League of Women Voters of Lawrence-Douglas County
P.O. Box 1072, Lawrence, Kansas 66044

RECEIVED
AUG 22 2011
City County Planning Office
Lawrence, Kansas

August 21, 2011

Mr. Richard Hird, Chairman
Members
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
Lawrence, Kansas 66044

RE: AGENDA ITEM NO. 6: TA-4-6-11, A TEXT AMENDMENT TO THE CITY OF LAWRENCE DEVELOPMENT CODE; SYNTHETIC TURF AS LANDSCAPING MATERIAL (MKM)

Dear Chairman Hird and Planning Commissioners:

Please see the attached letter that we sent to you for your June 19, 2011 Planning Commission meeting regarding the use of synthetic turf in landscaping—Agenda Item No. 6 in this current Agenda. In our June letter we commended the staff for their report on its use and their recommendation for denial.

We reiterate our position, and have two other points to mention against the use of artificial turf.

(1) Because of its heat absorption and reflection, in order to avoid that effect, it needs water for cooling, negating the argument that it saves water.

(2) Depending on its location, the heat island effect that it produces is likely to increase energy use for air conditioning, in contrast to the cooling effect of natural vegetation for landscaping materials.

Again we thank the staff for their recommendation for denial of this proposed text amendment, and hope that you will not recommend approval of TA 4-6-11.

Sincerely yours,

Alan Black

Caleb Morse
Member of the Board

Alan Black, Chairman
Land Use Committee

Attachment

ATTACHMENT

League of Women Voters of Lawrence-Douglas County
P.O. Box 1072, Lawrence, Kansas 66044

June 19, 2011

Mr. Charles Blaser, Chairman
Members
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
Lawrence, Kansas 66044

RE. ITEM NO. 11: TEXT AMENDMENT TO CITY OF LAWRENCE DEVELOPMENT CODE; CHAPTER 20; SYNTHETIC TURF AS LANDSCAPING MATERIAL (MKM)

Dear Chairman Blaser and Planning Commissioners:

We would like to thank the Staff for providing the valuable background information on the use of artificial turf. We especially appreciate staff recommendation of denial for its use in landscaping, and in its place the use of "low maintenance (natural) landscaping."

The reference material, as did the Staff Report, made clear the important reasons why this material should not be substituted for natural vegetation as groundcover. When it is so important to save energy, conserve our soil and protect the environment from pollution, the use of artificial turf for landscaping is not only counterproductive, but also environmentally damaging. As one of our members pointed out, artificial turf doesn't even save water because the other portions of the landscaping such as trees and shrubs must still be watered.

Thank you for your valuable information and negative recommendation on the use of artificial turf in landscaping.

Sincerely yours,

Caleb Morse
Member of the Board

Alan Black

Alan Black, Chairman
Land Use Committee

LWV6-19-11pcAgenda Item 11 Artif.turf LTR 2.wpd

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GLEE S. SMITH, JR.
OF COUNSEL

September 2, 2011

Via e-mail

Jane M. Eldredge
Email: jeldredge@barberemerson.com

Lara Burger
Lawrence-Douglas County Metropolitan Planning Commission
laraplancomm@sunflower.com

Re: Synthetic Grass Text Amendments

Dear Ms. Burger:

On behalf of our clients and myself, I wish to thank you for your time and attention to the issue of text amendments for synthetic grass. While we were disappointed in the initial result regarding the clarification of the appropriateness of synthetic grass for developments that require site plans, we are confident that synthetic grass will become an accepted product in the Lawrence-Douglas County community.

We believe that we were able to show that there were no longer any safety concerns arising from the use of high quality synthetic grass. As you know, it has been approved for our children's use at our local schools. It is a sustainable product that reduces many of the environmentally negative affects of development such as the application of chemicals (such as pesticides, fertilizers and herbicides) that get into the air we breathe, into our storm sewers and our sanitary sewers. It also eliminates the need to mow, to trim, to aerate, to reseed, etc. While synthetic grass does heat up faster than traditional grass, it also cools off faster. It has not created any problems for our high school athletes, band members or others who have used the high school fields.

Thank you for the time and attention that you spent considering this matter. If you have any questions about synthetic grass, please do not hesitate to contact me and I will give my best effort to find the answer to your questions.

Sincerely,

BARBER EMERSON, L.C.

Jane

Jane M. Eldredge

JME:dkh

MEMORANDUM

To: Jane Eldredge
From: Melissa Vancrum
Re: Artificial Turf use as Landscaping in Lawrence
Date: July 21, 2011

The Lawrence Development Code appears to prohibit the use of artificial turf as part of any landscaping plan except as an alternative compliance element. However, many other localities encourage the use of artificial turf in landscaped areas and offer rebates for installing it and reducing water usage. Horizon 2020 encourages sustainable landscaping and a sustainable physical environment. Such goals include the use of artificial turf in many other circumstances.

Artificial turf has evolved dramatically in the last decade in safety, environmental friendliness, attractiveness, and durability. It has received LEED points in a number of projects. Artificial turf today can be indistinguishable from natural grass without close inspection. In addition, it can support Lawrence's goal of sustainability through decreased water consumption, pesticide and herbicide runoff, emissions from mowers, and grass clipping waste. The natural grass lawn is not sustainable and several alternatives need to be evaluated. Perhaps a focused study session would be helpful to more clearly analyze today's artificial turf products and determine if they should become a beneficial option of the local landscape.

The Natural Grass Lawn

The manicured grass lawn is a status symbol of the wealthy borrowed from European manor houses.[1] It is not "natural". It is highly cultivated. The grass lawn

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[1] Donaldson, Cameron, History of the American Lawn, The Limpkin: Newsletter of the Spacecoast Audubon Society of Brevard County Florida.

proliferated in the U.S. after World War II as suburbia exploded. Americans previously used their yards primarily for growing food.

The natural grass yard is anything but natural. "[A] typical U.S. lawn, one-third of an acre in size, receives as much as 10 pounds of pesticides, 20 pounds of fertilizer, and 170,000 gallons of water annually. What's more, in a year a homeowner could spend the equivalent of a 40-hour workweek simply mowing that lawn (producing pollution equal to that created by driving a car 14,000 miles) and hundreds of dollars caring for it."[2] In the effort to cultivate a sustainable environment, it is difficult to support the natural grass lawn. However, many alternatives exist, including artificial turf.

Use

Artificial turf has evolved considerably since it was introduced in the 1960's for sports fields. Today artificial turf is used in parks, upscale residential yards, commercial developments, and golf courses. Its use is now widespread in professional sports and continually expanding for kids' athletic fields, including those of the Lawrence Unified School District. In recent years, artificial turf has become popular in celebrities' yards.[3] Walt Disney World, Disneyland and Epcot Center utilize artificial grass in some of their landscaping.[4] New York City uses the turf in some parks, and California agencies use it for some building landscaping.[5]

Appearance

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[2] Bogo, Jennifer, Going the Extra Yard, Audubon Magazine, March 2002.
[3] Synthetic Turf Becomes Latest Celebrity Trend, A-Listers and Landmarks Conserve Water While Beautifying Grounds" Synthetic Turf Council, May 31, 2001.
[4] Id.
[5] See California utillitClaudio, Luz, Synthetic Turf: Health Debate Takes Root, Environmental Health Perspectives, March 2008,

One reason for the widespread adoption of artificial grass is the improvement in look. Artificial turf can be selected in different shades of green with variegated strands and even the look of dead thatch mixed within the green blades.[6] Artificial turf also comes in different lengths to mimic the look of different types of natural grass even up close.

Health and Environmental Impacts

Use of artificial turf in select applications provides a significant benefit in the form of a large reduction in water consumption and allergens. Artificial turf may require occasional cleaning with water to remove dust and debris. This consumption is minimal compared to the needs of natural grass. Water is used on artificial turf athletic fields to cool the surface and provide traction before games. However, this would be unnecessary for landscaping purposes. Artificial turf also reduces allergens such as pollen in the environment. Crumb rubber from recycled tires often provides a sublayer for the artificial turf which makes the surface of the turf softer. Concerns have been raised about the irritation to latex allergy suffers due to the crumb rubber infill used in some artificial turf installations. However, levels of latex in tires are much lower than in latex gloves and other consumer products. To date no study has confirmed an issue of latex allergens released from artificial turf.[7]

Scientific studies are in disagreement over the potential for environmental harm from artificial turf. A CDC report identified lead dust on decaying old artificial turf

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[6] Synthetic Turf Council, http://www.syntheticturfcouncil.org/.

[7] *See, e.g.,* Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.

fields as a potential health issue.[8] While old artificial turf may contain high lead content, the grass produced today must meet strict lead standards.[9] The industry has done this in part by utilizing organic pigments. The Synthetic Turf Council has agreed to further restrict lead content by complying with stringent lead standards proposed for children's products.[10] In 2008, the Consumer Product Safety Commission released a report that concluded that young children are not at risk of lead exposure from artificial turf in athletic fields.[11] In addition, an EPA study found that lead from recycled tires was not a concern in artificial athletic fields and playgrounds.[12]

Other potential issues including zinc continue to be studied. The EPA found levels in of zinc in the air and surface to be below levels considered harmful at athletic fields and playgrounds using recycled tires.[13] A 2008 study found levels of zinc in stormwater collected from artificial athletic field drainage systems to be below the Connecticut water quality standard.[14] Other chemicals such as lead, selenium and cadium were not detected in the drainage.[15] While some studies have found elevated zinc levels, risk to humans is minimal as most zinc is absorbed into soil and does not dissolve in water.[16] In addition, zinc is not very toxic to humans so the danger is mostly to aquatic

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[8] Artificial Turf, Centers for Disease Control and Prevention, http://www.cdc.gov/nceh/lead/tips/artificialturf.htm

[9] Good News about Lead Problems in Artificial Turf, Center for Environmental Health, Fall 2010 Newsletter, http://www.ceh.org/component/content/article/454.

[10] STC's Voluntary Commitment, Synthetic Turf Council, http://www.syntheticturfcouncil.org.

[11] CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On, News from CPSC, U.S. Consumer Product Safety Commission, July 30, 2008.

[12] Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces, United States Environmental Protection Agency, December 10, 2009.

[13] Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces, United States Environmental Protection Agency, December 10, 2009.

[14] Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.

[15] Id.

[16] Artificial Turf Field Investigation in Connecticut, Final Report, University of Connecticut Health Center, Section of Occupational and Environmental Medicine, 21 July 27, 2010.

and plant life. The California Environmental Protection Agency released a report based on two New York studies of air quality showing that exposure was "unlikely to produce adverse health effects in persons using these fields."[17] "Extensive research has pointed to the conclusion that these fields result in little, if any, exposure to toxic substances."[18]

Some studies have indicated concern with elevated temperature on artificial athletic field surfaces. The surface temperature of the synthetic grass blades has been recorded upwards of 150 degrees on sunny days. However, in temperatures recorded at 5 feet above the surface is dramatically lower and in some cases shows little difference in temperature.[19] Also, athletic fields consist of a large expanse of unshaded open space. Landscaping includes smaller patches of artificial grass shaded by trees and buildings which will reduce temperatures.

Summary

Other cities have found artificial turf to be a beneficial part of their landscape encouraging it with rebates and laws and using it in city parks and building landscaping. California even passed a law banning Home Owner's Associations from prohibiting the use of artificial turf in landscaping.[20] It was recently vetoed by the governor who said the

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[17] Chemicals and particulates in the air above the new generation of artificial turf playing fields, and artificial turf as a risk factor for infection by methicillin-resistant Staphgylococcus areus (MRSA) Literature review and data gap idenfication, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, July 2009.
[18] Review of the Impacts of Crumb Rubber in Artificial Turf Applications, Rachel Simon, University of California, Berkeley, Laboratory for Manufacturing and Sustainability, College of Engineering & Manex Consulting, February 2010.
[19] Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.
[20] *See* Cal. S.B. 759 (2011).

decision was better left up to the associations.[21] New York Parks and California utilities have taken advantage of the benefits of artificial grass.

Use of artificial grass may provide a sustainable alternative to natural grass in landscaping in Lawrence. Artificial turf reduces water use, pesticides, herbicides, emissions, grass clipping waste. Lead use has been dramatically reduced through industry efforts such as using organic pigmentation. There does not appear to be a clear threat to human health through release of zinc or other chemicals though studies continue. In addition, artificial turf can provide an attractive look as it is used for upscale homes, building landscaping, and even Disney World.

Recommendation

In a study session to which USD #497 officials who have installed and used artificial turf athletic fields would be invited, Lawrence can better determine whether to permit artificial turf use in landscaping as most other communities have and as the local school district has chosen for children to play on.

[21] Jerry Brown vetoes artificial turf bill backed by conservationists, Capitol Alert, The Sacramento Bee, July 15, 2011.

NEWS from CPSC

U.S. Consumer Product Safety Commission

Office of Information and Public Affairs Washington, DC 20207

FOR IMMEDIATE RELEASE
July 30, 2008
Release #08-348

CPSC Hotline: (800) 638-2772
CPSC Media Contacts: (301) 504-7908

CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On

WASHINGTON, D.C. - The U.S. Consumer Product Safety Commission (CPSC) staff today released its evaluation of various synthetic athletic fields. The evaluation concludes that young children are not at risk from exposure to lead in these fields.

CPSC staff evaluation showed that newer fields had no lead or generally had the lowest lead levels. Although small amounts of lead were detected on the surface of some older fields, none of these tested fields released amounts of lead that would be harmful to children.

Lead is present in the pigments of some synthetic turf products to give the turf its various colors. Staff recognizes that some conditions such as age, weathering, exposure to sunlight, and wear and tear might change the amount of lead that could be released from the turf. As turf is used during athletics or play and exposed over time to sunlight, heat and other weather conditions, the surface of the turf may start to become worn and small particles of the lead-containing synthetic grass fibers might be released. The staff considered in the evaluation that particles on a child's hand transferred to his/her mouth would be the most likely route of exposure and determined young children would not be at risk.

Although this evaluation found no harmful lead levels, CPSC staff is asking that voluntary standards be developed for synthetic turf to preclude the use of lead in future products. This action is being taken proactively to address any future production of synthetic turf and to set a standard for any new entrants to the market to follow.

As an overall guideline, CPSC staff recommends young children wash their hands after playing outside, especially before eating.

A Video News Release will feature b-roll of synthetic turf in use, on-site and laboratory testing, and soundbites in English and Spanish.

Video Feed Satellite Coordinates

Wednesday, July 30, 2008
2:30 PM – 3:00PM ET
Galaxy 25
Transponder 13
C-Band
Downlink Freq: 3960V

Thursday, July 31, 2008
10:30 AM – 11:00AM ET

Galaxy 3
Transponder 21
C-Band
Downlink Freq: 4120H

For Technical Information, DURING FEED ONLY, contact Daniel Conboy at (800) 920-6397 x 221.

EPA: United States Environmental Protection Agency

Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces

Release date: 12/10/2009

Contact Information: Dale Kemery kemery.dale@epa.gov 202-564-7839 202-564-4355

FOR IMMEDIATE RELEASE
December 10, 2009

WASHINGTON - The U.S. Environmental Protection Agency has released results of a limited field monitoring study of artificial-turf playing fields and playgrounds constructed with recycled tire material or tire crumb. The study was intended to gain experience conducting field monitoring of recreational surfaces that contain tire crumb. EPA will use the information to help determine possible next steps to address questions regarding the safety of tire crumb infill in recreational fields.

"The limited data EPA collected during this study, which do not point to a concern, represent an important addition to the information gathered by various government agencies," said Peter Grevatt, director of EPA's Office of Children's Health Protection. "The study will help set the stage for a meeting this spring, where EPA will bring together officials from states and federal agencies to evaluate the existing body of science on this topic and determine what additional steps should be taken to ensure the safety of kids who play on these surfaces."

Recycled tire material, or "tire crumb," is used in many applications, including as a component in synthetic turf fields and playground installations. In response to concerns raised by the public, EPA conducted a limited "scoping study" of tire crumb, which consisted of collecting air and wipe samples at three locations near EPA laboratories at Raleigh, N.C., Athens, Ga., and Cincinnati, Ohio. Sampling also was conducted in the Washington, D.C. area.

The limited study, conducted in August through October 2008, found that the concentrations of materials that made up tire crumb were below levels considered harmful. However, given the limited nature of the study (limited number of constituents monitored, sample sites, and samples taken at each site) and the wide diversity of tire crumb material, it is not possible, without additional data, to extend the results beyond the four study sites to reach more comprehensive conclusions.

The study confirmed that most of the methods tested were accurate, reproducible and appropriate for measuring concentrations of tire crumb constituents and therefore can be used in future studies.

Study findings

- Particulate matter, metals and volatile organic compound concentrations were measured in the air samples and compared with areas away from the turf fields (background levels). The levels found in air samples from the artificial turf were similar to background levels.

- No tire-related fibers were observed in the air samples.

- All air concentrations of particulate matter and lead were well below levels of concern.

- More than 90 percent of the lead in the tire crumb material was tightly bound and unavailable for absorption by users of the turf fields.

- Zinc, which is a known additive in tires, was found in tire crumb samples. However, air and surface wipe monitoring levels of zinc were found to be below levels of concern.

EPA is aware that studies by other agencies were undertaken or completed while this survey was under way. EPA is planning a 2010 meeting with federal and state agencies to review all new study data and determine next steps.

Read the full 123 page report: http://www.epa.gov/nerl/documents/tire_crumbs.pdf

More information on artificial turf: http://www.epa.gov/nerl/features/tire_crumbs.html

STC's Voluntary Commitment

Throughout the years, the synthetic turf industry has developed and tested new pigment formulations to enable the removal of all or most of the lead from over 90% of the pigments used to color synthetic turf. Now the STC plans to reduce lead levels in the remaining 10% of all colored fibers that still require lead chromate to meet the consumer's demand for longterm colorfastness.

The STC voluntarily agrees to comply with the revised lead restrictions currently proposed for children's products in H.R. 4040. Specifically, the level of lead will be reduced in all pigments used to color synthetic turf to 300 ppm or less by no later than January 1, 2010, and to 100 ppm or less by no later than January 1, 2012.

Related Links

- Guidelines and Professional Standards
- Technical Guidelines
- ASTM Standards
- Voluntary Lead Standards
- Business Conduct and Ethical Standards

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Google Map / Download Directions

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manex The Corporation for Manufacturing Excellence

Manex and UC Berkeley Issue Study on Recycled Rubber in Artificial Turf Applications

Review of studies from past 12 years combined with independent analysis yields most comprehensive report to date.

SAN RAMON, CA – April 5, 2010 -- The Corporation for Manufacturing Excellence (Manex) and the Laboratory for Manufacturing and Sustainability (LMAS) at the University of California, Berkeley, have released the results of their study on the impact, effectiveness, and safety of recycled tire crumb in artificial turf applications.

The Manex/UC Berkeley study reviews the benefits of recycled crumb rubber in artificial turf applications, providing insight foı the material's growth in popularity and addressing common issues surrounding its efficacy and safety. The research also analyzes the primary features, economic benefits and other advantages that have led to the widespread expansion and adoption of artificial turf using recycled crumb rubber infill.

The research conducted by Manex and Berkeley is among the most comprehensive reports to date, reviewing and assessing existing studies from the past 12 years, as well as containing independent analysis. The conclusions of this study validate key findings from other recent studies, demonstrating the materials are both cost-effective and safe. Reasons for the dramatic growth in popularity of this material include excellent playability, all-weather availability, increased playing hours, significantly reduced maintenance, cost-effective investment, safe application, fewer injuries and positive environmental impacts, through the creative re-use of materials.

Jonathan Lee, Vice President at Manex adds perspective to misconceptions about crumb rubber. "Prior studies have been limited in scope, often assessing artificial turf and crumb rubber in and of themselves rather than in comparison to their real-world substitutes. Instead of focusing entirely on the potential hazards, these materials should be compared against the popular alternative, such as natural turf, for a balanced perspective. For example, even natural turf is not necessarily a benign or sterile material, and may contain chemicals, pesticides, chemical and organic fertilizer (such as manure) and other potential hazards. Grass fields are almost always maintained using equipment that generates pollution. In other words, artificial turf containing recycled crumb rubber is quite safe and cost-effective when compared to natural turf alternatives."

According to Rachel Simon of UC Berkeley who led the study for LMAS, "People tend to think that products more closely derived from nature are safer and better for the environment than those that are synthetic based. However, in many cases synthetic materials perform better than their 'more natural' counterparts across the various metrics used in evaluations. This has been shown to be the case with artificial turf, which offers several distinct advantages over grass, while using materials that are already prevalent in peoples' lives, such as recycled tires."

As part of this study, independent product test results were obtained and reviewed for crumb rubber produced by BAS Recycling of Moreno Valley, CA, a high-volume producer of cryogenic crumb rubber for synthetic turf. The test results confirmed that crumb rubber is safe for use in sports and athletic field environments.

About Manex
Founded in 1995, The Corporation for Manufacturing Excellence (Manex) provides a broad array of proven advisory and implementation solutions exclusively to manufacturers, distributors and their supply chains, enabling them to increase growth, productivity, quality and profitability. Manex delivers high-impact solutions in four key areas: strategy, people, process and performance. Meaningful, rapid impact and ROI are achieved through a modular-yet-holistic approach encompassing corporate strategy and planning, marketing strategy, training and development, Lean Manufacturing, supply chain and logistics, Six Sigma, ISO, and performance management systems. Manex is the Northern California affiliate of the NIST Manufacturing Extension Partnership.

For more information about Manex, visit www.manexconsulting.com.

About UC Berkeley's Laboratory for Manufacturing and Sustainability (LMAS)
Research at LMAS is concerned with the analysis and improvement of manufacturing processes, systems and enterprises and the development of tools to analyze their sustainability. Research is focused on: metrics and analytical tools for assessing the impact of processes, systems and enterprises, modeling sustainable, environmentally-conscious

manufacturing processes andsystems, green supply chains, manufacturing technology for reduced impact manufacturing, technology for producing advanced energy sources or storage, cleantech and sustainable products and systems. Specific projects include: design for sustainability, green machine tools, sustainable packaging, impact and life cycle assessment tools for manufacturing (including embedded energy, materials, water, consumables), metrics for assessing green technology ROI (e.g. GHG ROI, Energy payback time, etc.), risk assessment for energy and resource use and enterprise carbon accounting.

For more information about UC Berkeley and LMAS, visit http://lma.berkeley.edu.

UNIVERSITY OF CALIFORNIA, BERKELEY
LABORATORY FOR MANUFACTURING AND SUSTAINABILITY
COLLEGE OF ENGINEERING

Review of the Impacts of Crumb Rubber in Artificial Turf Applications

Rachel Simon
University of California, Berkeley

February 2010

Prepared For:
The Corporation for Manufacturing Excellence (Manex)

manex
Business Transformation. Delivered.

Prepared By:
UNIVERSITY OF CALIFORNIA, BERKELEY
LABORATORY FOR MANUFACTURING AND SUSTAINABILITY

LMAS

About The Corporation for Manufacturing Excellence (Manex)

Founded in 1995, The Corporation for Manufacturing Excellence (Manex) provides a broad array of proven advisory and implementation solutions exclusively to manufacturers, distributors and their supply chains, enabling them to increase growth, productivity, quality and profitability. Manex delivers high-impact solutions in four key areas: strategy, people, process and performance. Meaningful, rapid impact and ROI are achieved through a modular-yet-holistic approach encompassing corporate strategy and planning, innovation, marketing strategy, training and development, lean manufacturing, supply chain and logistics, Six Sigma, ISO and performance management systems.

Manex is a public-private partnership and the Northern California affiliate of the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP) program. We work in concert with MEP to solve industry challenges by advancing best practices in manufacturing strategy, innovation, operations, methods and processes.

For more information about Manex, visit www.manexconsulting.com

About UC Berkeley's Laboratory for Manufacturing and Sustainability (LMAS)

Research at LMAS is concerned with the analysis and improvement of manufacturing processes, systems and enterprises and the development of tools to analyze their sustainability. Research is focused on: metrics and analytical tools for assessing the impact of processes, systems and enterprises, modeling sustainable, environmentally-conscious manufacturing processes and systems, green supply chains, manufacturing technology for reduced impact manufacturing, technology for producing advanced energy sources or storage, cleantech and sustainable products and systems. Specific projects include: design for sustainability, green machine tools, sustainable packaging, impact and life cycle assessment tools for manufacturing (including embedded energy, materials, water, consumables), metrics for assessing green technology ROI (e.g. GHG ROI, Energy payback time, etc.), risk assessment for energy and resource use and enterprise carbon accounting.

For more information about UC Berkeley and LMAS, visit http://lma.berkeley.edu

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EXECUTIVE SUMMARY

There are many characteristics of infill systems that have lead to resurgence in the popularity of synthetic turf. The industry has been experiencing a period of growth with the development of crumb rubber infill system, which initially debuted in 1997. These systems are preferable to the carpet-like turf of the past because they more closely resemble natural grass.

Crumb from used tires have been used in artificial turf fields for over a decade, and even longer in playgrounds and tracks. The EPA's view is that scrap tires are not hazardous waste and approves the use of crumb from used tires for sports fields. Recycled tires that were used in this capacity prevented an estimated 300 million pounds of ground rubber from scrap tires from ending up in landfills in 2007 (Rubber Manufacturers Association, 2009). In addition, this application uses recycled material; scrap tires, which otherwise would have to be handled as waste. It typically takes between 20,000 and 40,000 scrap tires to produce enough infill to cover a football field (City of Portland, 2008). The EPA's decree has afforded the opportunity for 4.5% of U.S. scrap tire to be applied as crumb rubber in sports surfacing in 2007 (Rubber Manufacturers Association, 2009).

The Corporation for Manufacturing Excellence (Manex), a National Institute of Standards and Technology Manufacturing Extension Partnership (NIST MEP), in collaboration with the Laboratory of Manufacturing and Sustainability (LMAS) at the University of California, Berkeley have studied the benefits of crumb rubber in artificial turf applications, and provide research and insight as to why this material has grown in popularity. This analysis will also include the primary features, economic benefits and other advantages that have led to the widespread expansion and adoption of artificial turf that includes the crumb rubber.

Playability is one of the primary benefits of synthetic turf, with the newer generation of infill systems exhibiting improved playability over traditional synthetic varieties. The play quality of a field is most impacted by aspects of construction and maintenance. Irrespective of the field type, the quality of play can vary dramatically according to factors such as: moisture, hardness, grass cover and root density (Orchard, 2002), naps in the turf, the distribution and compaction of infill, and infill depth (James and McLeod, 2008). Most literature comparing the play quality of natural and synthetic fields suggests that the differences between them have miniscule affects on playability in comparison with variance in the set-up of the field itself. Where differences do emerge, data is out of date and not applicable to current generations of turf technology.

Research indicates that artificial turf provides a greater number of playable hours than natural turf. Studies suggest that average hours of playability in a three-season year for synthetic turfs range between 2,000 and 3,000 hours, with most research pointing towards 3,000 hours. Natural fields, on the other hand, provide far less playability, with studies estimating a range between 300 and 816 hours in a three-season year on average. Studies show, furthermore, that switching from natural to synthetic turf results in a drastic increase of play-time. This is due, in part, to the vulnerability of natural fields to fluctuations in weather. In addition, natural fields require rest, with managers recommending against using fields more than 20-24 hours a week. Natural fields are also vulnerable to poor management, which can detract significantly from use-time.

Synthetic turf is praised for its availability in all weather conditions: more use per year, and a quick install. This factor influenced the amount of use that can be had on the turf, and thus the payback on investment on the turf. It can be used quickly after installation, usually within a few days, rather than the weeks it takes for a sod to become robust enough for use. Also, it can be used in snow, and in general is not affected by precipitation due to the drainage system involved. However, high heat can create an obstacle for synthetic turf use, as the surface can become uncomfortable to play on. It has been shown that the difference between turf temperatures and the surrounding air can be significant. However, there are means to temper such effects, and the field can still be made useable. Also, the use of turfs are not typically greatest during the hottest parts of the year, as sports seasons typically fall in the late summer through the spring. These impairments do not compare to the degree to which natural fields are compromised during rain and snow. With all weather considered, artificial turf has greater availability over natural grass when taking weather into account.

The value of a field can be determined by its availability and by amount of maintenance a field requires. The Sports Turf Managers Association (2005) states that these costs depend on: the amount of use; the type of use (i.e. sports played); climate and weather; existing soil and terrain; irrigation and water needs; labor; field type; and field security (protection against vandalism, non-regulated play, etc.). Activities that can be classified as grooming are the most important components of maintenance for both turf types. In addition, debris control, additional cleaning, and needs-specific maintenance may be required. A brief review of suggested maintenance practices produced a list of over 22 possible pieces of equipment, and 8 possible supplies for field maintenance. In general the maintenance that is necessary for a synthetic field has a similar maintenance requirement on a natural field. However, natural fields require a more nuanced balance of activities such as mowing, fertilization, and aeration to ensure their health.

One of the primary concerns for organizations considering the implementation of synthetic turf is whether it poses any significant health or injury risks. Numerous studies have been conducted assessing the likelihood of injury on natural grass and synthetic turf. Some studies reveal that there is very little difference in the rate, type, severity, or cause of injuries obtained on natural grass or synthetic turf (Fuller et al. 2007a, 2007b). A more recent study by Meyers (2010) shows that the latest generation of synthetic surface, FieldTurf, is safer to play on than natural grass fields. Through the analysis of the various injuries that occurred over the course of 465 collegiate games, Meyers shows that FieldTurf has lower incidence of: total injuries, minor injuries (0-6 days lost), substantial injuries (7-21days lost), and severe injuries (22 or more days lost). FieldTurf also had significantly lower injury rates that natural turf when comparing across play or event type, grade of injury, or various field conditions and temperatures. In addition, there was no significant difference found in head, knee, or shoulder trauma between the two playing surfaces. Meyers' (2010) research is the most comprehensive study to date, and it addresses previous inconsistencies in findings on injury patterns.

The use of athletic fields made of recycled tires has also been called into question because of concerns regarding toxicity. Authorities are worried that because of the chemical content of the material, exposure by various means could endanger the health of field users, especially children. However, extensive research has pointed to the conclusion that these fields result in little, if any, exposure to toxic substances.

A review of existing literature points to the relative safety of crumb rubber fill playground and athletic field surfaces. Generally, these surfaces, though containing numerous elements potentially toxic to humans, do not provide the opportunity in ordinary circumstances for exposure at levels that are actually dangerous. Numerous studies have been carried out on this material and have addressed numerous different aspects of the issue. For the most part, the studies have vindicated defenders of crumb rubber, identifying it as a safe, cost-effective, and responsible use for tire rubber. As part of this study, independent product test results were obtained and reviewed for crumb rubber produced by BAS Recycling of Moreno Valley, CA, a high volume producer of cryogenic crumb rubber for synthetic turf. Test results confirm that crumb rubber is safe for use in sports and athletic field environments.

In general, the environmental impacts of natural grass are more complex than those of synthetic turf. This is due in large part to the fact that natural grass requires the continual addition of inputs to sustain a field's health. As with any agricultural practice, draws on water and the addition of agrochemicals can become problematic. These practices draw on scarce resources and have the potential to effect surrounding ecosystems. Additionally, the maintenance of grass is associated with the use of large quantities of fuel, to mow grass down to the appropriate length. The Athena Institute sufficiently shows the weight of these impacts in regards to global warming. However it is recommended that a more comprehensive inclusion of material inputs into grass maintenance be calculated in any future life cycle assessments.

The environmental issues related to synthetic turf mainly revolve around the use and disposal of materials. Many see the use of recycled waste products for field infill as one of the primary benefits of artificial systems. However, such systems also require the use of many virgin materials. As such, the greatest greenhouse gas emissions of either two system types are the impacts associated with the production of synthetic turf components. These material impacts increase the total emissions by a multiplicative factor when considering the entire life cycle, due to related increases in processing and transportation needs.

1.0 INTRODUCTION

1.1 Background

Growth in the popularity of synthetic turf has been followed by increased scrutiny of its usage. The industry has been experiencing a period of growth with the development of crumb rubber infill system, which initially debuted in 1997. These systems are preferable to the carpet-like turf of the past because they more closely resemble natural grass. They consist of longer simulated grass blades that do not compact because of the infill material that supports it. As of 2008 over 3,500 new-generation synthetic turf fields had been implemented (Jackson, 2008). In addition over half of all NFL teams currently play on synthetic turf (Synthetic Turf Council, 2008a).

There are many characteristics of infill systems that have lead to resurgence in the popularity of synthetic turf. First, it is believed that infill systems perform better than traditional synthetic turf for athletic applications (Popke, 2002). Also, artificial turf is available year around and requires less monetary and natural resources than natural grass.

Crumb from used tires have been used in artificial turf fields for over a decade, and even longer in playgrounds and tracks. The EPA's view is that scrap tires are not hazardous waste and approves the use of crumb from used tires for sports fields. Recycled tires that were used in this capacity prevented an estimated 300 million pounds of ground rubber from scrap tires from ending up in landfills in 2007 (Rubber Manufacturers Association, 2009). In addition this application uses recycled material: scrap tires, which otherwise would have to be handled as waste. It typically takes between 20,000 and 40,000 scrap tires to produce enough infill to cover a football field (City of Portland, 2008). The EPA's decree has afforded the opportunity for 4.5% of U.S. scrap tire to be applied as crumb rubber in sports surfacing in 2007 (Rubber Manufacturers Association, 2009).

1.2 Objectives

The Corporation for Manufacturing Excellence (Manex) in collaboration with the Laboratory of Manufacturing and Sustainability (LMAS) at the University of California, Berkeley has been enlisted to study the benefits of crumb rubber in artificial turf applications, and provide research and insight as to why this material has grown in popularity. This analysis will also include the primary features, economic benefits and other advantages that have led to the widespread expansion and adoption of artificial turf that includes the crumb rubber.

1.3 Scope of Work

This study identified and assessed existing research on the benefits, advantages and safety concerns of crumb rubber. A sample from a California scrap tire recycler was also assessed to support and confirm key conclusions. Material was provided from a leading cryogenic crumb rubber producer, BAS Recycling, primarily for the purpose of reviewing and assessing safety concerns. Test results from an independent lab were obtained, and then reviewed, against some of the key health concerns regarding contamination. The research provided by Berkeley sought to confirm or invalidate the following findings from existing research/studies:

- **Excellent Playability** – synthetic turf does not inhibit or deflect the bounce or roll of balls. Traction, rotation and slip resistance, surface abrasion and stability meet the rigorous requirements of the most respected sports leagues and federations.

- **All-weather Availability** – synthetic turf can be used within hours of installation, in all types of weather. No significant downtime is required in case of rain, drought or other climate conditions. Increased availability equates to higher return on investment for owners, and more practice and skill development for players. Additional questions to be answered are: whether artificial turf can be utilized more per year without the rest that grass fields require, and what the maximum hour of playing time is for the two field types.

- **Increased Playing Hours** – in most climates, synthetic turf fields can be used 3,000 hours per year over a four-season window, with no damage to the turf. Natural turf fields become unplayable after 680 to 816 hours per year, and are typically available only for three seasons.

- **Reduced Maintenance** – natural turf fields require approximately 70,000 gallons of irrigation water each week, approximately 15 to 20 pounds of fertilizer each year per 1,000 square feet of turf, plus herbicides and pesticides. Synthetic turf maintenance costs are two to three times less than natural turf. No mowing, irrigation or chemicals are required.

- **Cost-effective Investment** – synthetic turf fields are typically warranted for about 3,000 hours of play per year, with no "rest" required. For schools with sufficient land, it would take three or four natural fields to withstand the usage of one synthetic turf field. Because of its consistent availability, a synthetic turf field is also a reliable source of rental revenue for schools and communities. In addition, the total cost of ownership for fields will be explored, including all of the maintenance resources (water, fertilizer, pesticides, labor, and equipment) needed to upkeep a field.

- **Generally Safe Application** – for most common and typical uses, the materials (e.g. crumb rubber) is a safe alternative to natural materials and landscaping. While the general public is exposed to articles suggesting the need to further assess the material, no conclusive study has proven these materials as unhealthy, nor have high incidences of physical harm occurred from approved and proper uses. Recent issues that have surfaced relate to Carbon Black and Lead, however, for the vast majority of applications, serious physical harm has not occurred from these particulates.

- **Fewer Injuries** – synthetic turf fields are far more uniform and consistent than the natural turf fields most schools and communities are able to maintain. Also, they are made of resilient materials that provide a level of impact attenuation that is difficult to obtain on hard, over-used natural turf fields. An NCAA study comparing injury rates during the 2003-2004 academic year showed that the injury rate during practice was 4.4% on natural turf and 3.5% on synthetic turf.

- **Environmentally Friendly** – using synthetic turf eliminates the need for water, pesticides, herbicides and fertilizers. The used auto tire rubber used as infill recycles 25 million used auto tires per year that would otherwise end up in U.S. landfills. The EPA encourages the use of recycled auto tires for playgrounds, running tracks and sports fields.

2.0 IMPACT ANALYSIS

2.1 Playability

Playability is one of the primary benefits of synthetic turf, with the newer generation of infill systems exhibiting improved playability over traditional synthetic varieties. Research suggests that the play quality of any particular field is determined more by how the field is constructed and maintained than by the type of field material that is used. Factors such as moisture, soil compactness, and root or infill density can cause wide variance in play quality, playing a greater role in determining quality than the type of field. Components of qualitative play factors can be organized into ball-surface interactions and player-surface interactions. (Bell, Baker, and Canaway, 1985; Schmidt, 1999)

A surface can decrease play performance and prevent players from achieving their objectives. Pasanen et al. (2007a) note that there are two factors that influence surface-related injuries: shoe-surface friction and surface hardness. Schmidt (1999) also includes surface evenness as a factor affecting player-surface quality.

Friction can impact play by leading to slippage, foot fixation, and increased running speeds resulting in collisions and ankle and knee injuries. Surface friction depends on multiple factors. Orchard (2002) notes that moisture, hardness, grass cover, and root density are turf properties that influence shoe-surface traction. Existing research comparing the rate of surface traction injuries on synthetic and natural fields is outdated, as it considers previous generations of synthetic turf rather than the current infill systems. For instance, Powell and Schootman (1992) compare injury rates of natural and synthetic fields from 1980-1989, and Orchard and Powell (2003) consider rates from 1989-1998. These studies predate the newer generation of turf, which was first implemented in 1997. In addition evaluations that attempt to compare field types may be difficult, as it has been shown other factors, such as weather, affect injury rates (Orchard and Powell, 2003). Findings such as these support the notion that shoe-surface traction impacts injury rates and play in general, but there is not sufficient evidence evaluating the affects of traction in the newer generations of synthetic turf.

Similarly, surface hardness can affect player-surface interactions. Ground reaction force is the impact energy caused by an athlete's foot striking the playing surface. This force has been cited as a risk factor in causing acute and long-term injuries (Boden et al., 2000; Chappell et al., 2007; LaStayo et al., 2003). Surface hardness is one measure used to assess the ability of the surface to absorb foot striking impacts. Brosnan and McNitt (2008a, 2008b) note that natural and synthetic turfs have comparable surface hardness values. For natural surfaces, hardness is related to the amount of soil moisture, while for infilled synthetic surfaces, infill depth is a major factor in determining surface hardness. Synthetic turf tends to provide a fairly consistent playing surface. This is partially because surfaces are leveled before the application of synthetic turf. Furthermore, synthetic surfaces are less vulnerable than natural turf to play-related damage such as divots. While factors such as the distribution of infill can impact the uniformity of synthetic fields, synthetic turfs tend to be more even throughout.

Several aspects of ball-surface interactions have been identified for evaluating play quality. Schmidt (1999) cites rebound, spin, and roll as the principle characteristics of ball-surface interaction. Meanwhile, James and McLeod (2008) list roll, bounce, spin, and deceleration as important measures of playability. Holms and Bell (1986) note the interrelationship between eleven factors on play characteristics such as rebound resilience, traction, and deceleration for natural fields.

The play quality of a field is most impacted by aspects of construction and maintenance. Irrespective of the field type, the quality of play can vary dramatically according to factors such as: moisture, hardness, grass cover and root density (Orchard, 2002), naps in the turf, the distribution and compaction of infill, and infill depth (James and McLeod, 2008). Most literature comparing the play quality of natural and synthetic fields suggest that the differences between them have miniscule affects on playability in comparison with variance in the set-up of the field itself. Where differences do emerge, artificial turf appears to be equal to or better than natural turf, due to its greater consistency. While such findings are incomplete, because of the lack of studies that evaluate the newer generations of turf technology, there were no studies that contradicted the superiority of synthetic turf.

2.2 All-weather Availability

Playability can also be evaluated according to its availability to users. Maintenance, weather, and resting periods are all factors influencing the amount of time that can be spent on a field. In addition, use-time plays a role in evaluating its value and the return on investment for owners. Synthetic turf has been praised for its superior availability to natural turf, their quick installation, and accessibility in all climates and weather types.

Synthetic turf can be installed quickly and is usable within hours of installation. Several professional installers quote an installation time of about two to three days, a time that can be significantly longer if the field is initially in poor condition (e.g. requires the removal of a considerable portion of the existing field). The European Synthetic Turf Organization (2010) estimates that an installations can take as long as two to three weeks. Yet once a synthetic field is installed, it can be used almost immediately, unlike sod fields, which can take up to a month to be fully functional, and seeded fields, which take considerably longer to become fully rooted.

Additionally, synthetic turf can be used in almost any climate and weather, while natural turf is more limited. Natural turf has reduced availability during rain or snow, and precipitation can cause grass turfs to become soggy or muddy. Meanwhile, snow can be difficult to remove from these fields, and may permanently damages grasses. Comparatively, winter weather conditions and precipitation are not harmful to synthetic surfaces, and if necessary snow and ice can be removed for play.

However, the playability of synthetic turfs may be hampered by hot weather conditions. The New York City Department of Health and Mental Hygiene (2010) reports that synthetic turf fields may become too hot to play on when temperatures are high. The material in synthetic turf absorbs heat, resulting in surface temperatures that are greater than surrounding air and other surfaces. However, these affects can be mitigated. Williams and Pulley (2002) found that increases in surface temperature were more impacted by solar radiation than ambient temperatures. As a result, surfaces can be made cooler when they receive less direct light exposure, like when they are painted lighter colors or are shaded. Temperature increases can also be assuaged by irrigation. Yet these solutions do not entirely mitigate hot temperatures. The difference between turf temperatures and the surrounding air can be significant. In one study, Brakeman (2004) found turf temperatures to be over 100 degrees hotter than surrounding air temperatures. In another, Williams and Pulley (2002) found synthetic surface temperatures as high as 200 degrees. Cooling effects have brief results (Williams and Pulley, 2002; McNitt, Petrunak, and Serensits, 2008) and can result in a large increase in resource use and costs.

While high heat can create an obstacle for synthetic turf use, there are means to temper such effects. Also, use of turfs are not typically greatest during the hottest parts of the year, as sports seasons typically fall in the late summer through the spring. These impairments do not compare to the degree to which natural fields are compromised during rain and snow. With all weather considered, artificial turf has greater availability over natural grass when taking weather into account.

2.3 Increased Playing Hours

Artificial turf provides a greater number of playable hours than natural turf. The Synthetic Turf Council (2008), an artificial turf advocacy group, estimates that natural fields provide 680-816 hours of play in a three-season year, as compared with 3,000 hours for synthetic turf. Kay and Vamplew (2006) offer an alternative estimate with approximately 300 hours of play time for natural grass, 800 for reinforced turf, and 3,000 for artificial turf. James and McLeod (2008) calculate the usable hours of synthetic turf to be closer to 2,000 hours per year on average, with a range from 450 to 4,200 hours. They also note that the typical weekly hours of use for synthetic turf pitches were 44 hours, as compared to 4.1 hours for natural turf. In direct applications of synthetic turf, many note a measured increase in use-time of these field types. For instance, with a switch from natural to synthetic turf, the City of Newport Beach (2009) found a 49% increase in field availability, and the Charlottesville City Schools reported a 60% increase in available playing time.

Weather is an important factor in use-times for natural turf. While artificial turf fields recover quickly after precipitation, natural fields may take days before they become playable again. Weather-related losses in use-time can be considerable. Even in the relatively temperate climate of Newport Beach (2009), Recreation and Senior Services Department staff estimates that fields are unavailable an average of ten days a year because of rain. In addition to weather-related use-time loss, all natural fields must be given time to "rest" to allow for growth. The Synthetic Turf Council (2008) states that the managers of natural fields recommend against the use of natural fields beyond 20-24 hours per week, to avoid overburdening them. In addition, poor management can impact the availability of fields. If elements such as drainage systems and watering and maintenance schedules are improperly planned they can unnecessarily impede on the use-time of fields.

2.4 Maintenance

The maintenance required, along with the number of playing hours a surface can provide, are key factors in assessing the value that a certain turf type provides. Reduced maintenance is often cited as one of the major benefits for synthetic turf. However, artificial turf does require a minimum level of upkeep. The savings in maintenance are apparent when considering the useful hours that are returned on the cost and time required for maintenance. One estimate for an ideal level of maintenance for a synthetic field is one hour for each ten hours of use (James and McLeod (2008)). Below is a comparison of the typical maintenance requirements and their estimated durations for synthetic and natural turf.

The amount of maintenance that is needed for any field type can vary depending on a multitude of factors. The Sports Turf Managers Association (2005) states that these costs depend on: amount of use; type of use (i.e. sports played); climate and weather; existing soil and terrain; irrigation and water needs; labor; field type; and field security (protection against vandalism, non-regulated play, etc.). The proper upkeep of a field will ensure that it reaches its lifetime potential, thereby yielding a greater return on investment. Both natural and synthetic turfs require a minimum level of upkeep to preserve surface quality. Activities that can be classified as grooming are the most important components of maintenance for both turf types. In addition, debris control, additional cleaning, and needs-specific maintenance may be required.

For synthetic fields, grooming is needed to maintain optimal play quality and proper functionality. Grooming practices include upkeep of seams, fibers, infill, and the drainage system. A broom or brush can be implemented to align the direction of fibers. Top dressing equipment and spiking equipment are employed to re-dress, redistribute, and de-compact the crumb rubber. Debris removal is also extremely important and should be done as quickly as possible to prevent more complicated problems, such as blockages in the drainage system. Sweepers, blowers, and vacuums are used to remove these materials. Additional cleaning steps may be necessary to get rid of the contaminants that cannot easily be eliminated. Pressure washing and spraying can flush the field or apply chemical agents and disinfectants. Also, depending on the specific needs of a particular field, other maintenance and equipment may be necessary. For instance, painters and scrubbers might be required to add and remove painted lines for various sports. In more severe climates and weather, snow removal is done with a plow. Irrigation systems can be helpful in environments with high temperatures, or when specified in warranty agreements. Additionally, any chemicals needed for the weed control, cleaning, and static-minimization are applied through spraying equipment.

Maintenance for natural turfs is also primarily focused on grooming. Mowing, watering, fertilizing, plant-protectant application, aeration, and irrigation should be carried out as necessary to ensure the proper growth of grass. In addition, debris may need to be removed, although the impact of debris is generally of less consequence than for artificial systems. Again, much like synthetic turf, there may be special equipment required for the specifics use needs of a field, such as painters, plows and sprayers.

An expanded list of possible maintenance requirements and their associated equipment has been complied in Table 1 below. The information in this table has been collected from various studies that discuss the possible maintenance entailed for a synthetic or natural turf system. For the purpose of identification each reference was assigned a number, which is then listed in the table when the reference suggests a specific type of maintenance. Maintenance needs can be categorized into seven types: general needs; debris removal, grooming, surface maintenance, systems, turf restoration, and user specific needs. From these, 13 specific needs were identified, with 22 pieces of associated equipment and 8 supplies. Additional maintenance factors that were suggested for inclusion were labor, weeding, and seam repairs. We will assume that all maintenance will require labor, and the differences in labor costs are included in Section 2.5.3, Table 2.6. Weeding is an activity that has been suggested for synthetic turfs by the Turfgrass Resource Center (2008) and Patton (2009). This activity does not need to be individually considered, as it is covered by the inclusion of labor and hand tool equipment. Lastly, seam repairs may be necessary, but are assumed to occur only a few times over the life span of a synthetic turf. If such repairs are necessary, it is assumed that they will be done by a contractor, so as to not violate any warranty on the turf. These three aspects will not be considered for the remainder of this section.

