design and construction methods that will be implemented. In addition to the lack of environmental concerns, the project will result in significant health and community benefits by providing a playing surface that is available for regular use throughout the school year.

Water pollution

Caused by synthetic turf materials (ie yarn degradation SBR infill) - A recently published Master's thesis from the University of San Francisco suggests that the microplastic environmental load from artificial turf blades in the San Francisco Bay area (a total of 426 artificial turf fields were mapped) is not substantial. However, the authors noted that given the persistent nature and accumulation in the environment any potential load should be minimized.[1]

A report by the Swedish Environmental Agency in 2021 estimated that the leakage of microplastics from artificial turf per unit area was estimated to be on average 5.3 g/m^2 (range 0.4–20 g/m^2 per year) for granulate-free artificial grass surfaces. For comparison a road surface with an annual mean daily traffic of 5,500–13,000 vehicles is estimated to produce 56 g microplastic/m^2. While some artificial grass surfaces release their artificial grass much more easily than others, well-designed and well-maintained granulate-free artificial grass surfaces – such as the proposed surface at Unley High School - are likely to meet the EU's proposed threshold limit for dispersion of microplastics at 7 g/m^2 per year[2].

The study further investigated the annual dispersion of microplastics from artificial turf into the stormwater system using various sized drain filters. The majority of microplastics captured in stormwater drain filters were larger than 200 µm (average 0.27 g/m^2 annually) with those microplastics sized 50µm-200µm accounting for 0.03 g/m^2 annually[2].

The size of Forestville Hockey Club's (FHC's) synthetic grass surface is approximately 5,747 m^2 (97.4 m x 59 m). Using the data from the Swedish Environmental Agency, the microplastic leakage from FHC's surface may be in the range of 2.3 kg – 114.9 kg (average 30.5 kg) per year, of which approximately 1.7 kg of microplastics (50 µm and larger) will be captured in stormwater drain filters annually. This suggests that only a fraction of the microplastics released may end up in the stormwater (~5%) with the vast majority of microplastics remaining within the perimeters of the pitch.

To prevent and mitigate microplastic release and hazardous chemicals from entering storm water systems, Polytan has confirmed that filters will be installed to capture microplastic runoff from the field. A total of 7 'trash boxes' will be installed across field, each one containing a Geo-textile filter inlay basket secured within the trash box.

Caused by pesticide and fungicides used on synthetic turf – both natural grass turf and synthetic grass turf will require products to control or eliminate pests such as weeds, moss, bacteria or bugs. In Australia any product used has to be approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA; www.apvma.gov.au). They decide how these chemical products can be used to ensure that people and the environment are protected from harm. The Environmental Protection Agency (EPA) in South Australia (www.epa.sa.gov.au) regulates the use of these products. The FHC pitch would be maintained to comply with these regulations.

Waste

Recycling: Earlier this year Victoria provided RE4FORM (in partnership with Tuff Group) funding for Australia's first dedicated synthetic turf recycling hub. It is estimated that the plant will process approximately 7,000 tonnes of used synthetic turf each year, diverting waste from local landfills and decreasing greenhouse gas emissions by 19,000 tonnes each year. (Source: www.sustainability.vic.gov.au/projects/australias-first-synthetic-turf-recycling-hub, https://re4ormrecycling.com.au/, and www.tuff-group.com.au/pages/sustainability). When the FHC pitch reaches the end of its playing life, approximately 10 years after installation, environmentally friendly options for recycling the pitch, such as the Victorian initiative, will be utilised. It is also likely that in the next 10 years more options will also have been developed.

