DELAWARE RIVERKEEPER NETWORK

Fact Sheet

Artificial/Synthetic Turf

While professional sports are turning away from artificial turf, it is gaining ground and use at the local level at schools and community fields. Producers of artificial turf make claims of environment, health and safety benefits associated with artificial turf – when they make these blanket claims they are not giving the full picture.

In terms of environment, health and safety, the jury is still very far out on artificial turf. There continues to be information documenting harm in each of these arenas. Most of all, there is a widespread demonstration and recognition that in terms of environmental, health and safety threats from artificial turf, much more study, analysis and consideration is needed. And whatever the final outcome of the research, manufacturers neglect the reality that as much as they try to mimic natural grass, artificial turf is not grass, and cannot provide the same natural feel, natural look, natural smell and environmental benefits that natural grass provides.

Artificial Turf is generally comprised of plastic fibers (generally made of polyethylene, polypropylene or nylon) attached to a polypropylene or polyester plastic webbing. A combination of sand and rubber, or sometimes rubber alone, fills between the fibers. The source for the rubber infill is generally recycled tires. Sometimes newly manufactured rubber granulate is used but the cost is so much greater than the recycled tire form that it is generally not the substance used. New developments in artificial turf technology seem continually in the works.

Water Quality:

Delaware Riverkeeper Network
300 Pond Street, Second Floor
Bristol, PA 19007
tel: (215) 369-1188
fax: (215) 369-1181
drkn@delawareriverkeeper.org
www.delawareriverkeeper.org

While it seems well recognized that there is a limited level of assessment and investigation into the environmental impacts associated with artificial turf, a growing body of scientific analysis is documenting a concerning level of environmental threat and harm and is further demonstrating the need for more research regarding artificial turf and its ramifications for the environment.

Synthetic turf is generally made with rubber from waste tires. Recycled rubber varies considerably in its chemical composition, even when from the same manufacturer.[1]

Hazardous substances found in tires may persist in the environment including polycyclic aromatic hydrocarbons (PAHs), phthalates and certain metals. These substances may be bioaccumulative, carcinogenic, reprotoxic, mutagenic and/or endocrine disrupting.[2] The chemicals in waste tires are of such concern that a report published by the Swedish Chemicals Inspectorate recommends: "waste tyres should not be used for synthetic turf surfaces." [3]

- Most PAHs are persistent, bioaccumulative and carcinogenic.[4]
- Phthalates are generally used as solvents and plasticisers in plastics. Phthalates are not chemically bound to the rubber and as a result can leach from the infill material.[5]
- Phenols likewise are not chemically bound to the rubber and so can leach. Phenols too are persistent and bioaccumulative and can have long-term effects on the environment.[6]
- Among the metals found in tires that may be of concern are zinc, lead, copper, chromium and cadmium. While zinc and copper are essential for living organisms, when absorbed at high levels they become harmful. Lead can affect reproduction, development of the nervous system leading to poor cognitive development, and is a particular threat to fetuses and young children. Chromium is carcinogenic and mutagenic. Cadmium is toxic to humans and if taken in can contribute to poor liver and kidney function, as well as osteoporosis. [7]

The Connecticut Agricultural Experiment Station conclusively found four compounds which out-gassed and leached into water from synthetic turf rubber crumb under ambient temperatures:

- Benzothiazole (a skin and eye irritant),

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[1] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 7.
[2] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[3] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[4] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[5] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[6] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[7] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

- Butylated hydroxyanisole (a "recognized carcinogen, suspected endocrine toxicant, gastrointestinal toxicant, immune toxicant, neurotoxicant, skin and sense-organ toxicant"),
- n-hexadecane (a severe irritant) &
- 4-(t-octyl) phenol ("corrosive and destructive to mucous membranes").[8]

As rubber degrades it can leach toxic substances which can contaminate soil, plants and aquatic ecosystems.[9] Study has concluded that the use of tires in artificial turf has the potential to pollute our environment with PAHs, phenols and zinc[10] and that runoff from an artificial turf field draining to a local creek can pose "a positive risk of toxic effects on biota in the water phase and in the sediment."[11] Other metal contaminants found to leach from tire crumb rubber include zinc, selenium, lead and cadmium.[12] Zinc has also been shown to leach from the artificial turf fibers.[13] Extreme temperatures or solvents are not needed to release these metals, volatile organic compounds or semi-volatile organic compounds from the rubber in-fill of artificial turf into the air or water – release takes place in ambient air and water temperatures.[14]

Leaching of substances as the result of surface water runoff from precipitation has, by some researchers, been predicted to be the greatest risk for the environment from artificial turf.[15] Study shows there is a risk of local effects for aquatic and sediment dwelling organisms in impacted water courses.[16] Recycled rubber, and associated

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[8] The Connecticut Agricultural Experiment Station, Examination of Crumb Rubber Produced from Recycled Tires, August 2007; Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.