Table 2.1: Equipment and Supplies Recommended for the Maintenance of Fields				
Category	Purpose	References that Recommend Maintenance Type		Equipment & Supplies
		Synthetic	Natural	
General	Transport	1, 3, 4, 5, 9	1, 4, 9	**Equipment**: tractor/utility cart for operating equipment
	Small Tasks	3, 4	4	**Equipment**: assorted hand tools (i.e. rakes, hammers, edger, etc)
Debris Removal	Clearing of Objects	1, 3, 4, 5, 6, 9	1, 4*, 9	**Equipment**: sweepers/blowers to remove surface debris
		1	4*, 9	**Equipment**: vacuum to remove small items
		5, 9		**Equipment**: field magnet dragged to capture metal objects
	Cleaning/ Clearing of Contaminants	1*, 3, 4*		**Equipment**: pressure washers/flushing equipment remove unwanted fluids or contaminants
		6, 9		**Supply:** chemical disinfectants
Grooming	Grass & Fiber Blades upkeep	1, 2, 3, 4, 5, 6, 9	9	**Equipment**: broom, brush or tine dragged to realign fibers and to distribute the crumb rubber
		5, 9	9	**Equipment**: roller keep fibers from forming grain
			1, 4, 9	**Equipment**: mower
Surface	Soil/Infill Compaction, Reapplication & Redistribution	1*, 3*		**Equipment**: spiking equipment: de-compaction, redistribution of crumb rubber
		1, 4, 9	1*,4*, 9	**Equipment**: top dressing equipment: for crumb rubber loss
		6, 9	9	**Supply:** top dressing (additional crumb/sand)
	Fertilizing		8, 9	**Equipment**: seed/fertilizer spreader
			1, 4, 9	**Supply:** fertilizer
	Aeration		1*	**Equipment**: de-thatching equipment
			1*, 4*, 9	**Equipment**: (deep tine) aerator
			4*	**Equipment**: core harvester: collect cores that are pulled to the surface following aeration. can be used to gather thatch, similar to a sweeper.
	Protectant application (Weeds, Static)	1, 4, 5, 9	1, 4	**Equipment**: spraying equipment: for the application of weed control, pest control, cleaning agents, wetting agents to lessen the static charge to aid in drainage.
			9	**Supply:** pesticides
		2, 6		**Supply:** sprays to reduce static (fabric softener)
Systems	Watering	1*, 4*	1*, 4*, 9	**Equipment**: irrigation system: for watering, cooling, and warranty requirements
		4*	4*	**Equipment**: hoses/nozzles: small scale irrigation (syringing)
		7, 9	9	**Supply:** water
Restoration	Lawn Renovation		1*	**Equipment**: groove or slit seeder
		7	8, 9	**Supply:** seeds/sod replacement
Needs Specific: Weather, Play Type	Painting	1*, 4*, 5, 9	1*, 4*, 9	**Equipment**: painters: adding lines
		6, 9	8, 9	**Supply:** paint
		4*		**Equipment**: mechanical scrubbers: cleaning painted lines on the synthetic turf.
	Snow Removal	3*	1*, 4*	**Equipment**: special rubber blade snow plow

*indicates the item was suggested as optional

References for Table 2.1

1) Sports Turf Managers Association (2005)
2) Patton (2009)
3) FIFA (2001)
4) Sports Turf Managers Association (2006)
5) "Synthetic Turf Maintenance Equipment" (Brakeman 2005)
6) "2004-2005 Maintenance Budget Synthetic Infill Field" (Brakeman 2005)
7) Chirillo (2008)
8) New Yorkers for Parks (2006)
9) Turfgrass Resource Center. (2008)

The primary purpose of Table 2.1 is to show the breadth of equipment that has been suggested for both field types. The inclusion of any item is not meant to suggest that it is a necessary item for the maintenance of a field. The next section will be dedicated to identifying which of these accessories are needed for the specific maintenance requirements of each field type. The premises upon which an inventory of equipment and supplies will be created is that it should: 1) be as comprehensive as possible; 2) identify items that are needed at a regular frequency; 3) identify items that are of environmental or financial consequence; 4) highlight the differences in requirements between the two field types.

Without financial constraints, the accessories that can be purchased to care for a field are virtually limitless. Therefore, some practicality must be employed to limit this analysis to the items and practices that are required to secure the health of the field, and thereby increasing its longevity. In addition, it is assumed that beyond what is identified, supplementary items will be needed to deal with unforeseeable circumstances. However, these instances will not be accounted for because they cannot be predicted to occur at any regular interval - or at all. Also, precautions can often be taken by turf managers to help minimize the risks and impacts of such occurrences that would require additional maintenance needs.

Table 2.2 below outlines the items deemed necessary for the maintenance for artificial and natural turfs. Also included is a discussion of the rational for the inclusion of any given items. Much of the equipment needed is necessary for both field types. Where differences in the equipment needs do occur between the two fields, it is generally because natural grass requires maintenance practices that artificial turfs do not (e.g. such as mowing, fertilization, and aeration) to keep them healthy.

Table 2.2: Equipment and Supplies Recommended for the Maintenance of Fields		
Maintenance Equipment & Supplies		Discussion
Synthetic	Natural	
Tractor/utility cart	Tractor/utility cart	A tractor or utility vehicle is useful for maintenance, and is often used as the primary machinery to which other equipment is attached.
Assorted hand tools	Assorted hand tools	Hand tools are the easiest way to ensure quick fixes to problematic spots in the field.
Broom, brush or tine		The regular dragging of a synthetic field is a key to the maintenance of its fibers. Similarly, drag brushes are useful to evenly spread infill. Equipment, such as a brush, broom, or tine is needed to carry out these tasks.
Sweepers/blowers	Sweepers/blowers	A sweeper or blower ensures the proper removal of debris for optimal play quality. While the accumulation of organic debris is more problematic on synthetic fields, inorganic debris is equally problematic for both turf types.
Roller		Frequent rolling is recommended to keep synthetic fibers from standing up and forming a grain.
	Mower	Blades of natural grass must be trimmed to ensure proper play quality. A mower is a necessary piece of equipment to keep blades at the appropriate length.
Top dressing	Top dressing	Top dressing for natural and synthetic fields is occasionally necessary, as soil and infill can be lost or displaced. On natural fields, topdressing promotes stronger root systems, a more resilient surface, and improved playing surfaces. On synthetic fields, infill and sand must be added when these materials get displaced.
	Fertilizer	Fertilizer is applied to most natural fields to ensure the growth of a robust and deep rooted field.
	Aerator	It is recommended that a lawn be aerated once or twice a year. Aeration needs depend on the presence of problematic elements (e.g. thatches), and the degree of soil compaction.
Spraying equipment	Spraying equipment	Spraying equipment serves a very particular purpose (i.e. liquid cannot be applied by hand with a shovel). Each field type requires the application of numerous liquids. For natural fields it is used to apply agrochemicals such as weed control and pest control. For synthetic turf it is used for cleaning, wetting, and static control of the surface.
Water	Water	Water is necessary for the survival of natural turf. In addition, synthetic turfs are often watered down to control temperatures, lubricate the surface, and stabilize infill and reduce migration.
Irrigation system	Irrigation system	In order to apply water, a method of irrigation is necessary.
	Seed/sod	One of the primary benefits of artificial turf is the infrequency with which it must be replaced. Thus, to fully consider the potential of artificial turf, the impacts of seed and sod replacement should be taken into account. Many lawns will benefit from a scattering of grass seed after top dressing and this will thicken the grass for the next year creating a dense healthy green lawn.
	Paint	For natural grass, field lines must be painted on. Also, these lines must be re-painted after as the painted lines are grown out and mowed away. For artificial fields, paint is used to make temporary lines when the field is used for diverse purposes. Permanent lines can be laid into the system, or can be painted on with fairly infrequent re-application.

In considerations of turf maintenance, the majority of the equipment suggested by the various authors was not deemed necessary for field maintenance or consequential to maintenance evaluations. Several items were excluded because they are needed relatively infrequently or on a circumstantial basis. For day to day upkeep, the needed equipment is fairly evident. However, for items that might only be used on an occasional basis or that serve to alleviate the build of long term problems, their necessity is highly subjective. Often, such items can be rented, or a contractor can be hired to do the job that the equipment is meant to serve. As such, the capital investment and storage required of these items may not be prudent. Examples of equipment used fairly irregularly are: field magnet, vacuum, and pressure washers or flushing equipment. Supplies that are used in small enough quantities in the long run to render any associated impacts negligible are: chemical disinfectants and liquids to minimize static on artificial turf. Similarly, on natural fields, pesticides should only be applied when needed, and are not recommend for application at regular intervals as a preventative measure. Bruneau et al. (2001) of North Carolina State University's Center for Turfgrass Environmental Research & Education notes that when a field is properly maintained, insects are seldom a problem.

Some of the suggested items that were disregarded serve very real field needs. However, in several cases, these needs can also be served by other equipment or additional labor. This is the case for devices such as spiking equipment, a groove or silt seeder, a core harvester, top dressing equipment, and a seed and fertilizer spreader. Other equipment is only needed in certain circumstances, which may not necessarily occur for any given field. For example, the need for painters, mechanical scrubbers, and rubber blades to plow snow and de-thatching equipment will vary from field to field.

Supply Use Rates

Equipment that is needed for maintenance will only have to be purchased a few times over the life time of a turf. On the other hand, supplies must be acquired at regular intervals. Quantities and associated impacts for any given supply can vary greatly. For a true comparison of turf requirements, the rate of use for each of these supplies will be evaluated below.

Fertilizer

Fertilizer requirements are determined primarily by the type of grass, climate conditions, and the percentage of nitrogen that a fertilizer contains. There is a slight variation in the suggested amounts of nitrogen per year. Multiple applications are usually necessary, as fertilizer can damage a field if applied in quantities greater than one pound of nitrogen per one thousand square feet. Pettinelli (2007) of the University of Connecticut suggests two to three pound of nitrogen per thousand square feet, depending on whether clippings are left on the field. Similarly, Johnson et al. (2002) suggests two to four pounds per thousand square feet. Reicher and Throssell recommend fertilizing 0.75-1.5 pounds per thousand square feet four times a year. For this study, we will assume a fertilization rate of three pounds of nitrogen per thousand square feet, broken up into two applications. Based on our assumptions, 225 pound of nitrogen should be applied to an 85,000 square foot field annually.

Water

The precise amount of water required for a natural field can vary dramatically. Irrigation needs will differ based on the climate the turf is located in: humidity, precipitation, and the temperature all play a role in determining the amount of moisture that must be added to a field. The condition of a natural field will also figure into its irrigation needs. Minimum levels of maintenance prevent the creation of problems such as thatches, which can impede water from reaching the soil. If systems are not kept in working order, the efficiency of irrigation will be compromised. Lastly, the way in which irrigation is carried out can change the amount of water needed. Demand on fresh water will change based on the time of day irrigation takes place (due to evaporation), and if alternative sources can be utilized. All of these factors can result in more or less water needed to achieve a static level of moisture. Duble (1993) provides a range of 12 to 36 gallons per square foot needed in Texas, depending on the irrigation needs for different regions. The Sonoma County Water Agency (2009) uses 22.5 gallons per square foot when watering city lawns.

Topdressing

Topdressing is the addition of sand, soil, compost, or other material to the turf surface. It serves to level the playing surface, promote stronger root systems, and create a more resilient surface. This is accomplished by the added material promoting the decomposition of the organic matter that is between the soil surface and the grass blades.

Generally the application of topdressing should be done following fertilization, especially in the spring. Chirillo (2008) notes that some fields might call for 2 to 3 applications per year. The Sports Turf Managers Association (2009) cites five applications per year for a sand based soccer field. For our purposes one application per year should be accounted for, while we acknowledge that additional applications may be necessary.

Rolawn (2010), a European supplier of topsoil and producer of cultivated turf, suggests that based on the time of year different quantities of topdressing be applied. They recommend that 1.5 liters of topsoil per square meter be applied in the summer, and twice that amount be applied in the spring and autumn.

For synthetic fields, topdressing consists of the addition of crumb rubber infill. Additional infill may be periodically necessary, as over time large quantities can be displaced. The Sports Turf Managers Association (2009) gives an estimated application rate of 10 tons of dressing, applied once during the year.

Paint

Field markings must be repainted on occasion to maintain the field's usefulness for various sports. Hall (2004), of TruMark Athletic Field Marker, notes that five gallons of diluted acrylic latex paint will cover 1,000 linear feet that is four inches wide. He also estimates that a standard football field requires 4,600 linear feet of paint to apply four sets of hash marks, and five yard lines. This equates to around 25 gallons of paint that is needed, according to his approximations. However, for a NCAA Division I Football game, he calculates paint needs for basic lines are 60% higher, with 27.5 gallons necessary for out of bounds lines, and 12.5 gallons for yard lines. In addition, in this instance 55 gallons of colored paint was also used.

Hall's (2004) figure may be a bit high when compared to the recommendations of others. The Sports Turf Managers Association (2007) suggests that for a regulation size football field seven and a half gallons of paint are needed for the hashes and field numbers. This figure is five gallons less than Hall's calculation. In another publication, the Sports Turf Managers Association (Natural Grass Athletic Fields 2009) suggests that for an 114,000 square foot sand based soccer field, around 100 gallons of paint are needed for 6 applications annually. Meanwhile, a provider of aerosol paint, the California Field Supply Company (2007), offers an even more conservative figure. They estimate that 3.36 gallons of aerosol paint is needed for the initial layout of the field—which must be reapplied a second time per year—and 1.68 gallons are needed for weekly over markings in a 30 week year (or half of that for lower volume fields). Although the California Field Supply Company does not indicate the size and purpose of the field they are considering, only indicating that it was a field of "standard dimensions."

The amount of paint required for an application of field markings becomes even more muddled when considering the actual materials that go into the painting of Florida State University's Football Field. Theacc.com (2005) estimates that 460 gallons of paint are applied to the field prior to each game. They note that approximately 100 gallons is used to apply white lines, numbers and hash marks. An additional 360 gallons is used on the sidelines, and to paint the team emblem midfield and in the end zones.

The amount of paint needed per application is difficult to determine, given the broad range of estimates suggested. However, the slight differences in the amount and type of paint needed for natural and synthetic fields are insignificant when comparing the number of applications required. Since natural grass is mowed frequently to maintain its proper length as it grows, lines must be reapplied at regular intervals. Most literature seems to suggest that paint should be reapplied to grass prior to each event. On the other hand, a synthetic turf needs far fewer applications of paint. In fact, the Sports Turf Managers Association (Natural Grass Athletic Fields 2009) only accounts for two applications per year on artificial fields. However, a field manager may choose to apply paint more frequently to meet more rigorous aesthetic needs.

Replacement Seed and Sod

It is assumed that over time natural grass will get old and need to be replaced. With that, new seed or sod will be required once the old turf is removed. The frequency with which this is expected to occur can also affect the costs and life cycle of the field. Another practice that consumes an excess of seeds is over seeding. Over seeding is done to make the surface greener in the winter, and to support sports that go later into the season (i.e. that are played late into the winter or in the spring). However, this practice is not recommended for general maintenance, as it can compromise the health of the existing grass that must compete with the additional seed grass variety.

2.5 Cost

In this section the cost of natural and synthetic fields will be explored for comparison. Estimates will be based on a sample field of 85,000 square feet. This field size is large enough for a regulation size American Football (57,600 sq. ft.) or International Soccer (69,300 sq. ft.) field plus side lines.

2.5.1 Installation Costs

The cost of turf construction varies dramatically based on numerous factors. As to be expected, the needs requirements for a field determine its associated cost. The size and type of play that will occur are the principle considerations when calculating construction costs. The drainage and irrigation systems necessary to suit the capacity of any particular field also must be taken into account when gauging expenses. The location of a field installation also factors into its total price, determining its costs related to labor and the difficulty of installation based on factors like soil and climate. For example, additional costs may result from the labor necessary to prepare a difficult surface or to offset weather-related delays in the construction schedule.

The construction price for a natural field can span a wide range depending on the properties of the land it is built on. If native soils are very sandy, they can support the installation of new turf without additional materials to improve the surface stability. Native soil fields are the least expensive of all natural fields. Of native soil fields, there are two options: seeding and sod. Seeding is the less expensive option, because it does not require the purchasing of sod or top soil. This option runs at about $1.20 per square foot. (Sports Turf Managers Association, 2008; Turfgrass Resource Center, 2008). Sod, on the other hand, costs about $2.25-$5.25 per square foot (Sports Turf Managers Association, 2008). Other types of natural turf require the addition of sand, and possibly other materials, to improve the robustness of the root zone for greater availability. The Turfgrass Resource Center estimates that basic sand-based field installations cost between $2.94 and $4.12 per square foot. However, they note that more elaborate sand-based systems can cost over $7 per square foot to install. Meanwhile, the Sports Turf Managers Association estimates the average cost of construction for sand based systems as $5.25 for a sand cap and $8.50 for a sand and drainage. Using these figures, estimates for a sample 85,000 square foot field are calculated in Table 2.3 below:

Table 2.3: Installation Cost for a 85k Square Foot Grass Field

Natural Field Type	Cost
Seed	$102,000
Sod	$191,250 - $446,250
Basic Sand	$250,000 - $350,000
High-End Sand	$722,500

Meanwhile, the cost of a synthetic turf varies based on many of the same aspects as natural turf. The existing condition of the field affects the cost of surface preparation, including: excavating the site, adding any necessary foundational materials, and compacting the foundation. The more material that must be removed, the greater the cost of installation will be. A proper drainage system is critical for artificial fields; without it, damage typically occurs from moisture that is trapped in the turf components. This is true even of indoor turfs, as liquids are often applied to clean and maintain their surface. Choices of turf components also influence price, including: the quality of fibers, padding, backing, and infill. In addition, specialized logos or sports lines have associated costs based on whether they are painted or sewn in. The price range of synthetic turf per square foot is $6 to $11.76. The Sports Turf Managers Association (2008) estimates that the construction cost for a synthetic turf runs between $6.50 to $11 per square foot. The Turfgrass Resource Center (2008) approximates installations to be on the higher end from $10 to $11.76 per square foot. Meanwhile, Sporturf, a synthetic turf provider, estimates that installing an artificial turf field costs from $6 to $8 per square foot. However, they also note that a

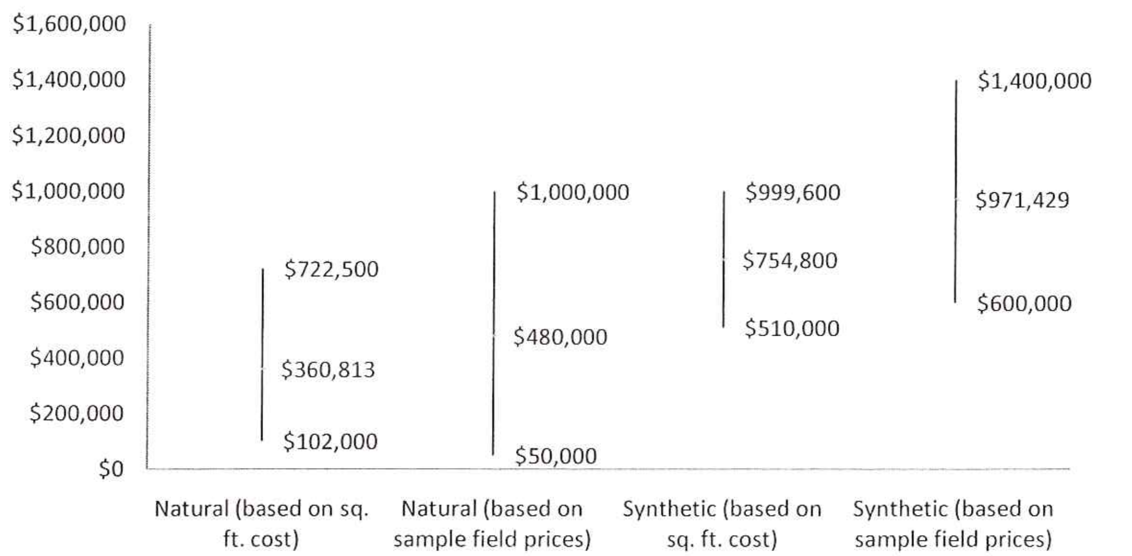
10,000 square foot "state-of-the-art fake grass" turf was installed in Shaw Park, GA for $30,000 (a price of $3 per square foot). Using these figures, the cost of an 85,000 square foot synthetic turf field ranges from $510,000 to $999,600. This figure is significantly higher than the range of $102,000 to $722,500 found for natural fields.

Comparisons of the costs to install natural and artificial fields in other studies show similar differences in price between the two field types. Several case studies provide estimates of the installation costs for the two types of fields without noting the size of the field. Despite this omission, these works provide insight into the potential construction costs of fields, as well as the difference in costs between synthetic and natural turfs. The price estimates from these various works are listed in Table 2.4. Of note is the minimum of all of these costs for natural fields, which has been estimated to be about half of the cost calculated above, at $50,000. Meanwhile, the prices quoted for synthetic turfs are on the higher end of the range found earlier. Furthermore, our calculations show synthetic field installations as costing from 0.7 to 9.8 times more than a natural field. Several of the additional studies show artificial fields as ranging from twice the cost of grass to 20 times the cost.

Table 2.4: Price Estimates for the Total Costs of Installation for Natural and Synthetic Fields				
Resource	**Context of Research**	**Synthetic**	**Natural**	**Number Of Times Greater Cost Of Synthetic Turf Installation as Compared To Natural Turf**
Turfgrass Resource Center (2008)	A publication that addresses concerns about synthetic turf using scientifically backed data for a non-profit trade association that represents the turfgrass sod industry.	$850,000 – $1,000,000	$50,000 – $600,000	1.4 to 20
Williams and Pulley (2002)	An investigation conducted at Brigham Young University for their football field, half of which is synthetic, and the other half which is sand-based natural field.	n/a	n/a	11.8
Powell (2005)	A conference presentation aimed at athletic field managers addressing the complexities of natural and synthetic turf. Powell is a turfgrass agronomist with the University of Kentucky.	*Basic:* $600,000 *High End:* $1,000,000	*Soil:* $50,000 *Sand:* $1,000,000	0.9 to 18:1
Claudio (2008)	A journal article in *Environmental Health Perspectives (EHP)*, a monthly peer-reviewed research and news publication by the U.S. National Institute of Environmental Health Sciences, National Institutes of Health, Department of Health and Human Services.	$1,400,000	$690,000	2.0
Skindrud (2005)	A case study for a installation at Springfield College in Springfield, Massachusetts, in an informational article comparing natural and synthetic fields for landscape contractors.	$800,000	$400,000	2

Using the information provided above, a precise estimate for the installation costs of different turf options will be determined for use in total system cost calculations. The range of comparative proposed prices can be seen graphically in Figure 2.1 below. This figure shows the minimum and maximum prices provided by various authors, as well as the mean price calculated for each proposed turf type. For our purposes, a single value is needed for a comparative analysis of the total cost of synthetic and natural turf systems. For this objective, the price per unit (i.e. per square foot) value is a more credible estimate because: 1) it is known to be a comparison of two fields of equivalent size, and 2) it is scalable by a known factor to achieve a specific case study field size. It should be noted that, regardless of whether the price per square foot or total price is used, the average cost for a synthetic field is twice that of a natural field. Using the square foot cost, the mean value of the research investigated will be used for cost calculations. Specifically, this is $8.88 per square foot of synthetic turf and $4.24 per square foot of natural turf, or $754,800 and $360,813 respectively for an 85,000 square foot field.

Figure 2.1: Initial Cost of Various Turfs



2.5.2 Equipment Costs

Equipment costs are calculated in large part by the equipment and supplies identified in the maintenance section of this report (see Section 2.4: Maintenance). The average cost associated with each of the identified items has been collected from various studies. These prices have been listed in Table 2.5 below. These estimates will be used to calculate the capital costs of maintenance.

Table 2.5: Suggested Cost for Equipment Based on Field Type		
Equipment:	**Synthetic**	**Natural**
Tractor/Utility Cart	$7,000 to $16,000 (a) $2,500 to $16,000 (b)	$7,000 to $18,500 (a)
Assorted Hand Tools	No cost estimate given	No cost estimate given
Sweepers/Blowers	$1,500 to 20,000 (a) $1,500 (c) $1,500 to $20,000 (b)	No cost estimate given
Broom, Brush Or Tine	$500-3,000 (a) $500 (c) $500 to $3,000 (b)	
Roller	$250 to $2,000 (a) $250 to $2,000 (b)	
Mower		$13,000 to $69,000 (a) $107* (d)
Spraying equipment	$1,000 to $35,000 (a) $1,000 to $35,000 (c)	No cost estimate given
Aerator		$3,500 to 17,000 (a)

*yearly cost for a five year lifetime

References for Table 2.5

a) Turfgrass Resource Center(2008)
b) "Synthetic Turf Maintenance Equipment" (Brakeman 2005)
c) "2004-2005 Maintenance Budget Synthetic Infill Field" (Brakeman 2005)
d) New Yorkers for Parks (2006)

The range of estimated prices given by any author can be quite large. For instance, spraying equipment is expected to run somewhere between $1000 and $35,000 (Brakeman, 2005). The equipment that is needed for the maintenance of both field types is assumed to be similar in price. These items—tractor/utility carts, hand tools, sweeper/blowers, and spraying equipment—are similar enough that for the purposes of estimations, they do not need to be differentiated , despite possible differences in the specific devices. In general, cost estimates will be made for equipment using the mean of prices provided. Where this is not the case, this will be noted. The specific price estimates that will be used are:

- A tractor/utility cart will be assumed to be around $10,375, the mean value of all suggested figures that range from $2,500 to $16,000.
- No estimates were given for the total price of hand tools. However, it is assumed that the cost of these is inconsequential in the comparative costs of artificial and natural fields. Therefore, these costs will not be included.
- The cost of a sweeper/blower will be assumed to be $7,667. The suggested prices range from $1,500 to $20,000.

- Some combination of a boom, brush, or twine will be assumed to be $1,333.
- A roller will be assumed to be $1,125, the mean value of all suggested figures that range from $250 to $2,000.
- It will be assumed that a quality mower will be needed given the frequency with which it will be used. The estimate given by New Yorkers for Parks (2006) will be disregarded, as it is questionable that the type of mower needed can be obtained for such a figure (i.e. $107 per year for five years). The midpoint price of $41,000 will be used in calculations.
- Spraying equipment is assumed to be $18,000.
- The suggested price for an aerator is $3,500 to $17,000. The mean of this, or $10,250, will be used in calculations.

Using these figures, the total equipment cost will be $38,500 for a synthetic field and $87,292 for a grass field.

2.5.3 Total Cost of Ownership

The table below provides examples of a 10-year total cost of ownership, comparing the cost to install and maintain natural sod turf versus synthetic turf. The example uses a 78,000 square foot field, private stadium.

Table 2.6: Total Cost of Ownership

	Artificial Turf	Sod
Installation Cost	$692,640	$330,720
Year 1 Costs	14,900	65,258
Year 2 Costs	14,900	65,258
Year 3 Costs	14,900	65,258
Year 4 Costs	14,900	65,258
Year 5 Costs	14,900	65,258
Year 6 Costs	14,900	65,258
Year 7 Costs	14,900	65,258
Year 8 Costs	14,900	65,258
Year 9 Costs	14,900	65,258
Year 10 Costs	14,900	65,258
10-Year Life cycle Cost	**$841,640**	**$ 983,300**
Uses during 10-Year Cycle	1,400	350
Cost per use	$ 601.17	$ 2,809.43

Key Assumptions:

Artificial turf cost of $8.88 per sq ft, $4.24 for natural turf (sod)

Includes general maintenance, equipment, and water costs (annualized average amounts)

Assumes field does not already consist of natural grass

Does not include "replacement" costs, which may or may not occur during mid-point of life of installation

2.6 Risk of Injury

One of the primary concerns for organizations considering the implementation of synthetic turf is whether it poses any significant health or injury risks. Numerous studies have been conducted assessing the likelihood of injury on natural grass and synthetic turf. Some studies reveal that there is very little difference in the rate, type, severity, or cause of injuries obtained on natural grass or synthetic turf (Fuller et al. 2007a, 2007b). A more recent study by Meyers (2010) shows that the latest generation of synthetic surface, FieldTurf, is safer to play on than natural grass fields. Through the analysis of the various injuries that occurred over the course of 465 collegiate games, Meyers shows that FieldTurf has lower incidence of: total injuries, minor injuries (0-6 days lost), substantial injuries (7-21days lost), and severe injuries (22 or more days lost). FieldTurf also had significantly lower injury rates that natural turf when comparing across play or event type, grade of injury, or various field conditions and temperatures. In addition, there was no significant difference found in head, knee, or shoulder trauma between the two playing surfaces.

Meyers' (2010) research is the most comprehensive study to date, and it addresses previous inconsistencies in findings on injury patterns. Prior studies on injuries suggest that rates for the two surfaces are similar, but that the type of injury varies (Meyers and Barnhill 2004; Steffen et al. 2007). Furthermore, there was no consensus amongst researchers on the difference in type and severity of injuries. Meyers and Barnhill (2004) found that injuries on natural turf tend to be more severe, with greater incidence of head concussions and ligament tears. Steffen et. al (2007), however, found that injuries on synthetic turf tend to be more long-term but occur at a lower rate than injuries on natural turf. Given this conflicting evidence, no major conclusions could be drawn about differences in risk levels between the two fields before the publication of Meyers' work.

The following section will discuss the specific health and injury risks posed by: surface hardness and traction, rates of abrasion, risk of staff infection, heat-related stress and injuries, and material safety.

2.6.1 Traction

Forces that resist shoe-surface motion have been termed traction forces, as they do not always obey the classical laws of friction (Shorten et al., 2003). If traction forces are too high, foot fixation may occur, placing a great deal of stress on lower extremity ligaments during movement (Shorten et al., 2003). This can result in an increased rate of knee injuries and collisions (Pasanen et al. 2007b). Several authors have noted that surface to shoe traction is correlated with increased incidence of injury (Pasanen et al. 2007A; Powell and Schootman 1992; Orchard and Powell 2003). Orchard and Powell show that cold weather reduced traction, leading to a lower injury rate, supporting the claim that traction plays a role in increased risk.

Research clearly points to a correlation between increased traction and greater rates of injury. Several researchers have noted that the more consistent, compliant surface that artificial turf offers is associated with lower shoe-surface traction (Noyes 1988; Schootman 1994). Meyers (2010) notes a lower incidence of injuries attributed to shoe-surface interaction during contact with synthetic turfs over natural grass turfs. In addition, Meyers attributes the lower incidence of ligament sprains on FieldTurf found by Ekstrand, Timpka, and Hagglund (2006) to the possibility of lower shoe-surface traction.

2.6.2 Hardness

Increased hardness is correlated with increased likelihood of severe head trauma. However, the hardness levels of synthetic fields, if set up correctly, fall well below these dangerous levels (McNitt and Petrunak, 2007c). Furthermore, it is easier to maintain an existing level of hardness on synthetic fields because hardness is related to infill depth. On the other hand, the hardness of natural fields varies according to soil-moisture, which is more labor-intensive to manipulate on an ongoing basis.

However, the solution is not to make fields as soft as possible. A surface that is not at the correct hardness level will affect athletes' performance, particularly by bringing on early onset of leg muscle fatigue (New York City Department of Health and Mental Hygiene, 2008). Set up should be carefully carried out to ensure proper hardness levels.

2.6.3 Abrasion

One of the major criticisms about synthetic turf is that it is seen by many to be more abrasive than natural turf. The old versions of synthetic turf elicited public complaint about incidence of abrasion (New York City Department of Health and Mental Hygiene, 2008). However, the newer versions have longer and softer fibers, making them less abrasive. At Penn State's Department of Crop and Soil Sciences, a study on synthetic turf systems included a measurement of the abrasiveness of the surface by pulling foam blocks over the turf's surface (ASTM Method F1015). The results, reported by McNitt and Petrunak (2007a), states that infill systems are less abrasive than older carpet-like turf generations. The abrasiveness was also affected by the grooming of the field surface (McNitt and Petrunak, 2007a).

Comparisons of the impacts of abrasions between natural and synthetic turfs are slightly favorable towards artificial fields. Unfortunately, the abrasiveness of natural fields has not been measured for contrast, as the ASTM Method F1015 is only applicable to synthetic surfaces. However, Meyers (2010) found that the rate of epidermal injuries caused by interaction with the surface were slightly lower on artificial turfs (1%) than on natural grass (1.3%). This research investigates some of the irregular injury patterns initially observed on artificial turf (Meyers and Barnhill, 2004). In this preliminary study, abrasion occurs more frequently on synthetic turf than natural turf (Meyers and Barnhill, 2004).

It should be noted that in and of themselves, abrasions are not usually severe injuries. However, these types of injuries can lead to more severe complications, including staph infections.

2.6.4 Staph Infections

Concerns have been expressed about the role that synthetic turf plays in facilitating staph infections. Methicillin-resistant Staphylococcus aureus (MRSA) is a drug-resistant bacterium that can result in severe, and sometimes fatal, infections. Due to increased outbreaks of MRSA in athletes, concerns have developed about whether turf fields increase the risk of such infections. While research suggests that abrasions from injury may play a role in the contraction of such infections, there has been no evidence of a causal relationship between synthetic turf and staph infections.

There are a variety of studies about the role that synthetic turf plays in the contraction of MRSA. All research indicates that synthetic turf is not a cause of MRSA. However, several authors point out that abrasions caused by turf may provide a means of entry for the outbreak of infection (Kazakova et al. 2005; The New York City Department of Health and Mental Hygiene 2008; McNitt 2008). The New York City Department of Health and Mental Hygiene claims that other factors are the primary cause of bacterial infections. Begier et al. (2004) reached similar conclusions, despite noting a seven-fold increase in the risk of MRSA contraction for athletes with turf burns. They concluded that it is not possible to assess the risk of outbreak associated with the playing surface because all players used artificial turf, and other factors, such as use of a poorly maintained whirlpool, which played a role in MRSA contraction. Furthermore, The New York City Department of Health and Mental Hygiene (2008) dismisses the associations that Begier et al. (2004) and Kazakova et al. (2005) make between synthetic turf and MRSA, because they did not compare them with abrasions caused by different sources. McNitt, Petrunak D, and Serensits (2008) determined that synthetic turf—and fields in general—do not provide an environment that is hospitable for hosting bacteria.

While infections may be associated with abrasions, not all abrasions result in MRSA. In addition, cases of MRSA have occurred in individuals who have not generally had contact with synthetic turf, such as dancers, wrestlers, fencers, and non-athletes. Furthermore, given that turf surfaces themselves do not harbor such bacteria, it is doubtful that there is an increased risk associated with abrasions that originate from synthetic turf surfaces over abrasions from other surfaces (McNitt, Petrunak D, and Serensits, 2008). However, since abrasions provide a means of entry for staph infections, rates of abrasion can be important to bear in mind (see the section on abrasion injuries).

Behavioral factors play a far greater role in determining whether staff infections will develop, including: the covering of wounds, physical contact with other players, and hygiene practices (McNitt 2008; Benjamin, Nikore, and Takagishi 2007; Nguyen, Mascola, and Bancroft 2005; Kazakova et al. 2005; Begier et al. 2004; Srinivasan and Kazakova 2004; Tobin-D'Angelo et al. 2003; Stacey et al. 1998).

2.6.5 Heat

There are two major concerns about the affect of heat on synthetic turf. The first is the material toxicity that can result from increased temperatures, a concern that will be discussed in the material safety section that follows. The second is the heat-related stress that can be caused by increased temperatures, such as heat exhaustion, heatstroke, burns, and blisters. We will examine these problems here.

Temperatures of synthetic turf do get higher than the surrounding air (see section on all-weather availability), which can play a factor in heat-related stress. There are two studies indicating that synthetic turf has resulted in heat blisters on players' feet (Williams and

Pulley, 2002; SI.com, 2007). However, behaviors play a more significant role in creating heat-related injuries, such as: reducing playtime and preventing dehydration (Anderson et al., 2000; New York City Department of Health and Mental Hygiene, 2008b). It has also been suggested that humidity plays a greater role in heat stress than temperature (New York City Department of Health and Mental Hygiene, 2008b).

As can be seen, there are a variety of concerns about the safety of synthetic turf for players. Evaluation of these concerns finds that these risks, in many instances, can be mitigated. There are some risks that people should be aware of, but there is no evidence that the dangers of synthetic turf greatly outweigh those of natural fields.

2.6.6 Injury Conclusions

Despite these findings which are generally favorable towards synthetic turf, there is still a strong public perception that it is more likely than natural turf to cause injury. A study shows that 91.2 percent of NFL players thought that artificial turf would be more likely to contribute to injury (NFL Association, 2004). However, this public perception could be rooted in a variety of factors beyond the grasp of science. Players may be used to other fields or associate new technologies with their earlier, less-developed versions.

2.7 Material Safety

The use of athletic fields made of recycled tires has also been called into question because of concerns regarding toxicity. For example, the state of New York has recommended a moratorium on future construction of such fields pending additional research. Authorities are worried that because of the chemical content of the material, exposure by various means could endanger the health of field users, especially children. However, extensive research has pointed to the conclusion that these fields result in little, if any, exposure to toxic substances.

On the face of it, concerns about the toxicity of crumb rubber fields is quite warranted. The raw material from which they are made – used car tires – is known to contain numerous toxic and potentially carcinogenic compounds. These chemicals include polynuclear aromatic hydrocarbons (PAHs), phthalates, volatile organic compounds (VOCs), zinc, iron, manganese, nickel, PCB, copper, mercury, lead, cadmium, volatile nitrosamines, benzothiazole, isononylphenol, and more.

These chemicals are of concern for various reasons. Many of the metals have been associated with damage to the nervous system, as well as irritation of the eyes, nose, and throat. PAHs have been identified as a cancer risk and as causing substantial organ damage. And VOCs have been implicated in causing organ damage, or symptoms of lesser consequence such as nausea, headaches, and sense organ irritation.

However, the mere presence of a substance is not necessarily cause for concern. For the most part, when these chemicals are present in tires, they occur in very small concentrations. Also, their presence does not automatically equal exposure. Tires are relatively, though not entirely, inert, and the vulcanization process that they undergo to prepare them for their second life as artificial turf, renders them more, rather than less, stable. Further, many of the chemicals of concern are already present at relatively high levels in urban environments, as a result of numerous human activities which are not presently considered controversial: driving, heating and cooling systems, and regular production of household and industrial waste. Even the consumption of certain foods has been noted to raise a person's exposure to substances such as PAHs (van Rooij and Jongeneelen, 2010).The primary issue is not whether artificial turf contains such materials, for this is undoubtedly true, but, whether there is sufficient human exposure to elevate the risk above accepted levels. While small increases in risk may not be insignificant, a generally accepted measure of danger should be adopted, namely the general scientific consensus in determining whether an elevated level of risk ought to be deemed significant.

Being in proximity to a substance is not in itself a risk. There needs to be a means through which one's body comes into contact with the substance – a path of exposure, if you will. For crumb rubber, as it is not radioactive, there are numerous possible paths of exposure through which a human could conceivably be subjected to potentially noxious chemicals. The first and most direct route of exposure would be through actual oral ingestion of pieces of the crumb rubber itself. Now, it is highly unlikely that most field users will decide to consume a chunk of the playing field. However, this is a valid concern when considering the most vulnerable portion of the population – very small children. It is entirely possible, and perhaps inevitable, that some small children will pick up infill pieces and swallow them.

Secondly, and more likely, would be hand-to-mouth exposure, especially of dust or small particles of crumb-rubber. If such matter got on the hands of a user of the field, and the user then touched his hand to his mouth, he could ingest infinitesimal amounts of crumb rubber particulate.

Thirdly, dermal exposure is highly likely. The skin of field users is bound to come into contact with the field's surface. Given the naturally protective qualities of skin, this is an unlikely route of exposure, unless the substance is abrasive to skin itself.

Fourth, there is concern about chemicals leaching off of the fields – especially if the fields are outdoors and subjected to periodic rainstorms (Moretto, 2007). Such chemicals, if water-soluble, could come to enter the groundwater or drinking water supply.

Finally, and perhaps most significantly, there is the possibility of inhalation of toxins from the field. Such inhalation would generally come about through one of two possible phenomena. The first is a process known as "out-gassing" or off-gassing." As noted above, recycled tires are substantially, though not entirely, inert. Some compounds within the material will, over time, come to be released from the material and to enter the air. This is a particular concern with so-called "volatile organic compounds," but also with PAHs. Secondly, repeated use of the field could cause atomized particles of the field to be produced as barely noticeable dust, or "particulate". Such particulate could be inhaled by users of the field.

The potential of toxic exposure along each of these pathways has been the subject of repeated inquiry. Numerous governmental agencies have carried out independent research into the toxic potential of crumb rubber, and we will review the results of this below. Generally, it has been found that crumb rubber fields do not present an elevated risk to health through exposure to toxic substances, but researchers have noted some areas of concern. More typically, though, they have noted the present existence of "knowledge gaps"; a lack of full understanding at the general theoretical level which renders the inquiries to some degree inconclusive.

2.7.1 Direct Ingestion

Two major studies of the potential for toxic transference through direct ingestion have been carried out. The first, by Birkholz, Beton and Guidotti (2003), involved immersing tire particulate in chemical solvent and testing the resulting chemical for increases in carcinogens. This test did not clearly demonstrate a significant increase in carcinogenic levels.

A similar study, by the California Integrated Waste Management Board (CIWMB, 2007), subjected 10mg of tire shred samples to a chemical environment that replicated the human digestive system. In all, 22 chemicals were released by the samples, but none at levels that were associated with significantly elevated risk levels. Scientists performing this experiment were particularly concerned with an elevated risk of cancer in children. The study found, though, that ingestion of a significant quantity of tire shred did not elevate a child's risk of developing cancer, relative to the overall cancer rate of the population.

2.7.2 Hand-to-Mouth Contact

This same study, by the CIWMB (2007), also evaluated increased risks due to hand-to-mouth exposure. For hand-to-mouth exposure, researchers took wipe samples from field surfaces and were able to identify five chemicals present in rates significantly higher than the general environment. Calculations were then made to determine the frequency with which these chemicals would or could enter the body through hand-to-mouth contact. Though a high degree of variability and uncertainty was acknowledged, researchers found that, on average, the degree of toxic exposure due to hand-to-mouth contact would be well below acceptable levels.

Lead ingestion is a matter of concern with crumb rubber fields, for it is well-known that lead is used in tire production. However, one mitigating factor should be pointed out: tires do not contain uniform amounts of lead, and it is therefore possible to selectively choose particles from tires with low lead concentrations.

The New Jersey Department of Health and Senior Services (2008) carried out a study subjecting tire particulate to a simulated gastric environment. This was done to determine whether the amount of lead which could be absorbed by human beings as a result of casual ingestion through hand-to-mouth contact with crumb rubber dust would release significant quantities of lead. The findings were that the amount of lead released through gastric processes was not significantly different from that of ordinary soil samples. However, in certain types of fields, particularly those which used nylon fibers, elevated lead levels were observed.

A similar study was undertaken by the Consumer Product and Safety Commission (2008). The CPSC analyzed wipes taken from various crumb rubber fields and assessed the risk of exposure to minors who might be using these fields. It was determined that in no case would exposure ever exceed chronic levels of ingestion of lead that could cause lead poisoning.

The Norwegian Building Research Institute's (2006) analysis of lead exposure similarly found that lead levels fell well within an acceptable range.

The US Center for Disease Control and Prevention (2008) has advised the careful selection of material for crumb-rubber fields. It is possible to select crumb rubber in which lead concentrations are low, and it is strongly advised that this be carried out.

PAHs are a source of concern for hand-to-mouth ingestion from artificial turf fields. The CIWMB (2007) investigated the possibility that four PAHs – such as the carcinogen chrysene—could be present at levels dangerous to humans. The study failed to show that this was the case.

2.7.3 Dermal Contact

In addition, PAHs have been studied for their risk associated with the dermal contact of crumb rubber. Such risks of PAH uptake have been determined as low amongst athletes (Hofstra 2007), based on certain assumptions regarding the circumstances of exposure and dermal bioavailability. Additional testing of real life exposure was conducted by Van Rooij and Jongeneelen (2010). Their study used biological monitoring (i.e. urine samples) to assess exposure. This method of assessment is advised when exposure can occur through multiple pathways, as is the case with PAHs. Their findings show that the uptake of PAH by athletes who have contact with crumb rubber synthetic turf is negligible. Additionally, diet and other environmental factors were identified as having the same level of PAH uptake as field exposure.

As far as dermal contact is concerned, the Norwegian Institute of Public Health and radium Hospital (2006) carried out an extensive analysis of possible health concerns. The only concern which they highlighted as potentially significant was the risk of allergic reaction to crumb rubber that contains latex, a well-known allergen. The study found, though, that there was no evidence to suggest that allergic reactions were caused by exposure to crumb rubber and speculated that latex in car tires was either "less available for uptake" or was "deactivated" as an allergen. The study acknowledges, however, the existence of knowledge gaps that make a full risk assessment in this particular area provisional.

2.7.4 Water Contamination

The question of whether chemicals will leach off of playing fields and enter the drinking or groundwater supply is of broader concern. Once again, the matter of whether or not such leaching ever takes place should not be the focus of concern. The question is: At what concentrations do chemicals leach off of fields, and will the natural environment be able to break down the chemicals at those concentrations?

Zinc is a metal of particular concern in this regard. Now, the simple presence of zinc is not necessarily problematic. Zinc is already present in significant concentrations in urban environments, and is in fact essential to the metabolism of most plants and animals. However, zinc at high concentrations can be quite toxic.

Three studies have looked into the presence of zinc as a result of leaching from crumb-rubber athletic fields. The first, carried out by the Norwegian Building Research Institute (NBRI)(Plesser, 2004), was the most critical. It noted that the concentration of zinc in granulate particles exceeded the Norwegian Pollution Control Authority's guidelines for "most sensitive land use." However, it should be noted that Norway's standard for this particular pollutant is unusually stringent; the report noted that the same concentration is deemed by Canadian Water quality guidelines to be well within acceptable range.

California's Integrated Waste Management Board (2007) tested the concentrations of zinc leaching from crumb rubber fields. Its analysis seemed to indicate that the levels detected were not a significant health or environmental concern.

New Jersey's Department of Environmental Protection (2007) carried out a review of the safety of crumb rubber fields that took careful account of the presence of zinc in water leaching from these fields. They noted that a Dutch study from 2007 indicated that the amount of zinc that could leach into water supplies would not be injurious to human health. It would fall below the level of toxicity advised against by the World Health Organization. However, the same study noted that the amount of zinc potentially leached into groundwater exceeded limits set by New Jersey's own environmental standards.

The Swedish Chemicals Inspectorate (2006) has confirmed this finding, noting that zinc levels exceed what is acceptable in runoff, for it could damage ground-dwelling organisms. For this reason the Inspectorate advised against the construction of new crumb-rubber fields, but did not urge the elimination of existing fields.

The Norwegian Institute for Water Research (2005) has indicated that not only zinc, but also but alkylphenols, and octylphenol in particular, are also predicted to exceed the limits acceptable for environmental health.

Birkholz, Belton, and Guidotti (2003) performed toxicity tests on four different aquatic species using crumb-rubber leachate. They determined that undiluted samples produced a moderate risk to all four species, but that diluted samples did not. Noting that the likelihood of undiluted rainwater runoff was slim to entirely unlikely, they concluded that crumb rubber leachate does not pose a risk to aquatic species. However, it should be noted that they specifically looked at toxin levels of lauryl sulfate and sodium chloride. Zinc exposure was not tested.

2.7.5 Inhalation

A particular concern when it comes to the potential of inhalation of toxins from crumb rubber fields is Volatile Organic Compounds, or VOCs. As discussed above, VOCs have been implicated in causing organ damage, nervous system problems, and irritation of eyes, throat and airways.

As pointed out by the New Jersey Department of Environmental Protection (2007), the likelihood of significant emission of VOCs from recycled tires is very low. This is because most VOCs would have already been emitted from tires while they were used for their original purpose of enabling automobile transit. The combination of frequently raised temperatures and long-term use would serve to eliminate most volatile gases from the material. Further, most tires spend up to a year in a scrap-yard between being discarded as tires and before being shredded for use in athletic fields. This additional year provides more opportunity for VOCs to be out-gassed. Studies serve to confirm these speculations.

The French National Institute for Industrial Environment and Risks (2007) carried out a study of the risk of exposure to VOCs from recycled tire athletic fields. The study found that the concentrations of VOCs emitted by such fields were low enough to not pose a risk to athletes using the fields, to officials, or to spectators.

The Norwegian Pollution Control Authority (2006) analyzed the levels of VOCs emitted from indoor fields to determine if a health hazard was indeed present. The finding was that, with adequate ventilation, these fields would not pose a health concern.

The New York City Department of Health and Mental Hygiene (2008b) commissioned a study of a number of the city's already-constructed athletic fields to determine if VOCs or metals were being out-gassed from the fields at significant levels. Though eight different VOCs were detected in the air, they were not at levels high enough to threaten human health. Additionally, it was not clear that the VOCs detected were indeed from the fields themselves, as there was no uniformity in the scores for the different fields, and VOCs were detected in control locations upwind from the sites.

