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Policy Recommendation on the Use of Artificial Turf on Landscapes, Schools and Playing Fields

Santa Clara County Medical Association
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Purpose: To educate and provide recommendations to physicians, officials, school administrators and teachers of the health risks and potential health and environmental hazards of artificial turf and synthetic grass on landscapes, schools, playgrounds and playing fields.

Recommendations: After careful consideration of the current scientific evidence of plastic and chemical contamination, sports injuries, urban heat effects, disposal, potential short and long-term health effects, as well as direct and indirect environmental costs, the SCCMA believes artificial turf is potentially harmful to both human and environmental health and is not a sustainable option when compared with natural grass. Taking a precautionary approach for the long-term protection of the children, the environment and public health, we recommend:

1) That artificial turf *not* be used on sports fields, playgrounds, landscaping, residential lawns or in schools, but instead that natural grass turf be used, a choice that will serve to benefit the health and safety of children, athletes and the environment, and

2) If artificial turf *is* in place, that at the end of its useful life it be replaced with natural grass and *not* artificial turf.

SCCMA Goals: The support of public health measures to prevent environmentally-related disease is a prime goal and objective of the Santa Clara County Medical Association (SCCMA). This especially applies to children who have greater lifetime exposures to- and accumulation of-toxins, and whose immune, cardiovascular, reproductive and neurologic systems are immature, increasing their vulnerability to acute and chronic diseases related to toxic exposures.

Introduction:

Rethinking Artificial Turf

Artificial turf was introduced into the sports world in 1965. Currently there are approximately 13,000 synthetic turf sport fields in the U.S. While in the past artificial turf initially seemed to be the better alternative due to reduced costs, reduced water usage and lower maintenance, newer information has come to light regarding the direct and indirect environmental and health impacts of synthetic grass, including a full life cycle analysis of costs. As more artificial turf fields are

installed, more long-term problems are being identified. Indeed, the environmental impacts of artificial turf components are now recognized as a global problem (Armada 2022). We think that artificial turf, based on available scientific studies, is not a sustainably safe alternative for landscaping, nor for use on sport fields, particularly for children. In addition, much progress has been made in developing state of the art drought resistant, water conserving grass fields that are sturdy, can be used year-round in California, and can be watered with non-potable recycled water. References follow.

Components of Artificial Turf

Artificial turf is a human-made surface of synthetic fibers, that was invented in the 1960's to look like and replace natural grass on sports fields and residential lawns. It consists of non-biodegradable plastic turf "blades" and a non-biodegradable backing. In the 1990's infill was added between the blades to soften the fields during play. Turf blades are composed of polyethylene, polypropylene or nylon.

The cushioning infill material is most often crumb rubber infill from crushed tires. Other materials have been used, such as silica from crushed quartz, synthetic rubber, polymer-coated sand, and other organic materials (cork and coconut fiber). However, these "eco-friendly" alternatives are typically coated with stabilizers and plasticizers for durability. The primary backing consists of woven or non-woven fabric made from high-strength polyester or polypropylene. The secondary backing is applied to permanently stabilize and secure the tufts of the artificial turf system. The most commonly used coating materials are latex and polyurethane.

Stated Benefits of Artificial Turf

The benefits widely promoted by the Synthetic Turf Council (STC) include less maintenance, less cost, no mowing, none-to-minimal water usage, no discoloration yearlong, no weeds, no allergies, no need for pesticides and durability, as the product withstands harsh weather conditions thus extending the sports season. We will look at some of these issues in the sections below.

Summary: Concerns about Artificial Turf

Chemical and Plastic Pollution

- Artificial turf and infill contain chemicals and heavy metals that are bio-accumulative, and thereby, harmful to humans and to the environment. These include polycyclic aromatic hydrocarbons (PAHs), phthalates, and perfluoroalkyl and polyfluoroalkyl "forever" substances (PFAS) (Ecology Center 2020; New Jersey State 2023; PEER 2024). Chemicals in artificial turf have a variety of biological effects and are known carcinogens, neurotoxicants, mutagens, and endocrine disruptors. Heavy metals such as arsenic, lead, chromium, zinc, antimony, and cadmium are also found in artificial turf components. (Armada 2022; Celeiro 2018**;** Llompart M 2013; Zhang 2008; Winz 2023). Some of the incorporated metals are found above regulatory limits (Negev 2022).

- Crumb rubber from crushed used tires is often used as infill, (well as on playgrounds) and has a unique chemical risk profile for humans and the environment (Duque-Villaverde 2024; Frederico 2023; Mayer 2024; Murphy 2022).
- There is close and often repetitive contact of players with artificial turf surfaces and infill, especially for soccer and football players, with particles sticking to shoes and clothing
- There can be direct inhalation and ingestion or dermal uptake of chemicals from the plastic grass and infill (Celeiro 2021).
- There can be leaching of harmful chemicals and microplastics into groundwater, drinking water and soil, causing water contamination, as well as damage to the living soil and organisms beneath them (Celeiro 2021**;** Armada 2022; Cui 2022; Zhong 2022).
- Many of the chemicals can be volatilized, and thus inhaled, especially with high temperatures (Armada D 2022; Celeiro 2021**,** Llompart M 2013).
- Biocides and pesticides applied to artificial fields to kill bacteria, mold, viruses and weeds can cause skin sensitization and may pose risks to the health of workers, children, and surrounding ecosystems (Hahn 2010).
- Artificial turf contains microplastics which are considered contaminants of emerging concern as they do not biodegrade, but do bioaccumulate in the environment, thus creating harm at every stage of the plastic life cycle in their production, use, and disposal (Landrigan 2023).
- Microplastics are inflammatory and also found in humans in the blood, brain, lungs, liver, gut, testicular tissue, thrombi and placenta (Gaspar 2022; Leslie 2022; Ragusa 2021; Danopoulos 2022; Wu 2023; Garcia MA 2024; Garcia MM 2024; Saha 2024; Hu 2024). Polyethylene (used in artificial turf) has even been detected in atherosclerotic plaque in 58% of carotid artery specimens showing "visible, jagged-edged foreign particles" that could contribute to vascular inflammation (Marfella 2024).
- Artificial turf adds to the plastic pollution crisis (IUCN 2022).
- Artificial turf microplastics have been found in 50% of urban waterways tested in Spain and comprised 15% of plastic found in the water (deHaan 2023).
- Artificial turf components have been found to be toxic to earthworms (Pochron 2018), aquatic organisms (Kruger 2013) and chick embryos (Xu 2019).
- Artificial turf infill components can reduce sport grass growth (van Kleunen 2019)**.**

Increased Surface Runoff

- Artificial turf is impervious and increases surface runoff that carries microplastics into storm water drains and local water bodies (de Haan 2023).

Increased Sports Injuries

- There is increased biomechanical stress on joints when playing on artificial turf fields versus natural grass, causing an increase in lower extremity sports injuries particularly in football and soccer (Gould 2023) and an increase in concussions because the artificial turf is laid over concrete or compacted earth (Mack 2019) with a resultant increased impact deceleration (Villanueva 2024).
- There is evidence of increased staphylococcus bacterial infections from turf abrasions

- Turf Toe injury is seen largely from artificial turf sports injury (Najefi 2018)

Athletic Preference for Natural Grass

- Athletes from high school to college to professional sports by far prefer to playing on natural grass (Owen 2016; Dumas 2023; NFLPA).
- National Football League (NFL) players prefer natural grass due to increased injuries from artificial turf (NFL Players Association).

Creation of Urban Heat Islands with Risk of Heat Injury

- Artificial turf can create harmful local heat islands with very high field surface temperatures which range from 40 - 60 degrees °F higher than natural grass - even with moderate air temperatures - causing poor athletic performance and heat related injury and illness, such as burns, heat stress, heat stroke and heat exhaustion, making the fields unusable (Mcfarlane 2015; Abraham 2019; Dujanovic 2017). In contrast natural grass fields rarely get above 100 degrees F.
- Cleats can get hot and have been known to melt on artificial turf (Litman 2015; Nazareth 2016).
- High synthetic field surface temperatures increase volatility and absorption of harmful chemicals from the synthetic turf (Armada D 2022; Llompart M 2013).
- A significant amount of water is used to manufacture, clean and cool synthetic sports fields (Alm 2016; Kanaan 2020).
- There is an expected rise in extreme heat events with a rise in heat-related illnesses and deaths in the next 20 years. Climate change will cause this to be more of an issue for athletes and children (California report "Indicators of Climate Change").
- With rising temperatures artificial turf fields are expected to be increasingly hotter for longer periods, thereby reducing the number of days they can be used in warm or hot weather compared to natural grass.
- Children are physiologically more vulnerable to heat-related illness, due to their greater skin surface area in relation to their bodies, immature sweat glands and higher metabolic rates (Bytomski 2003; Antoniades 2020; Malmquist 2021). Children can suffer a 24% longer *extreme danger* duration on artificial turf during sunny days than on natural grass (Liu and Kim).
- Parks with grass fields can be cooler than the surrounding urban environment by up to 7°C (Slater 2010).

Not Recyclable: Increasing Plastic Waste

- Artificial turf creates a significant waste problem at the end of its limited lifespan of 8-10 years, and it is difficult to recycle due to its complex plastic mixture. It often becomes landfill waste or is dumped on private land with persistent soil and water contamination leaching from the plastic, or is incinerated with accompanying adverse air quality impacts.