[9] Quoting Dr. Linda Chalker-Scott, Washington State University -- Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass; T. Kallqvist, Norwegian Institute for Water Research(NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 17.; Connecticut Agricultural Experiment Station, Examination of Crumb Rubber Produced from Recycled Tires.

[10] T. Kallqvist, Norwegian Institute for Water Research(NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 5; T. Edeskar, Lulea University of Technology, Technical and Environmental Properties of Tyre Shreds Focusing on Ground Engineer Application, 2004 as cited in KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

[11] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 6.

[12] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.

[13] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 17.

[14] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.

[15] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 5; NIVA (The Norwegian Institute for Water Research), Evaluation of the Environmental Risks of Synthetic Turf, 2005; KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

[16] T. Kallqvist, Norwegian Institute for Water Research(NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 5; NIVA (The Norwegian Institute for Water Research), Evaluation of the Environmental Risks of Synthetic Turf, 2005, as cited by KEM, Swedish Chemicals

leachate, has been found to contain a variety of metals (including lead, cadmium, copper, mercury and zinc), as well as organic pollutants such as PAHs, phthalates, 4-t-octylphenol and iso-nonyphenol.[17] The leaching of zinc has been determined to be of major environmental concern.[18] The leaching of zinc increases as the rubber infill weathers over time,[19] it is likely this is the same for other contaminants. While Zinc contributes the most risk, phenols (specifically octylphenol) and PAHs are also of concern.[20] Of the organic compounds at issue, Octylphenol represents the greatest risk, and possibly could occur at levels where hormone disrupting effects are a concern.[21] The varying content of tires makes this threat a moving target.

The Norwegian Institute for Water Research has determined that it is "appropriate to perform a risk assessment which covers water and sediments in watercourses which receive run-off from artificial turf pitches."[22]

While recycled rubber is a greater source of pollution, newly manufactured rubber also contains level of hazardous substances; in the case of zinc and chromium the levels of recycled and newly manufactured rubber are comparable.[23]

It is predicted that chemicals leaching from synthetic turf materials occurs slowly, and as a result the environmental harms may take place over many years.[24]

Leaching may not be the only source of water contamination from artificial turf. As the artificial turf is used there is a level of "erosion" that takes place and can result in

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Agency, Facts: Synthetic Turf, April 2007; KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007

[17] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 7.

[18] INTRON, Environmental and Health Risks of Rubber Infill, rubber crumb from car tyres as infill on artificial turf, February 9, 2007.

[19] INTRON, Environmental and Health Risks of Rubber Infill, rubber crumb from car tyres as infill on artificial turf, February 9, 2007.

[20] NIVA (The Norwegian Institute for Water Research), Evaluation of the Environmental Risks of Synthetic Turf, 2005, as cited by KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

[21] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 17.

[22] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 8.

[23] Byggforsk, SINTEF Building and Infrastructure, Potential Health and Environmental Effects Associated with Synthetic Turn Systems, 2004, as referenced in KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

[24] T. Kallqvist, Norwegian Institute for Water Research(NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 5; NIVA (The Norwegian Institute for Water Research), Evaluation of the Environmental Risks of Synthetic Turf, 2005, as cited by KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.

fine particles that could be carried to local waterways. This source of contamination needs study.[25]

The synthetic grass fibers can also be a significant source of pollution, particularly zinc, albeit significantly lesser amounts leach from the synthetic grass than the rubber infill.[26]