The Norwegian Institute of Public Health and Radium Hospital (2006) analyzed the presence of VOCs emitted from fields and determined that there was no cause for concern. This includes the substance known as carbon black. Recent discussions have included the topic of carbon black, and the potential damage to the respiratory system. Carbon black is used in tires to provide the pigmentation, as well as to dissipate heat and maintain the shape (and life) of the tire. However, there have been no findings that carbon black in crumb rubber has been a serious health issue to users of playground surfacing. Similar research was performed by the California Integrated Waste Management Board in a subsequent, related study in 2007.

A preliminary test by the Connecticut Agricultural Experiment Station (Mattina et al., 2007.) showed that VOCs were indeed released from rubber pellets made from ground-up tires, the raw material for crumb rubber fields. Though the study noted that the levels of released VOCs did not appear to occur at a level clearly injurious to humans, further study was recommended.

The same study looked into the presence of volatile nitrosamines emitted by a sample of twenty different fields. Volatile nitrosamines are chemicals such as benzothiazole and 4-(tert-octyl) phenol. The study did not indicate that such chemicals were emitted at levels of concern. A similar Dutch study looked into the levels of nitrosamines emitted from vulcanized crumb rubber and determined that such levels did not pose a risk to humans.

Both the Norwegian Building Research Institute (2006) and the California Integrated Waste Management Board (2007) have carried out tests of exposure to numerous potentially toxic metals present in tires, such as mercury, PCBs, nickel, cadmium, and chromium. Both studies identified levels that were either below detection limit or were at levels insignificant to health considerations. However, concerns were raised about levels of chemicals such as dibutylphthalate (DBP) and diisononylphthalate (DINP), whose presence can exceed EU standards.

2.7.6 Sample Testing

To investigate the issue of the content of lead and other metals in cryogenically produced crumb rubber, samples were sent out for laboratory evaluation. Materials were provided by a market leader, BAS Recycling of Moreno Valley, CA, from one of its primary customers, Environmental Molding Concepts (EMC). Synthetic field samples were sent to St. Louis Testing Laboratories, Incorporated, an independent third-party commercial testing laboratory, and analysis was conducted in February, 2009. Evaluations were carried out to ensure compliance with the U.S. Consumer Product Safety Improvement Act for Children's Products Containing Lead (i.e. CPSIA, Section 101), which places limits on the heavy metals content in children's product. The metals regulated by this act include: lead, antimony, arsenic, barium, cadmium, chromium, mercury, and selenium. Testing was done in accordance with American Standard Testing Method (ASTM) E1613, "Standard Test Method for Determination of Lead by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Flame Atomic Absorption Spectrometry (FAAS), or Graphite Furnace Atomic Absorption Spectrometry (GFAAS) Techniques."

In total, 40 tests were conducted, for each of the eight metals on five different color samples. Five colors (i.e. blue, green, rust, black, and gray) of turf were evaluated in order to account for possible variability of outcomes from different source contributions. All testing for lead indicated that sample contents were below problematic detection levels. For the remaining tests, all but one came back in compliance with regulation standards. In a single instance, the sample with blue colorization had slightly elevated levels of Barium. This test measured barium at 1228 ppm, which is 328 ppm above the limit. High levels of barium exposure can be troublesome. However, it should once again be noted that the mere presence of a substance is not necessarily cause for concern. It simply indicates a possibility of a risk of exposure. Further testing would be needed to measure the risk of contact. On the other hand, the absence of above limit concentrations precludes the possibility of exposure. In other words, a person cannot be at risk of exposure, if a substance is not present. As such, our testing found that the presence of lead—which was previously identified as being potentially problematic— does not pose a significant risk to people, and children in particular. In fact, the samples provided by BAS contained virtually no lead, at 20 parts per million, which surpasses the upper threshold limit of 400. Levels of lead even in soil are also acceptable at up to 400 parts per million, which signifies the insignificance of lead in the recycled rubber based material. Overall, cryogenically produced crumb rubber performed well against product safety standards.

2.7.7 Material Safety Conclusions

A review of existing literature points to the relative safety of crumb rubber fill playground and athletic field surfaces. Generally, these surfaces, though containing numerous elements potentially toxic to humans, do not provide the opportunity in ordinary circumstances for exposure at levels that are actually dangerous. Numerous studies have been carried out on this material and have addressed numerous different aspects of the issue. For the most part, the studies have vindicated defenders of crumb rubber, identifying it as a safe, cost-effective, and responsible use for tire rubber.

There remain a few objects of concern, though. First, the allergen potential of latex in tires used for athletic fields remains obscure. Though there has not been experimental confirmation of the risk of crumb rubber triggering a latex allergy, the possibility cannot be ruled out and needs to be investigated more thoroughly.

Second, lead exposure remains an object of some concern. The results of experimental evaluation of lead in these fields have been thus far inconclusive. Most studies have cleared the fields as safe in terms of lead risk, but others have noted an elevated presence of lead. Given the fact that lead levels in tires varies significantly according to production processes, it seems safe to conclude that given judicious selection of crumb rubber fill prior to constriction – that is, selection of material with low lead concentrations – lead exposure could be minimized significantly.

Finally, and most significantly, repeated testing has shown that the presence of zinc in leachate from crumb rubber fields remains problematically high. In many communities, these levels exceed what is allowable according to present environmental standards. Some studies have shown these levels to be acceptably low, and others have noted that certain governance areas – Canada's, for example – allow for higher levels of zinc in groundwater. However, generally speaking, it would appear that levels of zinc leaching into groundwater from crumb rubber fields are significant. Further research needs to be conducted into this question to determine whether it is a real concern, and if it is, greater innovation needs to be carried out at the level of product development to eliminate this concern. If this does not occur, the market for crumb rubber fields will be constricted to areas with relatively more relaxed groundwater-quality standards.

2.8 Environmental Impact

There are several issues that are encompassed in discussions of the environmental impact of a product or activity. Largely, these can be categorized into global warming impact, risks to human health (including toxicity), and disruption to ecosystems. The potential toxicity of synthetic turf, as well as its possible effects on human health was largely discussed in the previous sections (see Section 2.6: Injury, and 2.7: Material Safety). In addition, some of the aspects of ecological toxicity were also discussed in Section 2.7: Material Safety. The following section addresses additional environmental concerns related to natural and synthetic fields. The life cycle global warming impacts will be addressed specifically.

2.8.1 Environmental Concerns

Fertilizer

The environmental impact of fertilizers has garnered much attention in recent years, with growing concerns about bio-fuels. Fertilizers are made using very energy-intensive manufacturing processes to produce nitrogen. The basic feedstock for making nitrogen fertilizer is a petroleum product, natural gas. As a result, fertilizers can be the largest component of an agricultural product's energy consumption (Pimentel 1991; Shapouri et al., 1995; Pimentel 2002; Shapouri et al., 2002; Kim and Dale, 2004). With greater embodied energy, these products have a high global warming potential.

Given this, the amount of fertilizers needed for natural fields is an important environmental consideration. The global warming impact per pound of nitrogen in fertilizers has been shown to be 0.8 to 1.2 pounds of CO_2 (West 2002, Robertson 2000, Snyder 2007). Therefore, the carbon footprint associated with the fertilization of a natural turf field is between 204 and 306 pounds of CO_2 equivalent. This is between 0.092532 and 0.138799 tons.

Fuel Consumption

In assessments of global warming impacts, evaluations are often done by means of energy use as a proxy. While energy consumption alone does not account for all of the aspects of green house gas emissions, it is one of the major contributors of direct and indirect emissions. In an inventory of natural turf emissions, Townsend-Small and Czimczik (2010) find that the single greatest source of emissions is fuel use. For turf maintenance, fuel is used in transport, for mowing, and leaf blowing. Some of these emissions can be reduced by selecting electrically based machinery.

Grass grows quickly, and it must be mowed regularly to maintain optimal play quality. It is often assumed that such fields are cut on a weekly basis. Townsend-Small and Czimczik (2010) estimate that 2700 gallons of gasoline were used by the city of Irvine per month to maintain two million square meters of park area. The impacts associated with fuel use were greater than any other impact considered by about a factor of three or more.

Recycled Content

Products made from recycled content are generally preferable to those made from virgin material in two respects: 1) they do not draw on resources that may be limited; and 2) they address issues of waste. The crumb rubber used as infill in artificial turf fields is made from used tires. Recycled tires that were used in this capacity prevented an estimated 300 million pounds of ground rubber from scrap tires from ending up in landfills in 2007 (Rubber Manufacturers Association, 2009). It typically takes between 20,000 and 40,000 scrap tires to produce enough infill to cover a football field (City of Portland, 2008). The EPA's decree has afforded the opportunity for 4.5% of U.S. scrap tire to be applied as crumb rubber in sports surfacing in 2007 (Rubber Manufacturers Association, 2009).

Water

With over two-fifths of the world's population currently facing serious fresh water shortages, water scarcity is becoming an increasingly important issue. This figure is expected to get worse, as populations maintain growth, and glacier derived supplies continue to dwindle as a result of climate change. Water shortage has become the single greatest threat to food security, human health, and natural ecosystems (Seckler, 1999). In addition, irrigation not only requires the resource of water, but also needs energy to deliver it to the end user.

From a water standpoint, synthetic surfaces are advantageous over natural grass. Irrigation is a key component in maintaining natural turf. Artificial fields, on the other hand, do not usually require irrigation. Depending on their location and use, synthetic turfs may need to be watered down for cooling in hot temperatures, but the amount of water used for cooling is far less than that used to irrigate grass fields.

In addition to irrigation demands for water, a field's ability to take in storm water is another environmental consideration. There are several environmental problems associated with storm water runoff. In general, natural habitats are better able than impermeable surfaces to absorb storm water. However, synthetic turfs include drainage systems that compensate for their inability to take in water, while grass is poor at absorbing large quantities of water. Duble (1993) notes that runoff can vary greatly due to the seasonal distribution of rainfall. For a mean annual precipitation of 30 inches, runoff can be measured for the following amount at different locations: 3 inches in Nebraska, 6 inches in Tennessee, 12 inches in New York, and 22 inches in the Rockies. The resulting runoff that is created can lead to polluted ecosystems, as the flowing water picks up sediment, petroleum products, pesticides, fertilizers, bacteria, and metals. For example, in 2004, the water quality at San Francisco city beaches fell below quality standards 12 times in a single month, and storm water overflow contributed to over 40 closures during that year (Heal the Bay, 2004). This pollution, as well as other water capacity issues, such as flooding and the need for infrastructure, places stress on financial resources which may be lessened by a natural surface.

While natural turf may result in greater runoff than synthetic surfaces, they result in less aggregate waste water because they are able to absorb and use some of the precipitation. When viewed at a national level, the accumulated affects of water distribution and removal are not inconsequential. In aggregate, 3% of national energy, or a 56 billion kilowatt hours annually, goes to water deliverance and removal (EPRI 2002). This results in the release of approximately 45 million tons of greenhouse gas, when assuming the average mix of energy sources in the country (USEPA 2008). So, between the two field types there is a tradeoff of impacts: natural turfs may contribute to the problematic aspects associated with storm water runoff, while synthetic turfs play a role in issues regarding wastewater management.

Heat Island

One concern with synthetic turf is its role in the heat island effect - the increase of urban temperatures due to the replacement of vegetation with impervious surfaces that radiate heat. (New York City Department of Health and Mental Hygiene, 2008; Turfgrass Resource Center, 2008; Rosenzweig et al. 2006; New Yorkers for Parks, 2006). This effect occurs when heat from direct sunlight is absorbed by surfaces and then dissipated, raising ambient air temperatures. Urban heat island has an adverse impact on the environment because it increases the demand for cooling energy, intensifies air pollution—such as ground level ozone, and increases heat-related health problems (New York City Department of Health and Mental Hygiene, 2008; Rosenzweig et al. 2006; San Francisco Recreation and Park Department, 2008). Since synthetic turf has been shown to be hotter than the surrounding air and other surfaces (see Section 2.2: All-weather availability), it is a contributor to the heat island effect. However, the New York City Department of Health and Mental Hygiene (2008) notes that in New York, where summer temperatures can be about seven degrees higher than surrounding areas, synthetic turfs only make up a small portion of absorbent surfaces in the city, and therefore is not the primary culprit for this phenomenon.

2.8.2 Life Cycle Analysis

Various researchers have considered the emissions impact associated with turf systems, with much of this work focusing on calculating the capacity of natural grass to sequester carbon (Milesi, et al., 2005; Bandaranayake, et. al., 2003; Qian and Follett, 2002; Pouyat etal., 2009). Additional studies have investigated the N2O emissions of turfgrass (Guilbault and Matthias, 1998; Kaye et al., 2004; Bijoor et al., 2008; Hall et al., 2008). Townsend-Small and Czimczik (2010) note a lack of research investigating impacts of organic carbon storage and greenhouse gas (ghg) emissions. Additionally, studies exploring the emissions impacts of synthetic systems are lacking. One study by the Athena Institute (2007), a Canada-based nonprofit, compares the global warming impacts of natural and synthetic turf systems over the lifespan of the systems. This exploration of greenhouse gas inventories over the entirety of their life cycle will be utilized below to evaluate the emissions impacts of natural and synthetic turf systems. Given the scope of this study, our purpose here is not to conduct a comparative life-cycle analysis on turf systems, but rather, to provide some rough estimates of the comparative global warming impacts of natural and synthetic fields to see if we can clearly identify which field system has a lower impact.

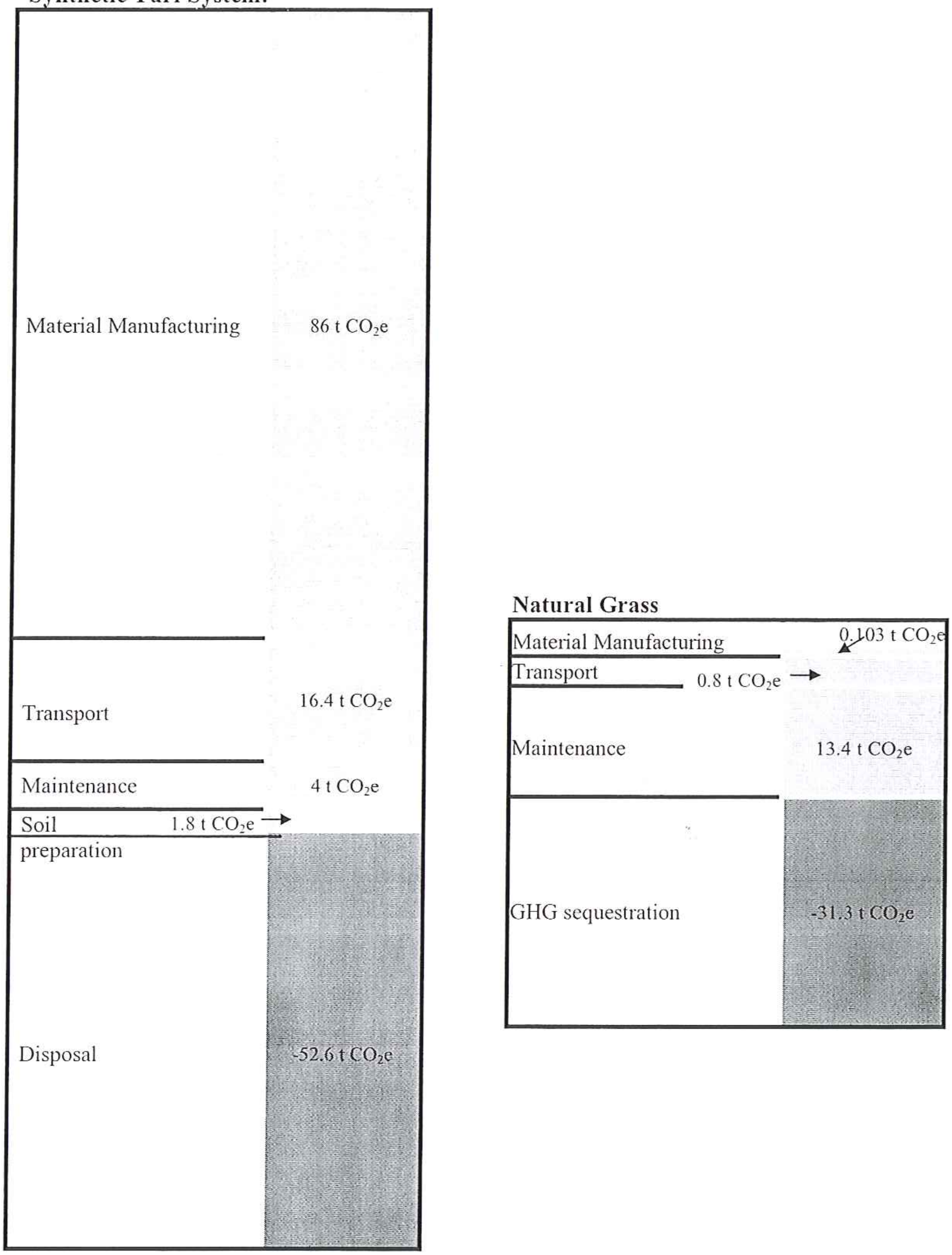
The Athena Institute (2007) study considers the entire scope of the product's life-cycle by means of SimaPro 7 LCA Software (2006). Assessments take into account various aspects of a playing field's life-cycle, including: the manufacturing of system components; transportation; surface preparation; maintenance; and end of life considerations. Impacts were calculated using various databases in conjunction with the SimaPro 7 LCA Software, based on the location where impacts occurred. For instance, the primary backing material, "Thioback Pro," is made from substances manufactured in the Netherlands, and is evaluated using the prominent European Life Cycle Inventory database, EcoInvent Library v.1.2, to estimate associated emissions. The Franklin 98/01-update Life Cycle Inventory database from the SimaPro 7 LCA Software was also used in calculations.

The data for this research was gathered from a case study on the installation of a synthetic field in 2006 for Upper Canada College, a school serving elementary and secondary students. The size of the field being considered was nine thousand square meters, or approximately 96,875 square feet. Five pieces were identified in construction of synthetic turf fields: the turf itself, primary backing material, a secondary elastomeric coating, rubber granule infill, and PVC piping for drainage. Meanwhile, the only components determined for natural fields are seeds and sod. Transportation includes all emissions from supplier to installation. Maintenance levels for artificial turf systems are adopted from the FIFA (2001) Guide. These include the brushing and removal of debris and contaminants using equipment such as: drag brushes, mats, and nets, hand tools, high-pressure cleanser, and sweeping machines. In addition, watering is recommended as needed, as is the removal of any snow, weeds, algae, and moss. In contrast, the maintenance considered for grass was irrigation and cutting, although the specifics about the methodology, amount, and frequency were not explicitly stated. Lastly, it is assumed that at the end of the artificial turf's life, the system is recycled.

Figure 2.2 below shows a summary of the comparative impacts found by the Athena Institute. Following that is a discussion of their findings.

Figure 2.2: Athena Institute's Green House Gas Emissions Assessment for Field Turf Systems

Synthetic Turf System:



Material Manufacturing & Transport

The Athena Institute considers the embodied energy for the components of natural and synthetic turf installations. In addition, transportation impacts for these components are calculated via the Upper Canada College case study.

For synthetic fields, the Athena Institute's calculations provide a good estimate for the impacts associated with the production of turf components. The parts that they considered were consistent with other descriptions of artificial turf systems. Also, evaluations for these impacts were conducted using widely accepted LCA software. At present, there is no other literature that considers the global warming impacts of synthetic turf systems. As such, it will be assumed that the Athena Institute's analysis of the impacts for manufacturing synthetic turf components has been adequately executed, and is equivalent to 86 t CO_2e.

For natural grass fields, meanwhile, the only components considered are the production of seeds and sod. The impacts of seed production have generally not been accounted for in research analyzing crop cultivation. This is especially true with urban fields. When evaluating the energy requirements of crop inputs, Moerschner and Gerowitt (2000) find that the effects of seed production are only a mere fraction of the total environmental impacts of fertilizer production. Flessa et al. (2002) cites the negligible contribution of seed production compared to the other agricultural product inputs as the reason for their exclusion in analysis. While attempts have not been made to account for the global warming emissions associated with seed production in grass fields, proposals for the inclusion of seed production have been made in the field of livestock production (Schils et al., 2007; Olesen et al., 2006), as well as in agricultural analysis in Europe (Weiske A., 2006; Kaltschmitt and Reinhardt, 1997).

It is unclear whether the entire scope of sod production is considered in the Athena Institute's analysis (i.e. whether the maintenance that goes into the production of sod is included). Much like seed production, there has been very little discussion of the emissions impacts associated with sod production. However, unlike seed production, the embodied global warming potential (gwp) of sod can be extrapolated from the maintenance requirements for grass fields. The next section will be dedicated to investigating whether Athena Institute's figure provides a good approximation based on some simplifying assumptions. First, to address their assessment, we must first explore the work of Townsend-Small and Czimczik (2010) for the data on the various maintenance impacts associated with natural grass turf.

In their study, Townsend-Small and Czimczik (2010) calculate the gwp of urban natural grass turfs, considering their organic carbon storage, direct N2O emissions, and the emissions associated with maintenance. The outcomes of these evaluations vary based on a number of factors, including: fertilization practices, soil moisture, temperature, and the existing soil organic carbon content. Their analysis of existing fields shows that the amount of organic carbon that is stored in natural grass fields is not enough to offset the direct and indirect emissions associated with the field. In fact, they found that in fields that absorb potential greenhouse gases, associated emissions are approximately three to four times greater. This is especially true in athletic fields, where it is assumed that turfs are installed with sod, instead of seeds--which is often used for ornamental fields. Based on this assumption, athletic fields offer no net sequestration of CO_2. More specifically, the addition of transplanted sod results in the addition of organic carbon to the system. While the original soil where the sod was planted is capable of storing organic carbon, the soil on a field with transplanted sod can take up to three decades before it begins to store organic carbon. In addition, maintenance practices such as tilling, aeration, and the re-sodding of dead grass disrupt the storage of organic carbon. The estimates for this study are listed in the table below:

Table 2.8: Townsend-Small and Czimczik' (2010) gwp of Urban Natural Grass Turfs

Impact Considered	Description	GWP (g CO2/m2/yr)
Organic carbon storage	Estimates of the sequestration of organic carbon based on an analysis of physical samples.	513
N2O emissions	A measurement used to estimate some of the impacts of greenhouse gas emissions from turf soil.	45-145
Fuel	This figure includes the emissions associated with the actual fuel requirements to maintain the turf being sampled, totaling about 2x10 6 m2 of park area. The amount of fuel was estimated to be approximately 2700 gallons of gasoline per month. This fuel covers the transport, mowing, and leaf blowing for weekly trimmings and mulching. The global warming potential from this fuel use was then calculated using the EPA's (2005) estimates of 2421 g C for a gallon of gasoline, and Lal's (2004) assessment of combustion efficiency of 85%, which is similar to farm equipment.	1469
Water conveyance	The fields for this study were watered regularly, using recycled wastewater. Impacts associated with irrigation consider the energy required to pump water. Calculations are made using Schlesinger (1999) estimate of 53 g C/m2/yr for associated energy.	193
Fertilizer production	Fields are assumed to be fertilized from two to 15 times per year. Figures provided by Schlesinger (1999), of 1.436 moles of C per mole of N produced, were used in the calculation of embodied emissions associated with the production of fertilizers. The range of emissions impacts varies based on the number of fertilizations.	45-339
Total		**1752-2146**

We will use the data provided by Townsend-Small and Czimczik's (2010), together with Athena Institute's assessments, to make an approximation of what seed and sod production impacts should be. We begin by stating the assumptions used in our analysis. First, we assume that sod is grown for about a year before it is transplanted to a new field. Powell (1999) estimates that a sod crop can be harvested six months to two years after establishment. Next, we assume that, at the very least, sod requires irrigation to grow. If we assume that Athena Institute's measurements for the watering and cutting (i.e. the "maintenance") of a grass field are correct, then the emissions for growing sod should be at least one year's worth of the watering impacts (sod impacts should be higher than this figure, as there are additional maintenance requirements that have associated emissions). Townsend-Small and Czimczik's (2010) ratio of impacts from fuel and water conveyance are 1469:193 g CO2e/m^2/yr; or more simply put, the fuel related impacts are 7.6 times greater than those from watering. Then, if we apply this ratio to Athena Institute's maintenance associated emission of 13.4 t CO_2e, watering impacts should be 1.56 t CO_2e for 10 years. If, as stated, we assume that the average sod production period is one year, the rough estimate just proposed suggests that the calculation of 0.103 t CO_2e for seed and sod production might be a slight underestimate, when compared to one year of watering. This figure appears to be an even greater underestimate when considering that Athena Institute's estimate includes the impacts from seed production, and that sod is generally fertilized multiple times prior to being transplanted (Powell, 1999a). The apparent under-estimation of these impacts suggests that a more accurate estimate of emissions associated with seed and sod production should be investigated. However, in the scale of the natural turf's life cycle, the production stage emissions will always be dwarfed by the global warming potential of grass maintenance. Thus, research into more precise measurements of seed and sod production emissions will not be addressed within the scope of this paper, and will be left to future research.

Soil Preparation

Depending on the existing condition of a field, significant efforts might be required to excavate topsoil in preparation of turf installation. For the purpose of this report, it is assumed that emissions associated with excavation are significant, and that they should be incorporated into impact inventories. The Athena Institute's analysis includes impacts related to topsoil excavation. However, they do not explicitly outline what is considered in the accounting of these emissions. We speculate that these impacts are associated with the operation of machinery to dig up and haul away topsoil. This theory is supported by the fact that hauling-related emissions do not appear to be included with transport emissions, which are instead focused on the delivery of components to the location of installation. Therefore, having identified possible impacts related to the excavation of topsoil, which are not covered in other aspects of Athena Institute's evaluations, and without alternative assessments available from other research, we will assume that their calculations are an acceptable estimate for excavation related impacts. However, it should be noted that it might be possible to obtain a more accurate measurement from further investigation.

Maintenance

The maintenance requirements considered by the Athena Institute vary dramatically for the two turf types. The maintenance tasks for artificial turf were adopted from the FIFA (2001) guide. These include the brushing and removal of debris and contaminants using equipment such as: drag brushes, mats, nets, hand tools, high-pressure cleanser, and sweeping machines. In addition, watering is recommended as needed, as is the removal of any snow, weeds, algae, and moss. In aggregate, the emissions associated with these activities are 4 t CO_2e over ten years. In contrast, the maintenance considered for grass is irrigation and cutting. The emissions associated with these activities are 13.4 t CO_2e.

The Athena Institute does not state the underlying assumptions that were made in calculations of maintenance related emissions. It is therefore assumed that all of the various aspects relating to these activities were considered, and that calculations are as comprehensive as possible. For instance, evaluations can change based on factors such as: the frequency with which activities are carried out, the methodology used to accomplish a maintenance task, the quantity of materials applied, and the scope of the supply chain considered (i.e. transportation and embodied energy associated with any material used).

While far more maintenance activities are considered for synthetic fields, the global warming potential for the maintenance of natural fields is greater. The differences in these impacts are partially due to grass fields' continual need for additional supplies to sustain their health. Emissions related to the continual input of supplies accumulate over time. The findings of Townsend-Small and Czimczik (2010) show that much of the global warming impacts of grass maintenance are associated with fuel use. On the other hand, the maintenance of synthetic fields only generally requires a capital investment in equipment and labor to carry out tasks. It is customary in LCA research to exclude the impacts of labor. This means that any work done by hand on a field has no associated emissions.

To achieve a more comprehensive analysis, additional maintenance requirements should be considered, as per the maintenance related equipment and supplies identified in Section 2.4: Maintenance. Of particular interest are the additional impacts associated with the application of fertilizer to natural fields. However, it should be noted, that even with the additional consideration of these elements, the general finding by the Athena Institute will remain largely unchanged. That is, the maintenance impacts of natural turfs will be larger than those of synthetic turf, only to a greater degree. However, these impacts will still be much less than the material related emissions associated with the manufacturing of the components of synthetic turf. Any considerations of additional maintenance practices will result in greater emissions being associated with natural systems. This increase will result from the input of materials that are needed in greater quantities, and with greater frequency than for synthetic turfs.

Table 2.9 below lists the maintenance needs and materials identified by the Athena Institute, as well as additional recommendations obtained from the maintenance materials identified in Section 2.4.

Table 2.9: Maintenance Needs and Materials

	Synthetic	Natural
Activities Considered	Watering	Irrigation
	Brushing	Mowing
	High-Pressure Cleaning	
	Sweeping	
	Dragging	
Material Inputs Needed	Water	Water
		Fuel
Additional Recommended Input Considerations	Paint	Paint
	Top Dressing	Top Dressing
		Fertilizer

Green House Gas Sinks

Natural Grass

For natural grasses, the photosynthesis process involves the intake of carbon dioxide and results in carbon compounds that enter the soil with root growth or when a plant sheds or dies. These compounds can be stored long-term as soil organic carbon, as well as other soil organic matter. This is significant in the evaluation of global warming impacts because it results in a more permanent removal of carbon dioxide from the atmosphere. Also, in aggregate, the ability of turf to sequester carbon is not insignificant: in 2005, turfgrass covered approximately 1.9% of land in the continental U.S., making it the most widespread irrigated crop (Milesi et al., 2005). As such, any evaluation of the emissions of natural turfgrass should involve the most current and relevant measure that has been proposed for these impacts.

For the measurement of organic carbon storage, the Athena Institute uses the mean value of sequestration rates proposed by Qian and Follett's (2002) of between 0.9 and 1.0 tons of carbon per hectare per year. These estimates come from soil testing data on golf courses in Denver and Fort Collins, Colorado (Qian and Follett, 2002). Bandaranayake, et al., (2003) found similar sequestration rates when modeling organic carbon sequestration in various geographically-based scenarios. The average rate of accumulation over a 30 year period was found to be 1.2 and 0.9 t C/ha/yr for Fort Collins and Denver, respectively. As previously noted, the ability of soil to store organic carbon can be influenced by a multitude of factors. Post and Kwon (2002) showed this to be true in the case of soils that were previously disturbed, which were found to have a lower C sequestration rate of 0.33 t C/ha/yr. These studies indicate that the figure for organic carbon sequestration used by the Athena Institute may be a bit high for a newly installed field, but are acceptable for a life time analysis of the field.

However, one aspect that the Athena Institute neglects in their calculations is the direct ghg emissions that occur from natural grass. While research on the total impacts of greenhouse gases, including absorption and direct emissions, are somewhat nascent, several studies have looked into the N2O emissions of urban turfgrass. Considerations of these emissions do not measure the full impacts of the direct emissions from grasses. However, they do serve to account for some of the impacts of urban grass, and to illustrate the complexities involved in modeling their global warming impacts. Much like organic carbon storage, there are numerous factors that create variability in emissions rates. Several researchers have modeled annual fluxes of N_2O emissions based on their relationship to temperature, soil moisture, and soil organic carbon content (Scanlon and Kiely, 2003; Flechard et al., 2007). Spikes in N_2O emissions have been shown to occur in urban turfs after irrigation or fertilization of the field (Guilbault and Matthias, 1998; Kaye et al., 2004; Bijoor et al., 2008; Hall et al., 2008). Estimates of N_2O fluxes from urban turfs range between 0.05 to 0.6 g N per meters squared per year (Guilbault and Matthias, 1998; Kaye et al., 2004; Groffman et al., 2009; Townsend-Small and Czimczik, 2010). For our purposes, we will use the estimates provided by Townsend-Small and Czimczik for annual N2O emissions, which is the mean of 0.1 to 0.3 g N/m2/yr.

Recycling of Synthetic Turf at the End of Life

Calculations for the end of life of a synthetic turf are based on the assumption that all components, except the rubber granule infill, are 100% recyclable. Based on this assumption, an emissions credit is awarded by the Athena Institute for the end of life of the system. Calculations are made using ICF Consulting's (2005) report on the ghg emissions factor for plastic. The materials that are assumed to be recyclable in synthetic turf are: polyethylene from the turf and primary backing material; polyurethane from a secondary coating; and PVC piping.

The flaw in Athena Institute's estimates for the end of life emissions for synthetic fields is that materials may not be recycled just because they are capable of being recycled. In fact, the San Francisco Recreation and Park Department (2008) notes that the cost and a lack of infrastructure are an issue with the end-of-life recycling of artificial turf. They note that at the time of the report's publishing only one company in the industry recycled turf material. When turf is not recycled, a large amount of waste must be disposed of at the end of the field's useful life. According to the City of Larchmont, California, 400 tons of debris is created when an 80,000 sq. ft. field is replaced (San Francisco Recreation and Park Department, 2008). Given these concerns, the actual rate of recycling is highly questionable, suggesting that emissions credit should not be accounted for in synthetic turf systems.

2.8.3 Environmental Impact Conclusions

In general, the environmental impact of natural grass is more complex than those of synthetic turf. This is due in large part to the fact that natural grass requires the continual addition of inputs to sustain a field's health. As with any agricultural practice, draws on water and the addition of agrochemicals can become problematic. These practices draw on scarce resources and have the potential to effect surrounding ecosystems. Additionally, the maintenance of grass is associated with the use of large quantities of fuel, to mow grass to the appropriate length. The Athena Institute sufficiently shows the weight of these impacts in regards to global warming. However it is recommended that a more comprehensive inclusion of material inputs into grass maintenance be calculated in any future life cycle assessments.

The environmental issues related to synthetic turf mainly revolve around the use and disposal of materials. Many see the use of recycled waste products for field infill as one of the primary benefits of artificial systems. However, such systems also require the use of many virgin materials. As such, the greatest greenhouse gas emissions of either two system types are the impacts associated with the production of synthetic turf components. These material impacts increase the total emissions by a multiplicative factor when considering the entire life cycle, due to related increases in processing and transportation needs.

The validity of the greenhouse gas emissions sinks identified by the Athena Institute is in need of further consideration. It appears that the evaluations associated with these credits are either based on some faulty assumptions or do not take all considerations into account.

3.0 CONCLUSIONS

This report explored the various aspects of crumb rubber and addressed some of the claims made by various researchers. A look into the existing literature and data supported many of the assertions made about crumb rubber. Crumb rubber and synthetic turf have many traits that make it a beneficial choice for athletic surfaces. Some of the findings that were found indicated that synthetic turf has:

- **Excellent Playability** – Most literature comparing the play quality of natural and synthetic fields suggest that the differences between them have miniscule affects on playability in comparison with variance in the set-up of the field itself. Where differences do emerge, artificial turf appears to be equal to or better than natural turf, due to its greater consistency. While such findings are incomplete, because of the lack of studies that evaluate the newer generations of turf technology, there were no studies that contradicted the superiority of synthetic turf.

- **All-weather Availability** – Synthetic turf is praised for its availability in all weather conditions: more use per year, and a quick install. It can be used quickly after installation, usually within a few days, rather than the weeks it takes for a sod to become robust enough for use. Also, it can be used in snow, and in general is not affected by precipitation due to the drainage sytem involved. However, high heat can create an obstacle for synthetic turf use, as the surface can become uncomfortable to play on. Since there are means to temper such effects, the field can still be made useable. Also, the use of turfs are not typically greatest during the hottest parts of the year, as sports seasons typically fall in the late summer through the spring. These impairments do not compare to the degree to which natural fields are compromised during rain and snow. With all weather considered, artificial turf has greater availability over natural grass when taking weather into account.

- **Increased Playing Hours** – Studies suggest that average hours of playability in a three-season year for synthetic turfs range between 2,000 and 3,000 hours, with most research pointing toward 3,000 hours. Natural fields, on the other hand, provide far less playability, with studies estimating a range between 300 and 816 hours in a three-season year on average. Weather is an important factor in the reduction of use times for natural turf. Beyond the weather related losses in the capacity of grass fields, all natural fields must be given time to "rest" to allow for growth.

- **Reduced Maintenance** – The value of a field can be determined by its availability and by the amount of maintenance a field requires. Activities that can be classified as grooming are the most important components of maintenance for both turf types. In addition, debris control, additional cleaning, and needs-specific maintenance may be required. In general, natural fields require a more nuanced balance of activities such as mowing, fertilization, and aeration to ensure their health.

- **Cost-effective Investment** – synthetic turf fields are typically warranted for about 3,000 hours of play per year, with no "rest" required. For schools with sufficient land, it would take three or four natural fields to withstand the usage of one synthetic turf field. Because of its consistent availability, a synthetic turf field is also a reliable source of rental revenue for schools and communities. The study found that the total cost of ownership over a ten year period is 10% - 20% less than a natural turf field, while being 70% or even 80% less on a cost-per-use basis.

- **Generally Safe Application** – Extensive research has pointed to the conclusion that these fields result in little, if any, exposure to toxic substances. A review of existing literature points to the relative safety of crumb rubber fill playground and athletic field surfaces. Generally, these surfaces, though containing numerous elements potentially toxic to humans, do not provide the opportunity in ordinary circumstances for exposure at levels that are actually dangerous. Numerous studies have been carried out on this material and have addressed numerous different aspects of the issue. For the most part, the studies have vindicated defenders of crumb rubber, identifying it as a safe, cost-effective, and responsible use for tire rubber.

- **Fewer Injuries** – Numerous studies have been conducted assessing the likelihood of injury on natural grass and synthetic turf. A more recent study by Meyers (2010) shows that the latest generation of synthetic surface, FieldTurf, is safer to play on than natural grass fields. Through the analysis of the various injuries that occurred over the course of 465 collegiate games, Meyers shows that FieldTurf has lower incidence of: total injuries, minor injuries (0-6 days lost), substantial injuries (7-21days lost), and severe injuries (22 or more days lost). FieldTurf also had significantly lower injury rates that natural turf when comparing across play or event type, grade of injury, or various field conditions and temperatures. In addition, there was no significant difference found in head, knee, or shoulder trauma between the two playing surfaces.

- **Environmentally Friendly** – In general, the environmental impacts of natural grass are more complex than those of synthetic turf. This is due in large part to the fact that natural grass requires the continual addition of inputs to sustain a field's health. These practices draw on scarce resources and have the potential to effect surrounding ecosystems. Additionally, the maintenance of grass is associated with the use of large quantities of fuel, to mow grass to the appropriate length. The environmental issues related to synthetic turf mainly revolve around the use and disposal of materials. Many see the use of recycled waste products for field infill as one of the primary benefits of artificial systems. However, such systems also require the use of many virgin materials. As such, the greatest greenhouse gas emissions of either two system types are the impacts associated with the production of synthetic turf components. These material impacts increase the total emissions by a multiplicative factor when considering the entire life cycle, due to related increases in processing and transportation needs.

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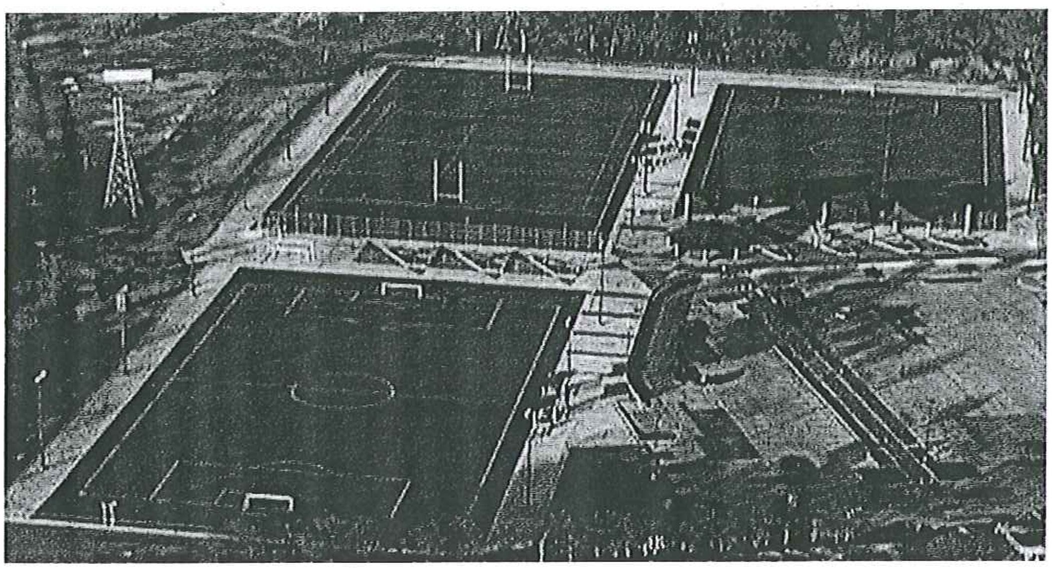
FINAL REPORT

Artificial Turf Study

Leachate and Stormwater Characteristics



Connecticut Department of Environmental Protection
July 2010

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APPENDICES

1. PROJECT OVERVIEW

In December 2008, four Connecticut State agencies, the University of Connecticut Health Center, The Connecticut Agricultural Experiment Station, the Connecticut Department of Environmental Protection and the Connecticut Department of Public Health, agreed to jointly develop and implement a study to evaluate the health and environmental impacts associated with artificial turf fields. The overall objectives of the study were to:

1. Identify comprehensively substances, including organic compounds and elements, which derive from the crumb rubber infill used on synthetic turf fields, as well as currently available alternative infill products, through off-gassing and leaching pathways;
2. Establish the level of chemical variability for infill at individual synthetic turf fields and between different synthetic fields in Connecticut;
3. Measure levels of off-gassed compounds and airborne particulate matter in the normal breathing zone of children during a "simulated worse-case scenario" at athletic field(s) in Connecticut (inhalation risk);
4. Measure levels of leached compounds in storm water runoff collected in actual field conditions (environmental risk); and
5. Utilize collected data to make environmental and public health risk assessments regarding outdoor artificial turf fields.

The Department of Environmental Protection ("DEP") was specifically tasked with: (1) collecting stormwater runoff samples from the four artificial turf fields selected for the study; (2) analyzing the stormwater samples for levels of compounds leached from the artificial turf materials; (3) scientifically evaluating the laboratory analysis results; and (4) developing an environmental risk assessment for the artificial turf fields.

This report is not intended to be a comprehensive investigation of the environmental risks associated with artificial turf fields, but a basic assessment of water quality data collected from a limited number of fields during a three-month period. It should be understood, that the ultimate conclusions in the report are based on eight stormwater sampling events, essentially a "snapshot", of an ongoing chemical and physical process.

2. SITE SELECTION

The four artificial turf fields selected for DEP's stormwater sampling plan were the same fields sampled in the summer of 2009 by the University of Connecticut Health Center for airborne contaminants. Specific field selection criteria included: crumb rubber infill, owner permission, installation date, different manufacturers and site location. The owners of the selected four fields provided engineered drainage plans to DEP. DEP staff reviewed the drainage plans and established sampling points that <u>only</u> collected stormwater draining from the artificial turf field.

3. ARTIFICIAL TURF FIELD SYSTEMS

The artificial turf fields selected were installed by different engineering, synthetic turf and construction companies, but are similar in general design. The fields are composed of a top layer of polyethylene or polypropylene grass fibers, with a crumb rubber (sometimes intermixed with sand) infill layer, and underlain by crushed stone/gravel with a piped drainage system (see Figures 1 and 2 below).

Figure 1.

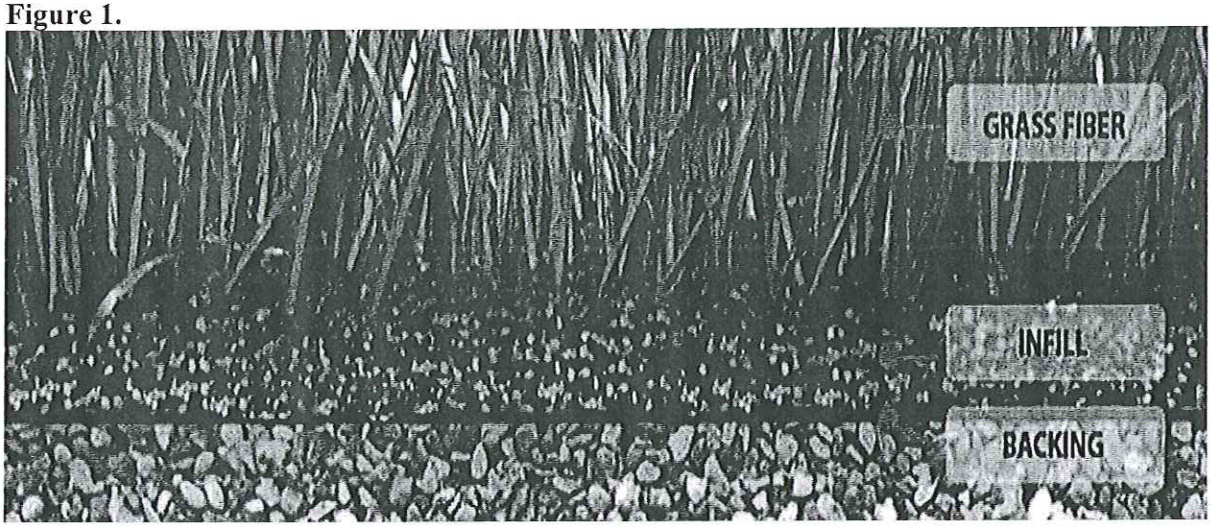
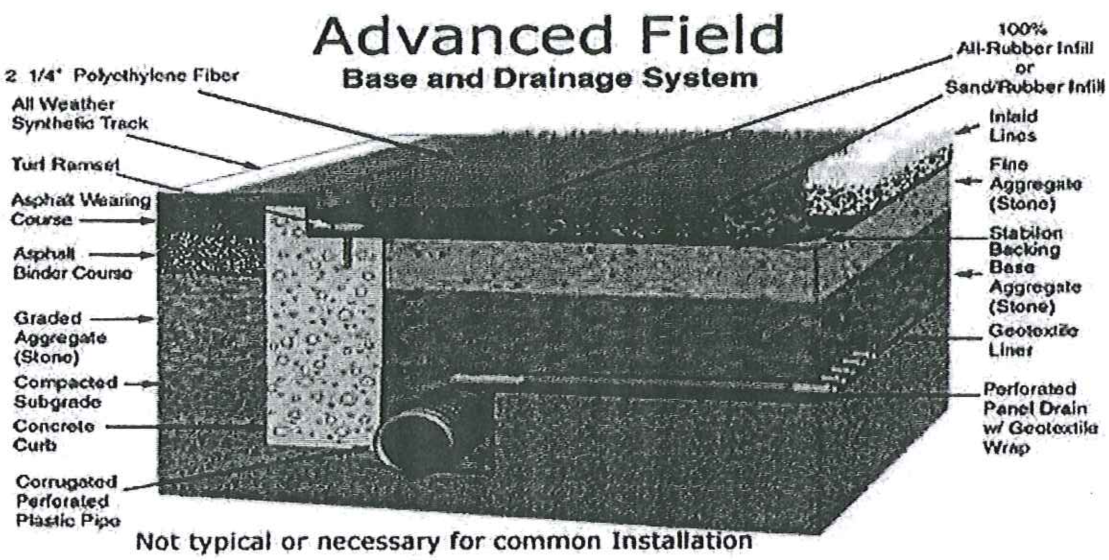


Figure 2. (source: www.suncountrysystems.com/.../syntheticgrass.jpg)



The critical field component for this study is the infill layer, which includes crumb rubber materials produced from recycled tires. The infill layer can be composed of entirely styrene-butadiene rubber (SBR) granules, produced by ambient and/or cryogenic grinding process, or intermixed with quartz crystals (sand). The assumption for this study, and the sampling plan, is that precipitation lands on the surface of the artificial turf field, flows downward through the infill and rock/gravel layers, collects in the subsurface drain pipes and then ultimately discharges from the field. The artificial turf drainage pipes often discharge to existing subsurface drainage systems at catch basin and/or manhole connections. The subsurface drainage pipes utilized under the fields can be solid or perforated.

4. SAMPLING PROTOCOLS

DEP staff reviewed EPA protocols and previous artificial turf leaching studies and established the following stormwater sampling plan:

1. Sampling Plan
    a. One sampling station was established at each of the four artificial turf fields;
    b. The sampling stations were located at a point where runoff was only from the artificial turf field;
    c. The size of the drainage area (in square feet) to each sampling station was calculated;
    d. Grab samples were collected and delivered to the laboratory by qualified individuals during the fall of 2009; and
    e. Samples were analyzed by an EPA certified laboratory.

2. Storm Event Criteria
    a. Samples were collected from discharges resulting from a storm event that was greater than 0.1 inch in magnitude and that occurred approximately 72 hours after any previous storm event of 0.1 inch or greater;
    b. Grab samples were collected during the first 30 minutes of a storm event discharge, or as close thereto as possible, and were completed as soon as possible;
    c. The following information was collected for the storm events monitored:
        i. The date, temperature, time of the start of the discharge, time of sampling, and magnitude (in inches) of the storm event sampled; and
        ii. The duration between the storm event sampled and the end of the previous measurable (greater than 0.1 inch rainfall) storm event.