- California does not recycle artificial turf and it has to be sent out of state to an "advanced recycling" plant, however there is controversy over the true recyclability of artificial turf and its carbon cost. Only recently has one plant in Texas opened for recycling, and the results have not been measured. Many decades of artificial turf remain stocked in piles above ground in the U.S. and abroad.
- Industry advertising claims stating that artificial turf is recyclable has been challenged in a formal complaint (PEER 2022, York Daily Report 2019).
- A recent comprehensive report "The Fraud of Plastic Recycling" reveals that the plastic industry and the oil industry knew for decades that plastic was not truly recyclable (The Center for Climate Integrity 2024).
- Typical sports fields are about 80,000 square feet and contain about **40,000 pounds of "grass" turf** along with **240,000 to 720,000 pounds of infill** according to the Synthetic Turf Council.

Water Use

- Valley Water, headquartered in San Jose, notes that water conservation no longer includes artificial turf as they recognize that, "there are healthier and more ecologically sound alternatives"
- California Senate Bill 676, signed into law Oct 8, 2023 by Governor Newsom, specifies "that drought-tolerant landscaping does *not* include the installation of synthetic grass or artificial turf."
- Water use on hot days is comparable for both natural grass and artificial turf that is cooled with water to allow playability (Kanaan 2020).
- Manufacture of *one* artificial turf field uses the same amount of water needed to maintain one natural grass field for *4 years* (Alm 2016).
- Recycled water may not be suitable for use on artificial turf due to high salt content which can break down artificial turf components (California Coastal Commission 2023). However, natural grass turf can withstand the salts in recycled water (Evanylo 2010; Hochmuth 2022)

Water Quality and Environmental Effects

- As artificial turf is used it degrades with wear and microplastic and chemicals leach into the soil, water and air on fields and in disposal sites (Wik 2009; Bessa 2018; Celeiro 2018 & 2021; de Haan 2023).
- Water contamination from artificial turf is recognized as a global problem with widespread pollutants in the aquatic environment. deHaan (2023) found artificial turf plastics were found in 50% of river samples and comprised 15% of all plastics in the water.
- Artificial turf is associated with a decline in diversity in soil and bird populations (Bernat-Ponce 2020; Sanches-Sotomayer 2022; Valeriani 2019).
- Integrated Pest Management Policies, Programs and Ordinances have been successfully implemented in many municipalities to reduce pesticide use on parks, landscapes and in agriculture (IPM EPA 2023; IPM San Francisco; IPM Santa Clara County; IPM Marin;

IPM-UC; IPM USDA). These programs protect biodiversity, reduce health risks and address long-term indirect consequences of toxic exposures.

Displacement of Green Space

- Artificial turf displaces natural green space, which is important to health, development and the well-being of children.
- California Extreme Heat Action Plan for California encourages natural plants and landscaping to strengthening community resilience.
- Artificial turf replaces natural grass, which provides soil organic carbon sequestration as well as oxygen.

Carbon Footprint

- Artificial turf is made of plastic that is derived from fossil fuels.
- Artificial turf produces greenhouse gas emissions during manufacturing and has been found to emit these gases as it degrades (Royer 2018).
- Natural grass sequesters carbon, especially when organic methods are used to maintain sports fields (Braun 2019: Cumming 2018; Hamido 2016; Kong 2014;Law 2017; Qian 2012; Zhang 2013).
- Turf farms used in industry can create a positive balance for carbon sequestration (Cummings 2018).

Cost is Less for Natural Grass Fields

- Using a Life Cycle Analysis which includes disposal, natural grass fields are less expensive in the long run (Daviscourt 2017; University of Arkansas; TURI U of Mass Lowell).
- Cleanup costs for current disposal sites and environmental toxins are not taken into account in the total cost of artificial turf.

Benefits of Natural Grass

- Sequesters carbon
- Groundwater preservation and recharge by preventing runoff
- Restoration ecology, bioremediation and soil restoration
- Maintains healthy soil microbiome
- Water conservation
- Improves wellbeing
- Supports biodiversity in soil and the ecosystem

- Cooler microclimate

Examples of Natural Grass Playing Fields
Note: The Sports Field Management Association gives awards every year to well managed natural grass fields

- Marblehead, MA
- Springfield, MA
- Martha's Vineyard, MA
- Snapdragon Stadium in San Diego
- Woodland Middle School, Portola Valley
- Woodside Priory, Portola Valley

No Proof of Safety for Artificial Turf

- There is a significant data gap in understanding the safety of artificial fields. Gaps remain in understanding the chemicals, their toxicity and concerns about the dosages.
- Long-term human health impacts, such as cancer, remain uncertain with some evidence pointing to a higher risk (Tarafdar 2020).
- There are no studies indicating that artificial playing fields are safe
- In February 2016, the Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds (FRAP) was announced. This multi-agency effort includes the U.S. Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and the U.S. Consumer Product Safety Commission (CPSC). The 2019 report released in 2024 discusses crumb rubber only.
- The Consumer Product Safety Commission recommends precautions to limit exposure to chemicals on artificial turf such as hand washing and limiting time on the playground on hot days. (CPSC)

Children are More Vulnerable

- It is well established that children are more vulnerable to toxic exposures due to their immature development that can be permanently disrupted (Carroquino 2012; Landrigan 2001, 2016, 2023; Endocrine Society).
- Children have a longer cumulative time of exposure.
- Children have close and repeated contact with turf surfaces.
- Children are more vulnerable to heat stress physiologically (Bytomski 2003; Antoniades 2020; Malmquist 2021: Liu and Kim)
- The Mount Sinai Children's Environmental Health Center Position Statement on the use of Artificial Turf Surfaces in Nov 2023, "recommends against the installation of artificial turf playing surfaces and fields due to the uncertainties surrounding the safety of these

products and the potential for dangerous heat and chemical exposures." (Mount Sinai 2023)

No Regulations on Artificial Turf for Children

- There are no federal safety regulations on artificial turf for children (Zucarro 2022)
- The European Union has banned the sale of products with intentionally added microplastics and products that release microplastics over time, including crumb rubber artificial turf infill (Zucarro 2024).
- Crumb rubber playgrounds and elementary school sports fields are not classified as a children's product by the Consumer Product Safety Commission (PEER 2015)

Policies to Ban Artificial Turf or Components

The concerns for harmful plasticizers and microplastics in artificial turf, long-term effects on children's health, as well as life cycle analyses have led to policies to ban artificial turf altogether as well as to ban specific toxic components (Millbrae, San Marino, Boston, Zucarro et al 2022). Millbrae, California, for example, recently passed an ordinance to ban artificial turf, including requiring natural grass replacements once artificial turf installations "begin to show visible signs of wear." (Millbrae Ordinance 806, Chapter 8.65)

The law allows local governments to ban artificial turf due to well-documented health concerns. Unfortunately, the artificial turf industry does not have to prove safety of their products for humans or the environment in order to market their product. In fact, few studies on human health have been done. Murphy (2022) notes, "The only human epidemiology studies conducted related to artificial turf have been highly limited in design, focusing on cancer incidence."

Background

1. Chemical Exposures and Contamination

Microplastics and Chemical Pollution: Plastics are now regarded "as a major threat to ecosystems worldwide" (de Haan 2023). Artificial turf is composed of plastic "blades of grass", a plastic composite backing and cushioning infill. The synthetic green blades are typically made up of polyethylene and polypropylene, and due to its propensity to degrade with UV light, "stabilizers" are added to the mix in the manufacturing process to reduce breakdown. Tire crumb rubber is often used for infill due to cost. All of these components are derived from petroleum products. These components contain microplastics as well as chemicals acknowledged as being hazardous substances, such as polycyclic aromatic hydrocarbons (PAHs), bio-accumulative ("forever") per- and polyfluoroalkyl substances (PFAS), phthalates, silica (silica crystal infill), polychlorinated biphenyls (PCBs), carbon black and metals such as lead, mercury, cadmium, chromium, cobalt, and arsenic. In addition, pesticides and biocides are used on

artificial fields to reduce bacteria, viruses and weeds, which could cause adverse reactions and skin sensitization.

A study by the United States Environmental Protection Agency (2019) noted, “a range of chemicals (metals and organic compounds) was found on fields,” but no biomonitoring studies on athletes has yet been done.

These chemicals can contaminate water supplies through runoff, as well as leach into groundwater and soil and persist in the environment (deHaan 2023). Children can be exposed via inhalation of off-gassing compounds, or ingestion of infill components. The crushed tire rubber infill adheres to skin, shoes and clothing, and then can enter cars and homes. Based upon the presence of known toxic substances in tire rubber and the lack of comprehensive safety studies the Children’s Environmental Health Center of the Icahn School of Medicine urged a moratorium on the use artificial turf generated from recycled rubber tires. The EPA states in their assessment that “the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb.” (Marsili 2014). Artificial turf fields are installed on top of a bed of crushed rocks and a drainage system that typically feeds the runoff to storm sewers or surface waterways. As such, artificial turf contributes to the plastic waste crisis.

a. PFAS

High levels of PFAS have been found in artificial turf sold at Home Depot and Lowe’s by the Center for Environmental Health who sent a notice of Violation of the Safe Drinking Water Act on March 4, 2024 (CEH 2024). New health concerns have risen from the ubiquitous chemical group called perfluoroalkyl and polyfluoroalkyl substances (PFAS), which are a class of persistent and highly toxic chemicals with widespread contamination across the United States, and which have been to date found in all samples of artificial turf. PFAS are typically added for water and stain resistance for a myriad of commercial products from packaging to clothes, to food containers and also found in cleaning products and non-stick cookware. Manufacturers of artificial turf state it is used in processing to enhance smoothness and reduce friction during manufacturing.

