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Sunnyvale City Council
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October 11, 2023

Recommendation to keep natural turf grass and not place it with artificial turf for the Sunnyvale Lakewood Park renovation

Dear Sunnyvale City Council Members,

We understand that on October 24, 2023 you are planning to vote to approve the Preferred Concept Plan (PCP) for the upcoming Lakewood Park renovation which includes placing a large area of artificial turf for an athletic sport field in the center of the park.

The SCCMA Environmental Health Committee has examined this issue and recommends that you keep natural living grass and not replace it with artificial turf for the health and safety of both your community and the environment. Although in the past artificial turf seemed to be the best 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 full life cycle analysis. This is a global problem (Armada 2022). In addition, proposed 2023 legislation in California, if it passes, would require replacing heat trapping surfaces such as artificial turf with natural systems or other cooler types of surfaces to mitigate extreme heat scenarios in schools expected in the future.

The cost of a natural field is less than synthetic fields in the long run. Daviscount (2017) performed a complete life cycle analysis comparing artificial turn versus natural turf over an 8-year period with turf replacements and revealed that the cost savings significantly favored natural turf grass. The University of Arkansas in came to a similar conclusion when looking at maintenance costs, which include mowing, cleaning, chemical applications, replacement costs, and water use. The additional costs for synthetic turf are described below and can be quite significant.

The creation of local heat islands are a known problem on artificial fields. Temperatures can be significantly higher even under normal weather conditions due to their solar absorption and lack of evaporative cooling that natural grass has. This poses risks of burns, heat stroke and heat exhaustion, making the fields unusable in certain conditions. With climate change this will be more of an issue for athletes and children.

There is also data showing increased risks of sports injuries on artificial turf, particularly in football and soccer, as well as the promotion of antibiotic resistant bacterial infections.

Artificial turf contains hazardous chemicals and heavy metals as discussed below. Children are more vulnerable to all toxic exposures due to their immature biological systems. On an artificial sport field children and athletes are routinely in contact with the surface, especially with soccer and football; therefore, they more readily inhale, ingest, and come in dermal contact with dust and chemicals emitted from the fields. Thus, it is reasonable to expect that these synthetic turf fields can pose an increased health risk to children. Precaution is thus imperative.

In addition, artificial turf fields will last 8 to 20 years before disposal. Plastic waste is an ongoing challenge at the end of their lifetime. Typical sports fields are about 80,000 square feet and contain about 40,000 pounds of “grass” turf along with 240,000 ± 720,000 pounds of infill according to the Synthetic Turf Council. This complex mixture of compounds is not recyclable and is usually sent to the landfill with continued leaching of chemicals.

As awareness of all of these factors increase, more cities, such as Boston, are banning artificial turf in parks and on sports fields. In addition, 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.

Chemical Exposures and Contamination

Artificial turf is composed of a plastic backing, plastic “blades of grass” and cushioning infill. Typically tire crumb rubber is used for infill. All of these components are derived from petroleum products. These components contain microplastics as well as chemicals acknowledged as being hazardous such as polycyclic aromatic hydrocarbons (PAHs), bio-accumulative (“forever”) per- and polyfluoroalkyl substances (PFAS), phthalates, silica (silica sand 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.

These chemicals can potentially contaminate water supplies through runoff, as well as leaching into groundwater and soil, persisting in the environment. 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 then 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 US Environmental Protection Agency states in their assessment that “the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb.” (Marsili 2014).

PFAS

PFAS are found in all samples of artificial turf. They are used in processing to enhance smoothness and reduce friction. 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 which makes them resistant to breakdown. They are typically used for water resistance, stain resistance and non-stick cookware. This group of chemicals bioaccumulates in the food chain and has contaminated water supplies throughout the nation. Human health risks include endocrine disruption, adverse effects on the liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity.

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, neurotoxins, 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).

Sports Injuries

Ford and Monsanto Industries joined efforts to make the first artificial turf in 1964 called Chemgrass which was first installed in the 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 was harder and caused more injuries. 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). There is both anecdotal and scientific evidence of higher rates of injuries on artificial fields. A 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.”* (Voos 2019) A 2005 high school football study noted that during higher temperatures there were reported higher incidences of noncontact injuries, surface/epidermal injuries, and muscle-related trauma, reported on artificial fields. (Meyer) Other surveys of high school and collegiate trainers have shown more serious concussions when athletes play on artificial fields that have a concrete foundation (Guskiewicz; Naunheim). Natural grass better absorbs physical impacts.

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

Health Risks

Working in the tire industry exposes workers to some 50 chemicals many of which are toxic. Occupational studies indicate an association of working in the manufacture of tires to bladder cancer, emphysema, esophageal cancer, larynx cancer, leukemia, liver cancer, lung cancer, multiple myeloma, pancreatic cancer, prostate cancer and stomach cancer. Most chronic diseases caused by occupational toxins don't appear until 10 to 40 years after first exposure.

Also, if crystalline silica is used as infill, then athletes can inhale fine dust from the breakdown of this substance. The occupational literature is consistent in showing an association of silica inhalation with lung cancer and other lung diseases. Chronic silicosis, an inflammatory lung disease, can occur after 10 or more years of exposure to inhaled crystalline silica. This particular infill has not yet been tested for safety.

Cancer is another concern for athletes and children playing on artificial turf. Although there are no studies to date associating an increased risk of cancer to artificial turf many questions remain about exposure to carcinogens on these fields.

Localized Heat Islands

Artificial turf fields significantly exceed temperatures of natural turf, at times 40 to 60 degrees higher than living grass. Even with moderate air temperatures artificial sports fields become heat islands, due to increased solar absorption and energy retention, as well as a lack of cooling water evaporation that natural grass provides. These higher temperatures can cause heat stroke, heat exhaustion, poor athletic performance and skin burns, making these fields potentially unusable under certain weather conditions. Irrigating the fields with water reduces temperatures, an effect that lasts for less than 20 minutes, according to research performed by Penn State Center for Sports Surface Research (Abraham 2019; Claudio 2008; NPRA 2019).