3. Sampling Procedures
    a. Grab sample collection, chain of custody and laboratory delivery were performed in accordance with the EPA NPDES Stormwater Sampling Guidance Document (EPA 833-B-92-001, 7/92); http://www.epa.gov/npdes/pubs/owm0093.pdf
    b. Laboratory analysis of grab samples included the following:
        i. Acute Toxicity 48 hour LC50 *Daphnia pulex* & 48 hour and 96 hour LC50 *Pimephales promelas* (EPA 821-R-02-012).
        ii. EPA Method 130.1, Hardness, Total (mg/L as $CaCO_3$)
        iii. EPA Method 150.2, pH
        iv. EPA Method 200.7, (Antimony, Arsenic, Barium, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Thallium, Vanadium and Zinc)
        v. EPA Method 624, Volatile Organic Compounds
        vi. EPA Method 625, Semivolatile Organic Compounds (TIC's for Benzothiazole, Butylated hydroxyanisole (BHA), n-hexadecane and 4-(t-octyl) phenol.

6. DEP STORMWATER SAMPLING RESULTS

a) Method 624/Method 625 and Tentatively Identified Compounds(TICs):

No standard volatile or semi-volatile organic compounds were detected in any sample using the EPA 624 and 625 analytical methods. All samples were analyzed for non-standard semi-volatile organic compounds, including the following rubber compounds benzothiazole, butylated hydroxyanisole (BHA), n-hexadecane and 4-(t-octyl) phenol. The semi-volatile analysis detected the analytical peaks of twenty-two compounds, of which nine were tentatively identified (see Table B below). The concentrations of these compounds ranged from 1 ug/l to 150 ug/l. The grey columns in Table B correspond to the three stormwater samples determined to be acutely toxic. Table C details the aquatic toxicity information found for the other tentatively identified compounds listed in Table B.

b) Pesticides and PCBs (Method 608)

Pesticides

Pesticides were detected in the samples of stormwater collected on September 11, 2009 from Field C and on October 28, 2009 from Field D. DEET and heptachlor were detected at estimated concentrations of 6.9 ug/l and 0.18 ug/l, respectively. It is assumed that these substances were not derived from the artificial turf, but were a result of pesticide applications at the site.

PCBs

No PCBs were detected during the stormwater sampling events.

c) pH, Hardness and Metals:

The results from the pH, hardness and metals analysis conducted on the stormwater runoff from the fields are presented in the table below.

pH

The pH of the stormwater samples ranged from 6.6 to 8.0. The pH of stormwater in Connecticut is generally considered to be between 5.6 and 6.0. Based on this fact, the pH of the stormwater samples are more alkaline than expected. It is possible that the crushed stone used as a sub-base in the fields affected the pH of the stormwater as it drained through the field.

The pH alone does not exhibit toxic effects unless it falls below 5 or is higher than 10. However, metals are often more soluble and toxic at lower pH's. The observed neutral pH in the stormwater may have reduced the concentrations and toxicity of the metals leaching from the fields.

TABLE B

Location:			Field C	Field A	Field A	Field A	Field D	Field D	Field D	Field D
Sample #			A	B	C	E	D	F	G	H
Sample date			9/11/2009	9/27/2009	10/7/2009	10/18/2009	10/18/2009	10/28/2009	11/20/2009	12/3/2009
Parameter:	Tentatively identified Compounds	CAS#								
Heptachlor							<0.10	0.18	NT	<0.05
Retention Times (min)										
3.55			6.2							
5.04					150					
6.12			4.3							
6.63										9.5
6.81					4.1					
6.83	2- propyl-methyl pentanoic acid	22632-59-3			14	6.6				
6.85	Benzothiazole	95-16-9		1	4.9					
6.88					6.1					
7.07									5.1	
7.08	methyl 2alpha -D-xylofuranoside	32469-86-6				5.8				
7.10	2 ethyltetra hydro thiopene	1551-32-2				28				
7.13	4-methyl4-Heptanol	598-01-6				7.4				
7.15	2- butyl tetrathydrothiopene	1613-49-6				12				
7.77										10
7.96								6.6		
8.13					7.4					
8.23									7	
9.48	Benzamide, N-N- diethyl-3-methyl	134-62-3	6.9							
9.56	2(3H)- Benzo thiazolone	934-34-9			5.7					
10.28						4.1				
12.60	2-2-7 trimethyl-3-Octyne	55402-13-6					4.5			
16.88			8.4							

TABLE C

Location: Sample # Sample date			Max Concentration	Location	Acute Water Quality Criteria	Chronic Water Quality Criteria	Comments
Parameter:	Tenatively identifeid Compounds	CAS#					
Heptachlor			0.18	D	0.26	.0038	CT WQS 2002
Retention Times (min)							
3.55			6.2	A			
5.04			150	A			
6.12			4.3				
6.63			9.5	D			
6.81			4.1	A			
6.83	2- propyl-methyl pentanoic acid	22632-59-3	14	A	2812.5	312.5	Toxicity info on pentanoic acid tier 2
6.85	Benzothiazole	95-16-9	4.9	A			One data point tier 2
6.88			6.1	A			
7.07			5.1	D			
7.08	methyl 2alpha -D-xylofuranoside	32469-86-6	5.8	A			No data
7.10	2 ethyltetra hydro thiopene	1551-32-2	28	A			No data
7.13	4-methyl4-Heptanol	598-01-6	7.4	A			No data on Heptanol either
7.15	2- butyl tetrathydrothiopene	1613-49-6	12	A			No data
7.77			10	D			
7.96			6.6	D			
8.13			7.4	A			
8.23			7	D			
9.48	Benzamide, N-N- diethyl-3-methyl	134-62-3	6.9	C	89.3	9.9	DEET tier 2
9.56	2(3H)- Benzo thiazolone	934-34-9	5.7	A	47.3	8.1	Different CAS # 149304 tier 2
10.28			4.1	A			
12.60	2-2-7 trimethyl-3-Octyne	55402-13-6	4.5	D			No data
16.88			8.4				

Hardness

The hardness of the stormwater samples ranged from 8 to 59 mg/L. Hardness in the range of 0 to 60 mg/L is generally termed "soft". Hardness can also influence the toxicity of metals; the greater the hardness, the less toxic the metals. It is not expected that the observed hardness had much effect on metal concentrations in the stormwater.

Metals

The metal parameters which had results reported above the detection limit are listed in Table C below. Silver, molybdenum, thallium and beryllium were analyzed but were below the detection limit for every sample. In Table C, the values bolded and underlined exceed Connecticut's acute aquatic life criteria. Metal concentrations in excess of the acute aquatic life criteria for more than one hour could cause mortality to the more sensitive organisms in the receiving surface waters. The values bolded meet or exceed Connecticut's chronic aquatic life criteria. Average metal concentrations which exceed the chronic life criteria for more than 4 continuous days are expected to impact the ability of organisms to survive, reproduce or grow. EPA recommends that neither of these criteria be exceeded more than once in three years (EPA TSD EPA/505/2-90-001). The samples highlighted in grey also exhibited acute toxicity. Since stormwater is an intermittent discharge, the acute criteria for aquatic toxicity are more applicable. A review of the data indicates that only zinc consistently violates the acute criteria.

TABLE D

Location	Sample #	Sample date	pH	Hardness	Conductivity	Cu ug/l	Zn ug/l	Ba ug/l	Fe ug/l	Al ug/l	V ug/l
Field C 2005	A	9/11/09	6.6	NA	18	4	**<u>150</u>**	4	320	**210**	40
Field A 2007	B	9/27/09	6.6	8	20	1.5	**<u>130</u>**	1.5	20	25	1.5
Field A 2007	C	10/7/09	7.5	29	65	1.5	10	6	50	**160**	5
Field A 2007	E	10/18/09	7.5	39	86	1.5	20	7	20	60	1.5
Field D 2007	D	10/18/09	7.6	53	130	5	**<u>260</u>**	**220**	170	**120**	6
Field D 2007	F	10/28/09	7.9	59	157	4	50	8	80	80	8
Field D 2007	G	11/20/09	8	56	153	4	30	7	160	**110**	9
Field D 2007	H	12/3/09	8	58	147	4	20	5	170	**100**	8
		acute standard	**<5.0 >10**			**<u>14.3</u>**	**<u>65</u>**	**<u>2000</u>**		**<u>780</u>**	**<u>150</u>**
		chronic standard	**<5.0 >10**			**4.8**	**65**	**220**	**1000**	**87**	**44**

d) Aquatic Toxicity

The toxicity tests conducted on the stormwater measured both an LC50 value (the concentration of stormwater that is lethal to 50% of the test organisms) and an NOAEL (No Observable Acute Effect Level, the concentration of stormwater where no acute toxicity is observed). Toxicity tests conducted on the samples of stormwater collected indicate that 3 out of 8 sampling events were acutely toxic. Acute toxicity is observed when there is less than 90% survival of the test organisms in the undiluted effluent. The frequency of occurrence for acute toxicity was at least one sample per field. Where both *Pimephales promelas*(Pp) and *Daphnia pulex*(Dp) toxicity tests were conducted, the fathead minnow (*Pimephales promelas*) seemed to be slightly more sensitive to the contaminants in the stormwater discharge. Due to laboratory issues, the test duration for the fish, *Pimephales promelas*, for the October 18, 2009 Field A and Field D samples was limited to only 48 hours. If the test duration was extended to 96 hours, both samples could have had an LC50 value less than the 100% reported. The results for the aquatic toxicity testing conducted are shown in Table E below.

TABLE E

Location:	Sample #	Sample date	Dp % Surv 100%	Dp LC50	Dp NOAEL	Pp % Surv in 100%	Pp LC50	Pp NOAEL
Field C 2005	A	9/11/2009	65.0	>100	12.5	NT	NT	NT
Field A 2007	B	9/27/2009	70.0	>100	50	45	93.89	50
Field A 2007	C	10/7/2009	100.0	>100	100	100	>100	100
Field A 2007	E	10/18/2009	100.0	>100	100	96	>100	100
Field D 2007	D	10/18/2009	70.0	>100	6.25	50	100	25
Field D 2007	F	10/28/2009	100.0	>100	100	95	>100	100
Field D 2007	G	11/20/2009	100.0	>100	100	100.0	>100	100
Field D 2007	H	12/3/2009	100.0	>100	100	95	>100	100

acutely toxic

7. CAES LABORATORY HEADSPACE AND LEACHING RESULTS

The CAES performed both headspace (off-gassing) and SPLP (Standard Precipitation Leaching Procedure) evaluations on seventeen samples of crumb rubber materials used as infill for artificial turf fields. These studies indicated the primary contaminants likely to be found in the stormwater coming from these sites. Organic compounds were identified by head space analysis, with results shown in Table F below. The other organic compounds detected from the crumb rubber infill, but not quantified in the analysis, included hexadecane, fluoranthene, phenanthrene and pyrene.

TABLE F. (Table 2. From CAES 2009) Concentration (ng /ml) of Volatile Compounds in Headspace Over Crumb Rubber Samples Analyzed at CAES (average of two analyses per sample)

DEP Sample ID	1-methyl naphthalene	2-methyl naphthalene	4-(t-octyl)-phenol	benzothiazole	butylated hydroxytoluene	naphthalene	butylated hydroxyanisole
A1001	0.13	0.19	0.28	3.98	n.d.	0.42	0.50
A1002	0.11	0.15	0.31	5.59	n.d.	0.31	0.61
A1003	0.03	0.07	0.19	8.67	n.d.	0.10	0.68
A1004	0.04	0.07	0.31	6.52	0.15	0.16	0.69
A1005	0.08	0.09	0.23	2.35	0.09	0.23	0.46
A1006	0.08	0.14	0.31	4.89	0.12	0.23	0.75
A1007	0.13	0.20	0.52	3.50	n.d.	0.23	0.69
A1008	0.06	0.10	0.18	1.93	n.d.	0.22	0.43
A1009	0.03	0.06	0.13	2.89	0.13	0.08	0.50
A1010	0.07	0.11	0.22	4.91	0.13	0.20	0.64
A1011	0.04	0.06	0.30	3.94	0.16	0.11	0.62
A1012	0.08	0.14	0.46	2.70	0.13	0.28	0.64
A1013	0.09	0.12	0.45	4.45	n.d.	0.30	0.65
A1014	0.10	0.15	0.49	4.25	n.d.	0.31	0.65
B1002	n.d.	n.d.	0.43	1.21	0.67	0.09	0.36
B1009	n.d.	n.d.	0.07	1.29	0.48	0.06	0.35
B1010	n.d.	n.d.	0.06	1.03	0.40	0.05	0.34

CAES also performed simulated weathering experiments on the crumb rubber samples to determine trends in organic compound emissions over time. The weathering test results show that, except for 4-(t-octyl)-phenol, all other detected volatile compounds significantly decreased in concentration after only 20 days of outdoor exposure. By the end of the eight week study, benzothiazole, butylated hydroxanisole and 4-(t-octyl)-phenol were detected at the highest concentrations. The results are shown in Table G. below.

TABLE G: (Table 9 from CAES, 2009) Concentrations (ng /ml) of Volatile Compounds in Headspace Over Crumb Rubber Samples Aged at CAES (average of two analyses per sample)

Sample ID (week)	benzothiazole	1-methyl naththalene	2-methyl naphthalene	naphthalene	4-(t-octyl)-phenol	butylated hydroxyanisole
T0	3.75	0.12	0.24	0.40	0.35	0.77
T1	1.95	0.05	0.09	0.12	0.28	0.45
T2	0.97	0.04	0.06	0.06	0.31	0.40
T3	1.56	0.04	0.07	0.08	0.31	0.44
T4	1.77	0.04	0.08	0.08	0.30	0.43
T5	1.59	0.05	0.07	0.10	0.30	0.48
T6	1.20	0.04	0.06	0.05	0.25	0.36
T7	0.99	0.04	0.06	0.04	0.24	0.33
T8	1.17	0.05	0.05	0.06	0.23	0.41

CAES also performed an SPLP test on the same seventeen samples of the crumb rubber infill material. The resulting leachate was then analyzed for metals and organic compounds. Based on communications with CAES, the leachate contained the same organic compounds that were identified in the head space analyses, however, only benzothiazole concentrations were estimated for the test. A summary of compounds detected and their concentrations are listed in Table H below. Based on these results, the predominant contaminant leaching from artificial turf fields is zinc, followed by barium, manganese and lead. It should be noted some metals associated with tires and rubber products were not analyzed in this experiment, such as iron and vanadium.

In Table H, the values which exceed Connecticut's acute aquatic life criteria are highlighted in yellow. The summary shows that zinc is present in the leachate at concentrations about 500 times greater than the toxicity criteria. The leachate study indicates that there is a high potential for the artificial turf to leach acutely toxic levels of metals especially copper and zinc. Certain samples of crumb rubber also leached acutely toxic levels of cadmium, barium, manganese and lead.

TABLE H

	Benzothiazole	Cr	Mn	Ni	Cu	Zn	As	Cd	Ba	Pb
ug/l										
average	0.153	6.24	263.16	19.88	22.31	34170.5	3.35	1.60	313.88	11.57
80th	0.209	11.28	348.45	27.48	20.41	50269.8	1.50	0.50	463.62	7.77
Max	0.268	31.47	1443.19	57.15	143.32	71535.5	27.94	17.01	502.91	69.90
Acute	21333.000	323	616	260.5	14.3	65	340	2.02	2000	30
Chronic	3200.000	42		28.9	4.8	65	150	1.35	220	1.2

8. DISCUSSION

a) Potential Contaminants

The analyses performed on the stormwater samples were focused on compounds previously documented to leach from crumb rubber material derived from recycled tires, primarily volatile organic compounds, semi-volatile organic compounds and metals. The stormwater samples were also assessed for whole effluent toxicity. Other potential parameters of concern in the stormwater were identified from the results of the CAES off-gassing and leaching laboratory studies performed on the crumb rubber material.

b) Organic compounds

The stormwater generated at the artificial turf sites did not include many readily identifiable, volatile or semi-volatile organic compounds, as evidenced by no detections using EPA Methods 625 and 624. Additional semi-volatile compound investigations were performed on the stormwater samples, resulting in nine tentatively identified compounds and thirteen unidentified chromatograph peaks. Benzothiazole, which CAES also detected in their leaching analysis, was identified in the September 27 and October 7, 2009 samples from Field A at concentrations of 1 and 4.9 ug/l, respectively. Of the compounds that were tentatively identified such as benzothiazole, pentanoic acid, and thiopenes, none of these compounds are considered particularly toxic to aquatic organisms at the estimated concentrations.

Although it is not possible to determine the potential impact of the unidentified semi-volatile compounds, it is important to note, that the six highest concentrations of the unidentified semi-volatile compounds detected (150 ug/l, 28 ug/l, 14 ug/l, 12 ug/l, 10 ug/l and 9.5 ug/l) did not correspond to the three acutely toxic samples of stormwater determined in the study.

The results from the CAES laboratory headspace, leaching and simulated weathering tests suggest that benzothiazole, 4-(t-octyl)-phenol, 1-methyl naphthalene, 2-methyl naphthalene, naphthalene, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are the likely semi-volatile compounds to be found in the stormwater discharge from artificial turf fields. The test results also suggest that Benzothiazole, 4-(t-octyl)-phenol and butylated hydroxytoluene (BHT) would be the most persistent SVOCs in the crumb rubber as the artificial turf fields aged.

Comparing the VOCs and SVOCs results to EPA's Maximum Contaminant Levels for drinking water (MCLs) and DEP's Remediation Standards Regulations, Section 22a-133k-1 through 22a-133k-3of the Regulations of Connecticut State Agencies (June 1996), no exceedences of groundwater standards have been identified.

Based on our results, no VOCs or SVOCs have been identified as risks to surface and groundwater resources.

c) Metals

The laboratory leaching analyses performed by CAES as part of the State of Connecticut Artificial Turf Study detected the following metals: arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn). Zinc was present in concentrations orders of magnitude greater than the other metals. CAES's leaching analyses indicated that both copper (Cu) and zinc (Zn) concentrations exceeded acute aquatic toxicity criteria for 80% of the tests, with limited (<20%) exceedences of acute criteria for cadmium (Cd), manganese (Mn) and lead (Pb).

The stormwater analysis results show that the artificial turf fields in our study leached significantly less contaminants, specifically zinc and copper, than predicted by the CAES leaching test results. The lower metal concentrations observed in the stormwater could be a result of alkaline pHs, the weathering (2-4 years since installation) of the crumb rubber infill, or the conservative approach inherent in the SPLP methodology.

The stormwater analysis results showed that zinc was the only metal to exceed the acute aquatic toxicity criteria (65 ug/l), with one exceedence at each of the three study fields. The overall mean concentration of zinc in the stormwater samples analyzed was 84 ug/l, with a maximum of 260 ug/l and a minimum of 10 ug/l. The stormwater analysis results showed that aluminum, barium, copper and zinc all exceeded chronic aquatic toxicity criteria at least once during the sampling. Since chronic toxicity criteria apply to four days of continuous discharge, these exceedences are not of significant concern for these intermittent discharges.

No metal concentrations exceeded EPA's and DEP's drinking water standards. However, the concentration of zinc in three stormwater samples did exceed the surface water protection criteria of 123 ug/l established in the Appendix D to Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies Surface-water Protection Criteria for Substances in Ground Water (June 1996). Since the mean concentration of zinc in the stormwater samples (84 ug/l) is below the surface water protection criteria, the discharge from the artificial turf fields to groundwater is intermittent, and zinc is immobilized in soils by adsorption, absorption and precipitation, the potential for impacts to surface waters being recharged by this groundwater is minimal.

Based on our results, zinc has been identified as a potential risk to surface waters. No other metals have been identified as a risk to groundwater or surface waters.

9. ENVIRONMENTAL RISK ASSESSMENT

a) Potential Risk to Surface Waters

The only potential risk to surface waters identified in the stormwater collected from the artificial turf fields is zinc, since it was the only chemical parameter that was detected above the acute aquatic life criteria of 65 ug/l. Acute toxicity is assumed to occur when the zinc concentration in-stream exceeds 65ug/l for one hour in any three year period. In three of the eight stormwater samples analyzed, zinc concentrations were detected at 130, 150 and 260 ug/l, well above the acute aquatic life criteria. It is important to note, that the three stormwater samples with acutely toxic levels of zinc were also determined to exhibit aquatic toxicity (<90% survivorship) for both species *Pimephales promelas* and *Daphnia pulex* in the whole effluent toxicity testing.

Other than the acute aquatic toxicity criteria, there are no specific zinc standards or permit limits that are applicable to artificial turf fields. For industrial sites that discharge to surface waters, DEP has set a stormwater general permit guideline (Section 5 (c) (1) (F) (i) of the General Permit) for total zinc of 200 ug/l. This industrial stormwater total zinc guideline assumes a default 5:1 dilution factor for the receiving surface water at the 7Q10 flow. The 7Q10 is the lowest flow expected to occur for seven continuous days at a frequency of every 10 years. The 7Q10 flow is the critical low flow used when evaluating toxicity and toxic impacts (CT WQS 2002). Based on the results of our study, the stormwater discharges from artificial turf fields would not be expected to regularly exceed this zinc limit.

However, the estimated 7Q10 flows for the receiving watercourse from Fields A, C and D did not meet the 5:1 dilution factor for stormwater discharges from artificial turf football fields (57,600 square feet), assuming a one inch rain storm over one hour with direct discharge to the watercourse over an hour. It is important to note, that this a conservative approach, which assumes the watercourse receives no other stormwater runoff from its representative watershed. For the three receiving streams in the study, the highest dilution factor at the DEP estimated 7Q10 flow was equivalent to a 0.14:1 ratio. Given this dilution ratio of the receiving streams in the study, there is a potential for acute toxicity due to zinc loading.

Since zinc concentrations in stormwater from artificial turf fields may pose a risk to surface waters, especially to smaller watercourses, it is important to note that these fields are not the only sources of stormwater runoff in any given watershed. During the sampling at Fields A, C and D, DEP staff observed stormwater runoff, generated by acres of parking lots, roadways and buildings, entering the same drainage systems that collected runoff from the artificial turf fields. Based on these observations, it appears that stormwater runoff from the artificial turf fields is combined with the runoff from the adjacent impervious surfaces prior to ultimate discharge at the site.

This is an interesting phenomenon, since the levels of zinc in urban runoff are comparable to the concentrations detected in the discharge from artificial turf fields. It has been well established that urban runoff contains many contaminants such as nutrients, suspended solids, hydrocarbons and heavy metals, including zinc. The average concentration of zinc in urban stormwater runoff has been estimated at 129 ug/l in recent studies (Smullen 1998). EPA's Nationwide Urban Runoff Program (NURP) has collected runoff data and determined that for urban sites the median concentrations of total zinc ranged from 179 -226 ug/l. The National Stormwater Quality Database (NSQD, version 1.1), dated February 16, 2004, compiled zinc concentration data in runoff from various land uses across the United States, which is shown in Table L below.

TABLE I

Land Uses	**Zinc Total (ug/l) Median**
Overall (All Uses)	117
Residential	73
Mixed Residential	99.5
Commercial	150
Mixed Commercial	135
Industrial	210
Mixed Industrial	160
Institutional	305
Freeways	200
Mixed Freeways	90
Open Space	40
Mixed Open Space	88
CT Artificial Turf Stormwater	**84 (mean)**

Since zinc concentrations in the runoff from artificial turf fields are consistent with those associated with urban runoff, it would be a logical step to apply the same best management practices (BMPs) to mitigate the toxicity effects to surface waters. The 2005 Stormwater Management Manual for Western Washington specifically recommends the following BMPs to remove dissolved zinc (and other metals) from stormwater runoff: stormwater treatment wetlands, wet ponds, infiltration structures, compost filters, sand filters and biofiltration structures. The 2004 Connecticut Stormwater Quality Manual suggest the same measures since these treatment practices incorporate biological removal mechanisms that are more effective in removing pollutants than systems that strictly rely on gravity or physical separation of particles in the stormwater. The 2004 Connecticut Stormwater Quality Manual further recommends a treatment train approach, which provides a series of BMPs each designed to provide targeted pollution control benefits.

The University of New Hampshire Stormwater Center has field tested many of these stormwater BMPs that demonstrate significant removal of dissolved zinc. For example, the Retention Pond, Subsurface Gravel Wetland and Bioretention System (Bio II) stormwater treatment measures, over a two year period, removed between 90% and 100% of the soluble zinc, based on a median annual influent Event Mean Concentrations (EMC) of 60ug/l (see Appendix B for fact sheets). The three highest zinc concentrations detected in the stormwater from artificial turf fields in our study were 130, 150 and 260 ug/l, respectively. Assuming 80% removal of zinc from the stormwater prior to discharge to surface waters, all three of the highest zinc concentrations would meet the acute aquatic toxicity criteria (26, 30 and 52 ug/l, respectively). To mitigate the risk to aquatic life and surface waters, the DEP strongly recommends that the aforementioned stormwater best management practices be incorporated into the design of the drainage system for artificial turf fields.

10. ENVIRONMENTAL RISK ASSESSMENT IN RECENT STUDIES

Several other studies were conducted to determine the risk to surface waters and groundwater from the stormwater discharges from artificial turf fields. Since artificial turf fields can either discharge to groundwater or surface water, the ecological risks must be evaluated for both potential pathways. This was confirmed by Nillson et al (2008), that drainage from artificial turf fields can enter the environment by either seeping through the underlying soil and potentially contaminate the groundwater, or alternatively, by stormwater runoff entering the adjacent watercourses.

a) Overall Surface Water Contamination Risk

1) Organic Compounds

The studies conducted by Plesser (2004) indicated that concentrations of the common polycyclic aromatic hydrocarbons (PAHs) anthracene, fluoranthene and pyrene, as well as nonylphenols, would exceed the limits for freshwater specified in the Canadian Environmental Quality Guidelines. Torsten (2005) from the Norwegian Institute for Water Research (2005) also predicted that concentrations of alkyl phenols and octylphenol in particular would exceed the limits for environmental effects in the scenario which was allowed a 10:1dilution of run-off. Torsten (2005) further determined that the leaching of chemicals from the materials in the artificial turf system would decrease slowly, so that environmental effects could occur over many years. However, Torsten (2005) anticipated only localized impacts due to the relatively small concentration of the leaching pollutants. The SVOCs analysis of the stormwater in our study, utilizing EPA Method 625, and a specific search for 4-(t-octyl)-phenol, detected no anthracene, flouranthene, pyrene or standard phenol compounds.

Kolitzus (2006) detected no appreciable PAHs concentrations in the runoff analyzed from artificial surface systems. The PAHs that were found above detection limit were ubiquitous substances in the environment. The PAH concentrations in the unbound supporting layer were determined to be in the range of analytic determination limit (0.02 µg/l). The sum of all 16 PAHs was 0.1 to 0.3 µg/l. Similarly, in a recent New York study (Lim et al 2009), no standard organics were detected utilizing EPA Method 624 and 625 in the stormwater sample collected. The

SVOC analysis of the stormwater in our study, utilizing EPA Method 625, detected no standard PAHs.

In surface systems with EPDM and recycled rubber infill, Kolitzus (2006) found several aromatic amino complexes and benzothiazole detected in the range of 10 – 300 μg/l. These concentrations were similar to the results of simulated normal tire wear tests. Lim et al (2009) reported a semi-volatile rubber compound, benzothiazole, at 1,000 ug/l as a Tentatively Identified Compound (TIC) in one stormwater sample. The SVOC analysis of the stormwater in our study, utilizing EPA Method 625, detected no standard aromatic amines, but further TIC analysis did detect identified and unidentified organic compounds. Benzothiazole was detected in two stormwater samples at estimated concentrations of 1.0 and 4.9 ug/l, respectively, which is significantly lower than concentrations found by Lim et al (2009). The Connecticut acute and chronic toxicity benchmark for benzothiazole are 21,333 ug/l and 3,200 ug/l, respectively, based on available toxicity information. The estimated concentrations of benzothiazole are insignificant compared to both the acute and chronic toxicity criteria. Also, a number of unidentified organic compounds were detected during the SVOC TIC analysis at concentrations ranging from 1 ug/l to 150 ug/l, with a median concentration of 6.6 ug/l. The 10/7/09 Field C stormwater sample, which the maximum unidentified compound concentration of 150 ug/l was detected in, was not found to be acutely toxic.

The results from our study appear to be consistent with the results from Kolitzus (2006) and Lim et al (2009), including the detection of benzothiazole in the stormwater samples. Overall, our study did not identify any organic compounds at sufficient concentrations to be considered a potential contamination risk to surface waters.

2) Metals

Based on our analysis of the stormwater collected from the artificial turf fields, zinc is the only metal detected in concentrations which could pose a risk to surface water resources. This finding is consistent with many recent studies which analyzed leachate and stormwater from crumb rubber infill, which indicate that zinc is the primary contaminant of concern coming from artificial turf sites. In sites with limited dilution both the Norwegian Pollution Control Authority (2005) and Verschoor (2007) conclude that the concentration of zinc in the leachate would exceed applicable water quality standards. The Norwegian Pollution Control Authority classifies artificial turf runoff as Environmental Quality Class V (very strongly polluted water) due to the high concentration of zinc in the leachate. The risk assessment conducted by Norwegian Institute for Water Research (2005) shows that the concentration of zinc poses a significant local risk of environmental effects in surface water which receives run-off from artificial turf fields.

Verschoor (2007) also conducted a risk assessment concluding that the estimated concentrations of zinc in the drainage water from artificial football fields to be between 1100-1600 ug/L. This concentration exceeded the Dutch legal criterion for surface water Maximum Permissible Chronic Concentration (MPC) of 40 ug/l by a factor of 27-40. Verschoor explained that drainage water concentrations would be diluted in the receiving surface waters, but indicated that zinc in "small ditches" could exceed MPA (Maximum Permissible Acute). Verschoor espoused a general discharge impact rule that only 10% of the permissible concentration of a contaminant (=

4 ug/l) may be consumed by a particular source. This would imply that the concentration of zinc in smaller receiving water would exceed the water quality criteria by a factor of 45-80. Verschoor identified zinc as a potential eco-toxicological risk to surface water, but did indicate that if the crumb rubber were to be replaced by infill materials with a lower zinc emission, the pollutant concentrations in runoff and adjacent surface water should drop quickly.

Lim et al (2009) conducted a mathematical assessment of the risks to aquatic life from crumb rubber leachate based on the SPLP test results for zinc, aniline and phenol. Based on these concentrations, NYSDEC's Division of Fish, Wildlife and Marine Resources concluded that there may be a potential aquatic life impact due to zinc being release from crumb rubber solely derived from truck tires. However, New York State also concluded that an impact is unlikely if the crumb rubber material is from mixed tires and concentrations of zinc from a column test were used rather than the SPLP. It should be noted, that for the column test to better simulate field conditions, the material in the column must reflect local soil conditions and pH.

Several recent studies analyzed stormwater samples collected from artificial turf fields for metals. Lim et al (2009) and Kolitzus (2006) detected concentrations of zinc at 59.5 ug/l and 20 ug/l, respectively. Milone and MacBroome (2008), conducted field studies and detected zinc in the stormwater from four of the six sampling dates , with a maximum concentration of 31 ug/l which is below acute aquatic toxicity criteria of 65 ug/l.

The zinc concentrations in our stormwater samples were significantly higher than those of Lim, Kolitzus and Milone and MacBroom, with three of the eight the samples tested exceeding acute surface water quality criteria. If not mitigated with appropriate stormwater treatment measures, the zinc concentrations found in our study could contribute to the environmental risk of aquatic organisms in surface waters.

3) Aquatic Toxicity

Wik (2006) studied the toxicity of various tire brands and determined that different formulas for rubber contributed to varying degrees of toxicity in the leachates to *Daphnia magna*. By conducting a toxicity identification evaluation on various tire leachates (EPA 600/6-91/003), Wik determined that although zinc was prevalent, the semi-volatile non polar organics also heavily influenced the toxicity of the resulting leachate. Passing the simulated tire leachates through carbon filters was the only manipulation that consistently reduced toxicity. Compared to the results from Milone and MacBroom (2008), this study reported significantly higher levels of both aquatic toxicity and zinc. This study found that three of the eight stormwater samples tested were acutely toxic to both the invertebrate (*Daphnia pulex*) and the fathead minnow (*Pimephales promelas*). These acutely toxic samples directly coincided with the exceedences of the acute aquatic life criteria for zinc. Consequently, zinc seems to be the primary pollutant of concern. This study indicates that there is risk associated with whole effluent toxicity and zinc.

b) Overall Groundwater Contamination Risk

Stormwater from the fields can impact groundwater directly by percolating through the artificial turf via an "open" underground drainage system (perforated pipes, coarse bedding materials, stone trenches). The stormwater discharges to the underlying soil layers, and ultimately, enters the ground water. Based on the nature of the underlying soil and the depth to groundwater, the field stormwater is likely to physically and chemically interact with a mineral soil layer (vadose zone) prior to encountering groundwater. This stormwater/soil interaction would be affected by pH, volume of stormwater and soil characteristics, such as moisture, chemistry, mineralogy, soil texture, hydraulic conductivity and drainage class. These interactions would likely influence the concentrations of contaminants found in the groundwater.

There are two primary concerns with the contamination of groundwater in the environment - the threat to drinking water and the threat to surface water resources via groundwater recharge. Several other studies were conducted on the crumb rubber fill from 2004 to 2009; (Plesser(2004), Nillson et al (2008), the Norwegian Institute for Water Research (2005) , Verschoor, A.J., RIVM Report 601774011/2007(2007) Study, (Milone & MacBroom Study 2007),NYSDEC May 2009 an Kolitzus, Hans J. (2006). These studies compared the relative concentration of contaminants found in laboratory leachates and/or artificial turf generated stormwater with various drinking water and aquatic life criteria.

1) Organic Compounds

It should be noted that substances, to a varying degree, will be absorbed by the sand/clay layers which the drainage water passes. Although Nillson et al (2008) found that concentrations of nonylphenols in the contact water from leaching tests were in the order of 20-800 times above the threshold values for drinking water, it was uncertain as to whether this concentration would be significant in the actual groundwater. The EPA aquatic life acute criteria for nonylphenol for freshwater and saltwater resources are 28 ug/l and 7.0 ug/l, respectively. It is important to note that nonyphenol has been associated with the disruption of fish endocrine systems at concentrations below EPA's criteria. No data was available for phthalates and nonylphenols under such realistic conditions from lysimeter data. Nillson determined that the assessment of the impact on water systems also requires more realistic lysimeter tests or measurements on drainage water from artificial turf fields over time.

Plesser (2004) compared leachate results with Canadian Environmental Quality Guidelines for ground water. Groundwater guidelines are developed for both protection of drinking water and protection of surface water via groundwater recharge. Plesser identified anthracene, fluoranthene, pyrene and nonylphenols as compounds in the leachate that could exceed the more protective criteria for groundwater. Plesser also concluded that analyzing possible paths and changes in leaching properties over time is necessary to determine the degree to which the concentrations of these compounds are actually harmful to people and the environment.

Lim et al (2009) conducted a leachate (SPLP) test on rubber crumble material, and analyzed for zinc, phenol and aniline. The results from recent leaching studies indicated a potential for release of aniline, benzothiazole, phenol, and zinc to the groundwater. However, concentrations of the organic contaminants analyzed were below levels that would impose a risk to drinking water. Lim also collected 32 groundwater samples from wells installed downgradient of four artificial turf fields and analyzed them for SVOCs, including aniline and benzothiazole, using SW-846 Method 8270C. The wells were installed in sandy textured soils with depth to the groundwater ranging from 8.3 to 70 feet. All test results were below the limit of detection for all groundwater samples analyzed. Based on test results of 32 samples, no organics were detected in the groundwater at the turf fields.

Our results are consistent with the leachate and groundwater sampling results in Lim et al (2009). The concentrations of organic compounds in our study did not exceed groundwater protection criteria.

2) Metals

In general, metals are immobilized in soils by adsorption, absorption and precipitation. All of these, mechanisms impede movement of the metals to ground water. Metal-soil interaction is such that when metals are introduced at the soil surface, downward transportation does not occur to any great extent unless the metal retention capacity of the soil is overloaded, or metal interaction with the associated waste matrix enhances mobility.

Zinc is the most prevalent contaminant in the leachate and stormwater studies. In several of these studies, zinc concentrations measured in leachate exceeded drinking water standards. Most of the zinc in soil is absorbed to the soil as zinc hydroxide or oxide and does not dissolve in water. Zinc does show moderate mobility under relatively acid soil conditions (pH 5–7) because of increased solubility and formation of soluble complexes with organic lignands (Elliott et al. 1986; Stevenson and Fitch, 1986; Klamberg et al. 1989). Zinc is retained in an exchangeable form at low pH in iron and manganese oxide dominated soils but becomes non-exchangeable as the pH was increased above 5.5 (Stahl and James, 1991). Therefore, depending on the acidity of the soil and water, some zinc may reach groundwater.

Nillson et al (2008) determined that although leachate concentrations of zinc were in excess of the drinking water quality standards, similar concentrations were not observed in (field) lysimeter tests. Nillson concluded that the concentration of zinc in the lysimeter tests were a more accurate reflection of zinc in the groundwater and, therefore, zinc concentrations would not exceed drinking water standards.

Lim et al (2009) was the only study that did not report concentrations of zinc in the SPLP leachate that exceeded drinking water standards.

Verschoor (2007) concluded that, for the majority of situations, the risks of zinc to public health are minimal since it is not very toxic to humans and the World Health Organization (WHO) drinking water criteria was not exceeded in tests. However, Verschoor (2007) did note that in sandy areas discharges to groundwater may exceed Dutch Intervention Values by a factor of 1.5 to 2.2. In sandy soils, infiltration of water with dissolved zinc will result in weak binding of zinc to the soil matrix and could cause protection criteria to be exceeded by a factor of 12. Verschoor concluded that zinc was a potential eco-toxicological risk to groundwater and soil.

Plesser (2004) and CAES (2009) indicated that zinc was the most likely contaminant to exceed drinking water standards in the leachate. All studies indicate that, although compounds were present in the leachate or stormwater, it was uncertain as to what affect the underlying soils and groundwater would have on the actual concentration of contaminants in the groundwater. Actual groundwater testing may be necessary to determine the impact.

The leachate results reported by CAES showed zinc concentrations up to ten times the drinking water standards and up to 500 times the surface water protection criteria. Our study detected concentrations of zinc in the stormwater significantly lower than CAES results, with no exceedences of drinking water standards and no significant concerns for groundwater quality. It is important to note that no groundwater samples were collected for our study.

11. CONCLUSIONS

The DEP concludes that there is a potential risk to surface waters and aquatic organisms associated with whole effluent and zinc toxicity of stormwater runoff from artificial turf fields. Zinc concentrations in the stormwater may cause exceedences of the acute aquatic toxicity criteria for receiving surface waters, especially smaller watercourses. The DEP suggests that use of stormwater treatment measures, such as stormwater treatment wetlands, wet ponds, infiltration structures, compost filters, sand filters and biofiltration structures, may reduce the concentrations of zinc in the stormwater runoff from artificial turf fields to levels below the acute aquatic toxicity criteria. Individual artificial turf field owners may want to evaluate the stormwater drainage systems at the fields and the hydrologic and water quality characteristics of any receiving waters to determine the appropriateness of a stormwater treatment measure.

This study did not identify any significant risks to groundwater protection criteria in the stormwater runoff from artificial turf fields. It is important to note, that the DEP study did not directly collect and analyze groundwater at these artificial turf fields. Consequently, this conclusion regarding consistency with groundwater protection criteria is an extrapolation of the stormwater results collected and the evaluation of data presented in recent studies, such as Nillson et al (2008) and Lim et al (2009). To make a final conclusion regarding the overall risk from exposure to groundwater affected by stormwater runoff from artificial turf fields, further sampling and analysis of groundwater at the artificial turf fields would be required.

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Engineering,
Landscape Architecture
and Environmental Science

MILONE & MACBROOM®

December 1, 2008

To Our Clients and Friends in the Athletic and Parks Community

Over the past year, Milone & MacBroom, Inc. has been studying the water quality, temperature, and air quality of three scholastic athletic fields constructed using synthetic surfaces in-filled with crumb rubber and silica sand. The results of our findings are contained in the attached document.

We hope you find the information useful when considering what type of field surface is appropriate for your program.

Should you have questions, please feel free to contact us.

Sincerely,

MILONE & MACBROOM, INC.

Scott G. Bristol, LEP
Project Manager

scottgb@miloneandmacbroom.com

Vincent C. McDermott, FASLA, AICP
Senior Vice President

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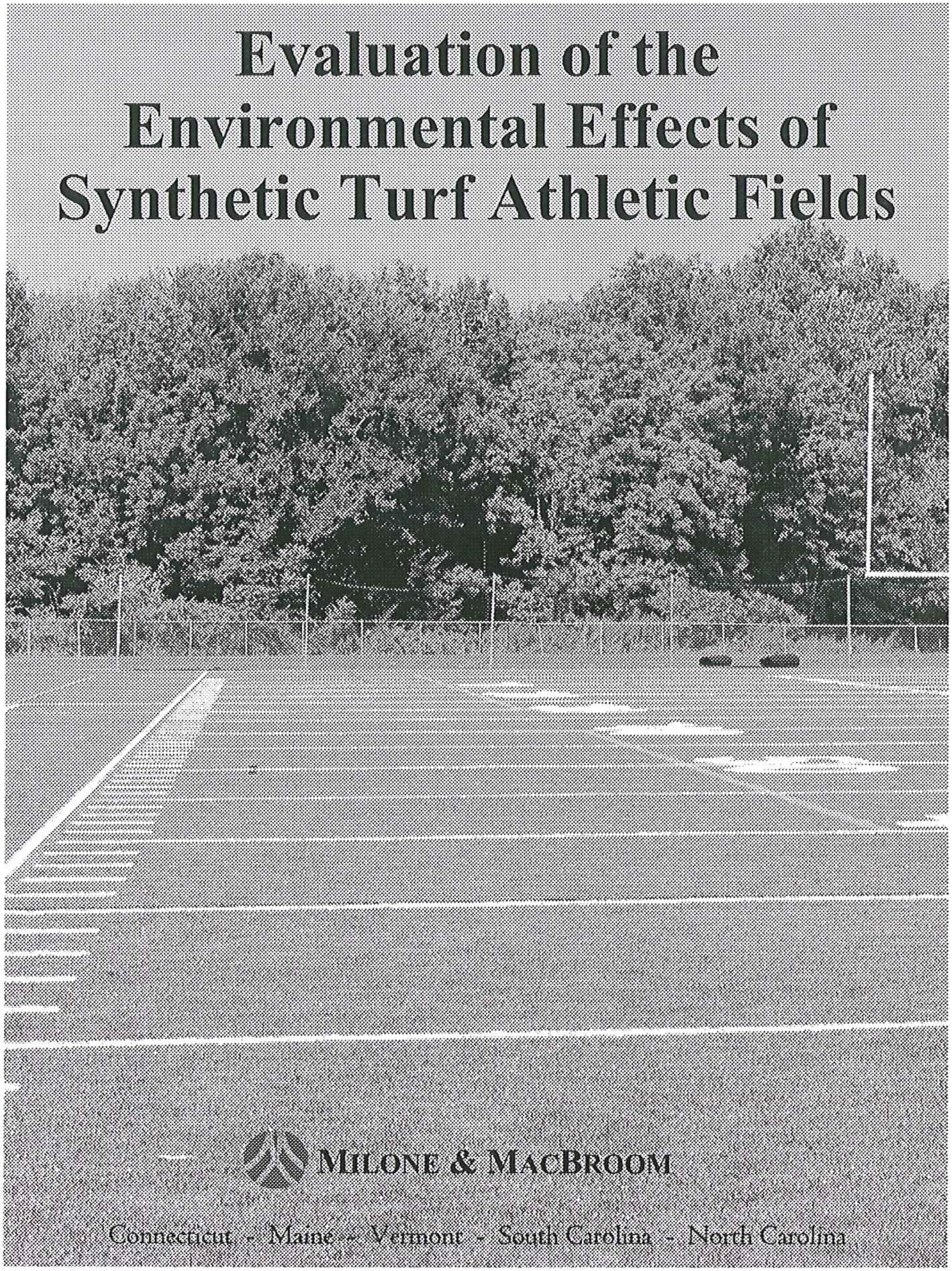
Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields



MILONE & MACBROOM

Connecticut - Maine - Vermont - South Carolina - North Carolina

PREFACE

Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields

Over the past year or so, Milone & MacBroom, Inc. (MMI) conducted a variety of tests of synthetic athletic fields in Connecticut in an attempt to contribute to the discussion regarding potential risks to the environment and human health associated with such facilities. In 2007, laboratory tests at the Connecticut Agricultural Experiment Station (CAES) raised a number of questions concerning the safety of such fields. As a company that advises clients and designs athletic fields using both natural grass and synthetic surfaces, Milone & MacBroom, Inc. believed that it would be prudent to undertake some first-hand observations and to become more confident that published literature was applicable to synthetic surfaces in the northeast.

When reading these papers, there are two points that should be clearly understood. First, by undertaking these studies, we are not promoting the installation of synthetic fields but recognize that they are a legitimate alternative to natural grass in some instances. Second, the cost of the testing was totally paid by Milone & MacBroom, Inc. and that the synthetic turf industry has had no involvement whatsoever in our testing program. We did consult, however, with representatives of the Connecticut Department of Public Health regarding testing protocols to be sure that our methodologies and the results of our efforts would be useful to the regulatory community.

The three areas of concern that Milone & MacBroom, Inc. addressed were water quality from the runoff that passes through the synthetic turf, the temperature of the surface of the turf, and the air quality on and surrounding the synthetic field. The questions we sought to answer are:

- Does the temperature of the synthetic field become excessively hot in summer months?
- Does the crumb rubber infill material have an effect on air quality?
- Do metals leach from the crumb rubber infill material at a level that would adversely affect the quality of water?

To address these issues, Milone & MacBroom, Inc. conducted three separate studies at locations where synthetic fields had been recently installed. The sites were selected for two reasons. First, we were able to secure permission from the owner of the fields to conduct the necessary tests. Second, we were familiar with the sites and understood how the fields were constructed and the materials that were used in the construction. The water quality monitoring was initiated in late 2007 and continued into the fall of 2008. The testing and observation of the temperature and the sampling of the air were done in mid-summer 2008. The results of the testing are presented in three separate documents as follows:

- **Thermal Effects Associated with Crumb Rubber In-filled Synthetic Turf Athletic Fields**
- **Evaluation of Benzothiazole, 4-(tert-octyl) Phenol and Volatile Nitrosamines in Air at Synthetic Turf Athletic Fields**
- **Evaluation of Stormwater Drainage from Synthetic Turf Athletic Fields**

We hope that our efforts will be useful to public officials and the consumer when evaluating which type of playing surface best suits their athletic field program needs.

Please contact Vince McDermott with any questions or to request additional copies of the research conducted by Milone & MacBroom, Inc.

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About Milone & MacBroom, Inc.

Milone & MacBroom, Inc. is a privately-owned, multidisciplinary consulting firm founded in 1984. The firm maintains a staff of over 145 technical and administrative personnel, with its main office located in Cheshire, Connecticut, and regional offices in Stamford and Branford, Connecticut; Greenville, South Carolina; Raleigh, North Carolina; Freeport, Maine; and South Burlington, Vermont. The team of professionals at Milone & MacBroom, Inc. is committed to building strong partnerships with our clients to deliver creative solutions that are technically sound, cost-effective, and environmentally sensitive. We strive to integrate the disciplines of engineering, landscape architecture, and environmental science in an exceptional work environment that is founded upon respect among ourselves, our clients, and our professional colleagues.

Thermal Effects Associated with Crumb Rubber In-filled Synthetic Turf Athletic Fields

Scott G. Bristol, LEP
Vincent C. McDermott, FASLA, AICP

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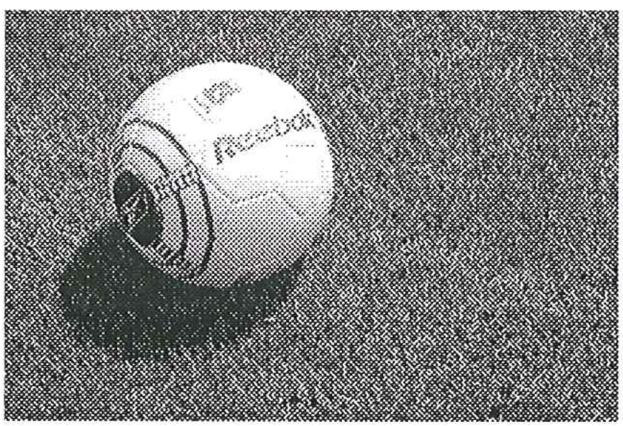
Cheshire, Connecticut 06410

Substantial focus has been given to possible environmental effects associated with the installation of synthetic turf athletic fields. Questions concerning the potential health effects have been raised by several groups. Generally, these questions have been related to claims that insufficient data has been collected to reach a conclusion regarding possible detrimental health effects. One component of these claims is the question concerning the effect of solar heating on the fields and in particular upon the crumb rubber that is used as in-fill material (Figure 1). A temperature evaluation study was designed and conducted to determine the temperature rise of the synthetic materials under a number of conditions.