PFAS in plastics are especially problematic because they are a category of chemicals that contain multiple fluorine atoms bonded to a chain of carbon atoms that makes them resistant to breakdown. This group of chemicals thus bioaccumulates in the food chain and has contaminated water supplies throughout the nation. PFAS are now found in breast milk, blood serum, urine, testicular tissue and placental blood. (ATSDR, Hall, Hu, Wu)

Human health risks include endocrine disruption, adverse effects on the liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity, with evidence of reduction of effectiveness of childhood vaccinations (Grandjean 2017) as well as developmental harm.

The Mindaroo-Monaco Commission on Plastics and Human Health Report 2023 concludes: "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 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…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)" Landrigan (2023).

The Mount Sinai Children's Environmental Health Center Position Statement on the Use of Artificial Turf Surfaces Nov 2023, "recommends against the installation of artificial turf playing surfaces and fields due to the uncertainties surrounding the safety of these products and the potential for dangerous heat and chemical exposures." They further state, "**To allow the installation of PFAS-containing surfaces would be extremely short-sighted as further restrictions and regulations on these chemicals are likely to come.**" Noting:

- Studies to assess the safety of artificial turf are ongoing and inconclusive.
- Questions remain about the safety of alternatives to crumb rubber.
- Undisclosed chemicals of concern are present in plastic grass blades and turf pads and matting.
- Chemical hazards escape from artificial turf surfaces to the environment
- Turf materials are transported home.

b. Infill

Infill is used to support synthetic fibers to prevent rippling of the blades, adds weight to the turf to keep it in place, acts as cushioning, assists drainage in high rains. Types of infill that are used include "crumb rubber" (crushed tires), Crystalline Silica sand, and newer alternatives such as coconut husk, walnut, wood and Zeolite.

Crumb Rubber Tire Infill

Crumb rubber from crushed used tires is used as cushioning infill on artificial turf. According the EPA 38 states ban pulverized scrap tires due to their hazardous components and tendency to catch fire, but in 2003 "markets for scrap tires were consuming 233 million, or 80.4%, of the 290 million annually generated scrap tires." In 2016 the EPA found that 12.5% of all scrap tires were used in crumb rubber infill. (EPA

2016). Crumb rubber was considered an “environmental success story”,according to the Rubber Manufacturers Association (Rappleye 2024).

Crumb rubber, however, exposes humans and ecosystems to a plethora of hazardous chemicals due to the complex mixture of toxic chemicals used in manufacturing. **Celiero (2021)** found, “40 target compounds, including polycyclic aromatic hydrocarbons (PAHs), plasticizers, antioxidants and vulcanization agents were determined in 50 synthetic football pitches of diverse characteristics”. **Duque-Villaverde (2024)** found, “11 compounds of environmental and health concern, including antiozonants such as N-1,3-dimethylbutyl-N'-phenyl-p-phenylenediamine (6PPD) or N, N´-diphenyl-1,4-phenylenediamine (DPPD), and vulcanization and crosslinking agents, such as N-cyclohexylbenzothiazole-2-sulfenamide (CBS), 1,3-di-o-tolylguanidine (DTG) or hexamethoxymethylmelamine (HMMM) from tire rubber… **antiozonant 6PPD** [recently **linked to acute mortality in salmon**] is present at the highest concentrations up to 0.2 % in new synthetic fields. **Federico (2023)** found, “Trace elements such as Zn, Al, Fe, Cd, Cr, Ni, Hg, and Cu”, as well as a filler called carbon black composing up to 22-40%, or silica for wear resistance. **Lead** has been found in artificial turf as well **(Graca 2022).** A 2020 report by the Ecology Center in Maryland found high levels of lead [up to 30,292 ppm in one sample] in Maryland and Virginia playgrounds made from rubber shred. **(Ecology Center 2020)**

Tire industry workers are subjected to some 50 chemicals, many of which are toxic. Occupational studies of workers in the tire industry reveal an association with emphysema, leukemia, multiple myeloma, as well as cancers of the bladder, esophagus, larynx, liver, lung, pancreas, prostate and stomach. Most chronic diseases caused by occupational toxins don’t appear until 10 or more years after first exposure. There are many studies on the toxicity of crumb rubber. **(Murphy 2022)**

Silica Infill

Crystalline silica from crushed quartz rock, also known as industrial sand, is a common alternative to crushed tire infill and contains 95% crystalline silicon dioxide. One manufacturer states: “Silica sand is one of the most ubiquitous forms of infill for the simple reason that it’s inexpensive.” [https://www.purchasegreen.com/blog/silica-sand-what-you-should-know/] It is also considered a hazardous material. Silica dust has long been known to cause a chronic restrictive lung disease called silicosis and was first documented in 1700 in stone-cutters by Dr. Bernardino Ramazzini, considered the founder of occupational medicine. Symptoms of this progressive irreversible lung disease are persistent cough, shortness of breath and difficulty breathing which may occur years after the exposure as scarring and inflammation progress. Silicosis is the most prevalent chronic occupational lung disease in the world (Upadhyay 2024). Australia banned engineered stone because of silicosis risk that is increasingly found in workers who polish engineered countertops. (Nogrady 2023). A silicosis epidemic was recently noted in the Northeast San Fernando Valley stoneworkers **(**Norris 2024).

Silica Infill is Not Sand or “Just Dust”

Some people say that silica infill is just beach sand and therefore is safe. Indeed, beach sand is 80 to 95% silica, but is composed of larger particles that do not pose a risk of pulmonary disease. However, silica (silicon dioxide) exists in both crystalline and amorphous forms. A Yale Environmental Health and Safety report points out that beach sand is amorphous silica. Crystalline silica on the other hand is "at least 100 times smaller than ordinary sand found on beaches or playgrounds. It is generated when silica-containing materials are manipulated in such a way that a dust is created, [and] some fraction of that dust may include particles small enough to become respirable."

The International Agency for Research on Cancer (IARC) Monographs Programme has classified crystalline silica as carcinogenic to humans, while amorphous silica was not classifiable as to its carcinogenicity in humans. The panel emphasized that crystalline silica in the form of quartz or cristobalite dust causes lung cancer in humans. [https://acsjournals.onlinelibrary.wiley.com/doi/10.3322/caac.21214]

The American Academy of Pediatrics (AAP) specifically recommends avoiding "Crushed crystalline silica (quartz)" in sandboxes or playgrounds. (American Academy of Pediatrics- Safety in the Sandbox). Some manufacturers state that the silica is contained inside a plastic or acrylic coating. This coating however may break down with use and pose yet more unknown and untested risks. Organic alternatives such as coconut husks or cork may have proprietary ingredients or coatings as well that stabilize the material but create regrettable substitutes with their own hazardous components. The alternative infill, Zeolite, can be toxic to the lungs with inhalation. (Sloan Kettering)

While new artificial infill and plastic technologies may make fields cooler or softer or bactericidal, we still do not know if they are safer. These alternatives may not have independent scientific studies to back their safety when inhaled, ingested or after they enter storm drains. A full toxic life cycle analysis is needed to fully inform a decision to place artificial turf.

Cancer is another concern for athletes and children playing on artificial turf and exposed to infill and a mix of synergistically harmful artificial turf chemicals. Although there are no studies to date associating an increased risk of cancer with artificial turf, questions remain unanswered regarding exposure to carcinogens on these fields.

2. Disposal of Plastic Waste and Recycling

Artificial turf creates an enormous plastic waste problem and recycling is problematic. Sports fields will last 8 to 10 years before disposal. As they are made of a complex mix of plastic and infill ingredients this produces an ongoing challenge at the end of their lifetime. There are over 15,000 artificial playing turfs in the US and about 1,500 are added yearly. The synthetic turf industry repurposes about one-twelfth of the 300 million auto tires that are withdrawn from use each year. An average soccer field of 80,000 square feet can use 27,000 crushed tires for infill at 4-15 pounds per square foot,

equivalent to 320,000-1 million pounds (160-500 tons) of infill along with 40,000 pounds(20 tons) of plastic (Claudio 2008).
Synthetic turf fields are typically under warranty for 8 years and have a lifespan of about 10 years. Thereafter the material must be disposed of and typically it is landfilled. While industry increasingly attempts to reuse or recycle their product, ultimately it is burned or chemically changed into substances that are potentially as harmful and disposed of somewhere later, adding to planetary pollution.

In general, these fields are never completely recycled and are increasingly dumped on unused private land (where owners are paid a rental fee), empty lots and sometimes illegally dumped where they continue to leach hazardous chemicals. Industry advertising claims that artificial turf is recyclable has been challenged in a formal complaint (PEER 2022, York Daily Report 2019). Even if the artificial turf can be recycled there is a substantial carbon footprint as well as economic cost to do so. Moreover, any increased recycling costs will be added on to the price paid by those purchasing artificial turf.

3. Sports Injuries

Injury prevention for athletes and children should be a fundamental objective as youth sports injuries can have not only short-term impacts but also more serious long-term impacts from orthopedic injuries. Many studies show an increased risk of lower extremity sports injuries from artificial turf in **high schools** (Paliobeis 2021;Voos 2019), **colleges** (Loughran 2019) and **professional sports (**Mack 2019;Calloway 2019; Robertson 2022; Gould 2023). It is concerning that Gould (2023) noted that studies showing a higher risk on natural grass were all funded by the artificial turf industry.