Attempts to alter turf materials to reduce surface temperatures have not been successful to date. Games can be cancelled if temperatures are too high. 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.

A University of Missouri study showed "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) Public schools have developed heat guidelines for playing on synthetic sports fields. (National Recreation and Park Association (NRPA) 2019) As global temperatures rise with climate change the heat effects of artificial turf is an ever-increasing concern.

Plastic Waste

There are over 16,000 artificial playing turfs in the US and about 1500 are added yearly. The synthetic turf industry recycles 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 to 1 million pounds of infill along with 40,000 pounds of plastic (Claudio 2008). Synthetic turf fields have a lifespan of 10 to 12 years. Thereafter the material must be disposed of and typically it is landfilled.

Cost of Synthetic versus Natural Turf

While the narrative has been that artificial turf costs less, an analysis of the entire life cycle of artificial turf versus natural grass confirmed that using natural grass was cheaper in the long run (DavisCourt 2017). This 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 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, irrigation for high temperatures, 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.

Mental Health and Wellbeing: Synthetic Turf Displaces Natural Green Space

Use of synthetic fields displaces natural green spaces which are also important to the health, development and wellbeing of children and adults. 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)

Policies to Ban Artificial Turf or Components

The concerns for harmful plasticizers and microplastics in artificial turn, 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.”*

- ❑ **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.
- **California AB 1423** is moving through the 2023 legislature process. The bill proposed will ban the manufacturing and sale of artificial turf containing some hazardous PFAS compounds.
- **California SB 499 (2023), The School Extreme Heat Action Plan Act of 2023**, also moving rapidly through the legislature, would require all school sites, the next time outdoor surfaces are resurfaced or replaced at the school site, to replace low specific heat surfaces, such as cement, asphalt and synthetic turf, with high specific heat surfaces, such as natural grass.

Benefits of Natural Grass

Turfgrass is a living organism and thus can provide environmental benefits (STMA). They cool the surrounding areas including homes and can help control soil erosion and run off. Carbon sequestration is another benefit. It is estimated that net carbon sequestration rates in urban lawns are between 200 and 1,800 lbs of carbon per acre per year. Research modeling of carbon sequestration by lawns indicates *"lawns in the United States alone can sequester between 12.5 million and 95 million tons of atmospheric carbon dioxide per year. That's equivalent to the annual emissions of between 2.4 million and 18 million typical passenger vehicles."* Sports fields compared to lawns or parks are not a carbon sink due to higher maintenance and operations. The University of Oregon has been researching this and recommends several management practices for irrigation, fertilization, and mowing which can help transform them into a neutral or carbon sink while also maintaining healthy turf.

Conclusion

There has been no proof of safety for artificial turf fields and many data gaps. There is growing evidence that the health and safety risks outweigh the benefits of artificial fields. It appears that natural grass is less expensive when a full life cycle analysis is performed. 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.

Sincerely,



Dr. Anlin Xu,
President, Santa Clara County Medical Association



CEO/Executive Director
Santa Clara County Medical Association

Scientific References

- Abraham (2019) **Heat risks associated with synthetic athletic fields.** International Journal of Hyperthermia. 24 Apr 2019.
<https://www.tandfonline.com/doi/full/10.1080/02656736.2019.1605096>
- Adamson (2007) **Synthetic turf fields present unique dangers.** Columbia (MO): University of Missouri-Columbia College of Agriculture, Food, and Natural Resources; 2007. Available from: http://agebb.missouri.edu/news/ext/showall.asp?story_num=3521&iln=8. Accessed March 2019. [\[Google Scholar\]](#)
- Armada D (2022) **Global evaluation of the chemical hazard of recycled tire crumb rubber employed on worldwide synthetic turf football pitches.** Science of The Total Environment. Vol 812, 15 March 2022, 152542. <https://www.sciencedirect.com/science/article/pii/S0048969721076208?via%3Dihub>
- Begin (2004) **A high-morbidity outbreak of methicillin-resistant Staphylococcus aureus among players on a college football team, facilitated by cosmetic body shaving and turf burns.** Begin EM et al. Clin Infect Dis. 2004;39:1446-1453. <https://pubmed.ncbi.nlm.nih.gov/15546080/>
- Bowers (2008) **Methicillin-resistant Staphylococcus aureus infections in collegiate football players.** Sci Sports Exerc. 2008 Aug;40(8):1362-7. <https://pubmed.ncbi.nlm.nih.gov/18614960/>
- Brennan (2021) **Trends in the Regulation of Per- and Polyfluoroalkyl Substances (PFAS): A Scoping Review.** Brennan NM et al. Int J Environ Res Public Health. 2021 Oct; 18(20): 10900. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8536021/>
- Buskirk (1971) **Microclimate over artificial turf.** Buskirk ER et al. J Health, Phys Educ Recreat. 1971;42:29-30. <https://www.tandfonline.com/doi/10.1080/00221473.1971.10617177>
- Celeiro (2021) **Evaluation of chemicals of environmental concern in crumb rubber and water leachates from several types of synthetic turf football pitches.** Chemosphere. 2021 May;270:128610. <https://pubmed.ncbi.nlm.nih.gov/33121811/>
- Claudio (2008) **Synthetic turf: health debate takes root.** Environ Health Perspect. 2008;116:A116-A122. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/>
- Daviscourt (2017) **A Life-Cycle Cost Analysis of Synthetic Infill and Natural Grass Systems.** International Turf Grass Society Research Journal. <https://onlinelibrary.wiley.com/doi/full/10.2134/itsrj2016.10.0848>
- Ekstrand (2006) **Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study.** Sports Med. 2006 Dec;40(12):975-80. <https://pubmed.ncbi.nlm.nih.gov/16990444/>
- Foguth (2020). **Per- and Polyfluoroalkyl Substances (PFAS) Neurotoxicity in Sentinel and Non-Traditional Laboratory Model Systems: Potential Utility in Predicting Adverse Outcomes in Human Health.** Foguth R et al. Toxics. 2020 Jun; 8(2): 42. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7355795/>
- Guskiewicz. (2000). **Epidemiology of concussion in collegiate and high school football players.** The American Journal of Sports Medicine, 28(5), 643-650. <https://pubmed.ncbi.nlm.nih.gov/11032218/>
- Hahn (2010) **Consumer exposure to biocides - identification of relevant sources and evaluation of possible health effects.** Environ Health. 9, Article number: 7 (2010) <https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-9-7>

