Athletic Playing Fields and Artificial Turf: Considerations for Municipalities and Institutions

This fact sheet introduces some of the considerations that are relevant to evaluating natural grass and artificial turf playing surfaces. For more of TURI's research on artificial turf and natural grass, see www.turi.org/artificialturf.

Principles of toxics use reduction

TURI's work is based on the principles of toxics use reduction (TUR). The TUR approach focuses on identifying opportunities to reduce or eliminate the use of toxic chemicals as a means to protect human health and the environment. Projects to reduce the use of toxic chemicals often have additional benefits, such as lower life-cycle costs.

Children's environmental health

People of all ages benefit from a safe and healthy environment for work and play. However, special concerns exist for children. Children are uniquely vulnerable to the effects of toxic chemicals because their organ systems are developing rapidly and their detoxification mechanisms are immature. Children also breathe more air per unit of body weight than adults, and are likely to have more hand-to-mouth exposure to environmental contaminants than adults.[1] For these reasons, it is particularly important to make careful choices about children's exposures.

Artificial turf and chemicals of concern

Artificial turf has several components, including drainage materials, a cushioning layer, synthetic grass carpet (support and backing materials and synthetic fibers to imitate grass blades), and infill that provides cushioning and keeps grass carpet blades standing upright. Here, we briefly review issues related to chemicals in synthetic grass carpet and infills.

Crumb rubber infill made from recycled tires. Crumb rubber made from recycled tires is widely used as infill. This material is also referred to as styrene butadiene rubber (SBR), or as tire crumb. Many peer-reviewed studies have examined the chemicals present in tire crumb. Tire crumb contains a large number of chemicals, many of which are known to be hazardous to human health and the environment. These include polyaromatic hydrocarbons (PAHs); volatile organic compounds (VOCs); metals, such as lead and zinc; and other chemicals.[2–5] Some of the chemicals found in tire crumb are known to cause cancer. [6–8] Because of the large number of chemicals present in the infill, as well as the health effects of individual chemicals, crumb rubber made from recycled tires is the option that likely presents the most concerns related to chemical exposures.

Other synthetic infills. Other synthetic materials used to make artificial turf infill include ethylene propylene diene terpolymer (EPDM) rubber, thermoplastic elastomers (TPE), waste athletic shoe materials, and acrylic-coated sand, among others. These materials also contain chemicals of concern, although the total number of chemicals and/or the concentration of chemicals of concern may be lower in many cases.[5] For more information on chemicals in these materials, see TURI's report, *Athletic Playing Fields: Choosing Safer Options for Health and the Environment*.[9]

Mineral-based and plant-derived materials. Other materials used as infill can include sand, zeolite, cork, coconut hulls, walnut shells, olive pits, and wood particles, among other materials. These materials are likely to contain fewer hazardous chemicals than tire crumb, but many of the materials have not been well characterized or studied thoroughly.[5] Some plant-based materials may raise concerns related to allergies or respirable fibers. In addition, zeolite and sand can pose respiratory hazards. Exposure to some types of zeolites may be associated with increased risk of developing mesothelioma, a type of cancer.[10,11] Using zeolite can be considered a regrettable substitution. For sand, it is important to understand the source and type of the material; industrial sand that is freshly fractured or that has been highly processed to contain very small particles can be a respiratory hazard when inhaled.[5]

Synthetic grass carpet. Toxic chemicals such as lead are also found in the artificial grass blades in some cases. [6,7] Recent research has identified per- and poly-fluoroalkyl substances (PFAS) in some artificial turf carpet materials. PFAS are a group of chemicals that are highly persistent in the environment. PFAS 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. 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. For more information, see TURI's fact sheet, "Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet." [12]

Artificial turf and heat stress

In sunny, warm weather, artificial turf can become much hotter than natural grass, raising concerns related to heat stress for athletes playing on the fields. Elevated surface temperatures can damage equipment and burn skin, and can increase the risk of heat-related illness.[13] Heat-related illness can be a life-threatening emergency. Experts note that athletic coaches and other staff need to be educated about heat-related illness and understand how to prevent it, including cancelling sport activities when necessary. [14,15]

Research indicates that outdoor synthetic turf reaches higher temperatures than natural grass, regardless of the infill materials or carpet fiber type.[13] The Penn State Center for Sports Surface Research measured surface temperature for infill alone, artificial grass fibers, and a full synthetic turf system. The study included several types and colors of infill and fibers. They found that all the materials reached high temperatures than grass when heated indoors (with a sun lamp), or outdoors.

Irrigation can lower field temperature for a short time. A Penn State study found that frequent, heavy irrigation reduced temperatures on synthetic turf, but temperatures rebounded quickly under sunny conditions. [16] Other studies found similar results. [17]

Approaches to determining safe temperatures for recreational field spaces. Several methods are available for measuring heat in a play area. It is sometimes necessary to use more than one method in order to determine whether conditions are safe for exercise or play.