Heat

Studies on thermal environments of artificial and natural turfs (in a subtropical climate) suggest that artificial turf can act as a 'heat island' but only on hot, sunny days[3,4]. On such days, heated artificial turf can be cooled down by watering[5]. In addition, artificial turf cools down rapidly after sunset and during periods of cloud cover[3,6]. During cloudy days or days with low solar radiation, there is no difference between the thermal environment of natural grass vs artificial turf[4,6]. It should be noted that these studies were all undertaken using synthetic turf with a rubber infill and thus may not represent the synthetic turf selected by FHC, which has a sand infill. A 2014 study conducted in Ballarat during summer months (February & March 2013) indicated that higher surface temperatures were recorded on synthetic turf with crumb rubber infill compared to natural infills (e.g. sand/organic or sand/PTE)[6]; hence, even the minimal heat island effects noted in these studies may not be as prevalent with the proposed FHC turf.

In summary, while synthetic turf gets hot due to heat absorption on (hot) sunny days, this effect is only temporary as it quickly cools down when clouds are present or at sunset and is less for sand filled turfs. In addition, since it absorbs the heat and does not radiate it, there should be no inconvenience to any of the properties located closest to the proposed pitch.

Carbon emissions

Inhibition of carbon absorption and carbon emission associated with synthetic turf production and deterioration - A report written by Meil and Bushi in 2006 calculated the global warming offsets required to achieve a carbon neutral synthetic field turf system installation for UCC (Upper Canada College) who were looking to replace their natural grass playing field used for Lacrosse, football, and rugby with artificial turf ("Thioback Pro")[7]. Using the Life Cycle Assessment tool to assess the potential environmental impacts of a product's life cycle, the report noted that over ten years a 9000 m^2 of artificial turf (the size of a football field) releases more greenhouse gases, expressed as CO_2 equivalence (CO2e), than natural turf (55.6 tonnes [± 30.1% uncertainty] vs. -16.9 tonnes [± 18.4 uncertainty], respectively) during the production, transportation, use, and recycling life stages of artificial turf. The assessment also indicated that recycling artificial turf removes more than 50 tonnes of CO_2e and that the rubber infill accounted for 10.5 tonnes CO_2e. Based on their calculations, to offset the greenhouse gas emissions for a 9000 m^2-field in 10 years they recommended a total of 1,861 trees to be planted.

When interpreting the data presented in this report from 17 years ago it is important to highlight that the artificial turf in question was an older generation artificial turf (containing rubber granular infill) compared to the one FHC proposes to install. In addition, the artificial turf for UCC was manufactured in The Netherlands and had to be transported to Canada. FHC's turf is manufactured in Australia which will significantly cut the transportation CO_2e. Since 2006, restrictions/changes have been introduced on certain manufacturing compounds for artificial turf which have made it a more environmentally friendly product. Lastly, possible playing hours on synthetic turf are substantially larger than on natural grass. To account for similar hours of use the CO_2e of multiple natural grass field should be taken into account. One artificial turf field can typically accommodate the play of 3–4 natural grass fields, and the playability (hours of use) of artificial turf fields can be up to 7.7 times that of natural grass fields. Artificial turf fields can allow up to approximately 3000 hours of playing time annually, whereas the typical annual playing capacity of natural grass (weather permitting) is 300 hours with 600 hours of activity regarded as the upper limit.[8] Hence if the CO_2e values of one artificial turf pitch are compared with those of 3 natural grass fields to provide a conservative equivalence in terms of hours of use, the values are very similar (55.6 tonnes turf cf. 50.7 tonnes grass based on the 2006 report), and it is also clear that current turfs would have a lower CO_2e value.

Human Health

A substantial amount of research has investigated the potential impact of playing on artificial turf on an athlete's health, through inhalation, dermal contact, or ingestion. Unfortunately, despite the vast amount of peer-reviewed research available only a small number are applicable to the synthetic turf FHC proposes to install at Unley High School. The majority of available research has been in relation to football/soccer pitches and the potential health effects of crumb rubber. Furthermore, most data were obtained from a laboratory setting and not through epidemiological studies.