Two fields within Connecticut were selected for this study. Both fields were constructed by FieldTurf in 2007. One field, identified as Field F, is located in the northern portion of the state, while Field G is located in the southern portion of the state. Selection of the fields was based upon the ability to obtain permission to perform the testing and was not based upon manufacturer or geographic location. Temperature monitoring occurred on June 10 and July 11, 2008, at Field F and on June 17, 2008, at Field G.

During the testing procedure, the air temperature was monitored at two elevations directly over the synthetic playing surface and at a location adjacent to the synthetic surface but within an area of natural grass. Also measured during the testing were the temperatures of the crumb rubber

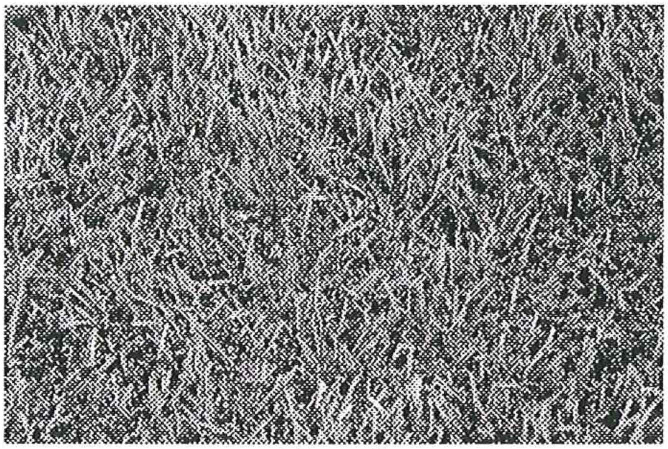


Figure 1

and the surface temperature of the polyethylene and polypropylene blended fibers used to simulate grass. Additional measurements were made of the soil at various depths in the area of the natural grass and the surface temperature of the natural grass itself. The air temperatures were measured using six-inch Enviro-Safe Easy Read Armor Case thermometers with a protective plastic jacket. These thermometers have a working temperature range of 0 degrees Fahrenheit (° F) to 220° F with two-degree graduations and are National Institute of Standards and Technology (NIST) certified. The thermometers were suspended within Styrofoam insulating cylinders. The inside dimensions of the cylinders were approximately $3^3/_8$ inches in diameter by 7¼ inches tall. Outside dimensions were approximately 4¼ inches in diameter by 7¾ inches tall. Twelve one-half inch holes were drilled into four sides of the cylinders to allow for airflow through the cylinder while still providing protection from the heating effect of the sunlight (Figures 2 and 3).

Figure 2

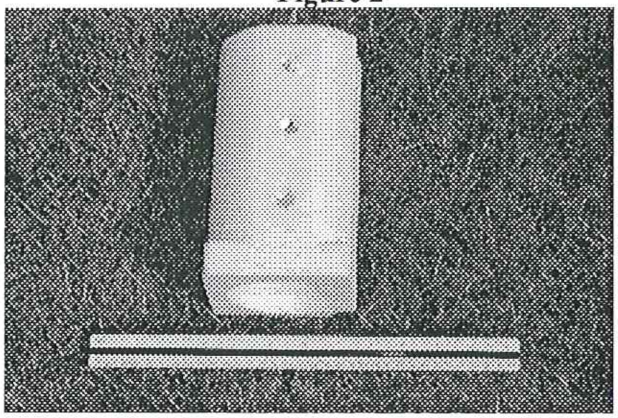
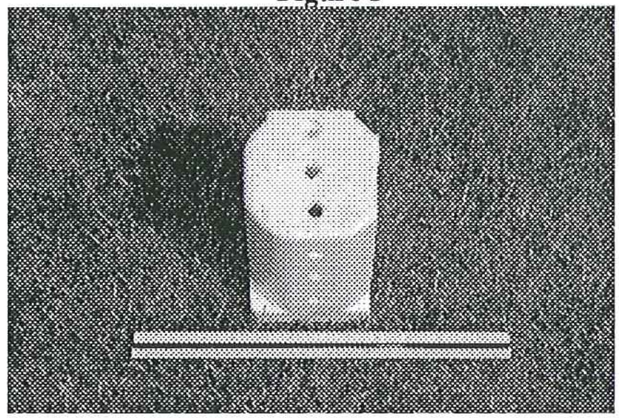


Figure 3



The Styrofoam cylinders were then mounted to a wooden pole measuring approximately 1¾ inch x 1¾ inch x 5½ feet tall using plastic wire ties (Figure 4). Each pole was then mounted to a metal and wooden surveyor's tripod (Figure 5).

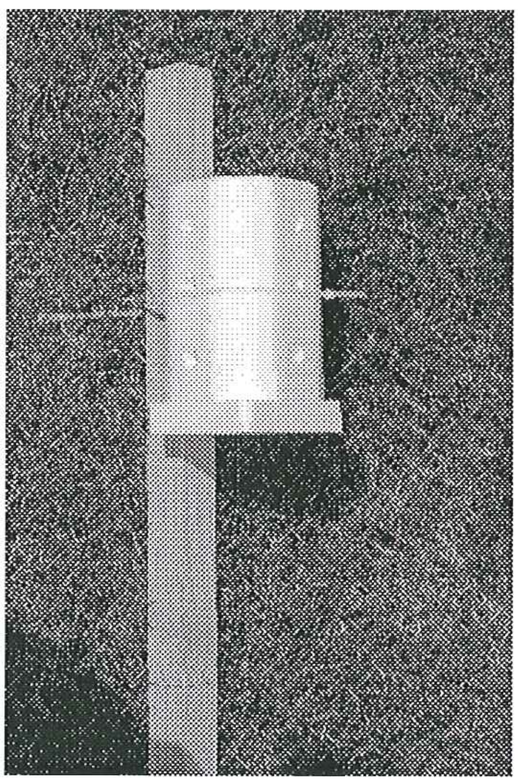


Figure 4

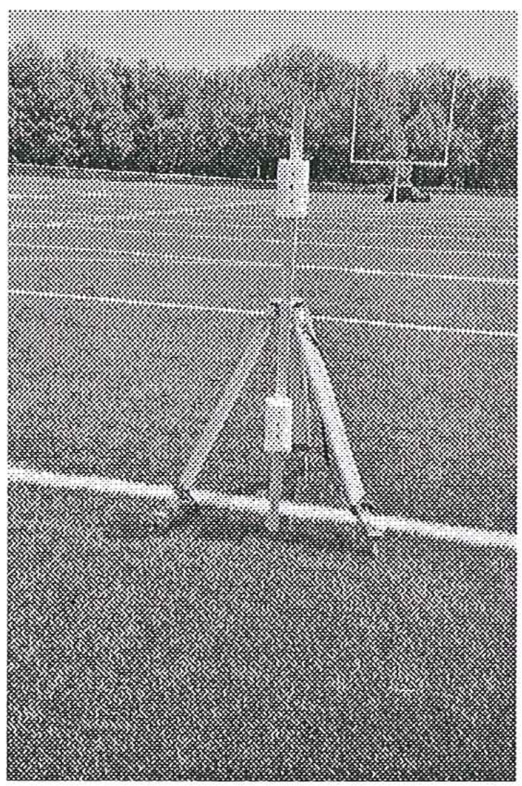


Figure 5

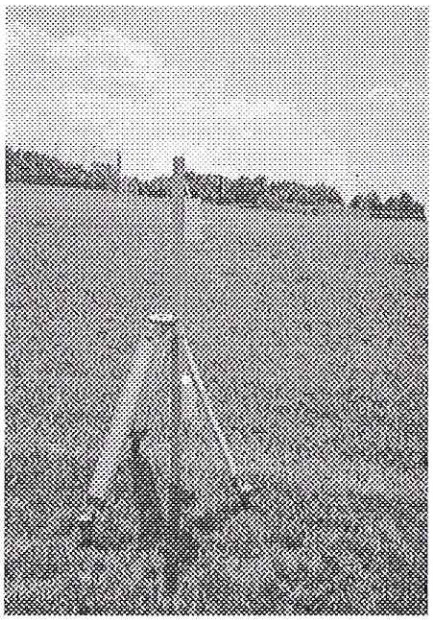
The surface temperatures of the natural grass and the synthetic fibers were measured using an infrared thermometer manufactured by EXTECH Instruments (EXTECH Pocket IR thermometer). The thermometer has a stated sensing range of -58° F to 518° F with an accuracy of +/- 2.5% of reading plus three degrees.

The temperature of the soil and the crumb rubber in-fill material was measured using a digital pen thermometer with a stated sensing range of -58° F to 536° F in 0.1-degree divisions with an accuracy of one degree. The sensing probe measured eight inches long and was constructed of stainless steel.

Methodology

The temperature monitoring stations were placed to allow a comparison of temperatures between the synthetic and natural turf surfaces. One station was placed in the center of the synthetic turf field, while the second station was placed approximately 50 feet (Field G) or 125 feet (Field F) away from the synthetic surface on natural turf. The natural turf monitoring station was located based upon the location of nearby structures (bleachers, parking lots, synthetic running track surfaces) that had the potential to affect the temperature readings (Figure 6).

Figure 6



Air temperatures were measured at two feet and five feet above the ground surface during the June 10 and June 17, 2008, monitoring events. The methodology was adjusted for the July 11, 2008, event, at which time the temperatures were measured at one foot and five feet.

Surface temperatures of both the synthetic "grass" fibers and the natural grass were measured using the infrared thermometer, while soil and crumb rubber temperatures were measured using the digital pen thermometer.

The air temperature measured at a distance of five feet above the natural turf was assumed to best approximate the actual ambient air temperature at the location of the monitored field.

Results

June 10, 2008

Temperature measurements were obtained at Field F on June 10, 2008. Official temperature data for this date was obtained from Weatherunderground.com for Bradley International Airport in Windsor Locks, Connecticut. The official high temperature was 98° F. Additional temperature and wind data was obtained from a private weather station associated with Weatherunderground.com. This weather station is located approximately 2.3 miles from Field F. A high temperature of 95.6° F and maximum winds of three miles per hour (mph) were recorded at this station during the study time period. Skies were clear throughout the study.

Collected data indicated that the air temperature as measured at a distance of two feet above the synthetic turf surface ranged from one to five degrees greater than the observed ambient air temperature, while the temperature at the same height above the natural turf ranged from 3° F lower to 1° F greater than the ambient air temperature (Figure 7).

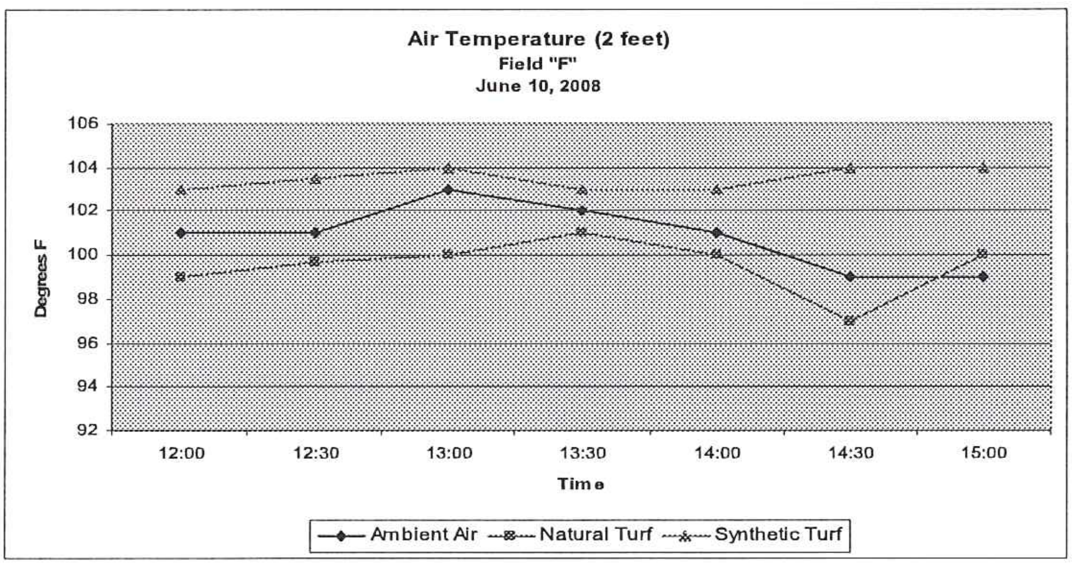


Figure 7

The measured air temperature at a height of five feet above the synthetic turf more closely approximated the ambient air temperature. Measured air temperatures ranged from 2° F lower to 2° F greater than the ambient air temperature (Figure 8).

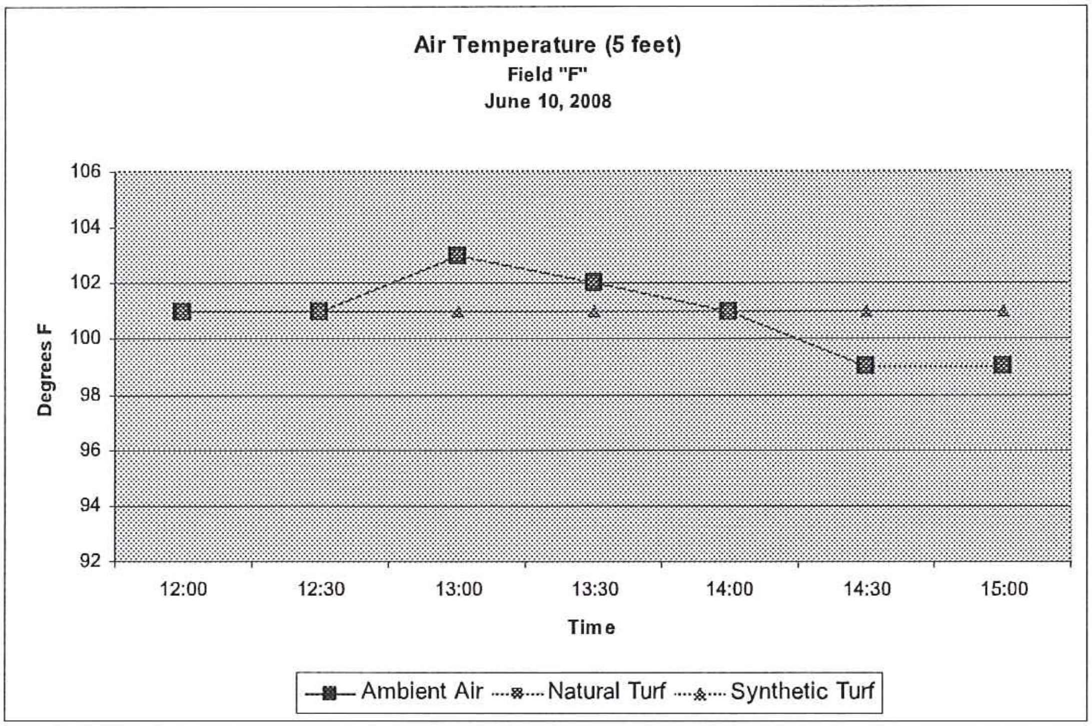


Figure 8

Note in Figure 8 the temperature identified as the ambient air temperature is the same as the temperature measured at a distance of five feet above the natural turf.

The temperature observed for the surface of the synthetic "grass" fibers was measured using an infrared thermometer and compared to the observed air temperatures and also the temperature of the crumb rubber in-fill material as measured at a depth of one inch. The surface of the synthetic fibers reached a maximum temperature of 156° F. The crumb rubber reached a maximum temperature of 111.5° F or approximately 44 degrees cooler than the surface temperature of the synthetic "grass" fibers. As noted above, the elevated temperature of the fibers did not result in a significant elevation of the air temperature above the synthetic field as compared to the air temperature over the natural grass field (Table 1 and Figure 9).

Table 1

Time of Day (hrs)	Ambient Temperature	Synthetic Turf Temperatures			
		Surface Temperature Synthetic "Grass" Fibers	Crumb Rubber Temperature (1 inch depth)	Air Temperature 2 feet above surface	Air Temperature 5 feet above surface
	°F	°F	°F	°F	°F
12:00	101	153	102.5	103	101
12:30	101	155	103	104	101
13:00	103	151	104.5	104	101
13:30	102	156	111.5	103	101
14:00	101	154	109.5	103	101
14:30	99	138	107.2	104	101
15:00	99	149	105.8	104	101

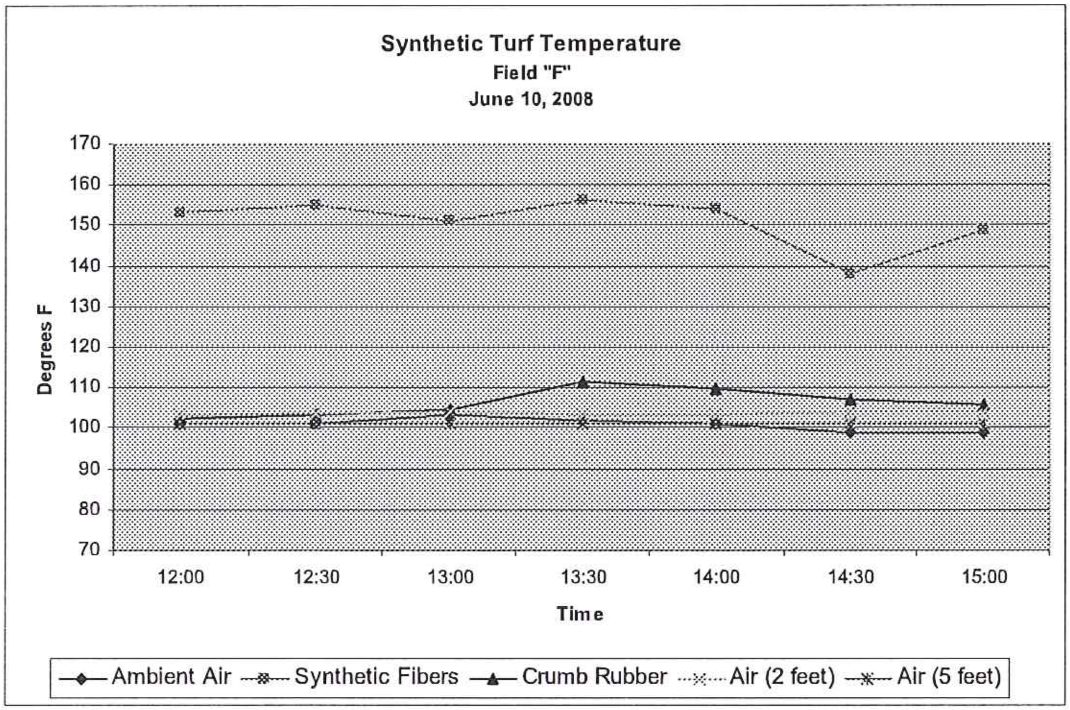


Figure 9

Temperatures measured in the area of the natural turf indicated that the surface of the natural grass blades closely approximated the ambient air temperature. The grass blades ranged from 3° F cooler to 5° F warmer than the measured ambient temperature. Soil temperatures were determined to decrease with increasing depth. The highest soil temperatures were noted at the end of the study period with a maximum temperature of 90.1° F being measured at 15:00 at a depth of one inch below the surface. The temperature of the soil at that depth increased approximately nine degrees over a span of three hours, while the temperature at a depth of six inches increased just two degrees.

Table 2

Time of Day (hrs)	Ambient Temperature	Natural Turf Temperatures					
		Surface Temperature Natural Grass	Soil Temperature			Air Temperature 2 feet above surface	Air Temperature 5 feet above surface
			1 inch depth	3 inch depth	6 inch depth		
	°F	°F	°F	°F	°F	°F	°F
12:00	101	100	81.5	78.8	77.3	99	101
12:30	101	101	86.5	79	77.3	99.7	101
13:00	103	102	89.2	79.8	77.3	100	103
13:30	102	99	86	81.6	78.2	101	102
14:00	101	101	89.4	82.5	79.5	100	101
14:30	99	104	87	81	78.9	97	99
15:00	99	100	90.1	85.1	79.3	100	99

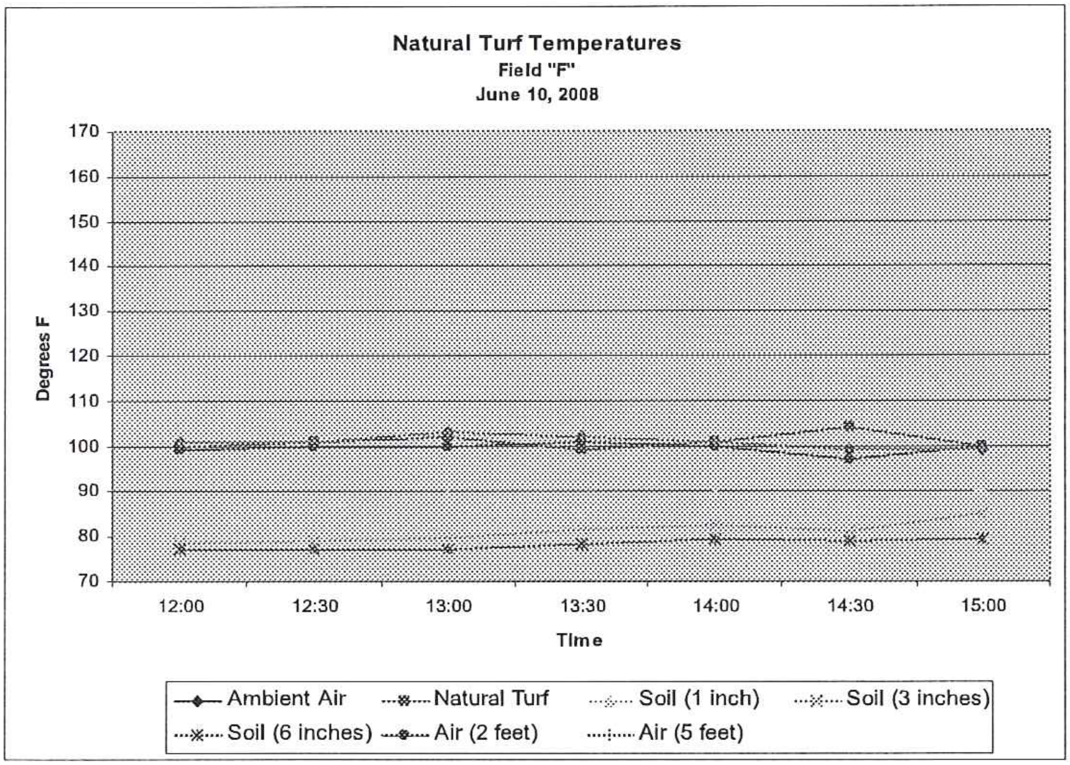


Figure 10

<u>June 17, 2008</u>

Temperature measurements were obtained at Field G on June 17, 2008. Field G is located in the southern portion of Connecticut and is believed by the authors to be susceptible to localized weather variations caused by Long Island Sound. Once again, temperature and wind data were obtained from a private weather station associated with Weatherunderground.com and located approximately 1.5 miles from Field G. A high temperature of 75.7° F and maximum winds of four mph were recorded at this station during the study time period. Intermittent clouds and sunshine were noted during the study period.

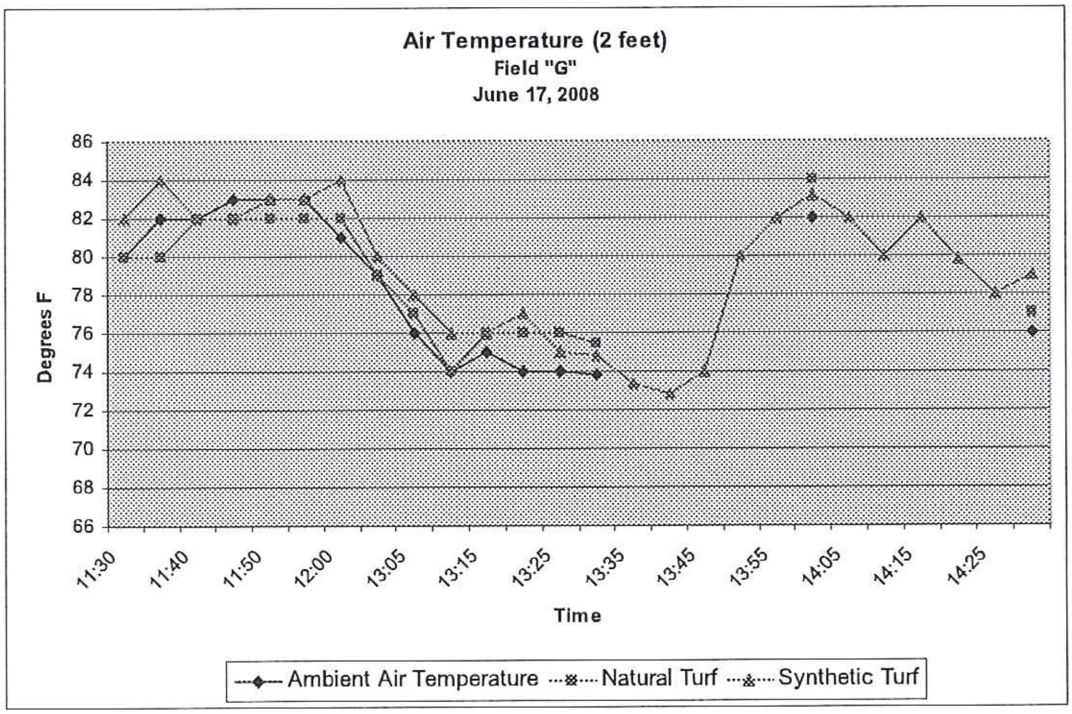


Figure 11

Collected data indicated that the air temperature as measured at a distance of two feet above the synthetic turf surface ranged from 1 degree lower to three degrees greater than the observed ambient air temperature, while the temperature at the same height above the natural turf ranged from 2° F lower to 2° F greater than the ambient air temperature (Figure 11). The air temperature two feet above the synthetic turf field was generally two degrees to four degrees greater than the temperature above the natural turf.

The time period between approximately 13:00 and 13:45 was characterized by clouds. The cooling effect of the cloud cover can be clearly noted in the data. This effect is also noted in the graph of the air temperature at five feet above the fields. At this height, the air temperature above the synthetic turf was generally two to three degrees greater than the natural turf field.

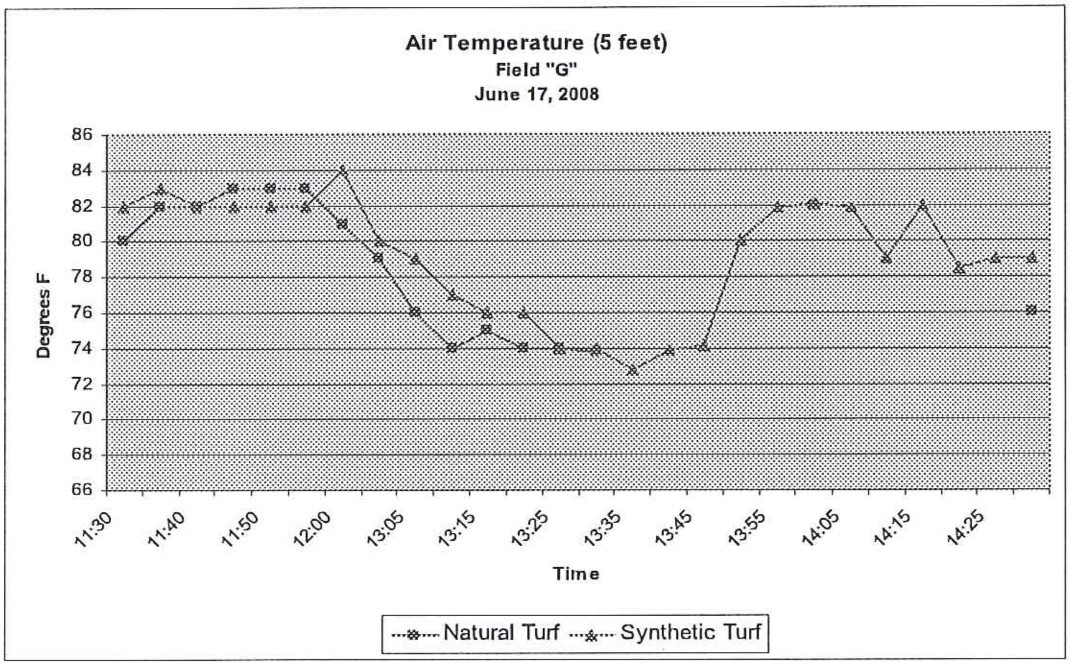


Figure 12

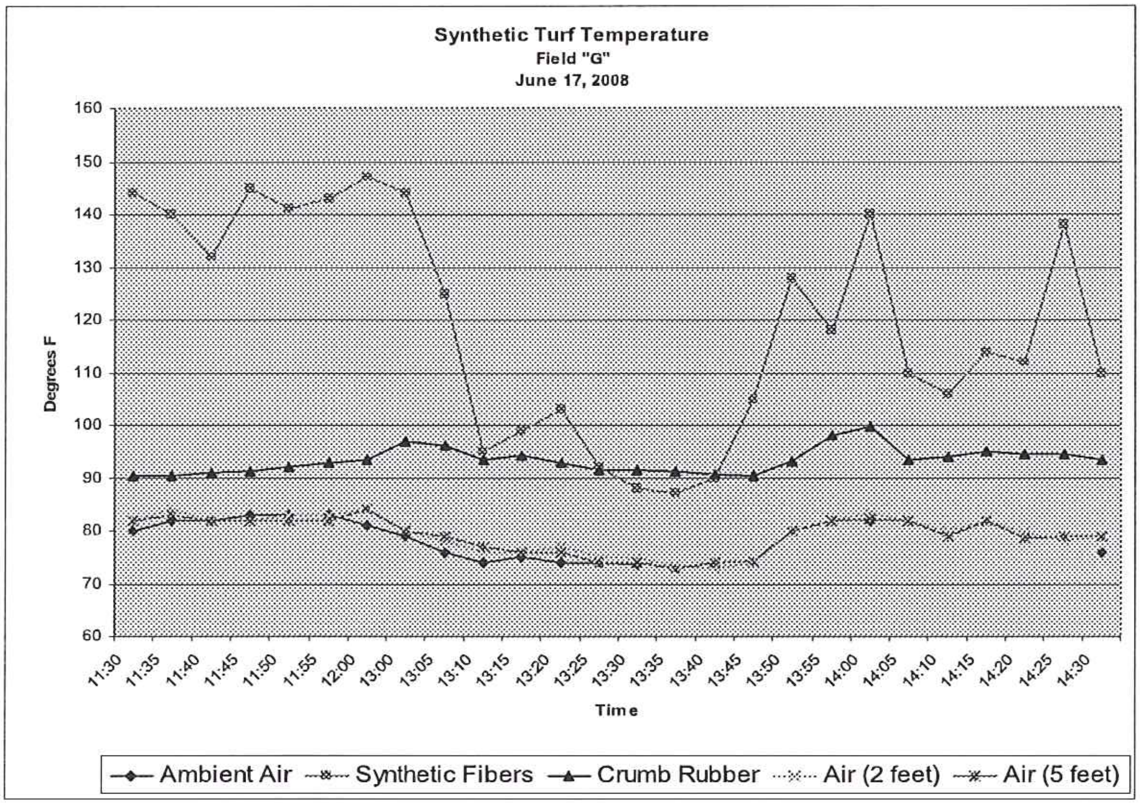


Figure 13

The results of the measurements of the temperature of surface of the synthetic "grass" fibers were similar to those obtained for Field F. A maximum temperature of 147° F was noted during periods of sunshine. The temperature dropped rapidly during cloudy periods and reached a minimum temperature of 87° F or approximately 15 degrees greater than the observed ambient air temperature. The crumb rubber in-fill material maintained a relatively steady temperature and averaged approximately 93° F or approximately 15 degrees greater than the average ambient air temperature (Figure 13). Once again, the elevated temperature of the fibers did not result in a significant elevation of the air temperature above the synthetic field as compared to the air temperature over the natural grass field.

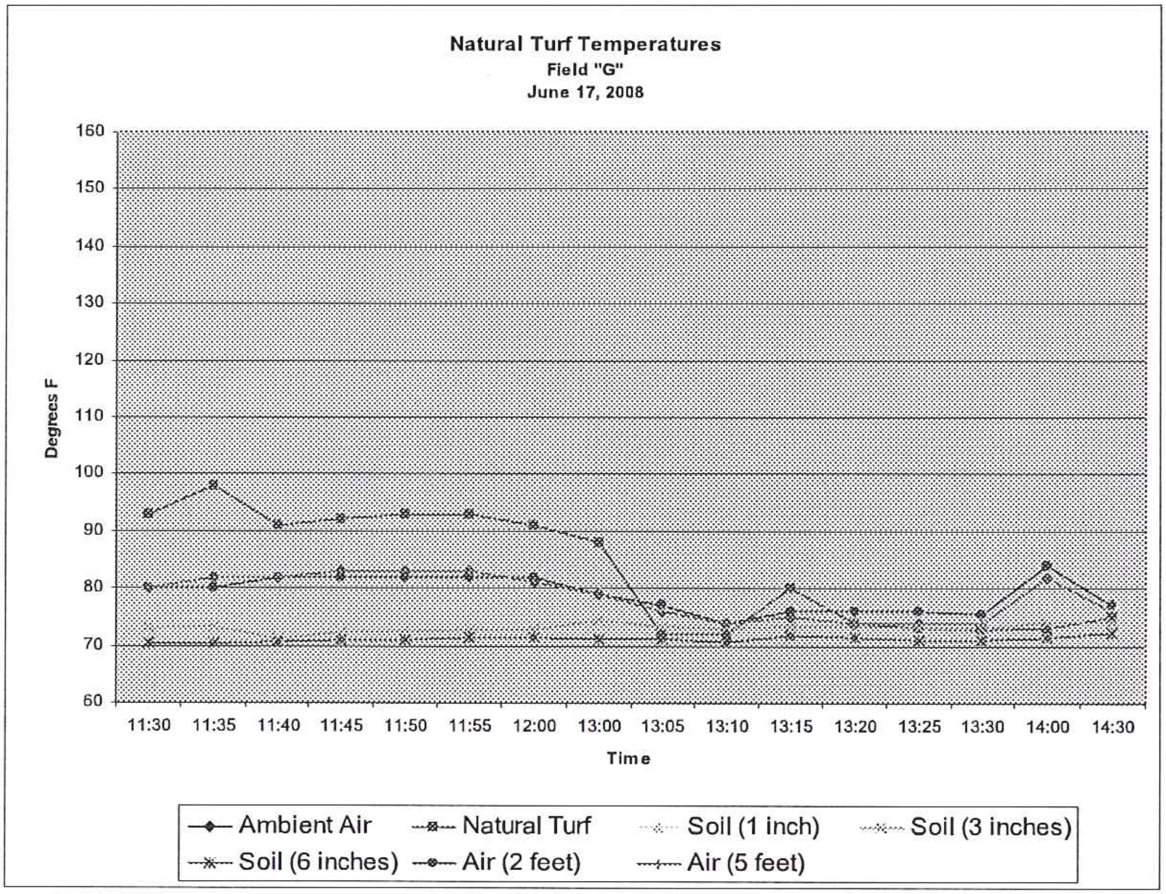


Figure 14

Measurements in the area of the natural turf near Field G indicated that the surface temperature of the natural grass blades was approximately 10 to 15 degrees greater than the ambient air temperature during periods of sunshine. The temperature decreased quickly to nearly the ambient air temperature once cloud cover was present. The soil temperatures were nearly constant throughout the monitoring period and averaged approximately 74° F (Figure 14).

July 11, 2008

The temperature monitoring was repeated at Field F on July 11, 2008. The exception to the above procedures was that the air temperature was measured at heights of one foot and five feet above the synthetic turf and the natural turf fields. The results are detailed in Figures 15 through 19 below. As noted previously, the elevated surface temperature of the synthetic "grass" fibers appeared to have minimal effect on the air temperature directly over the synthetic turf field. Likewise, only a moderate rise in the temperature of the crumb rubber was noted. The temperature rise noted at one foot above the synthetic turf field was generally two to four degrees as compared to the measured ambient air temperature, although a maximum of a nine-degree rise was noted to occur over a short time period early in the study. The temperature rise noted at five feet above the synthetic turf surface was generally between one to five degrees, which is comparable to the previously observed measurements.

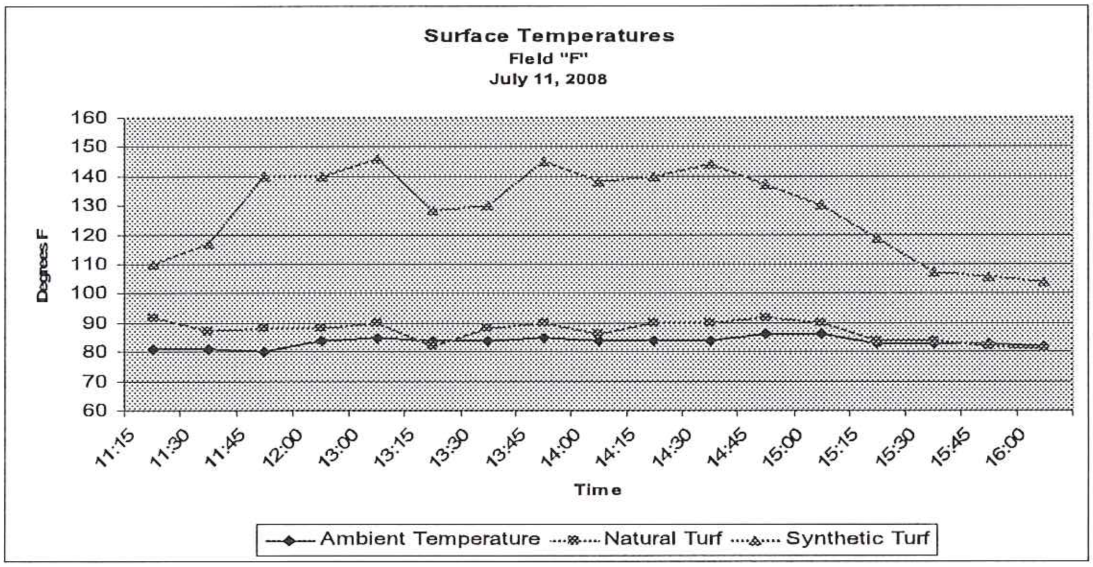


Figure 15

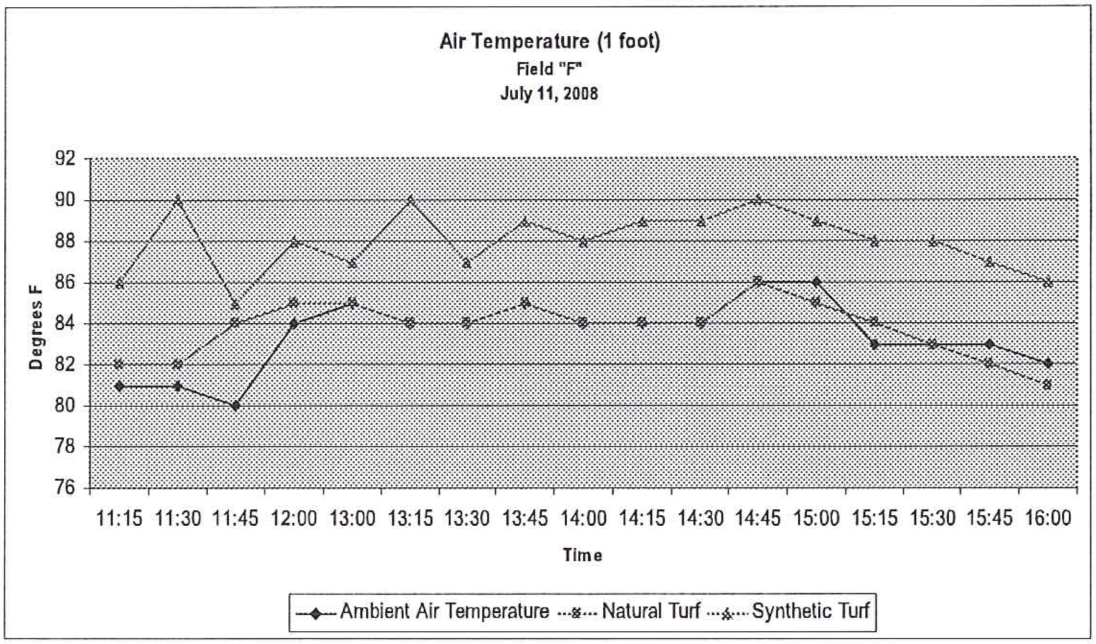


Figure 16

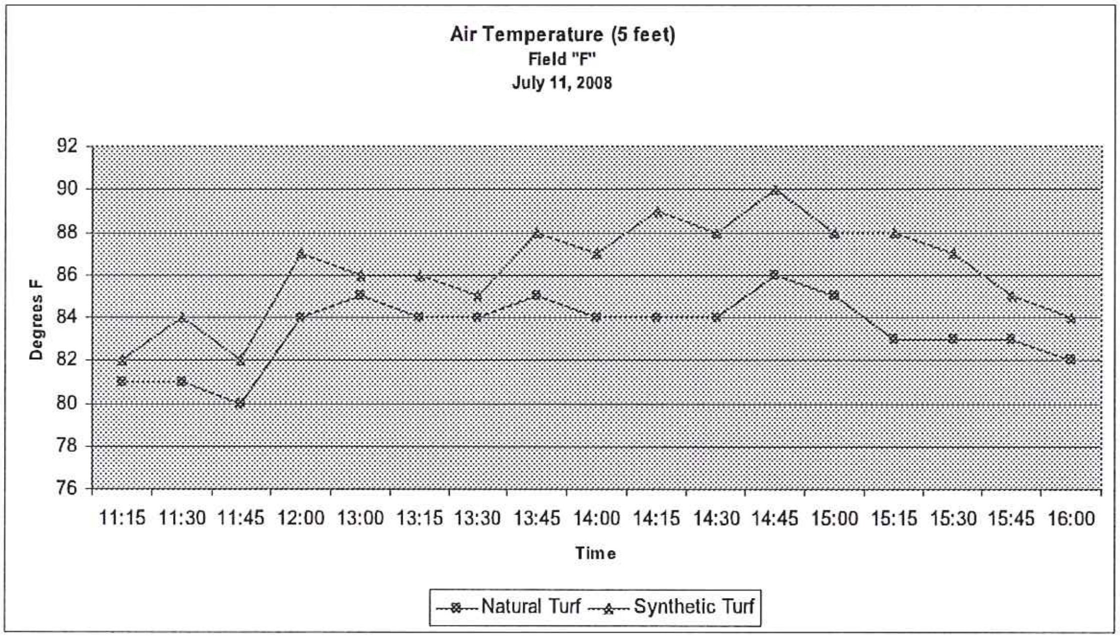


Figure 17

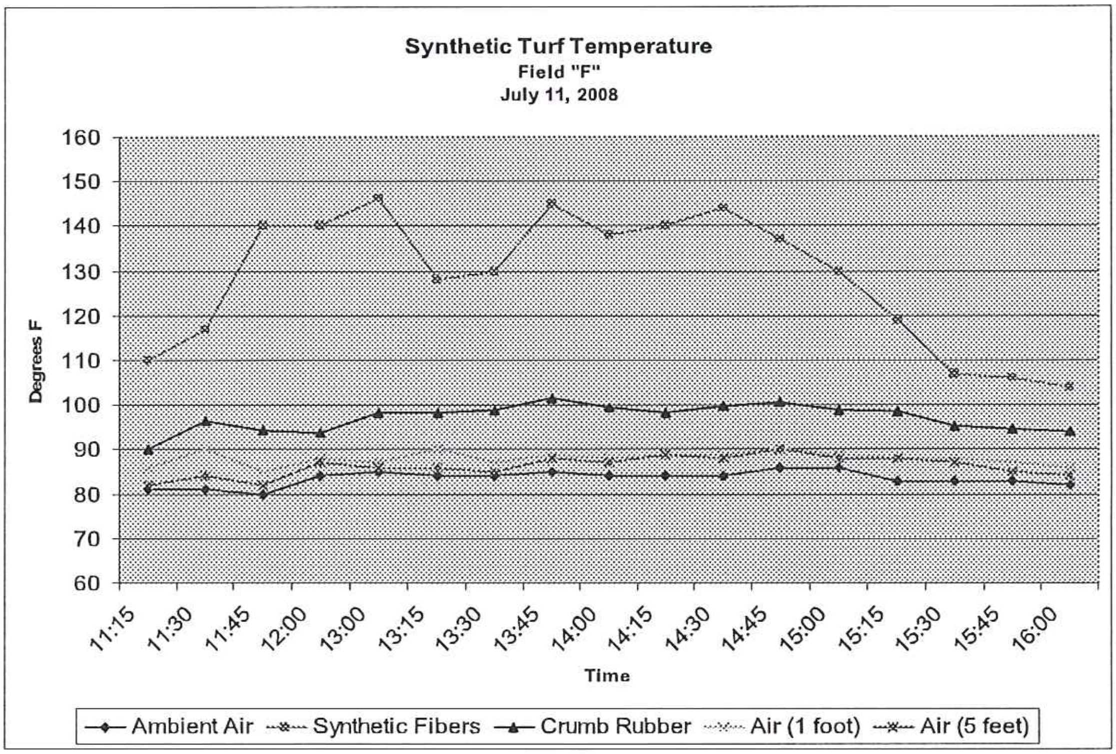


Figure 18

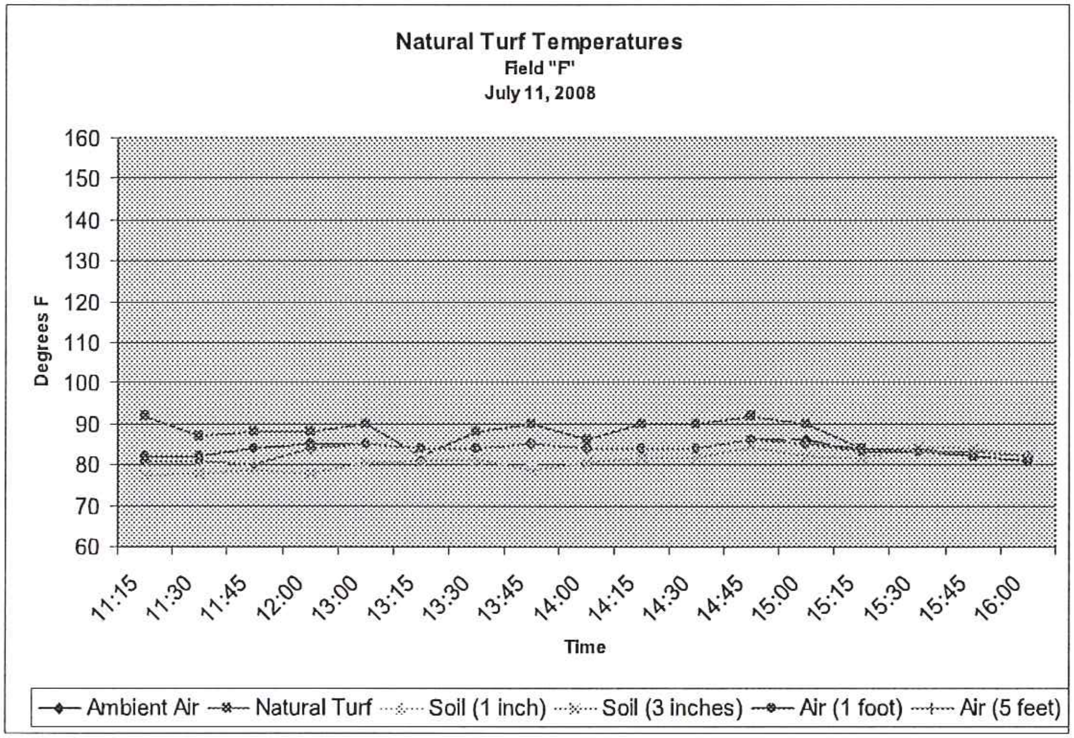


Figure 19

The sampling methodology on this date was also adjusted to evaluate the potential cooling effect due to the evaporation of water from the synthetic "grass" fibers. Two squares measuring one foot square were cut from a single sheet of white foam board (Figure 20). The surface temperature of the synthetic fibers was then measured using an infrared thermometer. One square was kept dry while the other side was wetted with one ounce of water using a spray bottle. The surface temperatures were measured and recorded over a period of 20 minutes. The foam board was then moved to a dry location, and the measurements were repeated using two ounces and then three ounces of water.

The results indicated that the applied water provided at least 20 minutes of effective cooling to the synthetic fibers. The amount of the cooling effect was generally between 10 and 20 degrees although slightly more of a cooling effect was noted when three ounces of water were used.