Biomechanical studies show there is increased frictional force at the shoe-surface interface with artificial turf compared to natural grass, thus likely explaining an increased incidence of injuries to the foot, ankle and knee. Furthermore, athletes' consistent perception is that natural grass is easier to play on and results in fewer injuries (Taylor 2012). Smeets (2012) concludes, "Torques on external rotational movements were significantly higher with blades [artificial turf]... High rotational torques between the shoe outsole and the sports surface has been correlated with torsional injuries of the lower limb and knee." Balazs (2015) notes this "is potentially relevant for the risk of anterior cruciate ligament (ACL) rupture, where noncontact mechanisms are frequent." Robertson (2022) performed the largest study of rugby player injury risk and surface type. They noted, "a significantly greater mean severity of hip/groin, and foot/toe injuries on artificial surfaces."

Turf toe is an injury initially coined by and most commonly seen on artificial turf. It typically occurs when an already hyperextended metacarpalphalangeal joint at the base of the toe has additional force placed on it from behind by another player contacting the heel or during play. If there is less "give" from the turf then a hyperextension injury occurs, resulting in anything from a minor sprain to a complete tear of the ligamentous complex

supporting the toe joint. (Najefi 2018) Turf toe is a rare but debilitating condition that requires accurate diagnosis and early definitive management to prevent a chronic condition.

Concussion and Playing Field Surface

Surveys of high school and collegiate trainers have shown more serious concussions occur when athletes play on artificial fields that have been built on a concrete foundation (Guskiewicz 2000; Naunheim 2002), or with firm gravel base. Natural grass absorbs physical impacts better. Villanueva (2024) tested this noting that "American football has the highest rate of concussions in United States high school sports. Within American football, impact against the playing surface is the second-most common mechanism of injury." The authors measured impact deceleration between natural grass and synthetic turf high school football fields and "showed significantly greater impact deceleration on synthetic turf compared to the natural grass surfaces."

Studies that confirm higher injury rates:

Gould (2022) in a review of 53 articles on sports injuries found a higher incidence of foot and ankle injuries on artificial turf, both old and new generation turf. He also revealed that," Only a few articles in the literature reported a higher overall injury rate on natural grass compared with artificial turf, and all of these studies received financial support from the artificial turf industry."

Paliobeis (2021) This study collected data from 26 high schools and found "Athletes were 58% more likely to sustain an injury on artificial turf. Football, soccer, and rugby athletes were at a significantly greater injury risk on artificial turf. Upper and lower extremity and torso injuries also occurred with higher incidence on artificial turf."

Voos (2019) This review of the above 2019 study from Case Western Reserve University and the University Hospital Sports Medicine Institute analyzed data collected by 26 high school athletic trainers during the 2017-2018 athletic seasons. The authors found, "athletes were 58 percent more likely to sustain an injury during athletic activity on artificial turf. Injury rates were significantly higher for football, girls and boys soccer, and rugby athletes. Lower extremity, upper extremity, and torso injuries were also found to occur with a higher incidence on artificial turf."

Mack (2019) examined injuries reported during the 2012-2016 regular season NFL games that were played on modern-generation surfaces. The study found that playing on synthetic turf "resulted in a 16% increase in lower extremity injuries per play than that on natural turf." They concluded, "These results support the biomechanical mechanism hypothesized and add confidence to the conclusion that synthetic turf surfaces have a causal impact on lower extremity injury."

Loughran (2019) looked at injury data from the National Collegiate Athletic Association American Football: 2004-2005 through 2013-2014 seasons and found a significantly higher rate of knee injuries on artificial turf, finding artificial turf a "risk factor".

Calloway (2019) looked at injuries over 4 Major League Soccer seasons (2013-2016) and concluded "overall ankle injury, Achilles injury, and ankle fracture were found to have a statistically higher incidence on artificial turf…[and] elite-level athletes prefer to play on natural grass surfaces due to a perceived increase in injury rate, discomfort, and fatigability on artificial turf."

Najefi (2018) describes "Turf Toe," which is a "debilitating condition, particularly seen in American footballers after the introduction of harder, artificial 'turf' surfaces." He noted that, "in a survey of 80 active professional American football players, 45% had suffered turf toe injuries in their professional careers, with 83% occurring on artificial turf (Rodeo) ."

Sousa (2013) performed a one-season prospective study of amateur soccer players on artificial turf and found, "Injury incidence in amateur soccer players is higher during matches played on artificial turf than during training sessions."

Meyer (2005) A 5-year prospective high school football study published in 2005 noted that during higher temperatures there were reported higher incidences of noncontact injuries, surface/epidermal injuries, and muscle-related trauma, reported on artificial fields.

4. Athlete Preference for Natural Grass Playing Fields

Ford and Monsanto Industries joined efforts to make the first artificial turf in 1964 called ChemGrass which was installed in the Houston Astrodome, when the grass died due to issues with the plastic covering of the dome. By the 1980's athletes were complaining that the turf, then typically made with a base of concrete, was harder and caused more injuries. Indeed, there were more concussions seen on artificial turf fields (Guskiewicz 2000). Earlier turf studies noted, "A number of high-profile professional football players have suffered career-ending concussions." (Naunheim 2002). Newer materials have been used with more infill placed on fields along with a compacted gravel base to address this issue. A poll by the National Football League in 1995 revealed that 95% of players believed that synthetic turf increased their risk of injuries (Claudio 2008). A recent National Football League Players Association (NFLPA) survey found similar results on newer artificial turf fields. (NFLPA 2020) As noted above, there is both anecdotal and scientific evidence of higher rates of injuries on artificial turf.

College and professional athletes prefer natural grass playing fields by far, due to reduced injuries and ease of play (Owens 2016; Dumas 2023; NFLPA). Players describe artificial turf as "sticky". The NFLPA has taken a strong public stance against artificial

turf fields, advocating that "NFL clubs should proactively change all field surfaces to natural grass." (J.C. Tretter) The NFL Players Association tracks the league's official injury reports and has consistently found that natural grass fields provide a much lower risk for injuries when compared to artificial surfaces, both during practices and games. The NFLPA analysis shows that players have "a much higher rate of non-contact lower extremity injuries on turf compared to natural surfaces. Specifically, players have a 28% higher rate of non-contact lower extremity injuries when playing on artificial turf. Of those non-contact injuries, players have a 32% higher rate of non-contact knee injuries on turf and a staggering 69% higher rate of non-contact foot/ankle injuries on turf compared to grass." NFLPA President Tretter explained, "When you put so much force and so much torque in the ground, eventually something has to give. When you're on turf, it's going to be your joint."

5. Infections

Methicillin-resistant Staphylococcus aureus (MRSA) has been recognized as a significant skin infection in the athletic population, causing minor to serious infections. MRSA is responsible for 33% of infectious outbreaks reported among competitive high school and collegiate athletes. Bowers looked at three Division-I collegiate football programs and found that of the 491 collegiate football players, "33 (6.7%) were diagnosed with MRSA infections. Cutaneous manifestations included abscess (70%), cellulitis (16%), folliculitis, impetigo, and necrotizing fasciitis. Of the infections, 90% underwent surgical drainage, whereas 27% received intravenous antibiotics." The most common areas for infections were in the extremities: elbow, knee and forearm (Bowers 2008).

It is notable that high school football players have a 4-fold increase in MRSA infections than that of the general student-athlete population. While locker room surfaces can harbor MRSA, artificial turf can as well. An EPA study on artificial turf showed that 42% had at least one sample with Staphylococcus aureus. Of those, 70% had a least one positive sample for methicillin resistance.

The abrasive nature of synthetic turf along with sheltered MRSA in the turf and infill can make athletes and kids more vulnerable to "turf burn" and infection (Keller 2020). Synthetic turf requires bactericidal chemicals to reduce bacterial growth on fields and infections in players. These liquid turf cleaners can also be toxic and may pose risks to the health of workers, children, and surrounding ecosystems. Bactericides have been shown to act as skin sensitizers (Hahn 2010).

6. Localized Urban Heat Islands and Athlete Heat Stress

Artificial sports fields are known to absorb and retain heat from the sun thus creating significantly higher temperatures, at times 40 to 60 degrees higher than living grass, even

with moderate air temperatures. Studies at Penn State University's Center for Sports Surface Research compared surface temperatures of various synthetic turfs versus natural grass and found "that the maximum surface temperatures during hot, sunny conditions averaged from 140° F to 170°, noting that grass fields rarely get above 100° F due to the cooling effect of natural water evaporation from the living grass (NRPA). These studies have been replicated many times. The heat can be so intense it has been known to melt the plastic (DeSocio 2015).

Heat Injury- These higher temperatures on artificial turf sports fields can cause heat stroke, heat exhaustion, poor athletic performance and skin burns, making these fields potentially unusable under hotter weather conditions. Irrigating the fields with water reduces temperatures; however, the effect lasts for less than 20 minutes, according to research performed by Penn State Center for Sports Surface Research (Abraham 2019; Claudio 2008; NPRA 2019).
The **Consumer Product Safety Commission** notes**,** "Most adults will suffer third-degree burns if exposed to 150° F water for two seconds. Burns will also occur with a six-second exposure to 140° F water or with a thirty second exposure to 130° F water. Even if the temperature is 120° F, a five-minute exposure could result in third-degree burns." **Note: A hot water heater is set to 120**° F, as above that burns can occur.