Hausmann (2022) **New study casts doubt on safety of synthetic turf.** March 15, 2022. <https://www.wvtf.org/news/2022-03-15/new-study-casts-doubt-on-safety-of-synthetic-turf>

IARC. **OCCUPATIONAL EXPOSURES IN THE RUBBER-MANUFACTURING INDUSTRY.** <https://www.ncbi.nlm.nih.gov/books/NBK304412/>

ITRC. **7 Human and Ecological Health Effects of select PFAS.** Interstate Technology Regulatory Council. <https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/>

Jaradat (2020) **Methicillin Resistant Staphylococcus aureus and public fomites: a review.** Jaradat ZW et al. Glob Health. 2020 Dec;114(8):426-450. <https://pubmed.ncbi.nlm.nih.gov/33115375/>

Keller (2020) **The Fate of Methicillin-Resistant Staphylococcus aureus in a Synthetic Turf System.** Keller M et al. Sports Health. 2020 May-Jun; 12(3): 263–270. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7222665/>

Kim S et al. (2012) **Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability.** *Environmental Health and Toxicology*, Volume 27. January 2012 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598/>

Landrigan (2023) **The Minderoo-Monaco Commission on Plastics and Human Health.** Ann Glob Health. 2023 Mar 21;89(1):23. <https://pubmed.ncbi.nlm.nih.gov/36969097/>

Liu (2022) **A toxicological profile of silica nanoparticles.** Liu and Sayes. *Toxicology Research*, Volume 11, Issue 4, August 2022. <https://academic.oup.com/toxres/article/11/4/565/6645393>

Mack (2019) **Higher Rates of Lower Extremity Injury on Synthetic Turf Compared With Natural Turf Among National Football League Athletes: Epidemiologic Confirmation of a Biomechanical Hypothesis.** Am J Sports Med. 2019 Jan;47(1):189-196. <https://pubmed.ncbi.nlm.nih.gov/30452873/>

Marsili L (2014) **Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes.** J Environ Anal Toxicol 2014, 5:2. <https://www.hilarispublisher.com/open-access/release-of-polycyclic-aromatic-hydrocarbons-and-heavy-metals-from-rubber-crumb-in-synthetic-turf-fields-2161-0525.1000265.pdf>

Menichini (2011). **Artificial-turf playing fields: contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment.** Menichini E et al. Sci Total Environ. 2011 Nov 1;409(23):4950-7. <https://pubmed.ncbi.nlm.nih.gov/21907387/>

Meyers and Barnhill (2004) **Incidence, causes, and severity of high school football injuries on FieldTurf versus natural grass: a 5-year prospective study.** Meyers and Barnhill. American J Sports Med. 2004 Oct-Nov;32(7):1626-38. <https://pubmed.ncbi.nlm.nih.gov/15494326/>

Naunheim (2002). **Does the use of artificial turf contribute to head injuries?** Journal of Trauma-Injury, Infection, and Critical Care, 53(4), 691-694. <https://pubmed.ncbi.nlm.nih.gov/12394868/>

New York State (2018) **Information About Crumb-Rubber Infilled Synthetic Turf Athletic Fields.** https://www.health.ny.gov/environmental/outdoors/synthetic_turf/crumb-rubber_infilled/fact_sheet.htm#:~:text=People%20playing%20on%20synthetic%20turf,particles%20suspended%20in%20the%20air.

NRPA (2019) **Synthetic Sports Fields and the Heat Island Effect.** National Recreation and Park Association Guidelines. <https://www.nrpa.org/parks-recreation-magazine/2019/may/synthetic-sports-fields-and-the-heat-island-effect/>

Owen (2016) **Elite Players' Perceptions of Football Playing Surfaces: A Mixed Effects Ordinal Logistic Regression Model of Players' Perceptions.** Owen A et al. Institute of Science & Environment, University of Worcester, Worcester, UK. Journal of Applied Statistics on 02 May 2016. https://static1.squarespace.com/static/57fe8750d482e926d718f65a/t/593ed5d15016e1b82e820b5f/1497290197957/Elite_players_perceptions_of_football_playing_surfaces_-_an_ordinal_regression_model_IR.pdf

Pavilonis (2014) **Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers.** Pavilonis BT et al. Risk Analysis, Volume 34. January 2014. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666>

PEER (2019) **Toxic Forever Chemicals Infest Artificial Turf.: Processing aids that contaminate synthetic turf with PFAS may be in other plastic goods.** PEER. Oct 10, 2019. <https://peer.org/toxic-forever-chemicals-infest-artificial-turf/>

Penn State University (2022). **Survival of Staphylococcus Aureus on Synthetic Turf:** Staphylococcus aureus is a common bacterium, but is capable of causing diseases ranging from minor soft tissue infections and food poisoning to serious medical problems such as toxic shock syndrome. Penn State University. <https://extension.psu.edu/survival-of-staphylococcus-aureus-on-synthetic-turf>