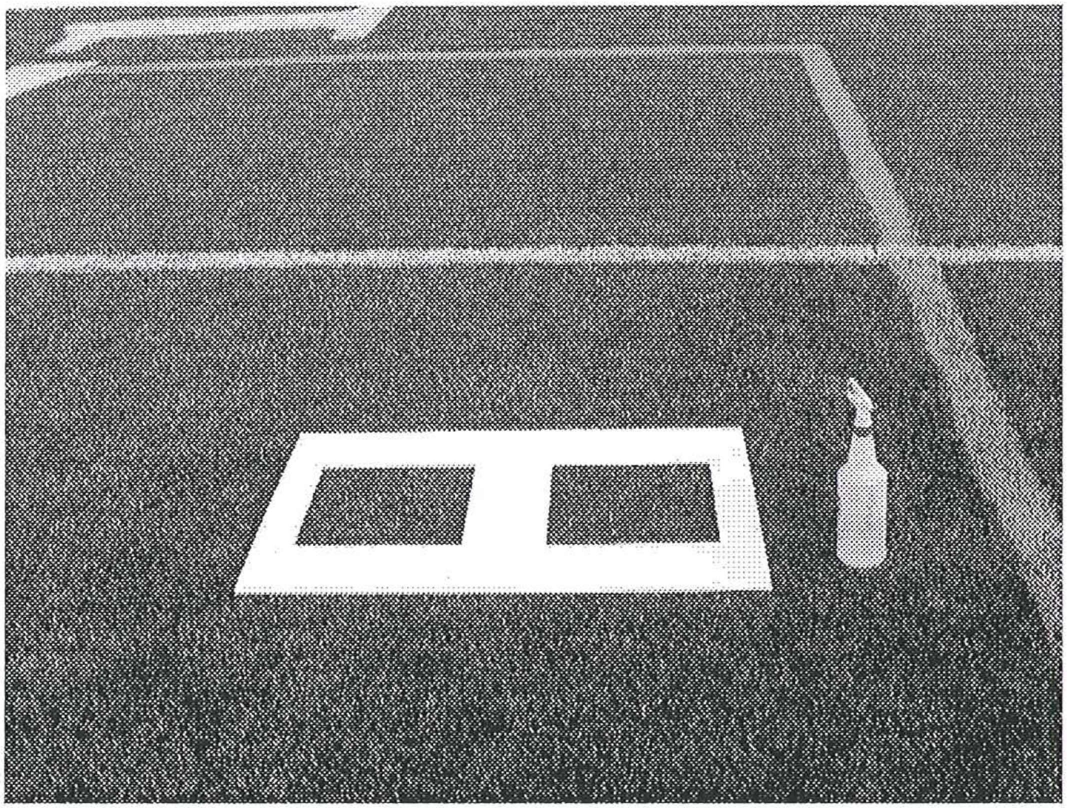


Figure 20

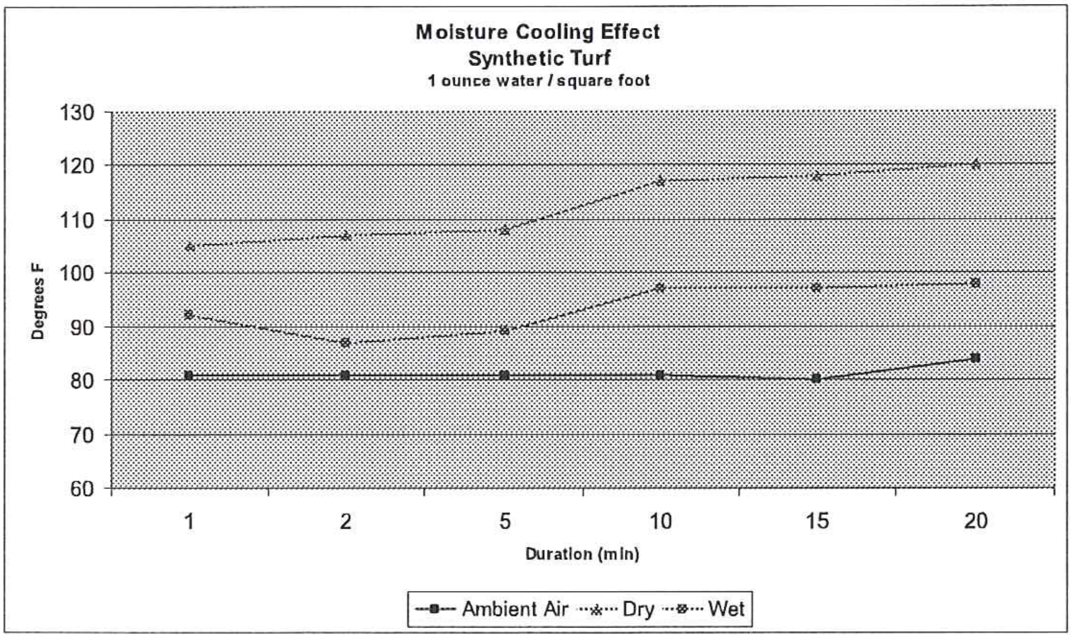


Figure 21

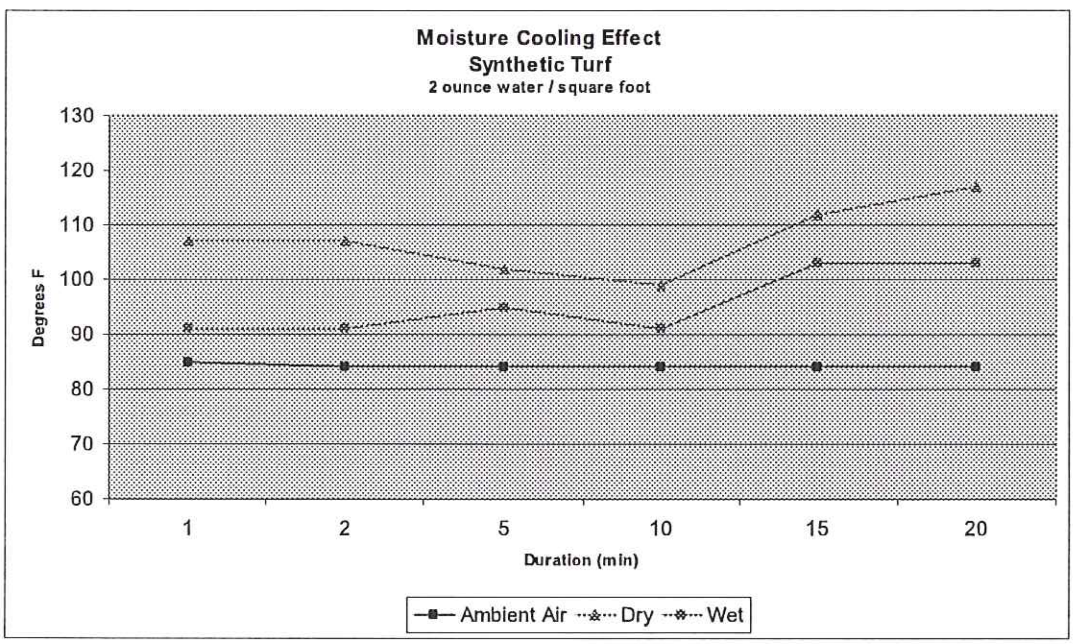


Figure 22

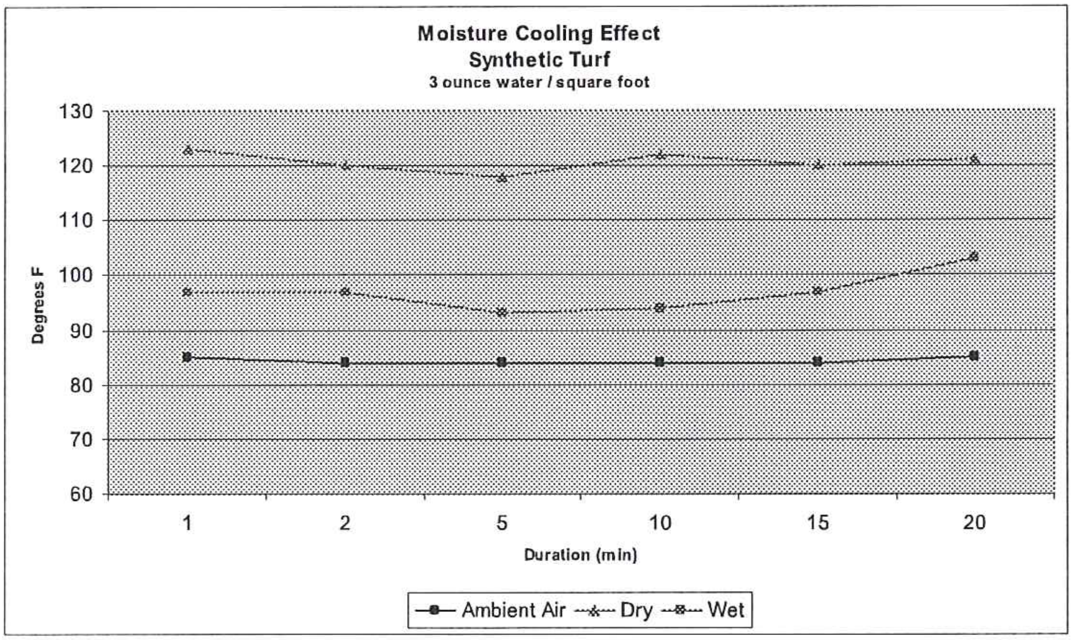


Figure 23

Summary

The results of the temperature measurements obtained from the fields studied in Connecticut indicate that solar heating of the materials used in the construction of synthetic turf playing surfaces does occur and is most pronounced in the polyethylene and polypropylene fibers used to replicate natural grass. Maximum temperatures of approximately 156° F were noted when the fields were exposed to direct sunlight for a prolonged period of time. Rapid cooling of the fibers was noted if the sunlight was interrupted or filtered by clouds. Significant cooling was also noted if water was applied to the synthetic fibers in quantities as low as one ounce per square foot. The elevated temperatures noted for the fibers generally resulted in an air temperature increase of less than five degrees even during periods of calm to low winds.

The rise in temperature of the synthetic fibers was significantly greater than the rise in temperature noted for the crumb rubber. Although a maximum temperature of 156° F was noted for the fibers, a maximum temperature of only 101° F, or approximately 16 degrees greater than the observed ambient air temperature, was noted for the crumb rubber.

Evaluation of Benzothiazole, 4-(tert-octyl) Phenol and Volatile Nitrosamines in Air at Synthetic Turf Athletic Fields

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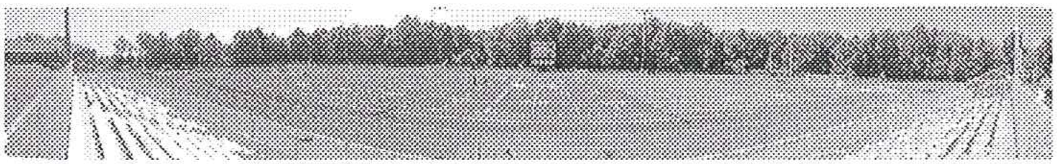
The growing popularity of crumb rubber in-filled synthetic turf playing surfaces has resulted in questions concerning the potential resulting human health effects from the inhalation of volatile chemicals by users of those fields. A limited number of studies have attempted to identify and quantify these chemicals. One such study, conducted in 2007 by the Connecticut Agricultural Experiment Station[1] identified benzothiazole, butylated hydroxyanisole, n-hexadecane, and 4-(tert-octyl) phenol as potential chemicals of concerns. This study, however, was laboratory based and did not include collection and analysis of samples from installed fields. Another study, conducted by the Norwegian Institute for Air Research[2], evaluated the air quality at three different indoor fields.

A study was designed and conducted to specifically evaluate the possible presence of benzothiazole, 4-(tert-octyl)phenol, and volatile nitrosamines in air above recently installed outdoor, crumb rubber in-filled synthetic turf playing surfaces in Connecticut.



Field G

Methodology

Two fields in Connecticut were selected for this study. Both fields were constructed in 2007 by FieldTurf using polyethylene fiber with cryogenically produced rubber and silica sand infill. One field, identified as Field F, is located in the northern portion of the state, while Field G is located in the southern portion of the state. Selection of the fields was based upon the ability to obtain permission to perform the testing and not based upon manufacturer or geographic location. Both fields are multipurpose fields used for sports such as football, soccer, field hockey, and/or lacrosse among others and are encircled by synthetic running track surfaces. These two fields were previously the subject of a separate study by the authors entitled "Thermal Effects Associated with Crumb Rubber In-filled Synthetic Turf Athletic Fields." The air sampling activities were conducted on August 15, 2008, at Field F and on August 18, 2008, at Field G.

Five sample locations were selected at each of the sampled fields. One location at each field was directly over the center portion of the playing surface, while the remaining four were located off the playing surface at either end or sides of the fields. These later locations were selected to provide "background" results to account for potential transport of vapors by wind and to evaluate the possible volatilization of target compounds from the running track surfaces.

A Davis Vantage Pro2 automated meteorological station was utilized to measure temperature, relative humidity, wind speed, and wind direction at the fields throughout the sampling period. The station was erected near the sampling location in the center portion of the field (Figure 1). The temperature sensor portion of the instrument was located approximately five feet above the synthetic turf surface.

Figure 1 - Meteorological Station

Additional measurements were made of the air temperature at heights of one foot and four feet above the synthetic turf surface using six-inch Enviro-Safe, Easy Read Armor Case thermometers with a protective plastic jacket. These thermometers have a working temperature range of 0 degrees Fahrenheit (° F) to 220° F with two-degree graduations and are National Institute of Standards and Technology (NIST) certified. The thermometers were suspended within Styrofoam insulating cylinders. The inside dimensions of the cylinders were approximately $3^3/_8$ inches diameter by 7¼ inches tall. Outside dimensions were approximately 4¼ inches diameter by 7¾ inches tall. Twelve one-half inch holes were drilled into four sides of the cylinders to allow for airflow through the cylinder while still providing protection from the heating effect of the sunlight (Figure 2).

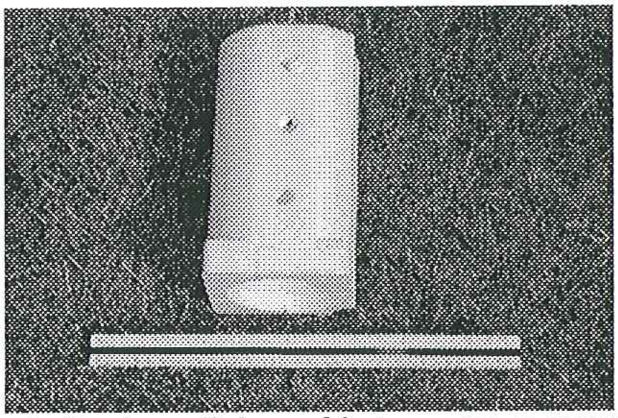


Figure 2 - Styrofoam cylinders used for temperature measurements

The Styrofoam cylinders were then mounted to the metal pole supporting the weather station. The mounted cylinders can be seen in Figure 1.

The temperature of crumb rubber in-fill material was measured using a digital pen thermometer with a stated sensing range of -58° F to 536° F in 0.1 degree divisions with accuracy of one degree. The sensing probe measured eight inches long and was constructed of stainless steel.

Air samples were collected through dedicated adsorbent media with the intakes set at approximately four feet above ground surface (Figures 2 through 5). The samples to be analyzed for benzothiazole and 4-(tert-octyl) phenol were collected using XAD-2 adsorbent media (Catalog #226-30, lot 4501, expiration date April 2012) produced by SKC Inc. of Eighty Four, Pennsylvania. A minimum of 480 liters of air was pumped through the adsorbent media at an approximate rate of two liters per minute using an SKC Airlite sampling pump. A 37 mm, 2 micron PTFE filter was placed inline before the adsorbent media tube.

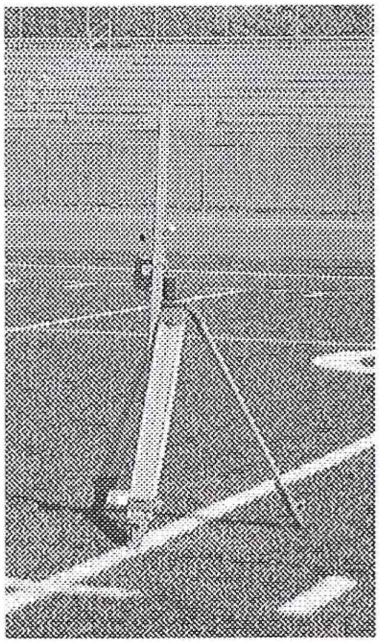


Figure 3 - Field Sample Location

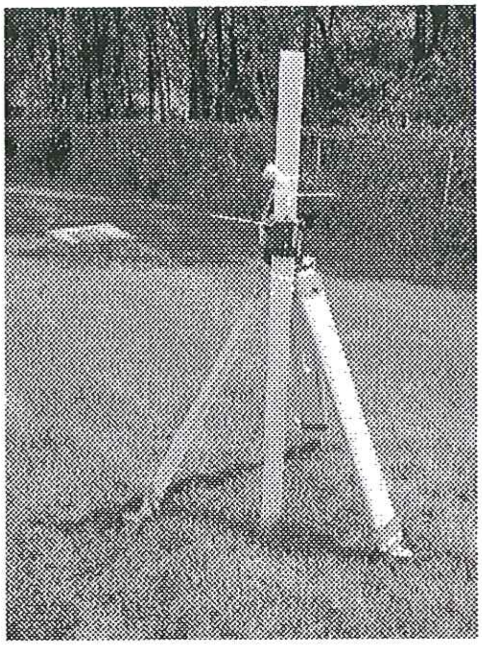


Figure 4 - "Background" Sample Location

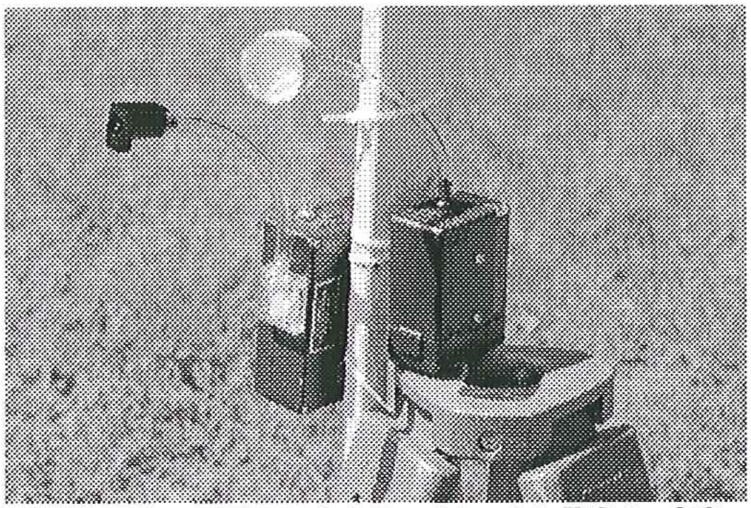


Figure 5 - Sampling Pumps. ThermoSorb N module on left; XAD-2 and filter on right

The samples to be analyzed for volatile nitrosamines were collected using ThermoSorb N adsorbent media produced by Advanced Chromatography Systems of Johns Island, South Carolina. A minimum of 75 liters of air was pumped through the adsorbent media at an approximate rate of one liter per minute using an SKC Universal Pump 224-PCXR8 sampling pump.

Both models of sampling pumps have a manufacturer's stated flow rate accuracy of +/- 5%.

The intakes for all samples were set at approximately four feet above either the playing surface or the grass surface surrounding the playing field. The sampling media was connected to the sampling pumps using approximately six inches of ¼ I.D. x 3/8 OD poly tubing. The pump was calibrated prior to sampling utilizing a BIOS DryCal DC-Lite air pump calibrator. A sacrificial media tube and poly tubing was used during the pump calibration.

All samples were delivered to the Wisconsin Occupational Health Laboratory at the University of Wisconsin via overnight courier service for analysis. The analytical methods employed for benzothiazole and 4-(tert-octyl) phenol analysis were based upon NIOSH Method 2550. The samples were desorbed with 10 minutes of sonication performed three times with three milliliters (mL) of methanol. The combined methanol fractions were then evaporated to approximately 0.5 mL with nitrogen and brought to a final volume of 1.0 mL with methanol. The extracts were then analyzed by reversed phase high-performance liquid chromatography employing a 0.1 percent formic acid:methanol linear gradient program. Detection was achieved by triple quadruple mass spectrometry using multiple reaction monitoring. A reporting limit of 100 nanograms was established for the analytes based upon statistical data analysis.

The analytical methods employed for the nitrosamine analysis were based upon OSHA Method 27. The samples were with approximately three mL of methylene chloride:methanol (75:25 v/v). Extracts were analyzed by reversed phase high-performance liquid chromatography employing a 0.1 percent formic acid:methanol linear gradient program. Detection was achieved by turbo ion spray triple quadruple mass spectrometry using multiple reaction monitoring in positive ionization mode. A reporting limit of 100 nanograms was established for the analytes based upon statistical data analysis; however, any discernable peak for n-nitrosodimethylamine was reported with appropriate comment.

Results

Field F

Air sampling activities were conducted at Field F on August 15, 2008. Five discrete sample locations were chosen. One location (SF-1) was near the center to the playing surface while the remaining four locations (SF-2, SF-3, SF-4, and SF-5) were around the perimeter of the synthetic running track. The sample locations are graphically presented in Figure 6. Sampling activities were initiated at 11:40 and were completed at 16:07.

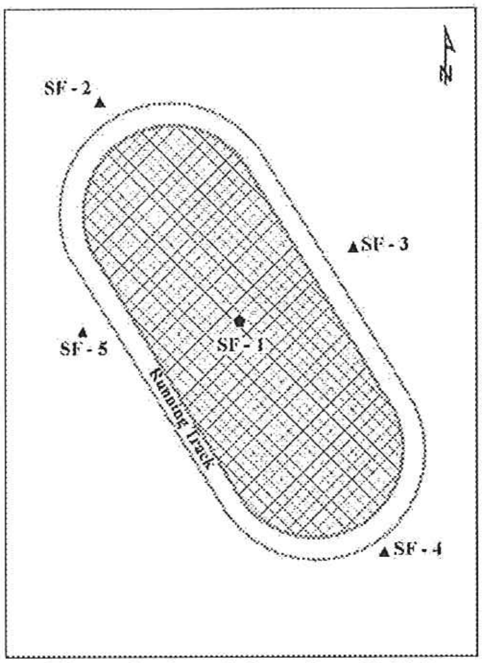


Figure 6 – Sample Locations Field F

Weather conditions on August 15, 2008, at the sample site were generally a mix of clear and partly cloudy skies with ambient air temperatures between 75° F and 80° F. Winds were generally light to calm. The late morning and early afternoon winds were measured

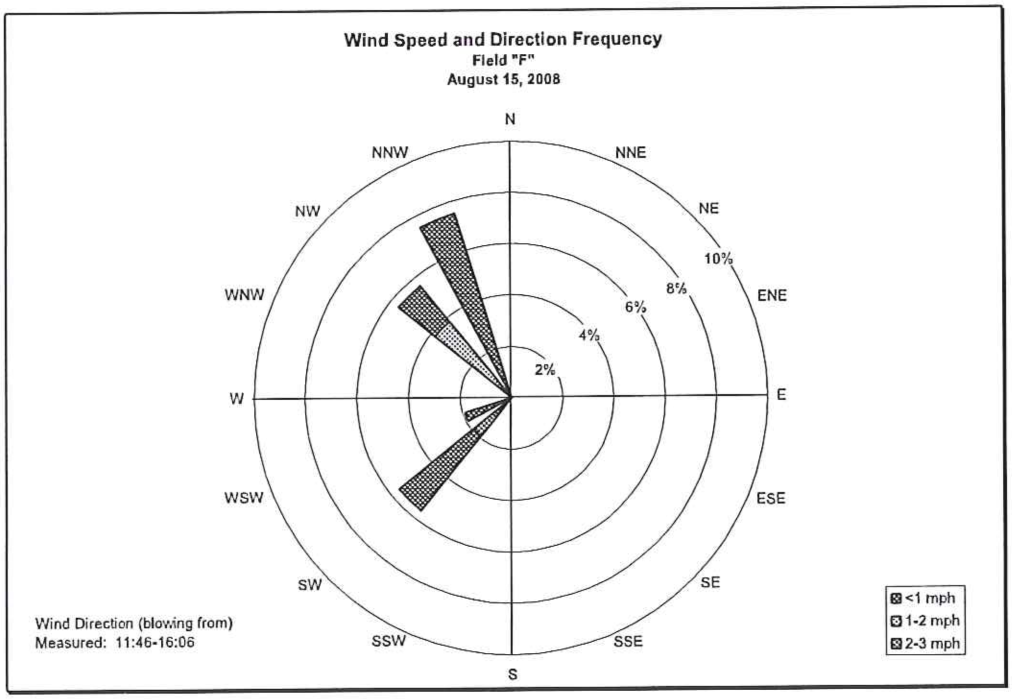


Figure 7 - Wind Speed and Direction

to be less than two miles per hour and were from the north and northwest. At approximately 15:30, the winds shifted to the southwest and increased to a maximum of three miles per hour. Figure 7 depicts the wind speed, direction, and frequency noted during the testing period. A brief rain shower occurred at approximately 14:45.

The air temperature was measured at three different heights (one foot, four feet, and five feet) directly over the playing surface near sample location SF-1. In addition, the temperature of the crumb rubber in-fill material was measured at a depth of approximately one inch. The measured temperatures are shown in Figure 8. The air temperature was noted to increase with decreasing height above the playing surface. The average air temperature measured at a height of five feet was 76.6° F, while the average temperatures at one foot and four feet were 85.7° F and 81.7° F, respectively. The average temperature of the crumb rubber was 91.7° F. Significant cooling of the crumb rubber and the air column at one foot and four feet above the surface was noted following the brief rain shower that occurred at 14:45.

Periodic measurements of the surface temperature of the synthetic "grass" fibers were measured using an infrared thermometer manufactured by EXTECH Instruments (EXTECH Pocket IR thermometer). A maximum temperature of 127° F was noted at 12:00.

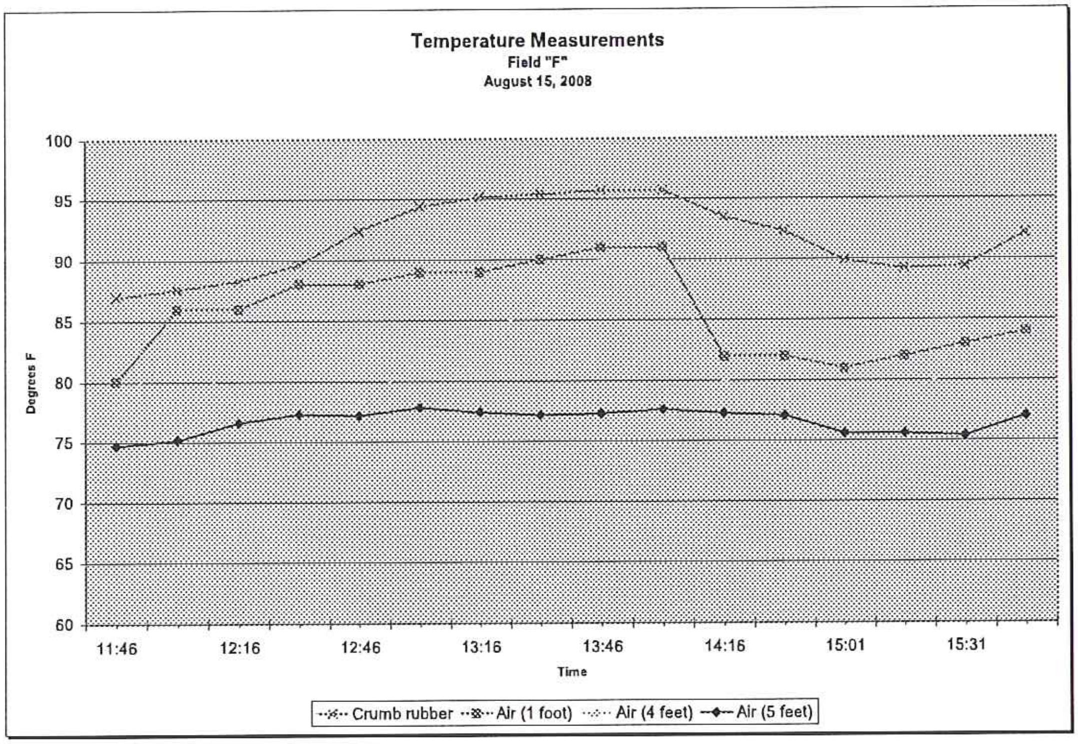


Figure 8 – Temperature Measurements Field F

All air sampling pumps were activated between 11:40 and 11:49. The pumps connected to the ThermoSorb N media were allowed to run at a flow rate of approximately one liter per minute for approximately 75 minutes. At the conclusion of the appropriate time interval, the SKC Universal Pump 224-PCXR8 was deactivated and the ThermoSorb N module was removed and sealed using the supplied caps. After approximately four hours, the SKC Airlite sampling pumps were also deactivated and the XAD-2 adsorbent tubes were removed and sealed using the supplied caps. The PTFE filters were capped and placed into plastic zip bags.

Table 1
Sampled Air Volumes - Field F
August 15, 2008

	ThermoSorb N Module			XAD-2 Module		
Sample ID	Start Time	End Time	Air Volume (L)	Start Time	End Time	Air Volume (L)
SF-1	11:49	13:04	76.13	11:49	16:08	519.04
SF-2	11:42	12:57	75.90	11:42	15:57	512.04
SF-3	11:45	13:00	75.98	11:45	16:04	519.55
SF-4	11:47	13:03	77.82	11:47	16:07	521.30
SF-5	11:40	12:55	78.75	11:40	15:46	493.23

The samples were packaged for delivery to the Wisconsin Occupational Health Laboratory at the University of Wisconsin. The analytical methods employed are described in the "Methodology" section above.

The volatile nitrosamine analysis indicated that there were no detectable concentrations of nitrosamines in the air directly above the synthetic turf playing surface (Table 2). The results also indicate that the air upwind and downwind of the playing surface lacked detectable concentrations of nitrosamines.

Table 2
Volatile Nitrosamines Results – Field F

	SF-1		SF-2		SF-3		SF-4		SF-5	
	μg/m³	ppbv	μg/m³	ppbv	μg/m³	ppbv	μg/m³	ppbv	μg/m³	ppbv
Nitrosodibutylamine (n-)	<1.1	< 0.18	<1.1	< 0.17	<1.4	< 0.22	<1.1	< 0.17	<1.0	< 0.16
Nitrosodiethylamine (n-)	<1.1	< 0.27	<1.1	< 0.26	<1.4	< 0.34	<1.1	< 0.27	<1.0	< 0.24
Nitrosodimethylamine (n-)	<1.1	< 0.38	<1.1	< 0.36	<1.4	< 0.46	<1.1	< 0.37	<1.0	< 0.34
Nitrosodipropylamine (n-)	<1.1	< 0.21	<1.1	< 0.20	<1.4	< 0.26	<1.1	< 0.20	<1.0	< 0.19
Nitrosomorpholine (n-)	<1.1	< 0.24	<1.1	< 0.23	<1.4	< 0.30	<1.1	< 0.23	<1.0	< 0.21
Nitrosopiperidine (n-)	<1.1	< 0.24	<1.1	< 0.24	<1.4	< 0.30	<1.1	< 0.24	<1.0	< 0.22
Nitrosopyrrolidine (n-)	<1.1	< 0.28	<1.1	< 0.27	<1.4	< 0.34	<1.1	< 0.27	<1.0	< 0.25

μg/m³ = mircograms per cubic meter

ppbv = parts per billion per volume

The laboratory analysis of the air directly above the synthetic turf playing surface also lacked detectable concentrations of benzothiazole and 4-(tert-octyl) phenol (Table 3). The upwind and downwind samples yielded similar results. No detectable concentrations of either compound were noted upon extraction of the two micron PTFE filters.

Table 3
Benzothiazole and 4-(tert-octyl) Phenol Results – Field F

	SF-1 µg/m³	SF-2 µg/m³	SF-3 µg/m³	SF-4 µg/m³	SF-5 µg/m³
Benzothiazole	<0.19	<0.20	<0.19	<0.19	<0.20
4-(tert-octyl)phenol	<0.19	<0.20	<0.19	<0.19	<0.20

µg/m³ = mircograms per cubic meter

Field G

Air sampling activities were conducted at Field G on August 18, 2008. The same procedures that were used in sampling at Field F were employed for the sampling at Field G. A potentially significant change in the sampling conditions was encountered during the activities at Field G. The owner of the field had groomed, or raked, the field three days prior to the air sampling activities. As a result of the grooming, the crumb rubber infill had not yet settled within the synthetic grass 'fibers" and was, therefore, more exposed at the surface.

As with the previous sampling, five discrete sample locations were chosen. The sample locations are graphically presented in Figure 9. Sampling activities were initiated at 11:17 and were completed at 15:33.

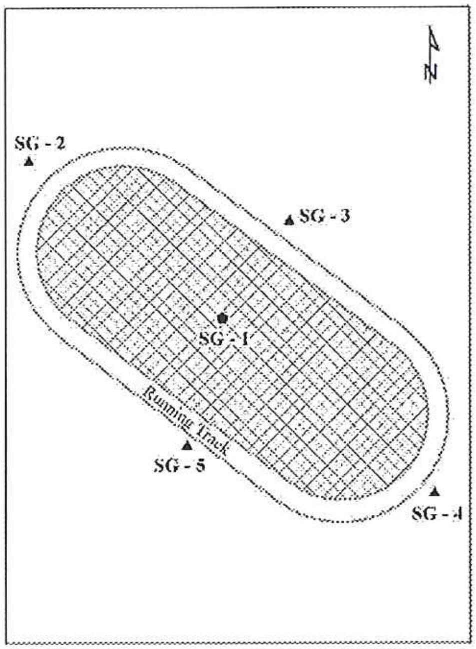


Figure 9 – Sample Locations Field G

Weather conditions on August 18, 2008, at the sample site were generally sunny with ambient air temperatures between 80° F and 85° F. Winds were generally light to calm and were variable in direction although were generally from a southerly direction. The maximum measured wind speed was three miles per hour. Figure 10 depicts the wind speed, direction, and frequency noted during the testing period.

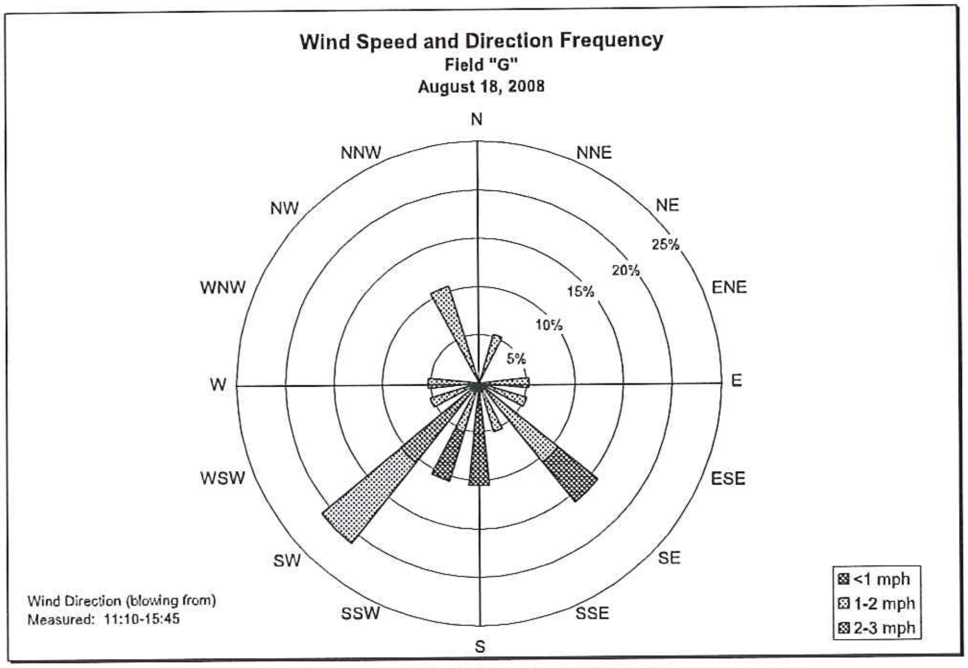


Figure 10 - Wind Speed and Direction

The air temperatures measured during the sampling at Field G are shown in Figure 11. As with Field F, the air temperature was noted to increase with decreasing height above the playing surface. The average air temperature measured at a height of five feet was 84.6° F while the average temperatures at one foot and four feet were 92.3° F and 88.4° F, respectively. The average temperature of the crumb rubber was 99.6° F. The surface temperature of the synthetic grass blades averaged 139° F.

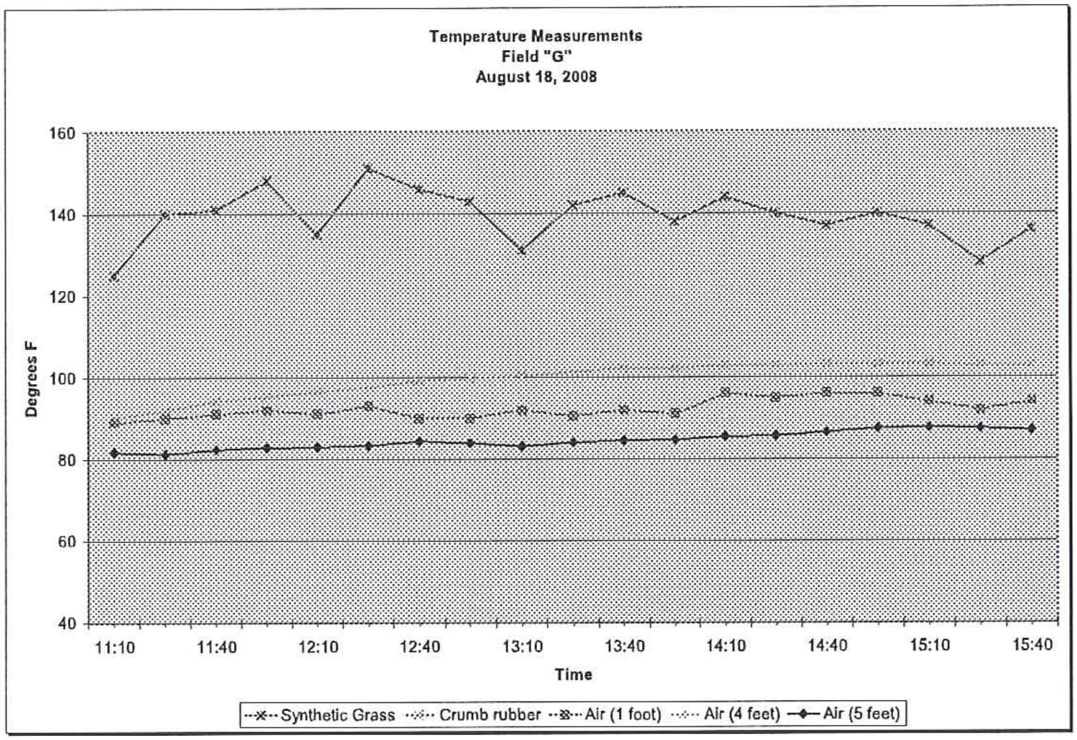


Figure 11 - Temperature Measurements Field G

All air sampling pumps were activated between 11:40 and 11:49. Table 4 details the start and stop times of the various sampling pumps and the volumes of air pumped during the sampling at Field G.

Table 4
Sampled Air Volumes - Field G
August 18, 2008

	ThermoSorb N Module			XAD-2 Module		
Sample ID	Start Time	End Time	Air Volume (L)	Start Time	End Time	Air Volume (L)
SG-1	11:22	12:37	75.75	11:22	15:23	480.96
SG-2	11:17	12:32	75.75	11:17	15:18	480.72
SG-3	11:25	12:40	75.15	11:25	15:25	481.44
SG-4	11:28	12:43	75.225	11:28	15:28	480.96
SG-5	11:33	12:48	75.525	11:33	15:33	481.20

The samples were packaged for delivery to the Wisconsin Occupational Health Laboratory at the University of Wisconsin. The analytical methods employed are described in the "Methodology" section above.

The volatile nitrosamine analysis indicated that there were no detectable concentrations of nitrosamines in the air directly above the synthetic turf playing surface (Table 5). The results also indicate that the air upwind and downwind of the playing surface lacked detectable concentrations of nitrosamines.

Table 5
Volatile Nitrosamines Results – Field G

	SG-1		SG-2		SG-3		SG-4		SG-5	
	µg/m³	ppbv	µg/m³	ppbv	µg/m³	ppbv	µg/m³	ppbv	µg/m³	ppbv
Nitrosodibutylamine (n-)	<1.3	< 0.20	<1.4	< 0.21	<1.4	< 0.21	<1.4	< 0.21	<1.4	< 0.21
Nitrosodiethylamine (n-)	<1.3	< 0.32	<1.4	< 0.33	<1.4	< 0.33	<1.4	< 0.33	<1.4	< 0.33
Nitrosodimethylamine (n-)	<1.3	< 0.44	<1.4	< 0.45	<1.4	< 0.45	<1.4	< 0.45	<1.4	< 0.45
Nitrosodipropylamine (n-)	<1.3	< 0.24	<1.4	< 0.25	<1.4	< 0.25	<1.4	< 0.25	<1.4	< 0.25
Nitrosomorpholine (n-)	<1.3	< 0.28	<1.4	< 0.29	<1.4	< 0.29	<1.4	< 0.29	<1.4	< 0.29
Nitrosopiperidine (n-)	<1.3	< 0.28	<1.4	< 0.29	<1.4	< 0.29	<1.4	< 0.29	<1.4	< 0.29
Nitrosopyrrolidine (n-)	<1.3	< 0.32	<1.4	< 0.33	<1.4	< 0.34	<1.4	< 0.34	<1.4	< 0.33

µg/m³ = mircograms per cubic meter
ppbv = parts per billion per volume

The laboratory analysis of the air directly above the synthetic turf playing surface indicated a concentration of benzothiazole of 0.39 micrograms per cubic meter of air. No 4-(tert-octyl) phenol was detected (Table 6). The upwind and downwind samples yielded similar results. No detectable concentrations of either compound were noted upon extraction of the two micron PTFE filters.

Table 6
Benzothiazole and 4-(tert-octyl) Phenol Results – Field G

	SG-1	SG-2	SG-3	SG-4	SG-5
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Benzothiazole	0.39	<0.21	<0.21	<0.21	<0.21
4-(tert-octyl)phenol	<0.21	<0.21	<0.21	<0.21	<0.21

µg/m³ = mircograms per cubic meter

Although the concentration of benzothiazole was quantified at 0.39 $\mu g/m^3$, the three trip spikes that were used as quality control recovered low for benzothiazole. The average recovery was 39% of the known spiked concentration, indicating that some degradation of the sample may have occurred prior to laboratory extraction. Assuming a similar degradation occurred for sample SG-1, the actual concentration of benzothiazole in the air directly above the synthetic playing surface may have been as high as 1.00 $\mu g/m^3$.

Summary

Twenty air samples were collected above and around two synthetic turf playing surfaces in Connecticut. Ten of the samples were analyzed for volatile nitrosamine content and 10 were analyzed for benzothiazole and 4-(tert-octyl) phenol content. The samples were collected on warm, late summer days during periods of light to calm winds. In one case, the synthetic turf surface had been groomed three days prior to the sampling. The sampling was conducted during periods when the temperature of the crumb rubber in-fill material was elevated due to exposure to the sun. The average temperatures of the crumb rubber were 91.7° F and 99.6° F. The surface temperature of the synthetic grass blades was noted to climb as high as 151° F. The combination of air temperatures, surface temperatures, wind speed and, in the case of Field G, the recent maintenance, are believed to be conditions favorable for generating maximum concentrations of the analytes in the air column above and around the playing surfaces.

This study determined that under favorable conditions for vapor generation, no detectable concentrations of volatile nitrosamines or 4-(tert-octyl) phenol existed in the air column at a height of four feet above the tested synthetic playing surfaces or in the air either upwind or downwind of the fields. The study did not evaluate if any of these two compounds were off-gassed from the fields, but simply that if they did, sufficient dilution within the air column existed to render them undetectable using methods based upon accepted OSHA and NIOSH procedures. The study also determined that benzothiazole, a common compound used in the manufacturing of rubber and plastics, was present at a very low concentration directly above one of the two fields sampled. This compound was not detected at the second of the two fields sampled nor was it detected in any of the upwind or downwind locations at either field. The field where benzothiazole was detected had recently been groomed, thereby bringing significant quantities of crumb rubber nearer to the surface of the field resulting in greater exposure to both the sunlight and air.

References

[1] Connecticut Agricultural Experiment Station (2007). Examination of Crumb Rubber Produced from Recycled Tires. AC005-8/07.

[2] Dye, C., Bjerke, A., Schmidbauer, N., and Mano, S. (2006). Measurement of Air Pollution in Indoor Artificial Turf Hall. Norwegian Institute for Air Research Report NILU OR 03/2006.

1001-22-1-n2408-rpt

Evaluation of Stormwater Drainage Quality From Synthetic Turf Athletic Fields

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Each year, millions of scrap tires are generated in the United States. The Rubber Manufacturers Association estimates that in 2005 seven-eighths of the scrap tires generated were ultimately consumed or recycled in end-use markets.[1] Approximately 290 million new scrap tires are generated each year.[2] Beneficial reuses of scrap tires include use as tire-derived fuel, landfill leachate collection systems, septic system drain fields, various civil engineering applications related to roadway and bridge construction, various stamped and punched rubber products, and use in athletic field and other recreational applications. The potential environmental effects resulting from the reuse of scrap tires in civil engineering applications have been evaluated by Humphrey[3, 4] and Brophy[5], among others. While these studies have concluded that the use of tire chip has a negligible effect upon ground water quality, few, if any, studies have been conducted concerning the effect on water quality resulting from the installation of synthetic turf athletic fields containing cryogenically treated crumb rubber produced from scrap tires.

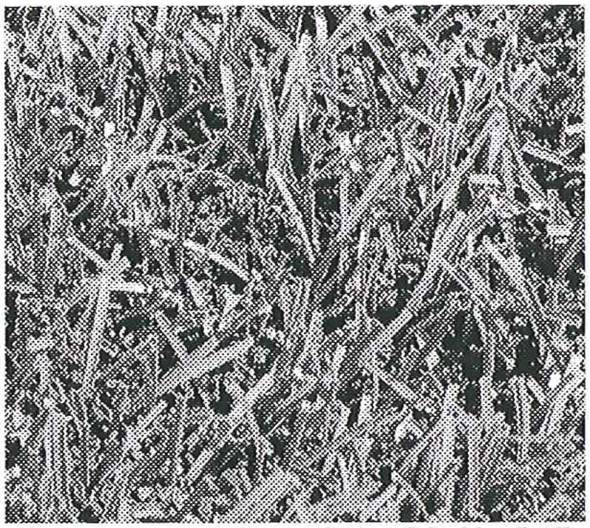

Figure 1 - Synthetic Turf with Crumb Rubber Infill

This paper presents the results of a study in which the stormwater drainage from crumb rubber and silica sand in-filled synthetic turf athletic fields was analyzed over a period of approximately one year.

Methodology

Three fields within Connecticut were selected for this study. Two of the fields are located in the northern portion of the state while the third is located in the southern portion of the state. Fields F and G were constructed by FieldTurf in 2007, and Field E was constructed in 2008. All fields are multipurpose fields used for sports such as football, soccer, field hockey, and lacrosse, among others, and are encircled by synthetic running track surfaces. In all cases, edge drains were present to capture the stormwater runoff from the running track surfaces (Figure 2).

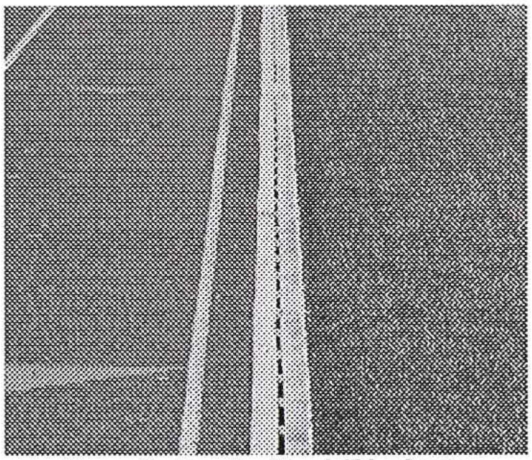

Figure 2 - Running Track Edge Drain

This allowed for sampling to be conducted of solely the stormwater that infiltrated the field surface and migrated downward through the in-fill material, through the polyethylene fiber backing, and into the underlying stone prior to entering the dedicated drainage piping. A typical cross section of a synthetic turf athletic field is shown in Figure 3.