Heat stress on artificial turf vs natural grass was reviewed by Liu and Kim (2021). Heat waves and hot weather threaten human health when one is not exercising. Those playing sports or participating in strenuous exercise are at increased risk of heat-related illness. Artificial turf creates a higher temperature microclimate due to heat absorption from the sun. The authors note that **children have been identified as a heat vulnerable group** physiologically compared to adults due to "a higher surface area-to-mass ratio (Cheng, 2020), higher metabolic rate (Fabbri, 2013), higher skin temperature during exercise (Cheng, 2020), quicker rise in core temperature (Vanos, Herdt, Lochbaum, 2017), and lower sweat production (Gomes, Carneiro-Júnior, Marins, 2013). Psychologically, children have less experience coping with or realizing the signs of heat stress than adults (Cheng, 2020). Their findings show that children suffer a 24% longer *Extreme danger* duration on artificial turf on sunny days than natural grass (Liu and Kim 2021).

An urban heat island effect arises when natural land cover, vegetation and trees (greenscapes), which have natural evaporative cooling, are replaced with buildings, pavements and other surfaces, such as artificial turf, also called hardscape, that absorb heat from the sun. These artificial surfaces store heat and upon release can raise air temperatures in adjacent areas or even communities. Urban heat islands can be seen from space and differentiated from natural green landscapes. (ESA) Cities can have temperatures much higher than rural areas with vegetation. Even within cities there is significant variation depending on greenspace, parking lots, and housing density. Urban heat islands are being addressed now in cities such as New York, which has a "Cool neighborhoods NYC" program to plant trees and increase vegetation to cool the surrounding area. (Johnson 2022).

Studies Showing High Heat on Artificial Turf Fields

Brigham Young University: After an athlete suffered a heat burn from artificial turf in Utah, Brigham Young University performed a study on the artificial turf and found that the artificial turf temperature was 87 °F hotter than natural grass (Williams and Pulley 2002). A temperature recorded on an artificial turf was 200°F, well above that which would cause a skin burn. Buskirk (2002) measured temperatures for 24 days on artificial turf, natural grass and in air and recorded turf temperatures that were 50 °F higher than natural grass temperatures and reached 70 °F higher than the air temperatures.

Penn State University Center for Sports Surface: Studies at Penn State University's Center for Sports Surface Research compared surface temperatures of various synthetic turfs and found "that the maximum surface temperatures during hot, sunny conditions averaged from 140- 170° F, noting that grass fields rarely get above 100° F due to the cooling effect of natural water evaporation from the living grass. (NRPA)

University of Missouri: A University of Missouri comparative study showed **with artificial turf** there were both "elevated air temperatures (138 °F) and elevated turf temperatures (173 °F) – while **adjacent natural turf temperatures** were 105 °F and local air temperatures were 98 °F". (Abraham 2019)

University of Tennessee: This study by Thom et al (2014) looked at ten synthetic turf surfaces at the University of Tennessee Centre for Athletic Field Safety with different infills. They noted that maximum temperatures on artificial turf were 187 degrees Fahrenheit with ambient air temperatures of 98.7 degrees Fahrenheit. The authors noted, "Despite differences in infill ratios of crumb rubber to sand (0 kg m-2 to up to 34.2 kg m-2 of crumb rubber and sand), synthetic turf surface temperatures varied less than 6 C between the systems suggesting that synthetic turf infill does not affect surface temperature as much as fibers."

Local Heat Island from Artificial Turf at Moffett Park, Sunnyvale, California: Locally the Moffett Park Specific Plan of 2020 also mapped out the local heat island effect and it was evident on the artificial sports fields. **The Twin Creeks Sports Complex**, built in 1985, has 10 all-purpose synthetic turf fields which can be identified in the report as having a temperature in the hottest range (111-138 °F) versus the immediately surrounding area of 102-111°F. Average summer temperatures are "expected to increase in Santa Clara County by ~4°F by 2050 and up to more than 6°F by 2100 (Maizlish et al. 2017), while the number of extreme heat events will double by 2050 and triple by the end of the century." (MPSP, Cal-Adapt.)

Slater (2010) Noted in his study that parks can be cooler than the surrounding urban environment by up to 7°C and this extends up to 100 meters beyond a park borders.

Cooling Methods Used for Artificial turf
Cooling of artificial turf is accomplished through irrigating the field with water. The cooling effect lasts only about 20 minutes (Penn State Center for Sports Surface Research). In arid or semiarid climate zones the amount of water used to maintain artificial turf at temperatures similar to irrigated natural turf grass were comparable (Kanaan 2020). Attempts to alter turf materials to reduce surface temperatures significantly have not been shown to be successful to date. The turf is still significantly hotter. Games can be cancelled if temperatures are too high.

Heat Guidelines for Play on Artificial Turf

National Recreation and Park Association (NRPA) Heat Guidelines for Artificial Turf: For the safety of children public schools have developed heat guidelines for playing on synthetic sports fields due to the higher artificial turf temperatures even with moderate air temperatures. The National Recreation and Park Association (NRPA) 2019 notes that above 120 degrees burns can occur, as well as dehydration with heat stroke, heat exhaustion and poor athletic performance, making these fields potentially unusable under certain weather conditions.
The Montgomery County Public Schools developed the following heat guidelines that apply to and are posted at all its artificial turf fields:

- Anytime the outdoor temperature exceeds 80 degrees, coaches exercise caution in conducting activities on artificial turf fields.
- When outdoor temperatures exceed 90 degrees, coaches may hold one regular morning or evening practice (before noon or after 5 p.m.).
- When the heat index is between 91–104 degrees between the hours of noon and 5 p.m., school athletic activities are restricted on artificial turf fields to one hour, with water breaks every 20 minutes.

It is recommended that artificial turf fields be monitored for temperature and play times adjusted. As global temperatures rise with climate change the heat effects of artificial turf is an ever-increasing concern.

7. Children are More Vulnerable

Artificial turf contains hazardous chemicals and heavy metals. Children are especially vulnerable to all toxic exposures due to their immature biological systems. Scientific evidence (CDC, Landrigan 2001, 2016, 2023) notes that:

- "Children breathe more air, drink more water, and eat more food per pound of body weight than adults.
- Children are more likely to put their hands in their mouth.
- A child's body may not be able to break down and eliminate harmful contaminants that enter their body.
- Rapid growth can be disrupted easily by toxic exposures

- "Health problems from an environmental exposure can take years to develop."

On an artificial sport field children and athletes are routinely in close contact with dust and chemicals emitted from the surface of the fields, especially with soccer, football, field hockey and lacrosse, making them more readily inhaled, ingested, and in closer contact with the skin. Thus, it is reasonable to expect that these synthetic turf fields can pose an increased health risk to children. Precaution is thus imperative. (The full list of references is listed below under Children's Vulnerability to Toxins)

Why Children are More Vulnerable:

- **Children's ability to metabolize**, detoxify, and excrete chemicals is different from that of adults. Children are less able to detoxify and excrete toxic chemicals (Carroquino 2012).
- **Children undergo rapid growth** and development, and their development phases are perfectly scheduled to achieve complete functional development. If a developmental phase is disturbed at a given time, the correct pathway can be lost, thus causing developmental delay or arrest (brain development, reproductive development, immune development, etc) with permanent and irreversible dysfunction. (Carroquino 2012).
- **Environmental toxicants can harm germ cells** which affect an adult's own fertility as well as the health of the offspring. (Carroquino 2012).
- **Chemicals can act as endocrine disruptors** that can block or enhance and endocrine effects and alter development at extremely low concentrations (Parts per trillion PPT -Lawson) and according to the OECD 2023, "They can trigger adverse effects at doses below the threshold values of traditional chemical analysis". Disruption of thyroid hormone changes is especially problematic as this can indirectly alter critical pathways of neural development.
- **The immune system is not mature** up to the age of 7 or 8 (Simon 2015), and beyond that is constantly changing thus is susceptible to toxins causing autoimmune disease even in adulthood, i.e. lead, cadmium and mercury (Kharrazian 2021) and in the case of PFAS even causing reduced immune response to childhood vaccines (Grandjean 2017), as well as reproductive harm (Rickard 2022) and with fetal exposure it is strongly associated with congenital heart disease (Li 2024).
- **The brain and nervous system are not fully developed** until the age of about 26, with different stages of growth and vulnerability. Many chemicals pregnant women and children are exposed are neurotoxic and exposures can lead to neurobehavioral developmental abnormalities. (Grandjean and Landrigan 2014) Lead can cause direct damage to neurons with no safe level of exposure.
- **The reproductive system is complex** and can be disrupted by toxic exposures in utero or even after birth. Male reproduction is particularly susceptible as sperm is constantly maturing. (Lahimer 2023). Female ovaries are partially mature at birth and subject to toxins which can "age" the germ cells in ovaries throughout a lifetime and cause later infertility, also affecting the health of the offspring (Rickard 2022). The measure of cumulative toxic exposure is infertility. (Thomas)