Concerns about the environmental and health effects of synthetic turf in European countries is so great that standards and/or guidelines have been set or are under consideration. For example: Germany has set standards for the use of synthetic turf including a maximum allowable level of pollution or contamination of water and soil, with a requirement of regular sampling to ensure these standards are not exceeded. Allowable pollution levels include: lead 0.04 mg/l, cadmium 0.005 mg/l; chromium 0.05 mg/l, mercury 0.001 mg/l and zinc 3.0 mg/l or 0.5 mg/l depending on the testing method used.[27] Holland has also suggested appropriate language for a standard applicable to use of synthetic turf including a ban on the use of carcinogens, mutagenic, reprotoxic, persistent, bioaccumulative and toxic, or very persistent and very bioaccumulative substances in the surface layer of the turf and a limitation on the level of substances in the rubber infill that may cause cancer, may cause heritable genetic damage, may cause cancer by inhalation, are toxic or harmful to aquatic organisms or may cause long term affects on the aquatic environment, that may impair fertility or cause harm to unborn children. Sweden has set guidelines and limiting values for some of the substances that are present in synthetic turf, specifically as it relates to air pollution, soil contamination and water pollution.[28] And because vehicle tires contain levels of several substances of "very high concern", the recycling and use of tires in synthetic turf is apparently in conflict with the Swedish environmental objective of A Non Toxic Environment.[29]

Part of artificial turf maintenance is the regular replenishment of the infill. There is a need for research into the loss of existing infill – where is it going and what impacts is it having?[30]

Maintenance of artificial turf can include application of algaecides or disinfectants to keep the surface clean.[31] Maintenance could also include application of fabric

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[25] T. Kallqvist, Norwegian Institute for Water Research (NIVA), Environmental Risk Assessment of Artificial Turf Systems, December 2005, p. 18.
[26] Byggforsk, SINTEF Building and Infrastructure, Potential Health and Environmental Effects Associated with Synthetic Turn Systems, 2004, as referenced in KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[27] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[28] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[29] KEM, Swedish Chemicals Agency, Facts: Synthetic Turf, April 2007.
[30] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.

softener to mask the odor of the artificial turf. [32] What is the final destination of these chemicals and their implications for the environment and those coming into contact with them while playing on the fields? More information is needed on this subject as well.

Stormwater:

There is no indication that artificial turf drains more effectively for purposes of a stormwater infiltration system than natural grass. In addition, infiltration systems are designed to work with whatever surface coating they receive from natural grass to porous paving. It should be noted that while generally there can be no assumed benefit from an infiltration perspective of natural turf or artificial turf, there are instances where schools have experienced problems with the drainage of their artificial turf fields. [33]

Natural grass provides a level of evapotranspiration, pulling water out of the soil and subsurface and releasing it to the air, providing benefits in reducing the volume of runoff that results from a site and/or needs to be addressed by other stormwater management strategies. Artificial turf has no evapotranspiration capabilities.

Grass does provide a level of pollution filtering and therefore water quality protection for nearby waterways. While this filtering may be limited in the case of turf grass; such filtering is nonexistent with artificial turf.

Heat Island Effect – for Human Health and Surrounding communities:

Extreme heat is a health concern. Studies document that the surface temperature on artificial turf is dramatically increased as compared to surrounding land uses including asphalt.

In a 2002 study it was found that "the surface temperature of the synthetic turf was 37° F higher than asphalt and 86.5° F hotter than natural turf." [34] A study published in the Journal of Health and Physical Education and Recreation showed "surface temperatures as much as 95 to 140 degrees Fahrenheit higher on synthetic turf than natural turfgrass when exposed to sunlight." [35] Random sampling at Brigham Young University identified temperatures ranging from 117.38 to 157 degrees on artificial turf while neighboring natural grass areas were in the range of 78.19 to 88.5 degrees Fahrenheit. "Two inches below the synthetic turf surface was 28.5° F hotter than

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[31] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.
[32] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.
[33] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.
[34] Dr. C. Frank Williams and Dr. Gilbert E. Pulley, Synthetic Surface Heat Studies, Brigham Young University.
[35] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.

natural turf at the surface."[36] And still another study comparing temperatures on artificial turf temperatures with air temperature found that artificial turf ranged from 58 to 75 degrees hotter than measured air temperature.[37] While irrigation provided significant cooling for the synthetic turf (lowering the temperature from 174° F to 85° F) after only 5 minutes the temperature quickly rose again to 120°F; after 20 minutes it rose to 164°F.[38]

Concerns regarding the excessive temperatures range from the implications for players who are already exerting themselves playing in such excessively high temperatures, to the implications for burns when players or pedestrians come into contact with the hot surfaces, to the implications for small children who may come into contact with the extremely hot surfaces during non-sporting events. Particularly when installed in already built up areas, what affect does the extreme heat associated with artificial turf have on the surrounding community in terms of temperature?