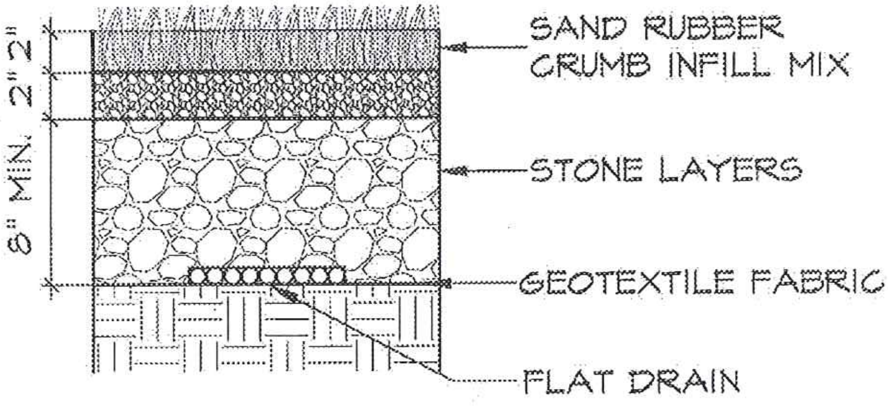

Figure 3 - Typical Field Cross Section

The use of the stone base and the flat drain systems is intended to drain stormwater out of and away from the playing surface as quickly as possible.

Each of the three sampled fields was constructed using nonmetallic underdrain systems that discharged directly to either a nearby catch basin or manhole. Grab samples of the discharge water were collected directly from the discharge pipe at the discharge location. Samples were generally collected on a calendar-quarter basis and were collected as soon as practical after the start of a rainfall event. The samples were collected using a high-density polyethylene dipper manufactured by Bel-Art and obtained from Forestry Suppliers, Inc. (catalog number 53915). The dipper was equipped with a six-foot polyethylene handle to allow for sampling without the need for entry into confined spaces. Tests performed included acute aquatic toxicity, dissolved metals (zinc, lead, selenium, and cadmium), and pH.

The aquatic toxicity monitoring was performed by GZA GeoEnvironmental, Inc. (GZA), of Bloomfield, Connecticut, in accordance with Method EPA-821-R-02-012. The water sample for this analysis was collected from Field F on October 12, 2007.

The analysis for dissolved metals content and pH was performed by Complete Environmental Testing (CET) of Stratford, Connecticut. The water samples for this analytical method were collected from Field F on October 12, 2007, October 20, 2007, November 6, 2007, February 5, 2008, April 28, 2008, and October 1, 2008. A single sampling event was conducted at Field G (April 29, 2008) and at Field E (July 24, 2008).

Subsequent to initiation of the study, the scope was expanded to include laboratory analysis of samples of the crumb rubber in-fill material. The laboratory analysis included the evaluation of metals content in an extract produced in accordance with EPA Method 1312. This methodology is referred to as the Synthetic Precipitation Leaching Procedure or SPLP. The purpose of the testing was to evaluate the potential to leach metals under acidic conditions in the controlled environment of a laboratory. The expectation was that the results would not be directly comparable to the actual in-place field conditions but would provide a useful check on the results of the drainage sampling. The analysis was performed by CET. Samples of the crumb rubber were collected from Field F on February 28, 2008, April 28, 2008, and October 1, 2008. A sample was collected from Field G on April 29, 2008, and from Field E on October 1, 2008. A sample of unused crumb rubber was also obtained from FieldTurf on October 23, 2007, and analyzed in accordance with the SPLP procedure.

Additional bench-scale testing was performed to evaluate the effect upon drainage water pH due to the stone layer that is installed under the synthetic surface materials. The tested fields were constructed using a stone layer consisting of broken basalt rock. A sample of basalt was obtained during the installation of Field E in order to perform the pH testing. The pH testing was conducted by first creating solutions of known pH. Five samples of stone, each having a mass of approximately 300 grams, were placed in separate glass jars. The known pH solution was then placed in contact with the stone samples, and the solution was monitored at five intervals up to 15 minutes. Separate control samples of tap water were prepared and served as quality control samples. Solutions of pH 4.2 and 5.2 were prepared for this evaluation.

Results

Aquatic Toxicity Evaluation

On October 12, 2007, a sample of stormwater was collected from the drainage system at Field F. The sample was placed into a container supplied by GZA and immediately delivered to GZA for an evaluation of the aquatic toxicity using *Daphnia pulex* as the test organism. The testing was conducted in accordance with EPA Method EPA-821-R-02-012. The results indicated >100% survival at both the 24- and 48-hour intervals at LC_{50} using copper nitrite as the reference toxicant.

Metals Content in Drainage Water

Samples of the stormwater were collected from Field F on October 12, 2007, October 20, 2007, November 6, 2007, February 5, 2008, April 28, 2008, and October 1, 2008. The samples were chilled and delivered to CET for analysis of the dissolved fraction of zinc, lead, selenium, and cadmium. The results were compared to the lowest aquatic life criterion for each element as established by the Connecticut Department of Environmental Protection. Table 1 summarizes the results of the laboratory analysis. The results of the laboratory analysis indicated that lead, selenium, and cadmium were not present in the drainage water. Zinc was determined to be present on four of the six sampling dates at a maximum concentration of 0.031 mg/L. The Water Quality Standard established by the Connecticut Department of Environmental Protection is 0.065 mg/L.

Table 1
Metals Content in Drainage Water - Field F

Constituent	Water Quality Standard[1]	Sample Date					
		10/12/2007	10/20/2007	11/6/2007	2/5/2008	4/28/2008	10/1/2008
metals (all units in mg/L)							
Zinc	0.065	<0.020	0.022	0.012	<0.002	0.019	0.031
Lead	0.0012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.005	<0.010	<0.005	<0.002	<0.002	<0.002	<0.002
Cadmium	0.00135	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
pH	--	7.30	7.41	7.34	7.48	7.85	7.83

[1] CT Department of Environmental Protection Standard for fresh water

A sample of stormwater was collected from the drainage system of Fields G and E on April 28, 2008, and July 24, 2008, respectively. The results, which are summarized in Tables 2 and 3, again indicated levels of dissolved zinc but at concentrations less than the applicable Water Quality Standard. Lead, selenium, and cadmium were not detected in the drainage from either Field E or Field G.

Table 2
Metals Content in Drainage Water - Field G

Constituent	Water Quality Standard[1]	Sample Date
		4/29/2008
metals analysis (all units in mg/L)		
Zinc	0.065	0.005
Lead	0.0012	<0.001
Selenium	0.005	<0.002
Cadmium	0.00135	<0.001
pH	--	8.7

[1]CT Department of Environmental Protection Standard for fresh water

Table 3
Metals Content in Drainage Water - Field E

Constituent	Water Quality Standard[1]	Sample Date
		7/24/2008
metals analysis (all units in mg/L)		
Zinc	0.065	0.036
Lead	0.0012	<0.001
Selenium	0.005	<0.002
Cadmium	0.00135	<0.001
pH	--	7.62

[1]CT Department of Environmental Protection Standard for fresh water

Laboratory Leaching Potential Evaluation

Samples of the crumb rubber and silica sand in-fill material were collected from Fields E, F, and G. The samples were collected on three different dates for Field F and on one occasion from Fields E and G. Approximately 150 grams of the in-fill material were collected on each date and delivered to CET for metals analysis in accordance with the SPLP extraction protocols. The results were compared to the criteria established by the Connecticut Department of Environmental Protection for the evaluation of the leaching potential of environmentally contaminated soil. The results, which are summarized in Table 4, demonstrate that the crumb rubber has the potential to leach metals but at concentrations less than the criteria established by the CT DEP for geographic areas that rely upon ground water as the source of potable water.

Table 4
Synthetic Precipitation Leaching Procedure - Crumb Rubber In-fill

		Date					
		10/23/2007	2/8/2008	4/28/2008	4/29/2008	10/1/2008	10/1/2008
		Raw Crumb Rubber	Field F	Field F	Field G	Field F	Field E
Constituent	Approximate "Age"	0 month	4 months	6 months	6 months	1 year	4 months
	Connecticut Pollutant Mobility Criteria	all units in mg/l					
Mercury	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Lead	0.015	<0.013	<0.013	0.006	0.004	<0.013	<0.013
Selenium	0.05	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01
Cadmium	0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005
Chromium	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	0.05	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium	1.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	0.036	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	1.3	<0.04	<0.04	<0.04	<0.04	na	na
Nickel	0.1	<0.05	<0.05	<0.05	<0.05	na	na
Zinc	5	1.6	0.91	1.9	1.1	2.4	4.7

na: not analyzed

Bench-Scale pH Analysis

The measurements obtained as part of the sampling of the drainage water discharge indicated a pH that was higher than anticipated. Measurements obtained of the pH of rainfall in the town of Cheshire, Connecticut during the study period indicated a pH of rainfall that was generally between five and six units. It was theorized that the basaltic stone base used in the construction of the athletic fields had a neutralizing effect on the infiltrated rainfall at the field locations. A limited bench-scale test was developed and performed to evaluate the effect of the stone on the pH level of various prepared solutions. The stone used for the performance of these tests was obtained during the construction of Field E.

In the first test, approximately 300 grams of crushed basaltic stone were place in each of five nine-ounce glass jars. The glass jars were then filled with tap water, and the pH was measured as a function of time by sequentially pouring the water out of each sample jar and into a separate clean glass jar for evaluation. A parallel set of jars was used containing just tap water as a set of control samples. The crushed stone was determined to have minimal effect on the tap water.

Table 5
pH Evaluation - Tap Water

Jar #	Weight of Stone (g)	Duration (min.)	pH	Water	Duration (min.)	pH
1	318	1:00	7.2	Control	1:55	7.4
2	272	2:00	7.7		2:05	7.8
3	304	5:00	8		6:00	7.8
4	312	10:00	7.9		11:00	7.9
5	322	15:00	7.9		16:30	8

The test was then repeated using a solution with a pH of 5.2 units. This test determined that the stone tended to raise the pH of the slightly acidic solution by nearly one full unit within the first minute of the test and then by approximately one-half unit at the conclusion of the test.

Table 6
pH Evaluation - Prepared Solution of pH 5.2

Jar #	Weight of Stone (g)	Duration (min.)	pH	Water	Duration (min.)	pH
1	306	1:00	6.3	Control	3:00	5.4
2	326	2:00	6.4		6:00	5.6
3	308	5:00	6.2		13:00	5.8
4	286	10:00	6.4		18:00	5.8
5	286	15:00	6.4		22:00	5.9

The test was repeated once again using a solution with a pH of 4.2 units. The stone was once again determined to have a neutralizing effect on the pH of the solution. A rise of over two units was noted immediately. The final pH was similar to the end point of the test that was conducted using a starting solution of pH 5.2.

Table 7
pH Evaluation - Prepared Solution of pH 4.2

Jar #	Weight of Stone (g)	Duration (min.)	pH	Water	Duration (min.)	pH
1	312	1:00	6.6	Control	3:00	4.2
2	290	2:00	5.9		6:00	4.2
3	304	5:00	6.2		13:00	4.8
4	304	10:00	6.2		18:00	4.8
5	304	15:00	6.5		22:00	4.4

Summary

The evaluation of the stormwater drainage quality from synthetic turf athletic fields included the collection and analysis of eight water samples over a period of approximately one year from three different fields, the collection and analysis of samples of crumb rubber in-fill from the same three fields plus a sample of raw crumb rubber obtained from the manufacturer, and the evaluation of the effect of the stone base material on the pH of the drainage water. The results of the study indicate that the actual stormwater drainage from the fields allows for the complete survival of the test species *Daphnia pulex*. An analysis of the concentration of metals in the actual drainage water indicates that metals do not leach in amounts that would be considered a risk to aquatic life as compared to existing water quality standards. Analysis of the laboratory-

based leaching potential of metals in accordance with acceptable EPA methods indicates that metals will leach from the crumb rubber but in concentrations that are within ranges that could be expected to leach from native soil. Lastly, it can be concluded that the use of crushed basaltic stone as a base material in the construction of the athletic fields has a neutralizing effect on precipitation.

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Chemicals and particulates in the air above the new generation of artificial turf playing fields, and artificial turf as a risk factor for infection by methicillin-resistant *Staphylococcus aureus* (MRSA)
Literature review and data gap identification

Office of Environmental Health Hazard Assessment
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Executive Summary

The Office of Environmental Health Hazard Assessment (OEHHA) is evaluating the safety of the new generation of artificial turf playing fields. This new generation of turf contains artificial soil termed "infill." Infill helps to soften the surface and prevent injuries. Infill also improves drainage.

Rubber crumb made from finely ground, recycled tires is commonly used as infill in the new generation of artificial turf. Tire rubber is a complex material, containing many naturally-occurring and man-made chemicals. Therefore, as part of its stewardship of tire recycling in California, the California Integrated Waste Management Board (CIWMB) has asked OEHHA to evaluate the following aspects of artificial turf playing fields:

1. Whether these fields emit levels of chemicals or particulates into the air that cause illness when inhaled.
2. Whether these fields infect athletes with the dangerous bacterium called methicillin-resistant *Staphylococcus aureus* (MRSA).

The following is our review of the published literature covering these two topics. In addition, we have attempted to identify data gaps that, when filled, will allow performance of a more accurate safety assessment.

Chemicals and Particulates Measured in the Air Above Artificial Turf Fields

Published studies were located that measured chemicals and particulates in the air above artificial turf playing fields. In all cases these fields contained crumb rubber infill. Prior to 2009, the most complete dataset was published by Dye et al. (2006). They identified almost 100 different chemicals and particulates. Another 200 chemicals were detected but not identified. This study covered fields in ***indoor*** stadiums.

Many of the chemicals identified by Dye et al. (2006) were also emitted into air by rubber flooring made of recycled tires. Similarly, laboratory studies of chemicals emitted into the air by crumb rubber made from recycled tires identified many of the same chemicals. A list of the chemicals and particulates emitted into the air during rubber manufacturing also overlapped with those identified by Dye et al. (2006). Therefore, the published literature suggests the data from Dye et al. (2006) are reliable.

In the spring of 2009 two studies were released that measured chemicals and particulates in the air above ***outdoor*** artificial turf fields containing recycled rubber crumb (New York State, 2009; TRC, 2009). Both studies targeted the same two fields in New York City. Totals of 65 and 85 chemicals were identified at relatively low concentrations in the air above the two fields. Many of these occurred at similar concentrations in the air sampled upwind of the fields. Concentrations of particulates above the fields were similar to the levels upwind of the fields. Both reports concluded that these fields did not constitute a serious public health concern, since cancer or non-cancer health effects were unlikely to result from these low-level exposures.

A comparison of the chemicals detected in the air above the same two artificial turf fields that comprised the studies by New York State (2009) and TRC (2009) shows that chemical concentrations were consistently higher in the New York State (2009) study, ranging from 1.7-fold to 85-fold higher. The reasons for these differences are unknown. These variable results highlight the difficulties faced in obtaining consistent results from potential point sources of outdoor air pollution. Despite this variability, both studies found that the chemical concentrations they measured were unlikely to produce adverse health effects in persons using these fields.

Is the Air Above Artificial Turf Fields Hazardous to Human Health?

OEHHA constructed a test scenario for an athlete playing soccer from ages 5 to 55 years on the new generation of artificial turf fields containing crumb rubber infill. The data from Dye et al. (2006) were used for chemical concentrations in the air above the fields, since this was the most comprehensive data set available at the time. Breathing rates were based on published data. Time spent on the fields for soccer games and practices was estimated.

From among the chemicals identified by Dye et al. (2006), eight appear on the California Proposition 65 list of chemicals known to the state to cause cancer. Exposure to five of these via inhalation (benzene, formaldehyde, naphthalene, nitromethane, styrene) gave increased lifetime cancer risks that exceeded one in one million (10^{-6}), generally considered the negligible risk level. In other words, more than one cancer case could be expected to occur in a hypothetical population of one million people regularly playing soccer on these artificial turf fields between the ages of 5 and 55. The highest risk was from nitromethane, which could cause about nine cancer cases in a hypothetical population of one million soccer players. While these estimated risks are low compared to many common human activities, they are higher than the negligible risk level of one cancer in a population of one million people. Data gaps exist that could lead to overestimates or underestimates of these risks.

Two of the chemicals identified by Dye et al. (2006) appear on the California Proposition 65 list as developmental/reproductive poisons (toluene and benzene). Using the same exposure scenario described above for soccer players, concentrations of both chemicals in the air above artificial turf soccer fields were below the Proposition 65 screening levels, suggesting a negligible risk of developmental or reproductive toxicity via the inhalation route of exposure.

From among the 20 chemicals detected at the highest levels by Dye et al. (2006), seven were also detected in the New York State (2009) study. Concentrations of these seven chemicals were from 5- to 53-fold higher in the air above indoor fields (Dye et al., 2006) compared to the air above outdoor fields (New York State, 2009). Concentrations of particulates were also higher in the indoor study. Therefore, using indoor data to calculate health risks from outdoor play overestimates the outdoor risks.

Does Artificial Turf Promote Infection of Athletes by the Bacterium Methicillin-Resistant Staphylococcus aureus (MRSA)?

MRSA Outbreaks in Sports

Staphylococcus aureus is a bacterium that can cause serious infections in humans. A strain has developed that is resistant to the antibiotic methicillin, termed methicillin-resistant *Staphylococcus aureus* (MRSA). This strain has caused a number of outbreaks in team sports including football, wrestling, rugby and soccer. Participation in contact sports increases the risk of infection by MRSA. Skin abrasions and other types of skin trauma also increase the risk of infection by MRSA. Person-to-person contact is the primary way MRSA is spread. Whether transmission occurs via inanimate objects (including playing surfaces) is less certain.

Artificial Turf and MRSA

It is not known if the new generation of artificial turf causes more MRSA infections than natural turf. However, one study of high school football demonstrated more "surface/epidermal injuries" for games played on the new generation of artificial turf compared to natural turf. Since skin trauma increases the risk of infection by MRSA, careful monitoring and treatment of such wounds may help prevent MRSA outbreaks.

It seems unlikely that the new generation of artificial turf is itself a source of MRSA, since MRSA has not been detected in any artificial turf field.

Data Gaps

- Using indoor data to estimate the health risks from outdoor fields probably overestimates those risks.
- Only two outdoor artificial turf fields were evaluated in the New York State (2009) study. The same two fields comprised the TRC (2009) study. Testing additional outdoor fields for the release of chemicals and particulate matter is warranted.
- Dye et al. (2006) did not determine what amount of each chemical was released by the artificial turf field and what amount was present in the ambient air. Therefore, future studies of artificial turf fields should include measurements from both above the fields and off of the fields.
- No study has measured the metals content of the particulates released by artificial turf fields. In addition, it is not known if field use increases particulate release.
- The variables of field age and field temperature should be monitored to determine whether they influence the release of chemicals and particulates into the air above these fields.
- Data are needed for the amount of time athletes spend on artificial turf playing fields. Data are needed for a variety of sports, age groups, and for both men and

women. Other subgroups with potentially heavy exposure to fields include coaches, referees, and maintenance workers.

- Only a single study was located that compared the rate of skin abrasions on the new generation of artificial turf to natural turf. This was for high school football. Similar studies are needed for other sports, age groups, and for both male and female athletes.
- No data were located on the seriousness of the skin abrasions suffered by athletes on the new generation of artificial turf compared to natural turf.
- The bacterium MRSA has not been detected in artificial turf fields. However, fields in California have not been tested. Therefore, fields from different regions of the state should be tested to verify that the new generation of artificial turf does not harbor MRSA or other bacteria pathogenic to humans.

Work in Progress

OEHHA is currently working to fill the above data gaps. OEHHA will sample air from above the new generation of artificial turf fields in outdoor settings and measure concentrations of potentially hazardous chemicals and particulates. Coaches will be surveyed to determine how much time athletes spend on these fields. Rates of skin abrasion will be measured on artificial and natural turf. Various components of the artificial turf, as well as soil and grass from natural turf, will be assayed for bacteria. Using these new data, OEHHA will determine whether the new generation of artificial turf playing fields releases chemicals or particulates into the air that pose an inhalation risk to persons using the fields. OEHHA will also determine whether artificial turf fields increase the risk of infection by dangerous bacteria such as MRSA.

particulates in the air above artificial turf are used to estimate the risk of cancer or developmental toxicity to soccer players using these fields. This screen only addresses the inhalation route of exposure. As mentioned above, since Dye et al. (2006) did not measure the metals content of inhalable particulates, this screen does not address the hazards posed by the inhalation of heavy metals such as lead.

OEHHA is currently performing a study to fill the data gaps identified in this report. OEHHA will sample air from above the new generation of artificial turf fields in outdoor settings and measure concentrations of potentially hazardous chemicals and particulates. Coaches will be surveyed to determine how much time athletes spend on these fields. Rates of skin abrasion will be measured on artificial and natural turf. Various components of the artificial turf, as well as soil and grass from natural turf, will be assayed for bacteria. Using these new data, OEHHA will determine whether the new generation of artificial turf playing fields releases chemicals or particulates into the air that pose an inhalation risk to persons using the fields. OEHHA will also determine whether artificial turf fields increase the risk of infection by dangerous bacteria such as MRSA.

Part I: Chemicals and Particulates in the Air above Artificial Turf

Studies that measured chemicals and particulates in the air above the new generation of artificial turf playing field

Table 1 shows five studies that measured chemicals and particulates in the air above the new generation of artificial turf playing field. For the studies by Dye et al. (2006), the Instituto De Biomecanica De Valencia (IBV, 2006), van Bruggen et al. (2007) and Milone & MacBroom (2008), the fields contained rubber crumb manufactured from recycled tires. The rubber crumb in the fields measured by Broderick (2007) was also likely recycled material, although this was not specifically stated in the reports. All fields were outdoors except those in Dye et al. (2006), which were soccer pitches in three indoor stadiums in Norway. Therefore, it is likely that the concentrations of chemicals and particulates measured by Dye et al. (2006) were higher than what would have been measured had the fields been outdoors.

Study quality and characteristics

The studies by Dye et al. (2006) and van Bruggen et al. (2007) were performed by governmental institutes located in Norway and The Netherlands, respectively. The study by IBV was performed by a university-affiliated research institute in Spain. Broderick (2007) refers to J.C. Broderick & Associates, Inc., an environmental consulting and testing firm located in New York State. Milone & MacBroom refers to an environmental consulting firm located in Connecticut.

The study by Dye et al. (2006) is the most detailed of the five, presented in a formal institute report. Multiple air samples were collected from above three indoor soccer pitches, two of which contained infill of ground rubber; however, samples from outside the stadiums were not collected, so that no conclusions can be drawn concerning the concentrations of chemicals and particulates in the vicinities of these stadiums. Thus, it is difficult to assess which chemicals were released by the artificial turf and which were already present in the ambient air. The study included data on the environmental conditions during sampling such as temperature, relative humidity and barometric pressure. Indoor ventilation rates were not measured. The chemical and particulate sampling height(s) above the pitches were not indicated. This study measured volatile organic chemicals (VOCs), polycyclic aromatic hydrocarbons (PAHs) in the gas phase and associated with particulate matter (PM_{10}), phthalates in the gas phase, and particulate matter ($PM_{2.5}$ and PM_{10}). Thirty-eight PAHs were assayed. Comparing the two fields containing infill made of ground rubber, there is generally good agreement between the chemicals and particulates detected over the two fields. For example, Table 6a in the report lists the concentrations of benzothiazole, toluene, 4-methyl-2-pentanone and total volatile organic compounds (TVOCs) measured over the two fields; the concentrations measured over the first field were within 0.7-, 5.6-, 1.0- and 2.5-fold, respectively, of the concentrations measured over the second field. For the three PAHs occurring at the highest concentrations over both fields (naphthalene, 2-methylnaphthalene, acenaphthylene), the values from the first field were within 2.7-fold of the values from the second field. With regard to particulate matter, the concentration of PM_{10} collected from the two fields was 40.1 and 31.7 micrograms per cubic meter ($\mu g/m^3$), while $PM_{2.5}$ was 17.3 and 18.8 $\mu g/m^3$, again demonstrating good agreement between the two fields.

Dye et al. (2006) also measured the air above a field containing infill made of "thermoplastic elastomer." Comparing this field to the other two fields containing recycled rubber infill, the air above the field containing thermoplastic elastomer contained lower levels of VOCs, PAHs (both in the gas phase and associated with particulates), total $PM_{2.5}$ and the $PM_{2.5}$ fraction consisting of rubber dust.

van Bruggen et al. (2007), also presented in a formal institute report, collected multiple samples from above four outdoor soccer fields made of artificial turf, as well as samples upwind of the fields to measure the ambient environmental levels. Weather data included wind speeds, and the heights above the fields where sampling was performed were also reported. This study only measured nitrosamines. Eight were assayed.

The short report from Broderick (2007) shows that while duplicate samples were collected from above two outdoor artificial turf fields, as well as off of the fields, no weather data (including wind speed) were presented. In addition, the reports do not indicate the height above the fields at which sampling was performed. This study only measured PAHs (in the gas phase and in particulates collected on a 2.0 μm filter). Sixteen PAHs were assayed.

The IBV (2006) study was in the form of a meeting presentation, available online at the Web site for the 2006 Dresden Conference entitled, "Impact of Sports Surfaces on Environment and Health." Six samples were collected over a single outdoor artificial soccer pitch. No background air samples were collected from off the pitch. Thus, it is difficult to assess which chemicals were released by the artificial turf and which were already present in the ambient air. No weather data were reported, and few other methodological details were provided. This study measured VOCs, PAHs (whether in gas or particulate phase was not indicated), and hydrogen sulfide.

The most recent study (Milone & MacBroom, 2008) collected a single air sample from above each of two artificial turf fields in Connecticut. Four additional samples were collected from off of each field. Temperature, humidity and wind speed/direction data were included, and a sampling height of 4 feet above the surface was utilized. Analysis was for seven nitrosamines, 4-(tert-octyl)phenol and benzothiazole. These last two chemicals had been detected volatilizing from recycled rubber crumb analyzed under laboratory conditions (see study by Environment & Human Health, Inc. (EHHI, 2007) in Table 4).

Comparing studies

Dye et al. (2006) identified 94 chemicals in the air above artificial turf fields located in indoor stadiums. Over 200 additional VOCs were detected in this study (13 to 16 percent by weight), but not identified. By comparison, the IBV (2006) study detected 13

Table 1. Air measurements above artificial turf fields

Reference	Scenario	Chemicals/particulates measured
Dye et al., 2006	Three indoor soccer stadiums 10-18°C 42-53% humidity One field 2 months old (other 2 ages not indicated) Two fields contained recycled rubber crumb (yielding values shown on right)	VOCs : 69 detected at ≥ 0.8 μg/m^3 PAHs: 22 detected at ≥ 1.0 ng/m^3 (mostly in the gas phase, some in the particulate fraction) Phthalates: 3 detected at ≥ 0.06 μg/m^3 (in the gas phase) $PM_{2.5}$: total = 18.8 μg/m^3, rubber = 8.8 μg/m^3 PM_{10}: total = 40.1 μg/m^3, rubber = 9.3 μg/m^3 Twenty highest VOCs were (in μg/m^3): toluene (85), butenylbenzene (82.5), benzoic acid (81), diethenylbenzene (41), benzothiazole (31.7), p- and m-xylene (25.5), ethylbenzaldehyde (19.7), acetonitrile (16.8), acetone (15.3), o-xylene (13.1), 4-methyl-2-pentanone (12.7), alpha pinene (10.5), 3-phenyl-2-propenal (10.2), cyclohexanone (9.8), pentenyl benzene (7.3), pentanedioic acid dimethylester (6.8), ethylbenzene (6.7), formaldehyde (6.5), hexenylbenzene (6.1), styrene (6.1) Ten highest PAHs (total in gas phase plus PM_{10}-associated) were (in ng/m^3): naphthalene (2700 or 56 for two different methods), acenaphthylene (78.1), 2-methylnaphthalene (57.8), 1-methylnaphthalene (42.6), biphenyl (32.8), phenanthrene (25), fluorene (19.2), dibenzofurane (17), acenaphthene (14.2), pyrene (4.4) Three phthalates were (in μg/m^3): dibutylphthalate (DBP, 0.38), diisobutylphthalate (DiBP, 0.13), diethylphthalate (DEP, 0.06)
IBV 2006	One outdoor soccer field	VOCs: 5 detected (highest value in μg/m^3): p- and m-xylene (4.4), toluene (3.1), o-

Reference	Scenario	Chemicals/particulates measured
	containing recycled rubber crumb	xylene (2.5), ethylbenzene (2.2), benzene (0.4) PAHs: 8 detected (highest value in ng/m^3): phenanthrene (6.9), pyrene (4.2), fluoranthene (1.1), fluorene (0.92), anthracene (0.46), acenaphthene (0.32), naphthalene (0.3), acenaphthylene (0.21)
Broderick 2007	Two outdoor high school athletic fields containing rubber crumb	All 16 PAHs assayed were below the minimum detection level of 6.0 $\mu g/m^3$
van Bruggen et al., 2007	Three outdoor fields containing recycled rubber crumb and one containing new rubber For fields with recycled rubber, one recently installed and two older than one year Sampling performed between 11-20°C on sunny days at 30-100 cm above pitch	All eight nitrosamines assayed were below the minimum detection limit of 8-16 ng/m^3
Milone & MacBroom 2008	Two outdoor fields containing recycled rubber crumb Sampling performed on	Seven nitrosamines were assayed: samples from both fields were below the minimum reporting limit of 1.0 to 1.4 $\mu g/m^3$ 4-(tert-octyl)phenol: samples from both fields were below the minimum reporting

Reference	Scenario	Chemicals/particulates measured
	summer days between 75 and 85°F with light winds Samples taken at 4 feet above surface	limit of 0.19 to 0.21 μg/m^3 Benzothiazole: one field's sample was below the minimum reporting limit of 0.19 to 0.21 μg/m^3; the other field's sample was 1.0 μg/m^3 (includes correction for 39% sample spike recovery)

chemicals and Milone & MacBroom (2008) detected one. The two remaining studies utilized detection levels that were too high; as a consequence, no chemicals were detected.

The failure to detect PAHs in the study by Broderick (2007) is consistent with the data in Dye et al. (2006). The individual PAH levels in Dye et al. (2006) were all $\leq 2.7\ \mu g/m^3$, while the individual PAH detection levels in Broderick (2007) were $6.0\ \mu g/m^3$. Utilizing nitrosamine detection levels of 8-16 ng/m^3, van Bruggen et al. (2007) did not detect nitrosamines above three outdoor fields containing recycled rubber. Some nitrosamines volatilize readily from soil and water surfaces, while others are considered nonvolatile. Their study was initiated after a single air measurement above an artificial turf field containing recycled rubber detected N-nitrosodimethylamine (NDEA) at 93 ng/m^3. Similarly, Milone & MacBroom (2008) did not detect nitrosamines above two fields (reporting limits 1.0 to 1.4 $\mu g/m^3$). Dye et al. (2006) also did not report any nitrosamines above two indoor fields containing recycled rubber, although the nitrosamine detection levels were not indicated in the report.

Table 2 shows a comparison of the concentrations of the eight PAHs and five VOCs detected by IBV (2006) to the highest values reported by Dye et al. (2006). Despite uncontrolled variables such as field age and temperature during sampling, all 13 chemicals detected by IBV (2006) were detected by Dye et al. (2006). For 12 of the 13, the concentrations were lower in IBV (2006). This might be expected, since the field in the IBV (2006) study was outdoors, while the fields in the Dye et al. (2006) study were indoors. For the eight PAHs, concentrations measured in IBV (2006) ranged from similar (pyrene) to 9000-fold (naphthalene) lower than the corresponding concentration measured in Dye et al. (2006). For the five VOCs the differences were less, ranging from 3-fold (ethylbenzene) to 27-fold (toluene) lower in the IBV (2006) study. The VOC benzothiazole was also detected over an outdoor field by Milone & MacBroom (2008); its concentration was 32-fold lower over this outdoor field compared to the concentration reported over indoor fields by Dye et al. (2006). Therefore, the data in IBV (2006) and in Milone & MacBroom (2008) support those of Dye et al. (2006) in that all 13 chemicals detected over outdoor fields were detected at higher levels over indoor fields. This suggests that persons using the new generation of artificial turf in outdoor settings are exposed to many of the same chemicals as persons exposed indoors, albeit at lower concentrations. Thus, exposure calculations for outdoor play based on the data from Dye et al. (2006) would probably overestimate exposure to most chemicals. Since neither the IBV (2006) study nor the Dye et al. (2006) study measured the background level of chemicals, it remains possible that the 13 chemicals discussed above were not emitted from the artificial turf, but were already present in the ambient air. However, due to the presence of a number of VOCs that Dye et al. (2006) considered to be typical rubber components (such as benzothiazole, 4-methyl-2-pentanone and styrene), the authors believed that the rubber infill was the source of many of the VOCs they detected.

Unfortunately, since the report of Dye et al. (2006) contained the only published values for $PM_{2.5}$ and PM_{10} from above artificial turf fields, there are no other studies for comparison. As discussed above, the good agreement between the PM values from the two fields measured in the study by Dye et al. (2006) provide some assurance that the data are reliable. However, it is difficult to use these indoor data from Dye et al. (2006) to predict the concentrations of PM over outdoor artificial turf fields.

Table 2. Comparison of chemical concentrations measured in the studies of Dye et al. (2006) and IBV (2006)

Chemical	Concentration in IBV (2006) (μg/m³)	Concentration in Dye et al. (2006) (μg/m³)[1]	[Dye]/[IBV]
PAHs			
Acenaphthene	0.00032	0.014	44
Acenaphthylene	0.00021	0.078	371
Anthracene	0.00046	0.002	4.3
Fluoranthene	0.0011	0.004	3.6
Fluorene	0.00092	0.019	21
Naphthalene	0.0003	2.7 or 0.056	9000 or 187
Phenanthrene	0.0069	0.025	3.6
Pyrene	0.0042	0.004	1
VOCs			
Benzene	0.4	2.4	6
Ethylbenzene	2.2	6.7	3
Toluene	3.1	85	27
o-Xylene	2.5	13.1	5.2
p and m-Xylene	4.4	25.5	5.8

[1]Highest value reported

Conclusions

- Only five studies were located which quantified the chemicals and particles in the air above the new generation of artificial turf playing fields.
- The study by Dye et al. (2006) of indoor soccer stadiums provides the largest dataset: 69 VOCs at ≥ 0.8 μg/m³, 22 PAHs at ≥ 1.0 ng/m³ (mostly in the gas phase), 3 phthalates at ≥ 0.06 μg/m³ (in the gas phase), $PM_{2.5}$ at 18.8 μg/m³ and PM_{10} at 40.1 μg/m³ were detected.
- The chemicals identified by Dye et al. (2006), as well as their concentrations, are consistent with the other four studies.

Data Gaps

- A study similar to that of Dye et al. (2006), that assays a large range of VOCs and particulates over multiple fields, is needed for outdoor artificial turf fields, since use of the Dye et al. (2006) data for estimating the health risks from outdoor fields probably overestimates those risks.
- Dye et al. (2006) did not sample air from outside the stadiums for comparison to the indoor samples. Therefore, it is not possible to know what amount of each

chemical was contributed by the artificial turf field and what amount was present in the ambient air.

- Approximately 200 of the 300 VOCs (13 to 16 percent by weight) detected by Dye et al. (2006) were not identified, but were only reported as peaks on a graph. Therefore, potential health risks posed by these chemicals cannot be estimated.
- Many of the chemicals identified in the study of Dye et al. (2006) have no associated health-based screening levels, so that their health risks cannot be estimated. Thus, any attempt to classify these chemicals as carcinogens or developmental/reproductive toxicants will be an underestimate.
- The Dye et al. (2006) study provides the only data on particulate levels from above artificial turf playing fields. Data from above outdoor fields are needed, where the values are likely to be lower.
- Dye et al. (2006) did not measure the metals content of the airborne particulate matter ($PM_{2.5}$ and PM_{10}). Thus, the health risks posed by inhaled particulates and the metals they contain, such as lead, cannot be determined.
- The effect of temperature on chemical and particulate levels has not been measured.
- The contribution of field age to chemical and particulate levels has not been measured.
- The effect of field use on the levels of either VOCs or particulates has not been measured. Thus, it is possible that air sampling before or during games would give different results.

Studies that measured chemicals emitted by rubber flooring made from recycled tires

CIWMB sponsored two studies (2003 and 2006) that measured chemical emissions from tire-derived rubber flooring. This type of flooring is used in indoor applications such as auditoriums and classrooms. The flooring contained at least 80 percent tire-derived rubber, making it chemically very similar to the crumb rubber infill used in many new generation artificial turf fields, including those in the study of Dye et al. (2006) and the other studies in Table 1. Emissions of individual chemicals were measured in environmental chambers and normalized to the surface area of flooring in each chamber, yielding chemical-specific emission factors. The data cannot be directly compared to the air concentrations from Dye et al. (2006). However, the emission factors were used to model the chemical concentrations expected to occur in a variety of indoor settings. Table 3 shows those concentrations for the largest rooms modeled: an auditorium and a classroom. The results for the largest rooms are presented since these are closest to the dimensions of the indoor stadiums in the Dye et al. (2006) study.

Table 3. Indoor emissions from tire-derived rubber flooring

Reference	Indoor area modeled	Modeled room chemical concentrations (μg/m³) based on measured emission factors
CIWMB, 2003	State auditorium, 70x70x15 ft, 73,500 ft³ 3.5 air changes per hour Flooring samples tested contained at least 80% recycled styrene butadiene rubber and ethylene propylene diene monomer Chemical emission rates were determined at 14 days, modeled concentrations in right column are based on the highest measured emission rate for each chemical	VOCs 21 identified: α, α-dimethylbenzenemethanol (420), acetophenone (160), diethyl propanedioate (80), propylene glycol (47), 1-ethyl-3-methylbenzene (43), 1,2,4-trimethylbenzene (40), α-methyl-styrene (38), benzothiazole (37), 1-ethyl-4-methylbenzene (22), 1,2,3-trimethylbenzene (18), triethylphosphate (18), 1-ethyl-2-methylbenzene (13), 2-ethylhexyl acetate (11), cumene (5.5), 2-ethyl hexanoic acid (3.9), 1-methyl-2-pyrrolidinone (1.8), dodecane (1.4), naphthalene (0.99), nonanal (0.74), decanal (0.5), ethyl benzene (0.5)
CIWMB, 2006	State classroom, 960 ft² x8.5 ft high, 8160 ft³ 0.9 air changes per hour Most flooring samples contained ≥ 81% tire-derived rubber Chemical emission rates were determined at 14 days, modeled concentrations in right column are based on the highest measured emission rate for each chemical	VOCs 31 identified: benzothiazole (1677), methyl isobutyl ketone (154), m-/p- xylene (142), carbon disulfide (116), acetophenone (86), cyclohexanone (77), toluene (60), acetone (43), ethyl benzene (32), benzene (24), chlorobenzene (23), nonanal (22), n-undecane (21), octanal (18), styrene (17), acetaldehyde (16), butyraldehyde (14), α-methylstyrene (12), phenol (10), decanal (9), isopropyl alcohol (9), 1,2,4-trimethylbenzene (9), formaldehyde (7), n-decane (6), 1-ethyl-4-methylbenzene (6), 1,3,5-trimethylbenzene (6), naphthalene (4), hexanal (3), 4-phenylcyclohexene (3), 1,2,3-trimethylbenzene, o-xylene (2)

In the 2003 CIWMB study, eight of 21 chemicals emitted by the tire-derived flooring were also detected above artificial turf fields in indoor stadiums (Dye et al., 2006). Half of these (4/8) were modeled as occurring at higher concentrations in the auditorium compared to the stadiums. In the 2006 CIWMB study, 18 of 31 chemicals emitted by the flooring were also detected above artificial turf fields in indoor stadiums (Dye et al., 2006), with 16 of the18 occurring at higher concentrations in the modeled state classroom compared to the indoor stadiums. For those chemicals detected in CIWMB (2003) or (2006) but not in Dye et al. (2006), it is not known if they were even assayed in the latter study. There were six chemicals detected in both CIWMB studies and by Dye et al. (2006): 1,2,4-trimethylbenzene, 1-ethyl-4-methylbenzene, benzothiazole, ethylbenzene, naphthalene and nonanal. Three of these were emitted by 100 percent rubber crumb heated under laboratory conditions: 1,2,4-trimethylbenzene, benzothiazole and ethylbenzene (see Table 4). This suggests that these three chemicals in the air are reliable markers for the crumb rubber from recycled tires used as infill in artificial turf. Ethylbenzene and naphthalene were also detected by IBV (2006) and benzothiazole was detected by Milone & MacBroom (2008) in outdoor air above artificial turf fields (Table 1), while all except 1-ethyl-4-methylbenzene were emitted by sections of artificial turf maintained in environmental chambers (see next section, Moretto, 2007).

It should be mentioned that recycled tire rubber used as indoor flooring (CIWMB 2003) emitted hundreds of low-level VOCs that were not identified. Hundreds of low-level VOCs were also detected in the air over artificial turf in indoor stadiums (Dye et al., 2006). When all VOCs were totaled (TVOCs), they reached up to 716 $\mu g/m^3$ in the Dye et al. study (2006) and exceeded one milligram $(mg)/m^3$ in the CIWMB study (2003). The health effects from breathing low levels of many volatile organic chemicals have not been adequately studied. This lack of information should be noted when calculating the health risks from individual chemicals that were identified in these studies.

Conclusions

- Twenty of the VOCs released by tire-derived indoor rubber flooring (CIWMB 2003 and 2006) were also detected in the air above indoor soccer pitches made of the new generation of artificial turf containing rubber infill.
- For the more recent flooring study (CIWMB, 2006), 18 of 31 chemicals emitted by the flooring were also detected in the air above the turf (Dye et al., 2006). This demonstrates good agreement between the studies and supports using the data from Dye et al. (2006) for making health risk estimates via inhalation.
- Three VOCs were consistent markers for tire-derived rubber: 1,2,4-trimethylbenzene, benzothiazole and ethylbenzene.

Data Gaps

- Tire-derived flooring emitted hundreds of low-level VOCs that were not identified, while other identified chemicals had no associated health-based screening levels. Therefore, the health risks posed by these chemicals cannot be estimated.

- Total VOCs (TVOCs) emitted by tire-derived flooring exceeded one mg/m^3. Similar measurements of TVOCs should be made above artificial turf fields, since breathing low levels of a mixture of many VOCs may pose a health risk.

Laboratory studies of the emission of volatile chemicals from tire-derived crumb rubber infill

Three studies were located which analyzed the gaseous emissions from tire-derived crumb rubber infill in laboratory settings (Table 4). The studies by Plesser and Lund (2004) and EHHI (2007) analyzed samples of 100 percent rubber infill heated to 60-70°C, while Moretto (2007) used whole sections of artificial turf (containing recycled crumb rubber infill) maintained at 23°C in environmental chambers.

Moretto (2007) identified 112 VOCs emitted from the artificial turf. This is more than reported in any other study. Twenty-seven of these were also detected by Dye et al. (2006) over artificial turf fields in indoor soccer stadiums. Moretto (2007) did not provide quantitative data on the amounts of chemicals that were released by the sections of artificial turf. Of the 12 VOCs identified by Plesser and Lund (2004), five were also detected by Dye et al. (2006). From among the four VOCs identified in EHHI (2007), only benzothiazole was also identified by Dye et al. (2006).

Conclusions

- The study by Moretto (2007) of artificial turf in environmental chambers confirmed 27 of the chemicals detected in indoor soccer stadium air by Dye et al. (2006). This supports the use of the data from Dye et al. (2006) for estimating the health risks posed by artificial turf playing fields.
- Benzothiazole was detected in two of three emissions studies in Table 4 (EHHI, 2007; Moretto, 2007), in both indoor flooring studies in Table 3 (CIWMB 2003 and 2008), and in air above artificial turf fields (Table 1; Dye et al., 2006; Milone & MacBroom, 2008). It appears to be a consistent and relatively high-level off-gassing product of rubber crumb made from recycled tires.

Data Gaps

- Many of the chemicals identified in the chamber emission study of Moretto (2007) were not detected in stadium air by Dye et al. (2006). This may be due to the conditions used by Moretto (2007): a sealed environmental chamber, maintained at 23°C, in which chemicals emitted at low levels have a chance to accumulate. Since chemical concentrations in the chambers were not provided in the report, this cannot be determined.

Table 4. Gaseous emissions per gram of tire-derived rubber in laboratory studies

Reference	Conditions	VOCs detected (in ng/g of rubber)
Plesser and Lund, 2004	Samples heated at 70°C for 30 minutes	Twelve VOCs detected: 1,2,4-trimethylbenzene (102), toluene (80), m/p-xylene (37), o-xylene (35), cis-1,2-dichloroethene (32), n-butylbenzene (31), p-isopropyltoluene (23), 1,3,5-trimethylbenzene (23), ethylbenzene (18), propylbenzene (15), iso-propylbenzene (12), trichloromethane (8)
EHHI, 2007	Samples heated at 60°C for 42 minutes	Four VOCs detected: benzothiazole (867), butylated hydroxyanisole or BHT alteration product (53), 4-(tert-octyl)-phenol (22), hexadecane (1.58)
Moretto, 2007	Samples off-gassed for 28 days in chambers at 23°C	112 VOCs detected, but emissions per gram of rubber not indicated

Chemicals and particulates emitted during rubber manufacturing

Due to the large numbers of chemicals and materials used to manufacture rubber, many occupational health studies have examined the safety of various steps in the manufacturing process. The studies listed in Table 5 measured the concentrations of volatile chemicals and particulates to which rubber workers have been exposed. While it is to be expected that the levels of these chemicals would be higher in factory air during the rubber manufacturing process compared to a setting where the rubber end product is used, such as in artificial turf infill, some of the more prevalent chemicals should be detected in both situations. Such a comparison can be a useful test of the validity of the studies presented in Table 1 that attempted to identify the chemicals and particulates above artificial turf fields containing recycled tire rubber as infill.

With respect to VOCs, Rappaport and Fraser (1977) measured six VOCs in a vulcanization area of a tire manufacturing plant. Three of these, toluene, ethylbenzene and styrene, were also detected by Dye et al. (2006) in indoor stadium air above new generation artificial turf containing recycled crumb rubber infill; the stadium concentrations were 51-fold, 73-fold and 78-fold lower than the factory concentrations, respectively. Cocheo et al. (1983) measured VOCs in the vulcanization and extrusion areas of a tire retreading factory. From among the 60 VOCs they identified, 15 were also detected by Dye et al. (2006) in the indoor stadium study; concentrations of the 15 VOCs were from 4-fold to 625-fold lower in the artificial turf application. Van Ert et al. (1980) investigated eight organic solvents used in a tire and tube manufacturing plant. Measurements were performed in the tire building and final inspection areas. Five of the eight solvents were also detected by Dye et al. (2006): heptane, toluene, octane, benzene and xylene. The concentrations ranged from 34-fold to 10,750-fold lower in the indoor stadium air compared to the factory air. Armstrong et al. (2001) identified five VOCs in rubber tire manufacturing plants. Of these, three (formaldehyde, benzene and toluene) were also identified by Dye et al. (2006), but at 34-fold to 238-fold lower concentrations. Lastly, two of four VOCs identified by Correa et al. (2004) in the outdoor air circulation area of a tire recapping unit were also identified by Dye et al. (2006); toluene and styrene were 131-fold and 7-fold lower in the air above indoor artificial turf fields compared to the tire recapping area. Thus, five separate studies of rubber manufacturing have detected VOCs that were also in the air over the new generation of artificial turf fields; in each case the chemical was at a lower concentration above the fields compared to the manufacturing setting. These findings support the use of the data from Dye et al. (2006) for estimating chemical exposures to persons using the new generation of artificial turf fields, at least until similar measurements can be performed in outdoor settings.