Selbes (2015) **Leaching of DOC [dissolved organic carbon], DN [dissolved nitrogen] and inorganic constituents from scrap tires.** Selbes M et al. Chemosphere, Volume 139. November 2015. <http://www.sciencedirect.com/science/article/pii/S004565351500082X>

Trowbridge (2023) **Extending Nontargeted Discovery of Environmental Chemical Exposures during Pregnancy and Their Association with Pregnancy Complications—A Cross-Sectional Study.** Trowbridge J et al. Environmental Health Perspectives. July 19, 2023. <https://ehp.niehs.nih.gov/doi/10.1289/ehp11546>

UMASS Lowell (2020). **Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet.** Toxics Use Reduction Institute. UMASS Lowell. Feb 2020. <https://www.turi.org/content/download/12963/201149/file/TURI+fact+sheet+-+PFAS+in+artificial+turf.pdf>

USGS (2023) **Tap Water Study Detects PFAS Forever Chemicals Across the US.** USGS. July 5, 2023. <https://www.usgs.gov/news/national-news-release/tap-water-study-detects-pfas-forever-chemicals-across-us>

van Rooij Joost **Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill.** van Rooij Joost and Jongeneelen Frans J. Int Arch Occup Environ Health (2010) 83:105–110. https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/environmental_health/Turf/ArtificialTurfVanRooij2010BioMpdf.pdf

Voos JE (2019) **Artificial Turf Versus Natural Grass. Which is playing surface is safer for playing high school sports?** Innovations in Orthopedics. August 26, 2019. University Hospitals. <https://www.uhhospitals.org/for-clinicians/articles-and-news/articles/2019/08/artificial-turf-versus-natural-grass>

Wang (2022). **Carbon Sequestration in Turfgrass–Soil Systems.** Plants (Basel). 2022 Oct; 11(19): 2478. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9571228/>

Waninger (2011) **Community-associated methicillin-resistant Staphylococcus aureus on artificial turf substrates survival.** Med Sci Sports Exerc. 2011 May;43(5):779–84. <http://www.ncbi.nlm.nih.gov/pubmed/20962684>

Williams and Pulley (2002). **Synthetic surface heat studies.** Provo (UT): Brigham Young University; 2002. https://scholar.google.com/scholar_lookup?hl=en&volume=42&publication_year=1971&pages=29-30&journal=J+Health%2C+Phys+Educ+Recreat&author=ER+Buskirk&author=ER+McLaughlin&author=JL+Loomis&title=Microclimate+over+artificial+turf

Zhang (2020) **The Association between Green Space and Adolescents' Mental Well-Being: A Systematic Review.** Int J Environ Res Public Health. 2020 Sep; 17(18): 6640.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7557737/>

Zucarro (2022) **Artificial turf and crumb rubber infill: An international policy review concerning the current state of regulations.** Environ Chall (Amst). 2022 Dec; 9.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9838222/>

Artificial Turf Components, Additives and Recycling

A GUIDELINE TO RECYCLE, REUSE, REPURPOSE AND REMOVE SYNTHETIC TURF SYSTEMS. October 2017.
https://cdn.ymaws.com/www.syntheticurfCouncil.org/resource/resmgr/guidelines/STC_Guideline_for_Recycle_Re.pdf

Do you want to keep your artificial grass in optimal conditions? Add silica sand to it, learn why. June 30, 2022.

<https://diamondartificialgrass.com/blogs/news/do-you-want-to-keep-your-artificial-grass-in-optimal-conditions-add-silica-sand-to-it-learn-why>

Zeolite vs Silica. Premium Grass Blades. <https://premiumgrassblades.com/silica-or-zeolite-infill-materials/>

TYPES OF INFILL FOR ARTIFICIAL GRASS. may 10, 2022.
<https://www.installartificial.com/how/artificial-grass-infill-types>

US Specialty Coatings- Synthetic Turf Disinfectants.
<https://usscproducts.com/field-marking-paints/synthetic-turf-disinfectants/c/6335>

ADVICE ON MAINTAINING THE INFILL ON YOUR SYNTHETIC FIELD. 2014.Sportsfield Management.
<https://sportsfieldmanagementonline.com/2014/07/18/advice-on-maintaining-the-infill-on-your-synthetic-field/4947/>

Infill: Why Infill for Artificial Grass? <https://www.purchasegreen.com/artificial-grass/product-info/supplies/infill/>

Claudio (2008) **Synthetic turf: health debate takes root.** Environ Health Perspect. 2008;116:A116-A122.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/>

Composition of Artificial Turf Surfaces Key to Preventing High School Football Injuries, Says New Research. Field Turf Sports Company. <https://fieldturf.com/en/articles/detail/composition-of-artificial-turf-surfaces-key-to-preventing-high-school-football-injuries-says-new-research/>

Bans and Turf Wars

Zucarro (2022) **Artificial turf and crumb rubber infill: An international policy review concerning the current state of regulations.** Environ Chall (Amst). 2022 Dec; 9.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9838222/>

Boston bans artificial turf in parks due to toxic 'forever chemicals. The city joins a growing number across the US in limiting the use of artificial turf made with dangerous PFAS compounds. The Guardian. Sept 30, 2022.

<https://www.theguardian.com/environment/2022/sep/30/boston-bans-artificial-turf-toxic-forever-chemicals-pfas#:~:text=Testing%20of%20multiple%20artificial%20fields,in%20drinking%20water%20is%20safe.>

City of Boston Parks and Recreation. MALCOLM X PARK CONSTRUCTION UPDATE. New artificial Turf ban. August 26, 2022.

<https://www.boston.gov/sites/default/files/file/2022/08/Malcolm%20X%20Park%208-26-22.pdf>

California makes strides to ban toxic 'forever chemicals' in artificial turf. April, 2023.

<https://www.ewg.org/news-insights/news-release/2023/04/california-makes-strides-ban-toxic-forever-chemicals-artificial#:~:text=Artificial%20turf%20has%20been%20a,shown%20some%20turf%20contains%20PFAS>.