- **Chemicals can act as direct neurotoxins** affecting brain development, i.e. lead causing damage to the hippocampus (memory center) and cerebellum and while nerve cells other than the brain can regenerate, brain cells have limited capacity for regeneration thus are more vulnerable to permanent damage. (Grandjean and Landrigan 2014)
- **Chemicals can also alter sections of DNA** without altering the base sequence i.e. epigenetic changes-and these alter the expression of genes throughout life-altering development and disease. (Ideta-Otsuka 2017)
- **Chemicals can have age dependent rates of absorption** and in one study, lead was absorbed 40-50 times more in younger animals (Sanders 2010)
- **Chemicals can also cause inflammation** of tissues in the body to create or enhance diseases in childhood throughout adulthood (Furman 2019)
- **Longer exposure from childhood**- "There is more time to develop chronic diseases triggered by early exposures…Many diseases, such as cancer and neurodegenerative diseases, are thought to arise through a series of stages that require years or even decades from initiation to actual manifestation of disease. Carcinogenic and toxic exposures, sustained early in life, including prenatal exposures, would then be more likely to lead to disease than similar exposures encountered later." (Carroquino 2012)
- **Synergistic exposures to multiple chemicals** together can enhance toxicity and adverse health impacts (Gaynor 2022)

8. Cancer and Chemicals Still a Question

While there is no proof that artificial turf causes cancer, scientific evidence shows that many chemicals used on artificial turf and components are carcinogenic, can be endocrine disruptors and can be toxic to aquatic organisms. Murphy (2022) highlights this concern, noting a troubling lack of scientific data noting, " The only human epidemiology studies conducted related to artificial turf have been highly limited in design."

While there is an unfortunate lack of independent scientific data on the health impacts of artificial turf, Tarafdar (2020) studied risks of poured rubber surfaces versus classical soil playgrounds in Seoul and noted that the "cancer risk is approximately 10 times higher in poured rubber surfaced playgrounds than in uncovered soil playgrounds. Cancer rates in children and adolescents are rising (Siegel; CDC - Cancer in Children and Adolescents)

9. Environmental Impacts of Artificial Turf: Toxic inputs and Outputs, Water Contamination, Harm to Wildlife, Air Pollution, Carbon Footprint

The components of artificial turf are derived from fossil fuels, which have a number of troubling negative externalities: air pollution, water contamination, and CO2 emissions

contributing to global climate change as well as toxic pollution from short lived as well as "forever" chemicals and microplastics that use petroleum as the base. Adverse effects on soil organisms, birds and biodiversity have also been identified. The true costs of artificial turf have not been added in.

Alms (2016) gathered data for a life cycle analysis (LCA) of artificial turf using data from the Carnegie Mellon "Economic Input-Output Life Cycle Assessment" (EIOLCA) to identify artificial turfs "unfiltered environmental toll". She found that during the manufacturing process artificial turf:

- Released multiple air pollutants including carbon monoxide, CO2, nitrogen oxide, sulfur oxide, PM 10, PM2.5 and volatile organic compounds.
- Produced about 143 metric tons of CO2 released per field
- Used 4,985 kGal of water to produce one synthetic field, while about 1,290 kGal are needed to maintain a grass field per year.

Magnussen (2017) highlights the harmful substances from artificial turf that "may leach to water from infill of both new and recycled material." The authors also identified increased energy use and greenhouse gas emissions from excavation and transportation of soil and rock materials, production and replacement of infills, maintenance with plowing, brushing and raking of the artificial turf field. Also noted was that the end-of-life emissions from disposal with incineration caused the highest energy use and emissions. They state, "One study found that natural grass was environmentally favorable to artificial turf, however the result was opposite if impacts were divided with the number of playing hours provided (Cheng et al., 2014)". These facts, nothwithstanding, are only estimates and do not take into account differences in playability on sunny days or increasing temperatures with climate change or extreme weather events. They also fail to take into account any health care costs for those injured or ill, or any costs for loss of habitat, degradation of the environment or cleanup costs.

Royer (2018) examined hydrocarbon gas emission from polyethylene, which is the most produced and discarded synthetic polymer globally, and the main plastic used in artificial turf blades. The authors found that as polyethylene ages it emits both methane and ethylene and this increases with time. The authors note that "plastics represent a heretofore unrecognized source of climate-relevant trace gases that are expected to increase as more plastic is produced and accumulated in the environment." Royer noted in an interview, **"Synthetic turf has a lot more effect on the environment than anything else made of plastic."**

Celeiro (2018 and 2021) looked at leaching of chemicals from sports fields and found multiple chemicals of environmental concern that were continuously entering the water, as well as chemicals identified in the air. The authors concluded, "The transfer of target chemicals into the runoff water poses a potential risk for the aquatic environment."

Pochron (2018) found that aged crumb rubber and new crumb rubber posed similar toxic risks to earthworms, noting, "This study suggests an environmental cost associated with the current tire-recycling solution."

Zhu X (2021) states, in his article, **The Plastic Cycle – An Unknown Branch of the Carbon Cycle**, "It is clear that plastic pollution has become a major environmental issue of our time. Due to the low degradation rates of plastic, almost every piece of plastic that is produced is still somewhere on this planet." He suggests using the "terminology of biogeochemical cycles" to help scientists address this issue with sinks, reservoirs and fluxes to denote particles moving from one location to another. This would create the "plastic cycle" to better characterize the global nature of this problem.

Sanches-Sotomayer (2022) surveyed 21 parks with artificial grass and 24 parks with natural grass in 18 towns in autumn 2020 looking at differences in bird populations and biodiversity in artificial turf versus natural grass fields. The researchers found "The parks with natural grass always harbored higher gamma diversity, species richness and abundance… the trend of replacing natural by artificial grass in urban parks has harmful effects on urban bird communities and is a threat to bird conservation." **Bernart-Ponce (2020)** found a similar loss of house sparrows where natural grass has been replaced with artificial turf.

A Report by the Center for Climate Integrity, "The Fraud of Plastic Recycling: How Big Oil and the plastics industry deceived the public for decades and caused the plastic waste crisis," notes that industry knew for decades that most plastics cannot be recycled and that recycling plastic is neither technically nor economically viable. The report states, "Some types of "advanced recycling" may produce materials capable of being reprocessed into new plastic (plastic-to-plastic)—however, the majority of these processes produce waste or fuel (plastic- to-fuel), which do not qualify as recycling. As such, plastics cannot be meaningfully recycled through either method."

SB 54- CA 2024-The Plastic Pollution Prevention and Packaging Producer Responsibility Act

The artificial turf industry states that at the end of life at about 10 years, artificial turf will be collected for "advanced recycling". California bill SB 54 (2022) California mandates recycling of many single-use plastic items but excludes chemical recycling of plastic which means that making fuels from used plastic are excluded as a definition of recycling. Artificial turf thus does not necessarily qualify for recycling. (SB-54)

10. Water Quality and Contamination from Artificial Turf

Artificial turf plastics were found in 50% of river samples and comprised 15% of all plastics in the water. deHaan (2023) Artificial turf blades are typically composed of polyethylene and polypropylene plastic along with a multitude of other chemicals. With wear and tear and UV light this plastic breaks down into micro and macro-plastics. As artificial turf is an impervious substance, the surface water from the fields runs off into storm drains, streams, rivers and the ocean.

Researchers at the University of Barcelona in Spain in 2023 looked at 417 samples of river and surface waters including several waterways entering the ocean and found distinctive plastic from artificial turf in 50% of the water samples. They also found that "artificial turf fibers accounted for up to 15% of meso- and macro-plastic abundance." deHaan (2023), **"The dark side of artificial greening: Plastic turfs as widespread pollutants of aquatic environments**."

11. Environmental Benefits of Natural Grass

Benefits of Natural Grass

Water Conservation
Using drought resistant deeper rooted turfgrass, allowing for taller growth on turfgrass, using recycled water and following proper irrigation practices will lead to water conservation, as many fields s are overwatered. Recycled water in some areas may contain too much salt to place on artificial turf, which will cause degradation, thus fresh water is needed to irrigate these artificial turf fields (Coastal Commission 2023). Recycled water can be used on natural grass turf, even though the water may have a higher salt concentration, as turfgrass is typically salt tolerant. "Turf grasses, most annuals, and deciduous trees are more tolerant of saline water" and do not accumulate high levels of salt because of frequent mowing. (UCANR)

Groundwater Preservation and Recharge
Dense above ground turfgrass biomass traps and holds water which reduces excess runoff and allows more water to infiltrate into the soil, enhancing groundwater recharge.

Healthy Soil
Organic turf fields which are designed to use few or no pesticides support healthy soil bacteria and earthworm populations, which contribute to "increased macropore space in the soil, resulting in higher soil water infiltration rates, higher water holding capacity, and improved soil structure."

Restoration Ecology, Bioremediation and Soil restoration
Soil bacteria are also capable of breaking down organic pollutants in the environment, such as pesticides and other manmade pollutants. This concept is now being used in a process known as bioremediation as a less expensive and more effective option for cleaning up contaminated sites. (Alori 2022). Grass fields thus could help restore environmentally damaged areas, and at least prevent further land degradation and chemical pollution. Principles of restoration ecology can be used throughout the conversion of the Santa Clara County fairgrounds to reverse and repair some of the damage done to ecosystems and biodiversity. (Vaughn 2010)

Integrated Pest Management Programs (IPM) to Reduce Pesticide Use

There are many well established IPM programs in the US addressing pesticide use in parks, landscaping and agriculture. These are in cities, counties (Santa Clara County, San Francisco, Marin), universities (University of California, Massachusetts), as well as formulated by the US Department of Agriculture (USDA) and US EPA. All of these programs focus on alternatives to pesticides to reduce harm to the environment and human health. (See IPM in references)

Carbon Sequestration by Natural Grass

Studies have shown carbon sequestration could be higher or the same when one considers energy inputs for maintenance and highly managed fields. A study of turf growers in Australia showed a positive carbon sequestration among other benefits on turf farms.