Analysis of micro-sized artificial turf fragments (MATF) which had either undergone 15 years of natural ageing and human activities or were obtained from turf samples exposed to simulated sunlight in a laboratory, suggests that exposure to sunlight (i.e. photoaging) can alter the morphology and surface properties of MATF. These changes enable the MATF to act as a carrier for environmental contaminants or pollutants such as polycyclic aromatic hydrocarbons (PAHs; a group of chemicals that are produced when burning fuels, garbage, or other organic compounds. Main sources are residential wood fires, bushfires, cigarette smoke, and exhaust fumes from vehicles) and heavy metals.[9] Compared to any potential contaminants present in the turf blades following manufacturing, the contaminants adsorbed to the microplastics tend to be more bioavailable[10,11] Despite these findings, field monitoring studies indicate that the levels of PAHs, particles (PM10 and PM2.5), and aromatic hydrocarbons (e.g. benzene, toluene, and xylene) found on football fields - both during warm and cold seasons and either with or without on-field activity – were comparable to those found in urban settings and within regulatory limits[12]. In addition, human exposure modelling suggested that the health risk associated with inhaling atmospheric dust and gases from traffic was greater than those due to playing soccer on synthetic turf[13]. A biological monitoring study also revealed that the level of a biomarker for PAH exposure in the urine of adult football players did not increase after playing on synthetic turf fields (with rubber crumb infill), suggesting the uptake of PAHs via dermal pathway (and other exposure pathways as well) was negligible[14,15]. However, risk assessment for PAH-emission exposure (worst-case scenario) from inhalation from a synthetic turf pitch with rubber granulate infill indicated a negligible excess lifetime cancer risk of 1 additional case of cancer per 1,000,000 exposed persons for professional athletes with 30 years of intense activity (5 h/day, 5 days/week, all year round), but no risk for discontinuous or amateur users[16].

Multiple literature reviews and reports on the health impacts of chronic inhalation, dermal, or oral exposure to artificial turf suggest they do not pose a health risk (cancerous- and non-cancerous) to the public[8,17,18]. Risk assessment studies showed that the doses of toxic chemicals exposed through dermal absorption were too low to cause any adverse health effects[8]. Similarly, no elevated risk was found with the exposure to respirable particulates (PM10 and PM2.5) at synthetic turf fields in both outdoor and indoor settings.

In 2019, Eykelbosh reported that by far the largest “gap” in research is “the amount of healthy physical activity that can be supported on various types of outdoor sports fields (bare earth, turf, artificial turf, asphalt, etc.), and what impact this activity has on public health”[17]. Approximately 25% of children and adolescents in Australia are overweight or obese (source: AIHW); therefore, having as many children as possible engage in physical activity/sport may be very significant to children’s health. Tester and Baker[19] observed a large increase in visitors to the soccer fields and increased levels of activity following an upgrade to landscaping, lighting, and converting bare earth soccer fields to artificial turfs in parks in two low-income San Francisco neighbourhoods. The installation of synthetic turf was only one aspect of the project, but the results indicate a positive effect of synthetic turf on engagement in physical activity.

Soil sterilization

Although soil sterilization is a recognised side effect of building a structure at a location that was a natural space beforehand, this phenomenon is not solely an issue when building an artificial turf pitch. For example, it also occurs any time an addition is added to a dwelling, a road is expanded for safety/increased demand by road users (e.g. intersection of Cross Road with Fullarton Road), or a large single-home suburban block is subdivided to allow the construction of townhouses (e.g. 102 Cross Road, Highgate). Since it is highly unlikely that the synthetic turf area will be returned to a natural turf surface in the foreseeable future, this issue is not considered to be critical.

PFAS in synthetic turf

PFAS (per- and polyfluroalkyl substances) are a large and complex group of synthetic chemicals that have been used in hundreds of different products around the world since the 1950's. Some PFAS have been associated with human and environmental health concerns, but these impacts differ depending on the specific PFAS being discussed.

The manufacturer of FHC's synthetic turf has indicated that from June 2023 all turf products made by their supplier in Australia, as will be used at Unley High School, are to the best of their ability and current knowledge free of PFAS.