California- AB-1423 Product safety: PFAS: artificial turf or synthetic surfaces. 2023.

https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=202320240AB1423

EU Restricts PAHs in Synthetic Turf Pitch Infill Materials and Other Sport Applications.

The EU has expanded the scope of restrictions on PAHs under entry 50 to Annex XVII of REACH. The new restrictions will become effective on August 10, 2022.

<https://www.sgs.com/en/news/2021/07/safeguards-10321-eu-restricts-pahs-in-synthetic-turf-pitch-infill-materials>

Holland banning crumb rubber on artificial turf. <https://www.wvtf.org/news/2022-03-15/new-study-casts-doubt-on-safety-of-synthetic-turf>

More games or more grass fields? Turf wars play out across Massachusetts. May 10, 2022.

<https://www.wgbh.org/news/local-news/2022/05/10/more-games-or-more-grass-fields-turf-wars-play-out-across-massachusetts>

Sierra Club opposes artificial turf at Los Gatos schools. November 14, 2021. Mercury News.

<https://www.mercurynews.com/2021/11/14/sierra-club-opposes-artificial-turf-at-los-gatos-schools/>

Los Gatos, Saratoga: High school district applying for drought rebates. July 22, 2015. Santa Cruz

Sentinel. <https://www.santacruzsentinel.com/2015/07/22/los-gatos-saratoga-high-school-district-applying-for-drought-rebates/>

RTM proactively bans crumb rubber artificial turf. Dec 13, 2018. Connecticut Insider.

<https://www.ctinsider.com/news/article/RTM-proactively-bans-crumb-rubber-artificial-turf-13464197.php>

ICAHN School of Medicine. Position Statement on the use of Recycled Tires in Artificial Turf Surfaces. Children's Environmental Health Center. Department of Environmental Medicine and Public Health, Icahn School of Medicine at Mount Sinai .

2017. <https://icahn.mssm.edu/files/ISMMS/Assets/Departments/Environmental%20Medicine%20and%20Public%20Health/CEHC/CEHC%20Artificial%20Turf%20Position%20Statement%205.2017.pdf>

EPA. Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields. EPA.

<https://www.epa.gov/chemical-research/federal-research-action-plan-recycled-tire-crumb-used-playing-fields>

Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds.

2016. https://www.epa.gov/sites/default/files/2016-02/documents/federal_research_action_plan_tirecrumb_final_2.pdf

Gove plans crackdown on fake grass in new housing schemes. Dec 20, 2022. Architects Journal.

<https://www.architectsjournal.co.uk/news/gove-plans-crackdown-on-fake-grass-in-new-housing-schemes>

The environmental impact of rubber infill near artificial turf field. 7/3/2018.

<https://www.rivm.nl/publicaties/verkenning-milieu-effecten-rubbergranulaat-bij-kunstgrasvelden>

Benefits of Natural Grass

Owen A. **Elite Players' Perceptions of Football Playing Surfaces: A Mixed Effects Ordinal Logistic Regression Model of Players' Perceptions.** Institute of Science & Environment, University of Worcester, Worcester, UK. Journal of Applied Statistics on 02 May 2016.
https://static1.squarespace.com/static/57fe8750d482e926d718f65a/t/593ed5d15016e1b82e820b5f/1497290197957/Elite_players_perceptions_of_football_playing_surfaces_-_an_ordinal_regression_model_IR.pdf

ENVIRONMENTAL BENEFITS OF NATURAL TURFGRASS

Sports Turf Managers Association. <https://www.stma.org/wp-content/uploads/2019/04/STMA-Infographc-Environmental-Benefits-Turfgrass-Long-2-STMA-logo.pdf>

What's Growing On: The environmental benefits of turf grass. Dec 9, 2021.
<https://www.wcjb.com/2021/12/09/whats-growing-environmental-benefits-turf-grass/>

Oregon State University (OSU). Through thoughtful practices, lawns can be climate-friendly. Oregon State University. <https://extension.oregonstate.edu/gardening/lawn/through-thoughtful-practices-lawns-can-be-climate-friendly>

Wang (2022). **Carbon Sequestration in Turfgrass-Soil Systems.** Plants (Basel). 2022 Oct; 11(19): 2478.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9571228/>

Zhang (2020) **The Association between Green Space and Adolescents' Mental Well-Being: A Systematic Review.** Int J Environ Res Public Health. 2020 Sep; 17(18): 6640.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7557737/>

Cancer Question

Artificial Turf: Cancers Among Players. Environment & Human Health, Inc. 2020.
<https://www.ehhi.org/turf-cancer-stats.php>

Did Artificial Turf Give More Than 200 Soccer Players Cancer?
Here's what the research says about turf safety. Feb 1, 2017.
<https://www.menshealth.com/health/a19538500/artificial-turf-cancer-risk/>

Turf Battle: New Study Finds No Increased Cancer Risk In Soccer Players. Jan 6, 2017. CBS.
<https://www.cbsnews.com/colorado/news/turf-battle-new-study-finds-no-increased-cancer-risk-in-soccer-players/>

Synthetic Turf and Crumb Rubber Investigation of Reported Cancer Among Soccer Players in Washington State. <https://doh.wa.gov/community-and-environment/schools/environmental-health/synthetic-turf>

Report of cancer in soccer players using crumb-rubber fields led to investigation. Jan 21, 2017.
<https://www.spokesman.com/stories/2017/jan/21/report-of-cancer-in-soccer-players-using-crumb-rub/>

Investigation of Reported Cancer among Soccer Players in Washington State. Washington State Department of Health. Revised April 2017.
<https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs/210-091.pdf?uid=64c0952cba096>