Natural grass, by comparison, provides a natural cooling affect and helps to dissipate heat from neighboring developed areas.[39] "The temperature of natural grass rarely rises above 85 degrees Fahrenheit, regardless of air temperature." [40]

The heat impacts of artificial turf need to be considered in the context of today's changing climate. Global climate change is expected to dramatically increase the number of days over 100 degrees communities in our region experience. Depending on how aggressively global warming gasses are reduced in coming years, communities nearby Philadelphia will begin to experience in the range of 10 days (in lower emission scenarios) to 30 days (if higher emission scenarios continue to prevail) over 100°.[41] By later in this century seasonable temperatures are projected to rise 6°F to 14°F in summer (depending again on emission reductions achieved in the future). [42] Educators and decisionmakers selecting artificial turf based on its long-term viability and community impacts should consider the affect of global climate change to magnify the heat impacts of artificial turf.

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[36] Dr. C. Frank Williams and Dr. Gilbert E. Pulley, Synthetic Surface Heat Studies, Brigham Young University.
[37] T. Sciacca, The Thermal Physics of Artificial Turf, January 2008.
[38] Dr. C. Frank Williams and Dr. Gilbert E. Pulley, Synthetic Surface Heat Studies, Brigham Young University.
[39] James B. Beard & Robert L. Green, The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans, J. Environ Qual. 23:452-460 (1994).
[40] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.
[41] Union of Concerned Scientists, Confronting Climate Change in the U.S. Northeast ● New Jersey, 2007.
[42] Union of Concerned Scientists, Confronting Climate Change in the U.S. Northeast ● New Jersey, 2007.

Health Issues:

Direct human exposure to the hazardous substances contained in the rubber in-fill of artificial turf is believed to occur via three pathways: inhalation, skin contact, or ingestion including by children or infants who come into contact with the material.[43]

In October 2006 and January 2007, respectively, two sites in New York where synthetic turf has been used (the large, 3 year old, Parade Ground in Brooklyn; the relatively small 5 month old Sara D. Roosevelt Park in Manhattan) were analyzed. This testing found PAHs at hazardous levels (as per New York standards) at each of the sites. At both sites dibenzo (a.h)anthracene, a probable human carcinogen, was found at hazardous levels, with two other PAH forms, both possible human carcinogens, found at hazardous levels at the Parade Ground site. Research into the pathways by which these substances may be absorbed into the bodies of children and athletes via skin contact, ingestion or other pathways, is very limited with additional research needed.[44]

A study by the California Office of Environmental Health Hazard Assessment (OEHHA) summarized 46 studies that identified 49 chemicals which are released from tire crumb. Of the 49, "seven of the chemicals leached from tire shreds were carcinogens. OEHHA calculated a cancer risk of 1.2 in 10 million based on a ***one-time*** ingestion of the tire crumb rubber over a lifetime."[45] While there are limited studies which assert that recycled tire crumb are stable in the gastrointestinal tract and that therefore this is not a pathway for exposure, there are other studies which contradict these findings.[46]

Concerns have been raised about the potential implications of recycled tire in-fill for individuals with latex allergies and that inhalation could result in a systemic response, as opposed to a contact response.[47]

While, "the status of the information about human exposures to recycled tire crumb rubber in-fill … is not sufficient to determine the safety of the use of the product in situations that involve continuous episodes of human exposure;" [48] "the available

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[43] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.
[44] Rachel's' Democracy & Health News #992, Hazardous Chemicals in Synthetic Turf, Follow-up Analyses, April 12, 2007.
[45] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007 citing California Office of Environmental Health Hazard Assessment (OEHHA), Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products, January, 2007.
[46] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.
[47] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.
[48] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.

information is sufficient and strong enough to raise plausible questions with respect to acute toxicity for susceptible persons, and for cancer risks."[49]

There is great debate about whether artificial turf can increase exposure to, and infection from, MRSA (methicillin-resistant staphylococcus aureus). Reports including a December 21, 2007 article in the Bloomberg Press reporting the affliction of an 18 year old football player from MRSA as the result (according to the boy's doctor) of an abrasion he received from playing on artificial turf, and citing other findings linking MRSA infections with artificial turf,[50] are a great concern for parents and sports players alike. Defenders of artificial turf often refer to studies like that of the Penn State Department of Crop and Soil Sciences which finds that *Staphylococcus aureus* is commonplace in the human environment, including on both artificial turf and natural grass fields.[51] But even this study acknowledges that there is no conclusive evidence currently available that the source of bacteria causing the infections of sports players is not artificial turf. In addition, the study does not consider the link between burns sustained while playing on artificial turf and available bacteria as a pathway for infection. New studies are emerging that demonstrate that turf burns may be facilitating infection by acting as a pathway for infection.[52] Study has found that turf burns increased the risk of infection regardless of the type and timing of care provided the burn. [53]