One heat metric, Wet Bulb Globe Temperature (WBGT), takes into account ambient air temperature, relative humidity, wind, and solar radiation from the sun. WBGT can help to guide precautions such as rest, hydration breaks, and cancellation of sports activities. However, WBGT may does not take account of field surface temperature.

Another approach is to measure the temperature of the playing field surface itself. One researcher has noted that artificial turf surface temperatures are not captured by either a heat advisory or by wet bulb temperature, and that "elevated risk of heat stress can stem from infrared heating from the ground, regardless of the air temperature." Thus, the researcher suggests, greater caution regarding heat is needed when athletes are playing on artificial turf, "even if the air temperature is not at an otherwise unsafe level." [18]

WBGT is used as the basis for a heat policy adopted by Massachusetts Interscholastic Athletic Association (MIAA) in 2019. This policy requires schools to select a method to monitor heat during all sports related activities, and modify activities as needed to protect student athletes.[19] The MIAA policy does not provide guidelines based on the type of playing surface, and does not take account of surface temperature specifically.

The school board of Burlington, MA has taken additional steps to protect student athletes by ensuring that both WBGT and surface temperature are taken into account.[20] Burlington's policy, "Utilizing Artificial Turf in the Heat," requires use of an infrared heat gun to determine field surface temperature. The policy includes information about the conditions under which athletes may use artificial turf fields and the conditions under which their activities must be moved to grass fields. For example, the policy states that if the National Weather Service issues a Heat Advisory, artificial turf cannot be used for physical education if the air temperature is higher than 85 degrees with humidity 60 percent or more. Under these conditions, only a grass surface may be used. The policy also lays out criteria to be taken into account in determining activity levels. For example, when air temperature is below 82 degrees, activities are permitted on artificial turf up to a surface temperature of 120 degrees, with three water breaks per hour. Above this surface temperature, activities must be moved to a grass field.

Injuries

Studies show variable outcomes in the rates and types of injuries experienced by athletes playing on natural grass and on artificial turf. [6,21,22] Among recent studies and reviews of studies, several suggest an increase in foot and/or ankle injuries on artificial turf as compared with natural grass[23–25]; several find no difference[26]; and one suggests a possibly lowered risk on artificial turf.[27] All of these studies recommend further evaluation of this question.

One particular concern is increased rates of turf burns (skin abrasions) associated with playing on artificial turf. For example, a study by the California Office of Environmental Health Hazard Assessment found a two- to three-fold increase in skin abrasions per player hour on artificial turf compared with natural grass turf.[6] The study authors noted that these abrasions are a risk factor for serious bacterial infections, although they did not assess rates of these infections among the players they studied.

Environmental concerns

Environmental concerns include loss of wildlife habitat, migration of synthetic particles into the environment, and contaminated stormwater runoff. A study by the Connecticut Department of Environmental Protection identified concerns related to a number of chemicals in stormwater runoff from artificial turf fields. They noted high zinc concentrations in stormwater as a particular concern for aquatic organisms. They also noted the potential for leaching of high levels of copper, cadmium, barium, manganese and lead in some cases. The top concerns identified in the study were toxicity to aquatic life from zinc and from whole effluent toxicity (WET).[28] WET is a methodology for assessing the aquatic toxicity effects of an effluent stream as a whole.[29] In addition, scientists have raised concerns about the contribution of artificial turf materials to microplastic pollution.[30–32]

Safer alternative: organically managed natural grass

Natural grass fields can be the safest option for recreational space, by eliminating many of the concerns noted above. Natural grass can also reduce overall carbon footprint by capturing carbon dioxide. Grass fields may be maintained organically or with conventional or integrated pest management (IPM) practices. Organic turf management eliminates the use of toxic insecticides, herbicides and fungicides.

Organic management of a recreational field space requires a site-specific plan to optimize soil health. Over time, a well-maintained organic field is more robust to recreational use due to a stronger root system than that found in a conventionally managed grass field. Key elements of organic management include the following.[33]

- **Field construction**: Construct field with appropriate drainage, layering, grass type, and other conditions to support healthy turf growth. Healthy, vigorously growing grass is better able to out-compete weed pressures, and healthy soil biomass helps to prevent many insect and disease issues.
- **Soil maintenance**: Add soil amendments as necessary to achieve the appropriate chemistry, texture and nutrients to support healthy turf growth. Elements include organic fertilizers, soil amendments, microbial inoculants, compost teas, microbial food sources, and topdressing as needed with high-quality finished compost.
- **Grass maintenance**: Turf health is maintained through specific cultural practices, including appropriate mowing, aeration, irrigation, and over-seeding. Trouble spots are addressed through composting and re-sodding where necessary. Aeration is critical because it makes holes in the soil that allow more air, water and nutrients to reach the roots of the grass and the soil system. Stronger roots make the grass better able to naturally fend off weeds and pests. Aeration also breaks up areas of compacted soil.