Urgent Need to Research Possible Link Between Artificial Turf Crumb Rubber and Cancer: Excerpt of speech by Amy Griffin, associate head coach at the University of Washington, recorded and produced by Melinda Tuhus. Between the Lines. Feb 20, 2019. <https://btlonline.org/urgent-need-to-research-possible-link-between-artificial-turf-crumb-rubber-and-cancer/>

Chemical Exposures and Contamination

Armada D (2022) **Global evaluation of the chemical hazard of recycled tire crumb rubber employed on worldwide synthetic turf football pitches.** Science of The Total Environment. Vol 812, 15 March 2022, 152542. <https://www.sciencedirect.com/science/article/pii/S0048969721076208?via%3Dihub>

Brennan (2021) **Trends in the Regulation of Per- and Polyfluoroalkyl Substances (PFAS): A Scoping Review.** Brennan NM et al. Int J Environ Res Public Health. 2021 Oct; 18(20): 10900. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8536021/>

Celeiro (2021) **Evaluation of chemicals of environmental concern in crumb rubber and water leachates from several types of synthetic turf football pitches.** Chemosphere. 2021 May;270:128610. <https://pubmed.ncbi.nlm.nih.gov/33121811/>

Foguth (2020). **Per- and Polyfluoroalkyl Substances (PFAS) Neurotoxicity in Sentinel and Non-Traditional Laboratory Model Systems: Potential Utility in Predicting Adverse Outcomes in Human Health.** Foguth R et al. Toxics. 2020 Jun; 8(2): 42. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7355795/>

Landrigan PJ et al. (2023) **The Minderoo-Monaco Commission on Plastics and Human Health.** Ann Glob Health. 2023 Mar 21;89(1):23. <https://pubmed.ncbi.nlm.nih.gov/36969097/>

Marsili L et al. **Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes.** J Environ Anal Toxicol 2014, 5:2. <https://www.hilarispublisher.com/open-access/release-of-polycyclic-aromatic-hydrocarbons-and-heavy-metals-from-rubber-crumb-in-synthetic-turf-fields-2161-0525.1000265.pdf>

Menichini (2011). **Artificial-turf playing fields: contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment.** Menichini E et al. Sci Total Environ. 2011 Nov 1;409(23):4950-7. <https://pubmed.ncbi.nlm.nih.gov/21907387/>

New York State. **Information About Crumb-Rubber Infilled Synthetic Turf Athletic Fields.** https://www.health.ny.gov/environmental/outdoors/synthetic_turf/crumb-rubber_infilled/fact_sheet.htm#:~:text=People%20playing%20on%20synthetic%20turf,particles%20suspended%20in%20the%20air.

Pavilonis (2014) **Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers.** Pavilonis BT et al. Risk Analysis, Volume 34. January 2014. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666>

PEER. **Toxic Forever Chemicals Infest Artificial Turf.: Processing aids that contaminate synthetic turf with PFAS may be in other plastic goods.** PEER. Oct 10, 2019. <https://peer.org/toxic-forever-chemicals-infest-artificial-turf/>

Selbes (2015) **Leaching of DOC [dissolved organic carbon], DN [dissolved nitrogen] and inorganic constituents from scrap tires.** Selbes M et al. Chemosphere, Volume 139. November 2015. <http://www.sciencedirect.com/science/article/pii/S004565351500082X>

UMASS Lowell (2020). **Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet.** Toxics Use Reduction Institute. UMASS Lowell. Feb 2020. <https://www.turi.org/content/download/12963/201149/file/TURI+fact+sheet+-+PFAS+in+artificial+turf.pdf>

USGS (2023) **Tap Water Study Detects PFAS Forever Chemicals Across the US.** USGS. July 5, 2023. <https://www.usgs.gov/news/national-news-release/tap-water-study-detects-pfas-forever-chemicals-across-us>

PFAS

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

By E.A. Crunden, Ariel Wittenberg | 08/03/2022. <https://www.eenews.net/articles/our-community-has-been-deceived-turf-wars-mount-over-pfas/>

UMASS Lowell (2020). **Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet.** Toxics Use Reduction Institute. UMASS Lowell. Feb 2020.
<https://www.turi.org/content/download/12963/201149/file/TURI+fact+sheet+-+PFAS+in+artificial+turf.pdf>

Zucarro P et al (2022) **Artificial turf and crumb rubber infill: An international policy review concerning the current state of regulations.** Environ Chall (Amst). 2022 Dec; 9.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9838222/>

"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."

Marsili (2014) **Release of polycyclic aromatic hydrocarbons and heavy metals from rubber crumb in synthetic turf fields: preliminary assessment for athletes.** Marsili L et al., January 2014 J. Environ. Anal. Toxicol 5 (2). <https://www.hilarispublisher.com/open-access/release-of-polycyclic-aromatic-hydrocarbons-and-heavy-metals-from-rubber-crumb-in-synthetic-turf-fields-2161-0525.1000265.pdf>

New Studies Show PFAS in Artificial Grass Blades and Backing. Environmental Working Group. 2019.
<https://www.ewg.org/news-insights/news/new-studies-show-pfas-artificial-grass-blades-and-backing>

Toxic Forever Chemicals Infest Artificial Turf.: Processing aids that contaminate synthetic turf with PFAS may be in other plastic goods. PEER. Oct 10, 2019. <https://peer.org/toxic-forever-chemicals-infest-artificial-turf/>

Tap Water Study Detects PFAS Forever Chemicals Across the US. USGS. July 5, 2023.
<https://www.usgs.gov/news/national-news-release/tap-water-study-detects-pfas-forever-chemicals-across-us>

What **are the health effects of PFAS?** Agency for Toxic Substances and Disease Registry.
<https://www.atsdr.cdc.gov/pfas/health-effects/index.html>

Costs

Daviscourt (2017) **A Life-Cycle Cost Analysis of Synthetic Infill and Natural Grass Systems.** International Turf Grass Society Research Journal.
<https://onlinelibrary.wiley.com/doi/full/10.2134/itsrj2016.10.0848>