Concussions (formally described as Mild Traumatic Brain Injury or MTBI) resulting from sports has, according to the US Centers for Disease Control, reached "epidemic proportions."[54] "'Mild' head traumas, and especially a series of such minor concussions can have long term, negative effects on cognitive function." [55] Study has documented that artificial turf increases the risk of MTBI over natural turf,

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[49] Environment & Human Health, Inc., Artificial Turf, Exposures to Ground-Up Rubber Tires, 2007.
[50] *Texas Football Succumbs to Virulent Staph Infection from Turf*, December 21, 2007, Bloomberg Press.
[51] Penn State Department of Crop and Soil Sciences, A Survey of Microbial Populations in Infilled Synthetic Turf Fields.
[52] A High Morbidity Outbreak of Methicillin-Resistant *Staphylococcus aureus* among Players on a College Football Team, Facilitated by Cosmetic Body Shaving and Turf Burns, study conducted 2004 for Connecticut Dept of Public Health, Student Health Services of Sacred Heart Univ, Centers for Disease Control and Prevention, Minnesota Dept of Public Health, Los Angeles County Dept of Health Svces; Dr. S.V. Kazakova et.al., A Clone of Methicillin-Resistant *Staphylococcus aureus* among Professional Football Players, The New England Journal of Medicine, Vol 352:468-475 No. 5, Feb. 3, 2005.
[53] A High Morbidity Outbreak of Methicillin-Resistant *Staphylococcus aureus* among Players on a College Football Team, Facilitated by Cosmetic Body Shaving and Turf Burns, study conducted 2004 for Connecticut Dept of Public Health, Student Health Services of Sacred Heart Univ, Centers for Disease Control and Prevention, Minnesota Dept of Public Health, Los Angeles County Dept of Health Svces.
[54] Dr. M. Shorten, J.A. Himmelsbach, BioiMechanica, Sports Surfaces and the Risk of Traumatic Brain Injury citing the US Centers for Disease Control.
[55] Dr. M. Shorten, J.A. Himmelsbach, BioiMechanica, Sports Surfaces and the Risk of Traumatic Brain Injury.

approximately doubling that risk, as well as causing a greater degree of trauma.[56] According to study, artificial turf presents a 5 times greater risk of the more severe head injury than natural turf, although it is still unknown the particular characteristics of the two surfaces that cause the difference in head injury incidence. [57]

Costs:

It is generally agreed that artificial turf costs more to install than natural grass, while natural grass costs more to maintain. Installation and maintenance costs for each must be assessed on a case by case basis depending on site specific conditions. But generally speaking, when the installation and maintenance costs of artificial turf are assessed for the life span of the turf, particularly when the cost of disposal is added, the cost of installing and maintaining natural grass is far less. The guaranteed life and/or lifespan of artificial turf is 8 to 10 years.[58] Some attempt to claim a longer life in order to assert a lower annual cost.[59] Comparative cost figures for artificial turf and natural grass include:

	Artificial Turf	Natural Grass
Source: San Francisco Rec and Parks[60]		
Installation	$800,000	$260,000
Annual Maintenance	$6,000	$42,000
Cost of Disposal	Unknown but significant as a hazardous waste	$0
Average annual cost for guaranteed life of 8 years.	$106,000	$74,500
Average annual cost for life of 10 years	$86,000	$68,000
Average annual cost for life of 15 years (maximum life span seen asserted in the	$59,333	$59,333

[56] Dr. M. Shorten, J.A. Himmelsbach, BioiMechanica, Sports Surfaces and the Risk of Traumatic Brain Injury.

[57] Dr. M. Shorten, J.A. Himmelsbach, BioiMechanica, Sports Surfaces and the Risk of Traumatic Brain Injury. See also K.M. Guskiewica, N.L. Weaver, D.A. Padua, W.E. Garrett Jr., Epidemiology of Concussion in Collegiate and High School Football Players, Sep-Oct 2000 & Does the Use of Artificial Turf Contribute to Head Injuries, The Journal of Trauma-Injury, Infection and Critical Care, Oct 2002 for the finding that artificial turf increases the level of injury in comparison to natural grass fields.

[58] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.

[59] San Francisco Recreation & Parks, Natural and Synthetic Turf: A Comparative Analysis, December 20, 2005.