Zirkle (2011) notes that "Lawns can be a net sink for atmospheric CO2 under all three evaluated levels of management practices [low to high]" and factoring in mowing, irrigating, fertilizing, and using pesticides.

Tidaker (2017) notes for golf course management the amount of fertilizer, watering and mowing can affect the greenhouse gas emissions and should be addressed to reduce carbon footprint and increase carbon sequestration.

Cumming J (2018). Environmental Assessment of the Australian Turf Industry.
The authors state, "The lifecycle assessment involved a review of five turf installation sites over one year. It showed that a well-maintained patch of turf is environmentally healthy, conserves natural ecosystems and will continue to sequester carbon dioxide from the atmosphere through the growth of soil organic matter… This study has also shown that all turf growers were able to provide a carbon positive product with net sequestered carbon dioxide averaging 1.6 kg of CO2eq per square meter of turf produced1… or 48,000 Tonne of CO2eq per year."

11. Environmentally Friendly Organically Managed Natural Turf Fields

Natural grass fields can provide a long-term, cost-effective, high-performance surface for athletic activities. Thoughtful management of natural grass organically improves the health of the soil and grass by supporting a reach microbial environment and promoting a strong root system that withstands wear. In addition, there is no need to put synthetic toxic pesticides or fertilizer on the fields. Water use may be reduced as well.

To reduce the risks of chemical exposure and to protect water quality some cities and schools have chosen to rehabilitate or rebuild natural grass turfs or replace artificial turfs with natural grass, learning how to maintain them organically, in a more ecological way with lower water inputs and with longer playability. These playing fields are living carbon sinks which contribute to biodiversity by their non-toxic nature and cooling effect that supports surrounding greenspaces, as well as living organisms such as bacteria, fungi, earthworms and birds. They also protect the health of humans and the environment.

Building an Organic Maintenance Program for Athletic Fields: Guidance from Experts and Experienced Communities. Toxics Use Reduction Institute, University of Massachusetts (TURI).

The key management elements used for increased performance and lower costs include:

- Aeration of the soil
- Proper irrigation and drainage
- Adjustments for mowing
- Soil testing for pH, moisture, nutrients and beneficial microorganisms
- The use of organic fertilizer
- Soil amendments

Examples of healthy safe natural grass turfs_

Marblehead, MA: In 1998 the Marblehead Board of Health adopted a policy to reduce pesticides for the health and safety of children and families. Since 2002 all of Marblehead's playing fields have been managed organically, using integrated pest management (IPM) techniques. It was noted that in the past they have only closed the field for high rainfall, however, in 2018 "the fields were closed five times due to rain and twice due to extreme heat. Each was a one-day closure. The heat-related closures were the first that the town has experienced."
Start Date: 2002
Acres: 20 acres
Hours of Use: 1360 hours
Maintenance Cost: $4,250 - $4,500 per acre
Cancellations: 7 times

Springfield, MA. In 2014 Springfield received support through a grant to implement organic land care and grass turf management practices on municipal and school properties. The city started with six test pilot cases and grew to 12 organically managed sites by 2019, including multiuse or single use fields. One of the multiuse sports parks, Forest Park Baseball and Soccer Complex, which is open 7 days a week, tallied 3,300 hours per year of use. For strictly soccer use Treetop Park Full-Sized Soccer Field there was 1,051 hours per year of use.
Start date: 2014
Acres: 67 acres
Hours of use: 3,300 for multipurpose and 1,051 for soccer
Total Annual Maintenance Cost: $98,080 for 12 fields
Cost per acre: $1,460.

Martha's Vineyard, MA. In 2017, a group of Martha's Vineyard parents established The Field Fund, Inc to provide support to Martha's Vineyard schools and towns to improve their grass playing fields using organic practices. By September 2020 **The Field Fund** was supporting five athletic field complexes. Using organic practices, the schools and parks were able to meet all of their use needs, with only a few cancellations due to weather-related field conditions. In 2019 none of the 5 athletic fields were closed.

Start Date: 2017
Area: 5 sports and recreational fields
Total Annual Maintenance Cost: $65,600
Cost per acre: $7620.

Grass Sports Fields on Colleges and Universities

Snapdragon Stadium at San Diego State University was placed in 2022 and is popular with athletes and spectators.

Texas A&M. Ellis Field opened in 1994 and still has natural grass (Tifway Bermuda) . https://12thman.com/facilities/ellis-field/9

University of Arkansas in 2019 replaced artificial turf with natural grass**.**

The Sports Field Management Association every year presents awards to the best natural grass sports fields that "exhibit excellent playability and safety and whose managers utilize innovative solutions, effectively use their budgets, and have implemented a comprehensive agronomic program. Five sport fields receive awards- baseball, football, softball, soccer, and sporting grounds. These are given to schools and parks, colleges and universities as well as professional fields throughout the Unites States. These awards promote natural grass sport fields for safety, quality and beauty. Prior winners were

- Jack Trice Stadium Iowa State University. Ames, IA
- Ryan Field. Northwestern University. Evanston, IL
- Folsom Field University of Colorado. Boulder, CO
- Ben Hill Griffin Stadium. University of Florida. Gainesville, FL
- Spartan Stadium. Michigan State University. East Lansing, MI
- Scott Stadium. University of Virginia. Charlottesville, VA
- Kyle Field. Texas A&M University. College Station, TX

12. Water Use of Artificial Turf Versus Natural Grass

Water is a limited and precious resource. One argument made to choose artificial turf over natural grass is the low water use compared to natural grass fields. A closer look at this shows that the differences are not as dramatic as claimed when a life cycle analysis is performed that includes manufacturing costs and irrigation for cooling. In in hotter, dryer climates where artificial turf is supposed to be most beneficial more water is used to cool

the field for players to extend use and reduce risks of heat related illness. Kanaan (2020) noted comparable water use for artificial turf and natural grass in hot climates in order to keep the temperature the same.

Alms (2016) looked at Carnegie Melon 2015 data on lifecycle analysis of production and found that the amount of water used to manufacture artificial turf was 4,985 kGal of water to produce one synthetic field, while about 1,290 kGal are needed to maintain a grass field per year. Thus, the **manufacturing of artificial turf itself equaled 4 years of natural grass irrigation not counting watering in hot weather or surface cleaning.**

Kanaan et al (2020) performed a study at New Mexico State University to evaluate the amount of water required to maintain surface temperatures comparable to those of natural turfgrass areas. They noted that, "In arid and semiarid climate zones the surface temperature of the artificial turf fields can exceed 80°C[176 degrees Fahrenheit during the summer, requiring irrigation and drainage systems to keep them cool enough for use…. The model indicates that over a 24-hr period, **the amount of water (3.00 to 5.00 mm) required to maintain artificial turf at temperatures similar to irrigated natural turfgrass are *comparable*."**

Artificial Turf is *Not* Drought Tolerant Landscaping

Regarding water use, the Santa Clara Valley Water District's Landscape Rebate Program for water conservation no longer includes artificial turf as they recognize that, "there are healthier and more ecologically sound alternatives". California Senate Bill 676, signed into law Oct 8, 2023 by Governor Newsom, specifies "that drought-tolerant landscaping does *not* include the installation of synthetic grass or artificial turf. [and]… drought-tolerant [natural] landscaping is a viable landscaping alternative that will further the goal of addressing long-term water conservation."

Recycled Water Can Be Used on Natural Grass but *Not* on Artificial Turf

The California Coastal Commission in 2023 rejected an artificial turf baseball field at University of California Santa Barbara due to water quality impacts. They noted that **recycled water could not be used on the fields** due to its high salt content but recycled water could be used on hardy natural turfgrass.

13. Cost of Synthetic versus Natural Turf: Lifecycle Analysis

As cities and counties struggle with their limited budgets cost considerations become a central concern. Which is cheaper artificial turf or natural grass? While the narrative has been that artificial turf costs less, an analysis of the entire life cycle of artificial turf versus natural grass by Daviscourt (2017) shows that using natural grass was cheaper in the long run. For grass fields there is initial equipment costs and it is noted that, maintenance decreases exponentially when additional fields are added. One full time skilled sports field

manager can maintain multiple fields. The disposal and replacement costs for a new field turf about every 8 to 10 years also need to be accounted for. Warranties for artificial turf are typically 8 years.
Identifying a complete lifecycle analysis for artificial turf versus natural grass is challenging due to variables and reviews seem to lack some of the direct or indirect costs, however, many articles provide some estimates. The additional costs for synthetic turf are described below and can be quite significant.

The Toxics Use Reduction Institute (TURI) performed a comprehensive cost analysis of artificial turf versus natural grass fields in 2015. They note that costs vary substantially depending on the type of field and the level of maintenance. They state, however, that "artificial turf fields have a higher life-cycle cost than natural grass fields. Once established, organic management of natural grass can be even more cost effective than conventional management of natural grass." In addition, nonprofit groups such as The Field Fund have been created to help fund rebuilding or installing natural grass fields in schools and cities.