Univ of Arkansas. **Synthetic Turf vs Artificial Grass Athletic Fields.** University of Arkansas.
<https://cms4files.revize.com/elkonv/Council%20Action%20Item%20II-G.pdf>

Claudio (2008) **Synthetic turf: health debate takes root.** Environ Health Perspect. 2008;116:A116–A122.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/>

Environmental Issues

Why are artificial lawns bad for the environment? University of Plymouth. UK.
<https://www.plymouth.ac.uk/discover/why-are-artificial-lawns-bad-for-the->

[environment#:~:text=Why%20is%20artificial%20grass%20harmful,soil%20dwellers%20such%20as%20worms.](#)

ENVIRONMENTAL BENEFITS OF NATURAL TURFGRASS

Sports Turf Managers Association. <https://www.stma.org/wp-content/uploads/2019/04/STMA-Infographic-Environmental-Benefits-Turfgrass-Long-2-STMA-logo.pdf>

Injuries

Ekstrand (2006) **Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study.** *ports Med.* 2006 Dec;40(12):975-80. <https://pubmed.ncbi.nlm.nih.gov/16990444/>

Guskiewicz. (2000). **Epidemiology of concussion in collegiate and high school football players.** *The American Journal of Sports Medicine*, 28(5), 643-650. <https://pubmed.ncbi.nlm.nih.gov/11032218/>

Mack(2019) **Higher Rates of Lower Extremity Injury on Synthetic Turf Compared With Natural Turf Among National Football League Athletes: Epidemiologic Confirmation of a Biomechanical Hypothesis.** *Am J Sports Med.* 2019 Jan;47(1):189-196. <https://pubmed.ncbi.nlm.nih.gov/30452873/>

Meyers and Barnhill (2004) **Incidence, causes, and severity of high school football injuries on FieldTurf versus natural grass: a 5-year prospective study.** *Meyers and Barnhill. American J Sports Med.* 2004 Oct-Nov;32(7):1626-38. <https://pubmed.ncbi.nlm.nih.gov/15494326/>

Naunheim (2002). **Does the use of artificial turf contribute to head injuries?** *Journal of Trauma-Injury, Infection, and Critical Care*, 53(4), 691-694. <https://pubmed.ncbi.nlm.nih.gov/12394868/>

Voos JE (2019) **Artificial Turf Versus Natural Grass. Which is playing surface is safer for playing high school sports?** *Innovations in Orthopedics.* August 26, 2019. University Hospitals. <https://www.uhhospitals.org/for-clinicians/articles-and-news/articles/2019/08/artificial-turf-versus-natural-grass>

Health Effects

Adamson (2007) **Synthetic turf fields present unique dangers.** Columbia (MO): University of Missouri-Columbia College of Agriculture, Food, and Natural Resources; 2007. Available from: http://agebb.missouri.edu/news/ext/showall.asp?story_num=3521&iln=8. Accessed March 2019. [\[Google Scholar\]](#)

Claudio (2008) **Synthetic turf: health debate takes root.** *Environ Health Perspect.* 2008;116:A116-A122. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/>

Hahn (2010) **Consumer exposure to biocides - identification of relevant sources and evaluation of possible health effects.** *Environ Health.* 9, Article number: 7 (2010) <https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-9-7>

Hausmann S. **New study casts doubt on safety of synthetic turf.** March 15, 2022. <https://www.wvtf.org/news/2022-03-15/new-study-casts-doubt-on-safety-of-synthetic-turf>

IARC. **OCCUPATIONAL EXPOSURES IN THE RUBBER-MANUFACTURING INDUSTRY.** <https://www.ncbi.nlm.nih.gov/books/NBK304412/>

ITRC. **7 Human and Ecological Health Effects of select PFAS.** *Interstate Technology Regulatory Council.* <https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/>

Kim S et al. (2012) **Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability.** *Environmental Health and Toxicology*, Volume 27. January 2012 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598/>

Liu A **toxicological profile of silica nanoparticles.** *Toxicology Research*, Volume 11, Issue 4, August 2022. <https://academic.oup.com/toxres/article/11/4/565/6645393>

Trowbridge (2023) **Extending Nontargeted Discovery of Environmental Chemical Exposures during Pregnancy and Their Association with Pregnancy Complications—A Cross-Sectional Study.** Trowbridge J et al. *Environmental Health Perspectives*. July 19, 2023. <https://ehp.niehs.nih.gov/doi/10.1289/ehp11546>

van Rooij Joost **Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill.** van Rooij Joost and Jongeneelen Frans J. *Int Arch Occup Environ Health* (2010) 83:105–110. https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/environmental_health/Turf/ArtificialTurfVanRooij2010BioMpdf.pdf

Lung Cancer Center. Tire and Rubber Industry Rates of Occupational Disease. <https://www.lungcancercenter.com/who-lung-cancer-affects/tire-rubber-industry/>

‘Unintended consequences’: The rubber industry’s toxic legacy in Akron. March 5, 2021. Public Integrity. <https://publicintegrity.org/health/unintended-consequences-rubber-industry-toxic-legacy-in-akron/>

OSHA. **Silica, Crystalline Hazards.** Occupational Health and Safety Administration. U.S. Department of Labor. <https://www.osha.gov/silica-crystalline/health-effects>

CDC. **Health Risks of Silica Exposure and Medical Monitoring.** The National Institute for Occupational Health. <https://www.cdc.gov/niosh/topics/silica/risks.html>

Infections

Begier (2004) **A high-morbidity outbreak of methicillin-resistant Staphylococcus aureus among players on a college football team, facilitated by cosmetic body shaving and turf burns.** Begier EM et al. *Clin Infect Dis*. 2004;39:1446-1453. <https://pubmed.ncbi.nlm.nih.gov/15546080/>