[60] San Francisco Recreation & Parks, Natural and Synthetic Turf: A Comparative Analysis, December 20, 2005.

literature)		
Source: Facts About Artificial Turf and Natural Grass[61]		
Cost of construction and maintenance per sq. ft.	$7.80 – $10.75	With high quality soil amendments $6.50 – $7.95 With native soils $2.50 – $5.25
Cost of disposal per sq. ft.	$1.75 - $2.25	$0
Springfield College case study installation and maintenance average annual cost during 8 year guaranteed life of artificial turf – no disposal costs included	$105,000 ($800,000 install & annual maintenance of $5,000) For a 10 year life the figure is $85,000; for 15 years it is $58,377	$78,000 ($400,000 install & $28,000 annual maintenance) For a 10 year life the figure is $68,000; for 15 years it is $54,666
Source: A Guide to Synthetic and Natural Turfgrass for Sports Fields.[62]		
Cost of installation per square foot	$7.80 to $10.75	$2.50 to $5.25 if done with native soils $3.50 to $5.25 if done with combination of native soils and sand. $6.50 to $7.95 if done with sand and drainage
Annual Maintenance	$5,000 to $25,000	$4,000 to $11,000 as per the case studies provided
Disposal per square foot – note this cost does not include the cost of transportation or landfill	$1.75 to $2.25	$0

[61] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.

[62] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations. While the cost figures in this document focus on the southeast, the figures provide a sound comparative for the relative cost figures provided.

surcharges for environmentally controlled products		

Artificial turf made from rubber contains a number of hazardous substances. As a result disposal is neither easy nor cheap. It is important to identify and consider the cost of disposal when considering an investment in artificial turf. The life expectancy of artificial turf generally ranges from 8 to 10 years[63] – therefore disposal of artificial turf should be amortized over this time frame.

Miscellaneous:

Artificial Turf is available for use immediately upon installation. Natural Turf generally requires 2 growing seasons before it should be heavily used.[64]

One of the biggest supporting assertions for artificial turf is the increased level of playing time it provides. While natural grass may not equal artificial turf in playing time, natural soil and grass science has progressed significantly, greatly increasing its durability for sports. Modern natural grass sports fields include sand in their soil profile to resist compaction and a combination of grass varieties. Natural grass is becoming the preferred surface for a number of professional sports teams.

Natural grass fields require regular maintenance including, mowing and watering, and may also result in the use of fertilizers and potentially herbicides. But there are less environmentally harmful alternatives available for maintenance including electric mowing equipment and environmentally sensitive lawn care strategies that do not rely on environmentally harmful chemicals. A number of schools, including Radnor Township, Delaware County, PA, have successful policies that prevent the use of dangerous chemicals on school grounds.

Artificial turf also requires regular maintenance. Artificial turf maintenance includes sweeping, dragging and watering to provide a clean and uniform appearance.[65] In addition, as the result of wear, the infill may need periodic replenishment. [66] Management of an artificial turf field requires special knowledge inseam repair and snow removal. [67] Special solvents and cleansers are needed to remove tough debris. [68]

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[63] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.
[64] Communication with Nancy Bosold, Extension Educator, Turfgrass Management, Penn Stat Cooperative Extension, Berks County, Aug 15, 2007.
[65] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.
[66] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.
[67] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.

Artificial turf is at risk of damage from plastic bottles, cigarettes and/or gum as well as general trash thrown on the field. When damaged special repairs may be needed. Artificial turf also becomes a recipient of a variety of bodily fluids which cannot be cleansed by natural action as is the case with natural grass. Maintenance can include application of algaecides and fabric softener to mask the odor of the artificial turf. [69]

Artificial turf systems that claim chemical treatment is not required do not seem to provide a mechanism for handling the germs associated with the bodily fluids on the turf when there is an absence of rain or when it is captured and reused in newly emerging artificial turf cooling systems.

It is important to note that the environmental, health and safety impacts of artificial turf are in need of further study by independent experts. Until such time as there are conclusive findings regarding the environmental, health and safety impacts of artificial turf the Precautionary Principle would direct decisionmakers away from artificial turf and towards the traditional use of natural grass for sports and public play fields.

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[68] SportsTurf Managers Association, A Guide to Synthetic and natural Turfgrass for Sports Fields, Selection, Construction and Maintenance Considerations.
[69] Turfgrass Resource Center, Facts About Artificial Turf and Natural Grass.