Massachusetts communities investing in organic grass fields. In Massachusetts, the city of Springfield and the town of Marblehead have both been successful in managing athletic fields organically. These communities' experiences are documented in case studies.[34,35] In addition, the Field Fund in Martha's Vineyard has invested in organic maintenance of a number of athletic fields and has documented the process at www.fieldfundinc.org.

Installation and maintenance costs: comparing artificial turf with natural grass

In analyzing the costs of artificial vs. natural grass systems, it is important to consider full life-cycle costs, including installation, maintenance, and disposal/replacement. Artificial turf systems of all types require a significant financial investment at each stage of the product life cycle. In general, the full life cycle cost of an artificial turf field is higher than the cost of a natural grass field.

Cost information is available through university entities, turf managers' associations, and personal communications with professional grounds managers. Information is also available on the relative costs of conventional vs. organic management of natural grass.

Installation. According to the Sports Turf Managers Association (STMA), the cost of installing an artificial turf system may range from \$4.50 to \$10.25 per square foot. For a football field with a play area of 360x160 feet plus a 15-foot extension on each dimension (65,625 square feet), this yields an installation cost ranging from about \$295,000 to about \$673,000. These are costs for field installation only, and full project costs may be higher. Costs for a larger field would also be higher.

In one site-specific example, information provided by the town of Natick, Massachusetts shows that the full project budget for the installation in 2015 of a new artificial turf field (117,810 square feet), along with associated landscaping, access and site furnishings, totaled \$1.2 million.[36]

For natural grass, installation of a new field may not be necessary. For communities that do choose to install a new field, costs can range from \$1.25 to \$5.00 per square foot, depending on the type of field selected. For the dimensions noted above, this would yield an installation cost ranging from about \$82,000 to about \$328,000.[37] However, in many cases communities are simply able to improve existing fields.

Maintenance. Maintenance of artificial turf systems can include fluffing, redistributing and shock testing infill; periodic disinfection of the materials; seam repairs and infill replacement; and watering to lower temperatures on hot days. Maintenance of natural grass can include watering, mowing, fertilizing, replacing sod, and other activities. Communities shifting from natural grass to artificial turf may need to purchase new equipment for this purpose. According to STMA, maintenance of an artificial turf field may cost about \$4,000/year in materials plus 300 hours of labor, while maintenance of a natural grass field may cost \$4,000 to \$14,000 per year for materials plus 250 to 750 hours of labor.[37]

Springfield, MA manages 67 acres of sports fields, park areas, and other public properties organically. Field management costs in 2018, including products, irrigation maintenance, and all labor costs, were just under \$1,500 per acre across all of the properties.[34]

Natural grass maintenance: Conventional vs. organic costs. Organic turf maintenance can be cost-competitive with conventional management of natural grass. One study found that once established, an organic turf management program can cost 25% less than a conventional turf management program.[38]

Disposal and replacement. Artificial turf requires disposal at the end of its useful life. STMA estimates costs of $6.50 to $7.80 per square foot for disposal and resurfacing.[37] Those estimates yield $426,563–$511,875 for a 65,625 square foot field and $552,500–$663,000 for an 85,000 square foot field.

Disposal is an increasing source of concern. Used synthetic turf is projected to produce between 1 million and 4 million tons of waste over the next decade, but there is a lack of plans or guidance for its disposal.[39,40] In most cases it cannot be completely recycled, and disposing of it in landfills is expensive and not an industry best practice, according to one article.[39] Used turf that is dumped illegally near a body of water can attract pests, and piles can pose a fire risk.[39] Repurposing used turf may also pose concerns. In August 2020, reuse of turf in a construction project lead to the release of 4- 6 cubic yards of crumb rubber into the Puyallup River in Washington State.[41]

Life-cycle costs. In 2008, a Missouri University Extension study calculated annualized costs for a 16-year scenario. The calculation included the capital cost of installation; annual maintenance; sod replacement costing $25,000 every four years for the natural fields; and surface replacement of the synthetic fields after eight years. Based on this calculation, a natural grass soil-based field is the most cost effective, followed by a natural grass sand-cap field, as shown in the table below.[42] Another study, conducted by an Australian government agency, found that the 25-year and 50-year life cycle costs for synthetic turf are about 2.5 times as large as those for natural grass.[43]

Table 1: Comparison of life-cycle costs

Field type	16-year annualized costs
Natural soil-based field	$33,522
Sand-cap grass field	$49,318
Basic synthetic field	$65,849
Premium synthetic field	$109,013

Source: Brad Fresenburg, "More Answers to Questions about Synthetic Fields – Safety and Cost Comparison." University of Missouri.

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