It must be noted that the manufacturer has used long-chain polyfluorinated polymer compounds as a process aid in the fiber production (less than 0.1 weight % of the fibers), but not for the production of the backing material. A 2022 Swedish study on non-extractable fluorines in artificial turf confirms this and identified polytetrafluoroethylene (PTFE) and fluoroelastomers as the processing aids being used. These findings align with the patent literature.[20] The same study concluded that "the combination of poor extractability and resistance toward advanced oxidation suggests that the fluorine in artificial turf does not pose an imminent risk to users." Some scientists argue that although fluoropolymers (such as PTFE and fluoroelastomers) fit the definition of PFAS, they have different physical, chemical, and toxicological properties and must be excluded from the PFAS class[21,22]. In contrast to other types of PFAS, fluoropolymers are insoluble in both polar and non-polar solvents; their molecules are too large to cross membranes, and therefore, they are not bioavailable. They argue that fluoropolymers must be considered polymers of low concern and therefore should be met with weaker regulations in some jurisdictions[22]. Further information about PTFE and fluoroelastomers is provided below.

PTFE

PTFE is a soft plastic that is considered the most inert material known. It is resistant to gastric juice and is extremely stable. In addition to its use as a process aid in synthetic fiber production, PTFE is also used in[23]:

- Medical applications such as vascular stents, shunts, sutures, bone replacements, heart valves and aorta implants.
- Non-stick cookware: PTFE in cookware is more commonly known as Teflon. Teflon has been reported to cause cancer; however, PTFE was not to blame for this. The culprit was the chemical PFOA (perfluorooctanoic acid) which was being used in the production of PFTE. PFOA has not been used in the manufacturing of non-stick coated cookware since 2013.
- Gore-Tex

PTFE exposure has been reported to cause 'polymer fume fever', which is a temporary condition that resolves once the source of exposure is eliminated. Polymer fume fever can occur when PTFE degrades after being exposed to extreme temperatures. The condition is considered extremely rare; examples include occupational exposure[24] as well as several cases in people who left a Teflon-coated pan on a burning stove for an extended period of time (4 hours[25] and 10 hours[26]).

The melting temperature of PTFE is 260°C. An Australian study on the surface temperatures of various types of artificial turf reported on a sunny day with an ambient temperature of 30°C the surface temperature of the various pitches tested did not exceed 60°C.[6] A similar observation was made in a study in New Mexico, USA (max surface temperature measured was 63°C).[5] These data suggest that no degradation of PTFE should occur on hot sunny days and that thus there will be no risk of PTFE fume being released into the atmosphere or the possibility of inhaling PTFE by players or people living near the pitch, noting again that this product is used as a manufacturing process aid and not as part of the turf material.

Animal studies on oral ingestion of PTFE (microplastics) also confirm the inertness of PTFE. Naftalovich *et al* showed that rats fed a diet containing 25% PTFE for 90 days showed no signs of toxicity.[27] In addition, Chemolin *et al* did not observe any changes in antioxidant as well as DNA damage markers in mollusks (periwinkle) fed a diet rich in PTFE[28]. A recent study evaluating the toxicity of PTFE microplastic (two sizes were studied, i.e. approx. 5 µm and 10-50 µm) ingested by mice could not establish a LD_{50} (lethal dose 50) or a no-observed-adverse-effect-level (NOAEL) as no effects were seen even at the highest dietary intake (2000 mg/kg). The study also showed that no PTFE microplastics were detected in blood.[29]A further detailed and extensive review on the biological safety of PTFE can be found in the article by Naftalovich *et al*[27].

Fluoroestemers

Fluoroestemers (also known as FKM, FPM or Viton®) are similar to PTFE; however, less research data is available. It is a product that can withstand aggressive chemical and temperature applications; for example, it can be found in the automotive, aerospace, and aviation industry in the linings of fuel hoses, gaskets, seals and O-rings[30,31]. It can withstand temperatures up to 230°C.

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