Bowers (2008) **Methicillin-resistant Staphylococcus aureus infections in collegiate football players.** *Sci Sports Exerc*. 2008 Aug;40(8):1362-7. <https://pubmed.ncbi.nlm.nih.gov/18614960/>

Jaradat (2020) **Methicillin Resistant Staphylococcus aureus and public fomites: a review.** Jaradat ZW et al. *Glob Health*. 2020 Dec;114(8):426-450. <https://pubmed.ncbi.nlm.nih.gov/33115375/>

Keller (2020) **The Fate of Methicillin-Resistant Staphylococcus aureus in a Synthetic Turf System.** Keller M et al. *Sports Health*. 2020 May-Jun; 12(3): 263–270. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7222665/>

Penn State University. **Survival of Staphylococcus Aureus on Synthetic Turf:** Staphylococcus aureus is a common bacterium, but is capable of causing diseases ranging from minor soft tissue infections and food poisoning to serious medical problems such as toxic shock syndrome. Penn State University. <https://extension.psu.edu/survival-of-staphylococcus-aureus-on-synthetic-turf>

Penn State University Extension. **Survival of Staphylococcus aureus on Synthetic Turf.** <http://plantscience.psu.edu/research/centers/turf/extension/factsheets/staphylococcus>

Waninger (2011) **Community-associated methicillin-resistant Staphylococcus aureus on artificial turf substrates survival.** Med Sci Sports Exerc. 2011 May;43(5):779-84. <http://www.ncbi.nlm.nih.gov/pubmed/20962684>

Temperature: Localized Heat Islands

Abraham (2019) **Heat risks associated with synthetic athletic fields.** International Journal of Hyperthermia. 24 Apr 2019. <https://www.tandfonline.com/doi/full/10.1080/02656736.2019.1605096>

Buskirk (1971) **Microclimate over artificial turf.** Buskirk ER et al. J Health, Phys Educ Recreat. 1971;42:29-30. <https://www.tandfonline.com/doi/10.1080/00221473.1971.10617177>

Claudio (2008) **Synthetic turf: health debate takes root.** Environ Health Perspect. 2008;116:A116-A122. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/>

NRPA (2019) **Synthetic Sports Fields and the Heat Island Effect.** National Recreation and Park Association Guidelines. <https://www.nrpa.org/parks-recreation-magazine/2019/may/synthetic-sports-fields-and-the-heat-island-effect/>

Williams and Pulley (2002). **Synthetic surface heat studies.** Provo (UT): Brigham Young University; 2002. https://scholar.google.com/scholar_lookup?hl=en&volume=42&publication_year=1971&pages=29-30&journal=J+Health%2C+Phys+Educ+Recreat&author=ER+Buskirk&author=ER+McLaughlin&author=JL+Loomis&title=Microclimate+over+artificial+turf

University of Arkansas. **Synthetic Turf vs Artificial Grass Athletic Fields.** University of Arkansas. Photos of different temperatures measured. <https://cms4files.revize.com/elkonv/Council%20Action%20Item%20II-G.pdf>

Mum's random experiment shows fake turf can be dangerous for kids and pets. Jan 5, 2019. <https://www.kidspot.com.au/health/family-health/safety/mums-random-experiment-shows-fake-turf-can-be-dangerous-for-kids-and-pets/news-story/a347bb4ca90e13af7eb2098ddf451a33>

Plastic Waste

ADVICE ON MAINTAINING THE INFILL ON YOUR SYNTHETIC FIELD. 2014.Sportsfield Management. <https://sportsfieldmanagementonline.com/2014/07/18/advice-on-maintaining-the-infill-on-your-synthetic-field/4947/>

Infill: Why Infill for Artificial Grass? <https://www.purchasegreen.com/artificial-grass/product-info/supplies/infill/>

The Dangerous Pileup of Artificial Turf: Recycling scrap tires into synthetic turf was supposed to be an environmental win. The Atlantic. Dec 19, 2019. <https://www.theatlantic.com/science/archive/2019/12/artificial-turf-fields-are-piling-no-recycling-fix/603874/>

News Articles

Say NO to Plastic Fields and Rubber Playgrounds. [https://www.sierraclub.org/maryland/synthetic-turf#:~:text=An%20average%20single%2080%2C000%20sq,waste%20sometimes%20mixed%20with%20sand\).](https://www.sierraclub.org/maryland/synthetic-turf#:~:text=An%20average%20single%2080%2C000%20sq,waste%20sometimes%20mixed%20with%20sand).)

Plastic Wars: Industry Spent Millions Selling Recycling — To Sell More Plastic. March 31, 2020.
<https://www.npr.org/2020/03/31/822597631/plastic-wars-three-takeaways-from-the-fight-over-the-future-of-plastics>

Synthetic Turf is HAZARDOUS

<https://www.beyondplastics.org/fact-sheets/synthetic-turf>

A New Turf War: Synthetic Turf in New York City Parks: A PARK POLICY PAPER. The Arthur Ross Center for Parks and Open Spaces, New Yorkers for Parks. 2006.
http://www.precaution.org/lib/new_turf_war.060415.pdf

Information About Crumb-Rubber Infilled Synthetic Turf Athletic Fields. New York State Department of Health.

https://www.health.ny.gov/environmental/outdoors/synthetic_turf/crumb-rubber_infilled/fact_sheet.htm

3 Dangers of Artificial Turf . http://www.huffingtonpost.com/maria-rodale/3-dangers-of-artificial-t_b_1661499.html

Artificial turf gets a closer look after report raises safety concerns. Washington Post. Sept 15, 2023.
https://www.washingtonpost.com/local/artificial-turf-is-getting-a-closer-look-after-a-report-raises-safety-concerns/2015/09/22/fcf6a0ee-5649-11e5-abe9-27d53f250b11_story.html