- **Installation costs for** an artificial turf field was about $1,223,829. Infill costs varied from $50,000 for crumb rubber to $451,000 for "organic infill" .
- **Maintenance costs** varied widely for both with estimates from $13,720-$39,220 for synthetic turf to $8,133-$48,960 for a natural grass field.
    - **Maintenance of artificial turf systems** includes "fluffing, redistributing, and shock testing infill; periodic static control and disinfection of the materials; seam repairs and infill replacement; field line erasing and repainting; organic matter removal; and watering to lower temperatures on hot days."
    - **Maintenance of natural grass** can include "irrigation, mowing, fertilizing, replacing sod, and other activities. A soil and grass health assessment of the field is needed to establish an appropriate maintenance program. Maintenance of a natural field may be minimized by substituting full field replacements and seam repairs with spot sod replacements

Daviscourt (2017) study noted, "The results of this case study support what has previously been estimated in the literature: synthetic fields cost more to install than natural turfgrass fields… The average cost of the life-cycle analysis for natural grass was $821,000 and for synthetic infill was $1,767,000."
The initial cost for artificial turf is about $1,350,000-$2,000,000. Synthetic soccer turf fields last about 10 years as synthetic turf breaks down and becomes a safety, playability and aesthetic issue. It then needs replacement that costs $350,000 to $650,000 per artificial turf field, not counting any work needed on the base layer or drainage (Sports Venue Calculator). This is an added long-term cost for replacement added into the disposal costs. There are typically no replacement costs for natural grass.

The University of Arkansas came to the same conclusion noting increased maintenance costs of artificial turf. The costs for artificial fields included:

- Installation Costs: More extensive subgrade work for artificial fields

- Annual Maintenance: Additional infill, chemical disinfectants, sprays to reduce static cling and odors removal of organic matter, erasing and repainting temporary lines, irrigation because of unacceptably high temperatures on warm-sunny days.
- Replacement Costs of synthetic turf vs grass
- Disposal costs: Due to complex plastic components a special disposal fee is often needed.

Sports Field Manager Jerad Minnick, who has managed both natural and artificial playing fields collected data on costs. He states, "Existing turfgrass managers, provided with a few tools, can produce a low-cost, environmentally friendly field. In an age of needed job creation, committing money to maintain grass fields instead of building synthetic will create numerous new environmentally friendly jobs in the sports and park industry." He also notes that for "grass fields, the cost numbers for maintenance decreases exponentially when additional fields are added." Below is cost data for different quality of fields. Although this is from 2013 the initial costs for artificial turf as well as disposal fees have increased. Minnick notes there is debate about durability of artificial turf and highlights that artificial turf can fail. This was noted in a WTHR news report showing that some turf fields sold to schools and universities were wearing out more rapidly and had to be replaced. Warranties are typically for 8 years of use.

- Synthetic Professional: $1,000,000
- Natural Grass Professional*: $600,000
- Synthetic, Practice/ Tournament: $850,000
- Natural Grass Practice/ Tournament*: $350,000
- Natural Grass Youth Field*: $150,000

Sports Venue Calculator (SVC) also showed that there is a range of costs for both, however, artificial turf is more expensive in terms of construction. Maintenance is generally in the same range to slightly more expensive for natural grass but this does not take into account disposal and replacement fees.

- Construction Costs Artificial Turf- $700,000 - $1,500,000
- Construction Costs Natural Grass Field- $400,000 – $820,000
- Maintenance Cost Artificial Turf per year $6,000 - $10,000
- Maintenance Cost Natural Grass Field per year- $18,000-$44,000

14. Year-Round Grass Playing Fields- The Grass is Always Greener

An argument made is that artificial turf withstands all weather and has more playing days. This may be true for winter sports at times, however, natural grass can be maintained with proper management in the winter (Neylan 2021). In hotter spring or even typical summer days artificial turf may be unusable. Artificial turfs must be constantly monitored if the outside air temperature is above 90 degrees and in sunny weather. In even moderate temperatures artificial fields can be unusable. This feature is not always calculated in field use data. Liu and Kim (2021) note the increased

vulnerability of children to heat related illness along with in increased risk of heat related illness on artificial turf. They found children suffer a 24% longer *Extreme danger* duration on artificial turf on sunny days than natural grass.

15. Mental Health and Wellbeing: Synthetic Turf Displaces Natural Green Space

Prior to 1970's all parks and sports fields were natural soft grass. Children and adults sat down on the grass, shared food and chatted. Small flowers often grew in the grass to create meadows. The use of synthetic fields displaces natural green spaces which are also important to the health, development and wellbeing of children. The tactile and sensory benefits of real grass are lost with artificial turf. Natural green spaces can reduce stress and improve wellbeing. (Zhang 2020) notes, "It is evident that time spent in, or exposure to, green space can improve positive mood and emotions, provide a retreat from daily hassles, and reduce the risk of psychological and physiological stress in adolescents. There is also evidence of lasting mental health benefits of green space exposure in childhood."

"Today's children largely grow up in synthetic, indoor environments. Now, with the growing popularity of synthetic turf fields, their experience with nature will be less than ever." (Claudio 2008) Athletes by far prefer playing on real grass (Owen 2016)

16. Policies to Ban Artificial Turf or Components

The concerns for harmful plasticizers and microplastics in artificial turf, long-term effects on children's health as well as life cycle analysis have led to policies to ban artificial turf altogether as well as ban specific toxic components. Zucarro (2022) reviewed policies on synthetic turf and wrote, "While nearly every country acknowledges the potential health risks posed by heavy metals, microplastics, PAHs, and PFAS chemicals, very few have actually implemented artificial turf and crumb rubber infill regulations and/or established adequate surveillance measures to protect those regularly exposed to the fields." Governments in the US and abroad are restricting the use of artificial fields with crumb rubber or certain hazardous plasticizers (EU and California) due to environmental bio-accumulation of toxic chemicals.

Montgomery County, Maryland banned the use of tire crumb on any newly constructed artificial turf fields due to health concerns in 2015.
[https://moco360.media/2019/11/18/turf-war/3/]

Westport, Connecticut banned crumb rubber in 2017 and passed an "Ordinance prohibiting the application of synthetic infill material on playing fields on town property," David Brown, a Westport resident with a doctorate in toxicology from Harvard University, formerly headed up a toxicology group at the state health department. He testified in favor of the synthetic infill ban and stated, "The primary problem with turf is

the off-gas from particles that contain toxic and carcinogenic chemicals. When people ingest the crumb rubber, the toxic chemicals are released in their body."

In 2021 the European Union (EU) expanded the scope of restriction of the eight polycyclic aromatic hydrocarbons (PAHs) in infill material in synthetic turf use on playgrounds or sports fields.

Boston banned artificial turf in parks due to toxic 'forever chemicals in 2022.

Holland is banning crumb rubber infill on artificial turf fields due to soil pollution under the turf.

Oak Bluffs Board of Health Banned Turf Fields. Martha's Vineyard, Massachusetts. April 23, 2024. https://vineyardgazette.com/news/2024/04/23/oak-bluffs-board-health-bans-turf-fields

California SB 676 (2023) reverses in part AB 349 (2015) to prevent city or county bans on drought-tolerant landscaping and specifies that "drought-tolerant landscaping does not include the installation of synthetic grass or artificial turf."

San Marino, California (2023) placed a temporary extended moratorium on Oct 27, 2023 banning the use of artificial turf or synthetic grass within the city (Ordinance No. O-23-1410.)

Millbrae, California (2023) banned artificial turf in 2023 in all areas of the city (Ord. 806, § 1).Chapter 8.65).

Sunnyvale, California in October 2023 rejected a proposal to place artificial turf athletic field in a park renovation.

Conclusion

There has been no proof of safety for artificial playing fields and there are many data gaps. Few studies exist on the health impacts of artificial turf, while numerous chemicals hazardous to human health and the environment are found in artificial turf and its leachate (Murphy 2022). There is growing evidence that significant environmental, as well as, health and safety risks outweigh the presumed benefits of artificial fields. It appears that natural grass is less expensive when a full life cycle analysis is performed. In addition, natural grass prevents storm water runoff of toxins and provides living carbon capture as well. Water use on artificial turf is not as low as stated with a full life cycle analysis. Considering that studies on the risks of long-term health have not been performed, along with absence of comprehensive data on the hazardous chemical components of artificial fields we recommend:

1) Not to place artificial turf on playing fields, and
2) Should artificial turf already be present, to replace this with natural grass

Children are increasing exposed to many toxins in the environment. As physicians we advocate for reduction in toxic exposures to reduce individual harm, societal harm, and health care costs which are rising. A precautionary preventative health approach is recommended to avoid unintended consequences and unintended downstream costs.

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Note: After Legislation and Reports other References are in alpha order as follows- Articles Scientific; Artificial Turf Components and Additives; Bans Artificial Turf; Cancer and Chemical Question; Chemical and Plastic Exposures and Contamination; Children's Vulnerability to Toxins; Climate Change; Costs; Disposal and Recycling; Environmental Benefits of Natural Grass; Environmental Impacts of Artificial Turf; Health and Safety; Heat Related Illness and Urban Heat Effect; Infections; Injuries – Sports(and athletic prefernces); Laws and Policy; Lawsuits and Litigation; Letters; Mental Health and Greenscapes; Natural Grass Field Examples; News Articles; PFAS; Videos; Water Use; Water Quality and Contamination.

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