Nitrosamines have been detected by sampling air in rubber manufacturing plants (Table 5). Oury et al. (1997) measured total nitrosamines in tire factory air. The highest concentration detected was 2.3 $\mu g/m^3$. Monarca et al. (2001) detected two nitrosamines (N-nitrosodimethylamine [NDMA] and N-nitrosomorpholine [NMOR]) in the range of 1-2 $\mu g/m^3$ inside a styrene-butadiene rubber factory. Iavicoli and Carelli (2006) sampled air in a rubber manufacturing plant. While the great majority of air samples had no

Table 5. Chemicals and particulates released into the air during rubber manufacturing

Reference	Work area sampled	Chemicals and particulates measured
Nutt, 1976	Tire factory areas including mixing, extrusion, curing, pressing, trimming	Benzo[a]pyrene was Soxhlet-extracted from particulates: mean concentration of 49 factory air samples (12.3 ng/m^3) was not significantly different from outside air B[a]P concentration
Rappaport and Fraser, 1976	Rubber vulcanization performed in the lab	Fourteen VOCs were identified, with the highest relative concentrations being methylbenzene, 4-vinylcyclohexene, styrene, tert-butylisothiocyanate, and 1,5,9-cyclododecatriene
Rappaport and Fraser, 1977	Tire vulcanization area in a factory	Six VOCs measured (mean values in µg/m^3): toluene (4,371), ethylbenzene (486), styrene (473), 4-vinylcyclohexene (408), 1,5,9-cyclododecatriene (105), 1,5-cyclooctadiene (28.5)
Van Ert et al., 1980	Tire building and final inspection areas in two tire and tube manufacturing plants	Eight organic solvents measured (highest mean values in mg/m^3): hexane (64), heptane (8.6), isopropanol (7.9), toluene (3.2), pentane (2.2), octane (1.9), benzene (1.3), xylene (1.3)
Cocheo et al., 1983	Vulcanization and extrusion areas in a tire retreading factory	Sixty VOCs measured, the following being the ten highest in concentration (mg/m^3): diisobutyl phthalate (2.5), cyclohexene-1-methyl-4-(1-methylvinyl) (1.7), benzene (1.2), toluene (0.8), methylcyclohexane (0.8), dibutyl phthalate (0.5), heptane (0.5), 1-isopropyl-4-methylbenzene (0.45), 2,6-di-ter-butyl-4-ethylphenol (0.42), cyclododecatriene (0.4)
Heitbrink and McKinnery, 1986	Tire manufacturing plants: mixing and milling areas	Mean total aerosol ranges (in mg/m^3): for mixing (0.08 to 1.54), for milling (0.2 to 1.22); mean respirable aerosol ranges (in mg/m^3): for mixing (0.06 to 0.34), for milling (0.08 to 0.4)
Oury et al., 1997	Tire factory including steps of mixing, pressing, quality control and storage	Total nitrosamines (NDMA, NDEA, NDBA, NPIP, NMOR) were between 0.01 and 2.3 µg/m^3 (range of 45 measurements)
Meijer et al., 1998	Rubber manufacturing areas in belt factory (compounding and mixing, calendaring, extruding, repair, curing)	"Inhalable dust" mean values ranged from 0.9 to 9.4 mg/m^3
Fracasso et al., 1999	Rubber manufacturing areas included weighing, mixing, calendaring, compounding,	PAH concentration ranges (in µg/m^3): phenanthrene (not detected), pyrene (0.006 to 0.213), benzo(a)anthracene (not detected to 0.005), chrysene (0.01 to 0.05), benzo(a)pyrene (not detected to 0.012), dibenzo(a,h)anthracene (0.003 to 0.106)

Reference	Work area sampled	Chemicals and particulates measured
	extruding	
Armstrong et al., 2001	Five rubber tire manufacturing plants	Aerosol particle concentrations (means in μg/m^3): PM_1 [<1 μm] (120); PM_1 to PM_5 [1 to 5 μm] (123); PM_5 to PM_{10} [5 to 10 μm] (109); VOCs (means in mg/m^3) formaldehyde (0.22), benzene (0.57), furfural (< 0.91), isopropyl alcohol (5.66), toluene (12.38)
Monarca et al., 2001	Styrene-butadiene rubber factory	Total mean PM_{10}=0.23 mg/m^3; mean nitrosamines (in μg/m^3): NDMA (0.98), NMOR (2.28); 17 PAHs were Soxhlet-extracted from PM_{10}, with the 10 highest (in ng/m^3): dimethylnaphthalene (1200), naphthalene (400), pyrene (29), benzo(ghi)perylene (20), indeno(1,2,3-cd)pyrene (18), phenanthrene (12), benzo(b)fluoranthene (7.3), fluoranthene (7.0), benzo(a)pyrene (5.7), benzo(a)anthracene (2.3)
Ward et al., 2001	Rubber manufacturing plant: high exposure areas (reactor, recovery, tank farm, lab); low exposure areas (blending, baling, packaging, coagulation, water plant)	1,3-butadiene concentrations, mean 12 hour time weighted averages (in mg/m^3) for: high exposure areas = 3.8, for low exposure areas = 0.15
Chien et al., 2003	Two tire shredding plants- chopping, shredding, granulating and storage areas	PM_{10}, means ranged from 0.23 to 1.25 mg/m^3
Correa et al., 2004	Outdoor circulation area of a tire-recapping unit	In μg/m^3 : toluene (11,100), styrene (44.3), 4-chlorotoluene (7.6), 4-chlorostyrene (9.0), benzo(a)anthracene (16.7 extracted from particulates), chrysene (17.5 extracted from particulates)
de Vocht et al., 2006	Tire factory: milling and mixing/curing departments	"Inhalable particulate matter" mean value was 0.3 mg/m^3
Iavicoli and Carelli, 2006	Rubber manufacturing (e.g., belts, no tires)	Great majority of nitrosamine samples were below the limit of detection (0.06 μg/m^3); however, some values were higher (in μg/m^3): N-nitrosodimethylamine (0.35 for one sample), N-nitrosomorpholine (0.16, mean of 4 samples), N-nitrosodiethylamine (0.15, mean of 5 samples), N-nitrosodi-n-butylamine (0.06 for one sample)
de Vocht et al., 2008a	Polish rubber tire plant;	Geometric mean concentrations for the different departments ranged from: 1.7 to

Reference	Work area sampled	Chemicals and particulates measured
	departments sampled included crude materials, milling and mixing, pre-treating, assembly, curing, finishing, storage	5.8 mg/m^3 for inhalable aerosols, <1.0 to 578 µg/m^3 for aromatic amines
de Vocht et al., 2008b	Rubber manufacturing in five European countries	Inhalable dust measured with personal samplers on workers, means ranged from 0.72 to 1.97 mg/m^3

detectable nitrosamines (detection limit = 0.06 μg/m^3), some had detectable levels, the highest being 0.35 μg/m^3 for N-nitrosodimethylamine. All the above nitrosamine concentrations are above the minimum detection level of 8-16 ng/m^3 used by van Bruggen et al. (2007) to analyze air samples from above outdoor artificial turf fields containing recycled rubber crumb (Table 1). There are at least two possible reasons for the failure of van Bruggen et al. (2007) to detect the volatile nitrosamines, given that they were present at detectable levels during manufacturing. First, most of the more volatile nitrosamines may have been emitted by the rubber crumb prior to field installation. Second, volatilization may be so rapid that the chemicals rapidly dissipate into the atmosphere.

PAHs have also been detected in the air of factories producing rubber (Table 5). Surveying the levels in factory air, all were well below the detection level of 6.0 μg/m^3 used by Broderick (2007) when sampling the air above outdoor artificial turf fields containing recycled rubber crumb (Table 1). Thus, it is not surprising that Broderick (2007) failed to detect PAHs. Using lower detection levels, Dye et al. (2006) reported 22 PAHs at $\geq$ 1.0 ng/m^3 in the air above artificial turf fields in indoor stadiums (Table 1). Comparing the PAHs detected by Dye et al. (2006) to those reported in the occupational studies in Table 5 yields the following: two of six PAHs detected by Fracasso et al. (1999), ten of 16 detected by Monarca et al. (2001), and none of two detected by Coorea et al. (2004) were also identified by Dye et al. (2006). The agreement between Monarca et al. (2001) and Dye et al. (2006) seems close; however, while six of the PAHs were at higher levels in factory air compared to the indoor stadium air, four were at higher levels in the stadium air. A possible explanation is that Dye et al. (2006) analyzed PAHs occurring in both the gas and particulate phases, while Monarca et al. (2001) only assayed the particulate phase. Thus, the more volatile PAHs might be expected at higher levels in the former case. The four PAHs detected at higher levels by Dye et al. (2006) were in fact the relatively volatile PAHs acenaphthylene, fluorene, phenanthrene and anthracene.

Values for respirable particulate (PM_{10}; particles capable of penetrating deeply into the lungs, into the region where gas exchange occurs) concentrations in factory air were distributed over a fairly narrow range: up to 400 μg/m^3 in a tire manufacturing plant (Heitbrink and McKinnery, 1986), up to 352 μg/m^3 in five tire manufacturing plants (Armstrong et al., 2001), and up to 1250 μg/m^3 in two tire shredding plants (Chien et al., 2003). The PM_{10} concentrations were roughly ten-fold lower in the indoor stadium air measured by Dye et al. (2006), ranging up to 40.1 μg/m^3, of which 9.3 μg/m^3 was identified as rubber particulate. Inhalable particulate (relatively large particles, capable of being inhaled but not penetrating deeply into the lungs) concentrations in factory air were generally higher than respirable concentrations, ranging as high as 5800 and 9400 μg/m^3 in the studies by de Vocht et al. (2008) and Meijer et al. (1998). These results for respirable particulates are similar to those for VOCs, in that concentrations above indoor artificial turf fields were much lower than those in the factories, including the tire shredding plant (Chien et al., 2003).

Conclusions

- A number of VOCs detected above third generation artificial turf fields by Dye et al. (2006) were also detected in the air of rubber manufacturing plants. In all cases, the concentrations were lower in the air over the artificial turf fields compared to the factory settings.
- For the nitrosamines, their levels in air above artificial turf fields and in rubber factory air suggest that either these chemicals volatilize from the rubber crumb prior to installation in a field, or their levels over a field are too low to detect.
- Air sampling data from rubber factories confirm most of the PAHs detected by Dye et al. (2006) in the air over artificial turf fields.
- Air sampling in rubber factories and tire shredding plants detected levels of respirable particulates (PM_{10}) that were approximately ten-fold higher than the levels measured above third generation artificial turf fields containing rubber crumb infill (Dye et al., 2006).

Data Gaps

- Measure the time dependence (as the fields age) of respirable particulate ($PM_{2.5}$ and PM_{10}) release from artificial turf fields containing rubber crumb.
- Determine if levels of respirable particulates ($PM_{2.5}$ and PM_{10}) vary with field use; i.e., are the levels in the air higher during games compared to periods when the fields are idle?

Estimating the risk of cancer and developmental/reproductive toxicity via inhaled air in soccer players on the new generation of artificial turf.

The purpose of this section is to estimate the increased lifetime cancer risk and increased risk of developmental/reproductive toxicity due to the inhalation of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) by soccer players using the new generation of artificial turf playing fields. To perform this screen, the chemicals detected above artificial turf fields were compared to the California Proposition 65 list of chemicals known to the state to cause cancer or developmental/reproductive toxicity.

As described earlier in this report, Dye et al. (2006) published a study analyzing the air above three artificial turf playing fields located indoors in Norwegian soccer stadiums. This section uses these values, along with published values for age-specific breathing rates, and estimated lifetime play scenarios for soccer players on artificial turf, to calculate the following for those chemicals that also appear on the California Proposition 65 list:

1. daily chemical intake rates averaged over a lifetime to estimate the increased lifetime cancer risk, and

2. daily chemical intake rates not averaged over a lifetime, for comparison to maximum allowable dose levels (MADLs) to estimate the increased risk of developmental/reproductive toxicity.

Estimating the daily intake of air above artificial turf playing fields

Table 6 estimates the daily intake of air by soccer players from above artificial turf playing fields. The breathing rates are recommended for persons in the indicated age group engaged in "heavy" activities over "short-term" intervals. The 1.5 and 2.0 hour intervals seem to us to be reasonable estimates for the time a soccer player spends playing a timed game or practicing.

Table 6. Intake of field air on days of artificial turf field use.

Age interval	**Breathing rate**[1]	**Time of field use per day (soccer game or practice session)**[2]	**Total intake of field air per day of field use**[3]
5-15 years	1.9 m^3/hr	1.5 hr/day	2.85 m^3/day
16-18 years	1.9 m^3/hr	2 hr/day	3.8 m^3/day
19-55 years	3.2 m^3/hr	2 hr/day	6.4 m^3/day

[1] For 5-18 years: recommended mean value for short-term exposures to a child ≤ 18 years and performing heavy activities (US EPA Child-Specific Exposure Factors Handbook, September 2002, Table 7-14); for 19-55 years: recommended mean value for short-term exposures to adults performing heavy activities (OEHHA Technical Support Document for Exposure Assessment and Stochastic Analysis, September 2000, Table 3.9).
[2] Estimates based on length of timed game or practice session for ages < 16 years (1.5 hours) or ≥ 16 years (2 hours).
[3] Calculated by multiplying the value in column two by the value in column three.

Estimating the daily intake of air from above artificial turf playing fields averaged over a 70 year lifetime

The play scenarios shown in Table 7 are our best estimates for a lifetime of soccer play by a soccer enthusiast. The scenarios are not based on data. The daily intakes of air from above artificial turf fields were averaged over a 70-year lifetime, including 51 years of organized soccer play (from age 5 to 55). The daily intakes were also averaged over an entire year, since it was estimated that at most, 102 days per year (for the 19 to 22 year-old age group) would include use of artificial turf (Table 7). We consider this lifetime exposure rate of 0.464 m^3/day (Table 7) a heaviest use scenario for soccer players, since this assumes all organized soccer games and practices over a lifetime would be on artificial turf.

Table 7. Intake of field air for 51 years of artificial turf field use (soccer) averaged over a 70-year lifetime.

[1]Age interval	[2]Soccer play scenario on artificial turf fields	[3]Field air intake per day of field use (practice or game) for this play scenario	[4]Days of use per year for this play scenario	[5]Years of use per 70 year lifetime for this play scenario	[6]Daily field air intake for this play scenario averaged over a 70 year lifetime	[7]Daily field air intake normalized to body weight in m^3/kg-d
5-15	Two 15-game club seasons/year with 30 associated practice days	2.85 m^3/day	60 day/365 days	11 years/70 years	0.074 m^3/day	0.0021
16-18	One 15-game club season/year with 15 associated practice days; one 10-week high school season (6 days/week)	3.8 m^3/day	90 days/365 days	3 years/70 years	0.040 m^3/day	0.0006
19-22	One 15-game club season/year with 15 associated practice days; one 12-week college season (6 days/week)	6.4 m^3/day	102 days/365 days	4 years/70 years	0.102 m^3/day	0.0015
23-55	One 15-game club season/year with 15 associated practice days	6.4 m^3/day	30 days/365 days	33 years/70 years	0.248 m^3/day	0.0034
Total					0.464 m^3/day	

[1] Estimated age intervals for each soccer play scenario.
[2] Estimated play scenarios, with game or practice times as shown in Table 6.
[3] From fourth column of Table 6.
[4] Estimated games and practices per year for the corresponding play scenario.
[5] Estimated years of play for the corresponding play scenario.
[6] Calculated by multiplying columns three, four and five.
[7] Body weight means for combined males and females over each interval were: 35.6 kg for the 5-15 interval, 67.5 kg for the 16-18 interval (US EPA, 2002); 67.2 kg for the 19-22 interval, 74.0 kg for the 23-55 interval (US EPA, 1997).

Estimating the increased cancer risk from inhaling air above artificial turf fields

Eight of the chemicals identified in the air above indoor artificial turf fields (Dye et al., 2006) also appear on the California Proposition 65 list of chemicals known to the state to cause cancer (PAHs below 0.001 $\mu g/m^3$ were not included). Table 8 shows the increased lifetime cancer risks from breathing each of these during soccer play on artificial turf fields. The risk for each chemical was calculated using the highest air concentration from among eight independent measurements over three different artificial turf fields (Dye et al., 2006). This may overestimate the true chemical concentration in the air. Risks for two age intervals per chemical were calculated, so that a safety factor of three could be added for the 5-15 year interval (US EPA, 2005). Five of the eight chemicals were associated with increased lifetime cancer risks that exceeded the broadly accepted negligible risk level of 10^{-6}: benzene, formaldehyde, naphthalene, nitromethane and styrene. Their increased cancer risks ranged from 1.6×10^{-6} for formaldehyde to 8.7×10^{-6} for nitromethane. Since these risks exceeded the 10^{-6} benchmark, it is important for future studies to measure the concentrations of these chemicals above outdoor artificial turf fields. In addition, their concentrations should be measured in the ambient air in the vicinities of the fields. Comparing the concentrations in the air over and off of the fields will establish which carcinogenic chemicals are emitted by artificial turf, and whether mitigation measures are required.

Table 8. Inhalation of chemicals from above artificial turf fields in indoor stadiums in Norway that also appear on the California Proposition 65 list of chemicals known to the state to cause cancer: increased lifetime cancer risks from soccer play.

Chemical	Age interval in years	[1]Daily field air intake in m^3/kg-d	[2]Indoor field air concentration of chemicals in mg/m^3	[3]Daily chemical intake in mg/kg-d	[4]Safety Factor	[5]Cancer Slope Factor in $(mg/kg\text{-}d)^{-1}$	[6]Increased lifetime cancer risk
Acetaldehyde	5-15	0.0021	0.0043	9.03×10^{-6}	3	0.01	5.0×10^{-7}
Acetaldehyde	16-55	0.0055	0.0043	2.37×10^{-5}	1	0.01	
Benzene	5-15	0.0021	0.0024	5.04×10^{-6}	3	0.1	2.8×10^{-6}
Benzene	16-55	0.0055	0.0024	1.32×10^{-5}	1	0.1	
Benzo[a]pyrene	5-15	0.0021	1.2×10^{-6}	2.52×10^{-9}	3	3.9	5.5×10^{-8}
Benzo[a]pyrene	16-55	0.0055	1.2×10^{-6}	6.6×10^{-9}	1	3.9	
Ethylbenzene	5-15	0.0021	0.0067	1.41×10^{-5}	3	0.0087	6.8×10^{-7}
Ethylbenzene	16-55	0.0055	0.0067	3.69×10^{-5}	1	0.0087	

Chemical	Age inter-val in years	[1]Daily field air intake in m^3/kg-d	[2]Indoor field air concentra-tion of chemicals in mg/m^3	[3]Daily chemical intake in mg/kg-d	[4]Safety Factor	[5]Cancer Slope Factor in $(mg/kg\text{-}d)^{-1}$	[6]Increased lifetime cancer risk
Formaldehyde	5-15	0.0021	0.0065	1.37×10^{-5}	3	0.021	1.6×10^{-6}
Formaldehyde	16-55	0.0055	0.0065	3.58×10^{-5}	1	0.021	
Naphthalene	5-15	0.0021	0.0027	5.67×10^{-6}	3	0.12	3.8×10^{-6}
Naphthalene	16-55	0.0055	0.0027	1.49×10^{-5}	1	0.12	
Nitromethane	5-15	0.0021	0.0041	8.61×10^{-6}	3	0.18	8.7×10^{-6}
Nitromethane	16-55	0.0055	0.0041	2.26×10^{-5}	1	0.18	
Styrene	5-15	0.0021	0.0061	1.28×10^{-5}	3	0.026	1.9×10^{-6}
Styrene	16-55	0.0055	0.0061	3.36×10^{-5}	1	0.026	

[1] From last column in Table 7. For the 16-55 interval, the value of 0.0055 is the sum of the values for the 16-18, 19-22 and 23-55 age intervals in Table 7.
[2]Dye et al., 2006; highest value from among eight independent measurements over three different artificial turf fields in indoor stadiums.
[3]Calculated by multiplying column three by column four.
[4]Safety factor for the increased sensitivity of 2-15 year old children to carcinogens (US EPA, 2005).
[5]All cancer slope factors were taken from the OEHHA Toxicity Criteria Database available at www.oehha.ca.gov except for nitromethane and styrene; nitromethane cancer slope factor is available at www.oehha.ca.gov/prop65/law/pdf_zip/NitromethaneNSRL120707.pdf ; styrene cancer slope factor from OEHHA, 2009, Public Health Goal for Styrene, under review.
[6]Increased lifetime cancer risks due to each chemical were calculated by multiplying columns five, six and seven and adding together the resulting risks for the two age intervals.

Estimating the risk of developmental/reproductive toxicity from inhaling air above artificial turf fields

Benzene and toluene were the two chemicals identified in Dye et al. (2006) that also appear on the California Proposition 65 list of chemicals known to the state to cause developmental/reproductive toxicity. Toluene is listed as a developmental toxicant, while benzene is listed as a developmental and male reproductive toxicant. For developmental toxicants, the subpopulation most at risk is pregnant females. Were a pregnant female to use these fields for a two hour interval, her exposure to benzene and toluene via inhaled air would be below the corresponding maximum allowable dose level (MADL, Table 9).

Table 9. Daily intake rates of chemicals inhaled via air from above artificial turf fields in indoor stadiums in Norway that also appear on the California Proposition 65 list of chemicals known to the state to cause developmental/reproductive toxicity: comparison to maximum allowable dose levels (MADLs).

Chemical	Indoor field air concentration detected in Norwegian study (ug/m^3)[1]	Chemical intake via field air (not averaged over lifetime) (ug/day)[2]	MADL (ug/day)[3]
Benzene	2.4	15.4	49
Toluene	85	544	13,000

[1] Dye et al., 2006; highest value from among eight independent measurements over three different artificial turf fields in indoor stadiums.
[2] Calculated by multiplying the daily intake of field air for 19 to 55 year-olds (6.4 m^3/day, Table 6) by the field air concentration shown in column two of this table.
[3] MADL = maximum allowable dose level, accessed 6/08 at http://www.oehha.ca.gov/prop65/pdf/2008MayStatusReport.pdf .

This section estimates the risk of cancer or developmental/reproductive toxicity in soccer players using the new generation of artificial turf playing field. A single study (Dye et al., 2006) was used as the source of VOC and PAH concentrations from above this type of field. Since Dye et al. (2006) was performed in indoor soccer stadiums, we believe it likely that the chemical concentrations over outdoor fields would be significantly lower, due to the dispersion of the chemicals into the atmosphere. Comparing Dye et al. (2006) to IBV (2006), as shown in Table 2 of this report, suggests that this is indeed the case. Support also comes from comparing the benzothiazole concentration measured indoors by Dye et al. (2006) to that measured by Milone & MacBroom (2008) outdoors: 31.7 compared to 1.0 $\mu g/m^3$. Thus, the daily chemical intakes calculated in Tables 8 and 9 probably overestimate the intakes that would result from breathing air over outdoor artificial turf fields. More accurate estimates of the cancer and developmental/reproductive hazards will be possible when air from above additional outdoor synthetic turf fields is analyzed, along with background levels from off of the fields.

The lifetime soccer play scenarios are not based on data but on personal experience and informal discussions. Relevant data may exist that will help reduce the uncertainty in this component of the exposure assessment. Until those data are located, we consider this cumulative play scenario from ages 5 through 55 exclusively on artificial turf to represent a heaviest use scenario for soccer players. However, soccer is only one of many sports played on today's artificial turf fields. Football, lacrosse, baseball, softball and rugby are some others, along with the unorganized, informal play that predominates for young children under the age of five. All these modes of play have characteristic ages for participants, years of expected play, and time spent on the field per game. This will result in chemical exposures via inhalation that are different from those calculated above for soccer. In addition, the people who coach, supervise or referee these sports will each have different exposures, as will the people who maintain artificial turf fields. Therefore, the risks calculated for soccer players in Tables 8 and 9 should not be interpreted as covering the risks for other sports, age groups or occupations.

Lastly, it should be noted that most of the VOCs detected above artificial turf fields in the Dye et al. (2006) study were never identified. For example, for the field yielding the highest level of total volatile organic compounds (TVOCs, 716 ug/m^3), 85 percent of the individual chemicals (representing about 20 percent of the mass of TVOCs) were not identified. This remains a significant source of uncertainty in assessing the health risks posed by these fields.

Conclusions

- The Dye et al. (2006) study provided the most complete dataset from which to calculate inhalation exposures to chemicals in the air above artificial turf playing fields.
- Lacking published data, the time that soccer players spend on artificial turf over a lifetime was estimated.
- Dye et al. (2006) quantified eight chemicals that appear on the California Proposition 65 list of chemicals known to the state to cause cancer.
- Estimated inhalation exposures of soccer players to five of these (benzene, formaldehyde, naphthalene, nitromethane and styrene) gave theoretical increased lifetime cancer risks that exceeded the insignificant risk level of 10^{-6} (OEHHA, 2006).
- Data from indoor fields were used to estimate outdoor exposures and calculate these cancer risks. In addition, it was assumed that all organized soccer play over a lifetime occurred on artificial turf fields. Together, these assumptions tend to overestimate the cancer risks for soccer players using artificial turf fields.
- Benzene and toluene were the two chemicals quantified by Dye et al. (2006) that also appear on the California Proposition 65 list of chemicals known to the state to cause developmental/reproductive toxicity. Their concentrations in the air over indoor artificial turf fields were below the associated screening levels for developmental/reproductive toxicity. This suggests there is a low risk for such health effects due to inhalation exposures in soccer players.

Data Gaps

- To calculate the inhalation health risks from outdoor artificial turf fields, an air sampling study similar to Dye et al. (2006) is needed, but it should be performed over outdoor fields, including ambient air samples from off of the fields.

- For more accurate exposure estimates, better data are needed for the hours per day, days per year, and years per lifetime that athletes spend using artificial turf playing fields. Data are needed for a variety of sports, ages and for both female and male athletes. Use of these fields for informal play by children under the age of five should also be considered.
- Exposures to professionals such as coaches, referees and maintenance workers should also be estimated.
- Approximately 300 of 400 VOCs detected by Dye et al. (2006) were not identified, so that their health risks cannot be determined.
- Since the airborne particulates measured by Dye et al. (2006) were not analyzed for metals, including lead, the health risks they pose via inhalation cannot be determined.
- While most of the VOCs identified by Dye et al. (2006) do not have MADLs developed under Proposition 65, data exist indicating that some cause developmental/reproductive effects in test animals. Thus, additional screening is required to more fully evaluate these risks.
- Health risks due to high levels of total volatile organic compounds (TVOCs) have not been adequately assessed.
- The variable of field age should be investigated since chemical release may decrease with time, leading to lower health risks. Conversely, particulate release may increase with time.
- One possible mitigation measure that should be investigated for indoor fields is to increase the ventilation rate.

Part II: Artificial Turf as a Possible Risk Factor for Infection by Methicillin-resistant *Staphylococcus aureus* (MRSA)

Is artificial turf a risk factor for infection by MRSA?

Staphylococcus is a genus of gram positive bacteria commonly found on the surface of human skin. These bacteria can infect the skin, causing diseases such as impetigo and boils. *Staphylococcus aureus* (*S. aureus*) is a species that is particularly pathogenic to humans. Besides infecting skin, it can also cause food poisoning. If *S. aureus* from a skin infection moves internally, it can spread throughout the body, causing serious organ damage. Normally, only a small percentage of *S. aureus* skin infections progress to the point where hospitalization is required.

Methicillin is a broad spectrum antibiotic often used to treat *S. aureus* infections. However, methicillin-resistant *S. aureus* (MRSA) has developed. A number of outbreaks of MRSA have occurred in athletic teams, including high school, college, professional and club teams. Thus, it is important to identify modes of transmission of MRSA and other risk factors for infection.

MRSA outbreaks in human populations are considered to be one of two kinds. Outbreaks in hospitals often occur in persons with weakened immune systems. This is considered healthcare-associated MRSA. Outbreaks in the general community, in otherwise healthy individuals, are considered community-associated MRSA. Risk factors for community-associated MRSA include young age and playing a contact sport (Boucher and Corey, 2008). In the case of athletes, this may be due in part to the frequent physical contact that occurs during play, as well as the propensity of these athletes to have skin cuts and abrasions.

A number of community-associated outbreaks of *S. aureus* and MRSA have been described in sports settings (Table 10; Lindenmayer et al., 1998; MMWR, 2003; Huijsdens et al., 2006; Turbeville et al., 2006; Kirkland and Adams, 2008). The outbreaks included boils (furunculosis), other types of skin abscesses such as impetigo, and cellulitis. In a review of the sports medicine literature (59 infectious disease outbreaks between 1922 and 2005) by Turbeville et al. (2006), the most common causes of outbreaks were *S. aureus* (often MRSA, 22 percent of outbreaks) and herpes simplex virus (22 percent of outbreaks). The sports with the most outbreaks were football (34 percent of outbreaks), wrestling (32 percent of outbreaks), rugby (17 percent of outbreaks) and soccer (3 percent of outbreaks). These are all considered contact sports, with player-to-player contact that ranges from incidental to violent. However, these sports also result in forceful impacts between the players and the playing surface. In the cases of football, rugby and soccer, the surface would usually be an outdoor field of natural or artificial turf. For wrestling, the surface would most often be a vinyl-covered wrestling mat.

The outbreaks mentioned above suggest two possibilities for the high incidence of *S. aureus* skin infections in contact sports: the bacteria are transferred by player-to-player contact or by player contact with a contaminated playing surface. The data from health-care associated MRSA outbreaks, as well as those from sports-associated MRSA outbreaks (Turbeville et al., 2006; Benjamin et al., 2007; Boucher and Corey, 2008; Cohen, 2008; Kirkland and Adams, 2008), suggest that person-to-person contact is a major mode of MRSA transmission. Whether contact with outdoor playing surfaces, such as occurs during falls to the surface, promotes transmission of MRSA is less certain.

An association between MRSA infection and player-to-playing surface contact could have at least two different explanations. Such contacts could cause relatively long-lasting skin abrasions that serve as efficient portals of entry for MRSA, perhaps during subsequent player-to-player contacts. Alternatively, the playing surface itself might be a carrier of MRSA, such that player contact with the surface transfers MRSA to the previously uncontaminated skin.

An association between skin abrasions due to falls to the turf (termed turf burns) and skin infection by MRSA has been tested in two MRSA outbreaks among football teams. In a college football team, players with MRSA-induced boils were 7.2-fold more likely to have had skin abrasions from artificial turf (new generation) than uninfected players (Begier et al., 2004). Comparative data for burns received from natural turf were not presented. In a professional football team, eight of eight MRSA-induced skin abscesses occurred at the site of a turf burn. Whether the turf burn was received on artificial (old generation Astroturf®) or natural turf was not reported. The results of these two studies demonstrated an association between skin trauma due to falls to the playing surface and skin infections by MRSA. This suggests that traumatized skin is more susceptible to MRSA entry and infection. An association between skin trauma and MRSA infection has been suggested in other outbreaks among competitive sports teams, where skin trauma was produced by other means, including irritation by protective equipment (MMWR, 2003), body shaving (Begier et al., 2004) and falls to wrestling mats (Lindenmayer et al., 1998). Other studies also support an association between skin trauma and MRSA infection during contact sports (Bartlett et al., 1982; Sosin et al., 1989; Cohen, 2008; Kirkland and Adams, 2008). In consideration of these data, it seems justified to consider skin trauma in general, and turf burns in particular, to be risk factors for MRSA infection during competitive contact sports. Whether the incidence or severity of turf burn is greater on the new generation of artificial turf compared to natural turf is discussed below.

As mentioned above, a second possible explanation for why player-to-playing surface contact might be a risk factor for MRSA infection in competitive sports is that the playing surface itself is a source of MRSA. An inanimate object capable of transmitting infectious bacteria to humans is called a fomite. While player-to-player contact is considered the most important mode of sports-associated MRSA transmission, possible

Table 10. Sports-related skin abrasions and infections on artificial and natural turf

Reference	Sport	Turf type	Endpoint	Findings
Keene et al., 1980	American football at U. of Wisconsin	Old-generation Tartan Turf®	"Scrapes"	Significantly more ($p<0.001$) scrapes on artificial turf than on natural grass
Bartlett et al., 1982	High school American football	Not indicated	Boils (furunculosis) caused by *S. aureus*	Frequent open wounds or bruises were risk factors ($p<0.05$) for boils; concluded wounds and bruises are portals of entry for *S. aureus* into the body
Ekstrand and Nigg, 1989	Soccer played at different levels	Old-generation artificial and natural turf	"Abrasion injuries"	In three different studies, there were more abrasion injuries on artificial turf than on natural turf (severity not indicated)
Sosin et al., 1989	High school American football and basketball	Natural turf (wood floors for basketball)	Boils (furunculosis) caused by *S. aureus*	Players with >2 skin abrasions/week had 2.7-fold higher risk of infection ($p<0.01$); fomite contact not a risk factor
Begier et al., 2004	American football, one college team	New (third) generation artificial turf	MRSA-induced cellulitis and skin abscesses	Infected players were 7.2-fold more likely to have "turf burns" from artificial turf than uninfected players
Meyers and Barnhill, 2004	High school American football	New (third) generation artificial turf and natural turf	Injuries, including 0-day time loss (i.e., mild) and 1-22+ days time loss injuries	"Surface/epidermal injuries"(abrasions, lacerations and puncture wounds) were 9-fold more common on artificial turf compared to natural turf
Kazakova et al., 2005	Professional American football, one team	Old-generation Astroturf® and natural turf	MRSA-induced skin abscesses	8/8 infections occurred at site of turf burn; players reported more and more serious turf burns for games on artificial turf (2-3 per week); field swabs of artificial turf were negative for MRSA
Ekstrand et al., 2006	Elite soccer in Europe (male only)	New (third) generation artificial turf and natural turf	Time loss injuries	No difference in overall injury rate on artificial and grass; did not report skin abrasions, most of which are probably 0-day time loss
Benjamin et al., 2007	Various sports	Not indicated	MRSA infection	There is little evidence that MRSA infection occurs via fomite transmission; infection probably due to skin-to-skin contact
Fuller et al., 2007a	Collegiate soccer, male and female, matches only	New (third) generation artificial turf and natural turf	Time loss injuries occurring during matches	Overall injury incidence and severity similar on artificial and natural turf; only lacerations/skin lesions in men were higher (2.95-fold, $p<0.01$) on

Reference	Sport	Turf type	Endpoint	Findings
				artificial turf (relatively serious since they were time loss)
Fuller et al., 2007b	Collegiate soccer, male and female, training only	New (third) generation artificial turf and natural turf	Time loss injuries occurring during training	All injuries similar incidence and severity on artificial and natural turf
Steffen et al., 2007	Female soccer, under-17 league	Second and third generation artificial turf and natural turf	Acute, time loss injuries	Overall injury rate was the same on the artificial and natural turf; did not report skin abrasions, most of which are probably 0-day time loss
Andersson et al., 2008	Male elite soccer	New (third) generation artificial turf and natural turf	Number of standing and sliding tackles per player per game	Fewer sliding tackles on artificial turf compared to natural turf ($p<0.05$), possibly related to the risk of turf burn
Cohen, 2008	Various sports	Not indicated	MRSA infection	Risk factors identified: 1)skin-to-skin contact, 2)skin damage (such as mat burns in high school wrestling), 3)sharing equipment (e.g., towels)
McNitt et al., 2008	Not discussed	New (third) generation artificial turf and natural turf in Pennsylvania	Bacterial colony forming units (CFUs) cultured from turf samples	Rubber crumb from artificial turf yielded fewer CFUs on a per gram basis than soil from natural turf; no colonies were positive for *Staphylococcus aureus*
FIFA, undated	Male soccer, under-17 world championship games	New (third) generation artificial turf and natural turf	Time loss and total injuries during games	Overall injury incidence similar on the two surfaces

instances of fomite transmission have been reported. A MRSA outbreak in fencers is noteworthy, since this sport does not involve person-to-person contact (MMWR, 2003). The fencers used sensor wires under their protective clothing, which were shared by multiple fencers without cleaning. The wires were possible fomites for MRSA transmission in this outbreak. Shared soap bars were identified as a risk factor in a MRSA outbreak in a collegiate football team (odds ratio, 15.0; 95 percent confidence interval 1.69-180) (Turbeville et al., 2006). A shared weight room was the only common point of contact between a high school football team and the dance team (Kirkland and Adams, 2008). While only two football players and one dance team member became infected with MRSA, this may represent an example of fomite transmission. In a MRSA outbreak among members of a high school wrestling team, no risk factors for infection could be identified (Lindenmayer et al., 1998). Nonetheless, the study authors speculated that although most cases of transmission were probably due to wrestler-to-wrestler contact, the sharing of towels and locker room equipment, as well as shared wrestling mats, may have contributed. In emphasizing that fomite transmission of MRSA should be prevented, the National Collegiate Athletic Association (NCAA) medical guidelines recommend disinfecting wrestling mats before use.

One way to determine whether artificial turf is a reservoir for infectious MRSA is to inoculate bacterial cultures with various turf components or wipe test the components to measure bacterial growth. Very few such data have been collected from potential fomites associated with outbreaks of sports-associated MRSA, including artificial and natural turf. Following an outbreak of MRSA in a high school wrestling team, environmental sampling of the wrestling facilities failed to detect any MRSA (Lindenmayer et al., 1998). During a MRSA outbreak in a professional football team, environmental sampling included the stadium's artificial turf field, weight-training equipment, towels, saunas, steam rooms and whirlpool water (Kazakova et al., 2005). For the field sampling, one-foot square areas of Astroturf® located in the parts of the field with the highest numbers of tackles were wipe-sampled. No MRSA was detected; however, methicillin-sensitive *S. aureus* (MSSA) was detected in two samples of whirlpool water and on a gel-applicator stick used for taping ankles. The most recent test of whether artificial turf harbors MRSA is a study in which twenty new generation artificial turf fields were sampled at two locations per field (McNitt et al., 2008). The artificial blades of grass and infill material (crumb rubber or crumb rubber/sand mix) were sampled separately for bacterial culture. All field samples were negative for *S. aureus*. Quantitative data were only presented for the infill samples. Those samples contained unidentified bacteria at levels ranging from 0 to 80,000 colony forming units (CFUs) per gram of infill. In comparison, two samples of natural soil yielded 260,000 and 310,000 CFUs per gram of soil. *S. aureus* was detected on a number of surfaces including football blocking pads, weight equipment, a stretching table and used towels, demonstrating that the detection method for *S. aureus* was functional. Thus, considering the three studies described above, there is no evidence that artificial turf fields harbor *S. aureus* in general, or MRSA in particular. While these conclusions are based on a small number of samples, an absence of *S. aureus* from artificial turf playing fields is not unexpected, given the dry and often hot conditions of that environment.

As discussed above, skin trauma is a likely risk factor for MRSA infection in contact sports (Begier et al., 2004; Kazakova et al., 2005). Therefore, it would be informative to determine if falls to the new generation of artificial turf put players at greater risk for turf burns than falls to natural turf. It is also important to determine if the turf burns caused by artificial turf are more long-lasting or more prone to infection by *S. aureus* compared to burns received from natural turf.

Unfortunately, most injury studies comparing artificial and natural turf have concentrated on so-called "time-loss" injuries (Table 10). These are relatively serious injuries that cause at least some loss of practice or game time. The great majority of turf burns are not time-loss injuries, and would not have been monitored in those studies. However, some data on skin abrasions are available. In a study of college football played on the old generation of Tartan Turf®, players were described as acquiring significantly ($p<0.01$) more "scrapes" on artificial turf compared to natural grass (Keene et al., 1980). This was the only injury type that was significantly increased on artificial turf compared to natural turf. In a 5-year prospective study of injuries occurring on the new generation of artificial turf, both time-loss and 0-day time-loss (i.e., no playing time lost) injuries were recorded for eight high school football teams (Meyers and Barnhill, 2004). The latter category included "surface/epidermal injuries" that covered abrasions, lacerations and puncture wounds, but not contusions (i.e., bruises). This type of surface/epidermal injury had a 9-fold higher incidence on artificial turf (injury incidence rate = 0.9; 95% confidence interval = 0.5-1.4) compared to natural turf (injury incidence rate = 0.1; 95% confidence interval = 0.0-0.6). Players for a professional football team suffering a MRSA outbreak reported that skin abrasions happened more frequently and were more severe on first-generation Astroturf® (i.e., without infill) compared to natural turf, although no supporting data were presented (Kazakova et al., 2005). In a study of collegiate male and female soccer players that recorded time-loss injuries during official matches, only the incidence of "lacerations/skin lesions" in males was significantly higher (2.95-fold, $p<0.01$) on new generation artificial turf (i.e., with infill) compared to natural turf (Fuller et al., 2007a). However, this finding was not replicated in an identical study that covered injuries sustained during training (Fuller et al., 2007b). Lastly, male soccer players at the 2005 Federation Internationale de Football Association U-17 Championship in Peru played 86 matches on natural grass and 42 on new generation artificial turf (FIFA, undated). While skin abrasion incidences were not presented, the incidences of total injuries (0-day time-loss and time-loss) per player-hour were similar on the two surfaces.

Considering the small database presented above, two studies (one soccer and one football) found increased incidences of skin abrasions on the new generation of artificial turf compared to natural turf (Meyers and Barnhill, 2004; Fuller et al., 2007a), while two studies (both soccer) measured similar rates on both surfaces (Fuller et al., 2007b; FIFA, undated). No data were located on the relative severity of skin abrasions caused by the artificial and natural surfaces. Given that both studies by Fuller et al. (2007a and 2007b) only monitored time-loss injuries, these studies almost certainly missed the majority of skin abrasions, which do not cause loss of playing time. Furthermore, the FIFA (undated) study did not provide data on the incidence of skin abrasions, only on total injury incidence. This leaves only the football study by Meyers and Barnhill (2004) as evidence that new generation artificial turf puts football players at increased risk for skin abrasions relative to natural turf. Whether this conclusion is specific for male football players competing at the high school level is unknown, until studies can be performed for other sports and age groups.

Conclusions

- Participation in contact sports is a risk factor for infection by MRSA. Football and wrestling have recorded the most outbreaks.
- Person-to-person transmission of MRSA is the major mode of infection. Transmission by inanimate objects (termed fomites), such as the playing surface, is less well established.
- Skin abrasions and other types of skin trauma are risk factors for MRSA infection in contact sports.
- Whether the new generation of artificial turf causes more skin abrasions than natural turf has only been carefully addressed in a single study (Meyers and Barnhill, 2004) of male high school football players. In that study, artificial turf was associated with a 9-fold higher incidence of "surface/epidermal injury" compared to natural turf.
- Only one study has tested whether new generation artificial turf fields harbor MRSA (McNitt et al., 2008); none was detected in 20 fields in Pennsylvania.

Data Gaps

- Additional studies are needed to test the finding of Meyers and Barnhill (2004) that new generation artificial turf is associated with more skin injuries than natural turf. Studies should cover additional sports, age groups, and female participants.
- No study has reported on the severity of turf burn by the new generation of artificial turf compared to natural turf. Severity could include susceptibility to infection as well as the time required to heal.
- Additional new generation artificial turf fields should be sampled for MRSA and other bacteria pathogenic to humans, at different depths in the fields, and from different climatic regions in California.

Part III: Summary

Five studies were located that measured chemicals and particulates in the air above the new generation of artificial turf containing crumb rubber infill from recycled tires. The chemicals and particulates in the air over artificial turf were similar to those emitted by tire-derived rubber flooring, during rubber manufacturing, and in laboratory studies of rubber crumb heated in vessels. The most complete dataset, covering indoor artificial soccer fields in Norway (Dye et al., 2006), was used to estimate the risk of cancer or developmental toxicity. This screen only addressed the inhalation route of exposure in athletes using artificial turf fields for a lifetime of organized soccer play. Exposure estimates were used to calculate the increased lifetime cancer risk or risk of developmental toxicity for those chemicals appearing on the California Proposition 65 list. From among eight chemicals listed as carcinogens on the Proposition 65 list, exposure to five of these (benzene, formaldehyde, naphthalene, nitromethane and styrene) during a lifetime of organized soccer play exceeded the 10^{-6} negligible risk level. Since these risks exceeded the 10^{-6} benchmark, it is important for future studies to measure the concentrations of these chemicals above outdoor artificial turf fields. In addition, their concentrations should be measured in the ambient air in the vicinities of the fields. Comparing the concentrations in the air over and off of the fields will establish which carcinogenic chemicals are emitted by artificial turf, and whether mitigation measures are required.

Dye et al. (2006) also identified two chemicals appearing on the California Proposition 65 list as developmental/reproductive toxicants: toluene and benzene. Their concentrations in the air over indoor artificial turf fields were below the associated screening levels for developmental/reproductive toxicity, suggesting a low risk for such effects due to these two chemicals. This screen contains two steps that tend to overestimate the risks for both cancer and developmental toxicity. First, the screen utilizes data from indoor artificial turf fields to estimate exposures from outdoor fields. Second, the screen assumes that all organized soccer play from the ages of 5 to 55 occurs on artificial turf fields.

The scientific literature was also searched for studies addressing the possibility that artificial turf playing fields promote infection of athletes by methicillin-resistant *Staphylococcus aureus* (MRSA). While the data suggest that skin trauma is a risk factor for MRSA outbreaks in contact sports, it is less certain whether the new generation of artificial turf causes more skin trauma than natural turf. Whether artificial turf fields harbor MRSA has been tested in only a few studies. No MRSA has been detected in any indoor or outdoor natural or artificial turf field.

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Addendum, July 2009

Review of two studies released in the spring of 2009 that measured chemicals and particulates in the air above the new generation of artificial turf playing fields

Study quality and characteristics

The study of artificial turf fields containing recycled crumb rubber infill performed by New York State (2009) is the most comprehensive to date. To measure the chemicals released into the air by these fields, air sampling was performed over two fields, along with a sample taken upwind of each field to measure the ambient background. One field was four years old and one was less than one year old. Samples were analyzed for VOCs and sVOCs. Off-gassing experiments performed in the laboratory with recycled rubber crumb identified five chemicals which were added to the target list of chemicals: aniline, 1,2,3-trimethylbenzene, 1-methylnaphthalene, benzothiazole and tertbutylamine. Acceptable weather conditions for sampling were prescribed and followed (see Table 11). Particulate matter (PM_{10} and $PM_{2.5}$) in air was measured in real-time with monitors placed over or upwind of each field. In addition, particulate matter was collected by wipe and vacuum sampling of field surfaces and analyzed by microscopy.

A total of 65 chemicals were identified in the air over the four-year-old field and 85 over the one-year-old field (twenty highest concentrations shown in Table 11). For many chemicals the upwind air sample contained similar concentrations. Since eight samples were collected over each field compared to only a single upwind sample, it is likely that had more upwind samples been collected, more chemicals would have been detected in the upwind air. Most of the chemicals were tentatively identified compounds (TICs), i.e., identified by their gas chromatography/mass spectrometry (GC/MS) peaks. TICs with match qualities of less than 85 percent of the GC/MS peaks were considered "unknowns" and not included in the health evaluation (see below). Of the 19 TICs shown in Table 11, 17 fell into this category. Therefore, from among the chemicals occurring at the twenty highest concentrations, only benzothiazole, octane and nonane were evaluated for health effects. The "unknowns" in Table 11 are indicated by asterisks.

Comparing the two fields shows good agreement for VOCs and sVOCs on the target list. Air samples from over the four-year-old field contained 17 chemicals on the target list. Air samples from above the one-year-old field contained the same 17 plus an additional three. For TICs the agreement was not as close. From among the 20 largest TIC peaks corresponding to air samples from either field (Table 11), only five were reported for both fields.

Chemicals of potential concern for adverse health effects were chosen for health evaluation based on three criteria: 1) low levels in laboratory and field blanks, 2) a concentration that was at least 35 percent higher in at least one field sample compared to the upwind sample, 3) match quality of the GC/MS peaks of at least 85 percent for TICs. These criteria yielded 15 and 16 chemicals of potential concern for calculation of inhalation health risks for the four-year-old and one-year-old fields, respectively.

Table 11. Air measurements above artificial turf fields: New York State (2009) and TRC (2009)

Reference	Scenario	Chemicals/particulates measured
New York State Department of Environmental Conservation and Department of Health, May 2009	Two outdoor playing fields made of new generation artificial turf containing recycled crumb rubber infill. One field was less than one year old, the second was four years old. No precipitation the day before sampling and during sampling, sampling on two consecutive days of light to moderate winds out of a constant direction, 77 to 84°F, sampling at multiple heights above the field (a few inches, three feet, six feet), a total of eight samples collected from each field. One sample collected upwind of each field (six foot height) to measure ambient background.	VOCs and sVOCs: 65 detected over one field, 85 detected over the second field. PAHs detected (in μg/m^3): 2-dibenzofuranamine* (12), 3-dibenzofuranamine* (11), 4-dibenzofuranamine* (9), benzo[b]thiophene, 6-methyl-* (8.7). Phthalates: none detected. $PM_{2.5}$ and PM_{10}: both classes of particulates detected by real-time monitoring at approximately 15 μg/m^3, similar concentrations over field and upwind of field; microscopy of wipe and vacuum field samples detected rubber particles in the millimeter range but not in the micron range. Twenty highest VOCs and sVOCs were (in μg/m^3): cyclohexanol* (27), 5-hexen-2-ol, (.+/-.)-* (24), cyclopropane, 1-chloro-2-ethenyl-1-methyl* (23), 2-hexen-1-ol, (z)-* (22), pentanamide, 4-methyl-* (15), 1H-benzotriazole-5-amine, 1-methyl-* (13), benzenemethanol, arethenyl-* (13), nonanamide* (13), 2-dibenzofuranamine* (12), 3H-indazol-3-one, 1,2-dihydro-2-methyl-* (12), 3-dibenzofuranamine* (11), 4-dibenzofuranamine* (11), cyclopentanone-2* (10), benzene, 1-methoxy-4-(1-propenyl)-* (9.9), methanimidamide, N,N-dimethyl-N'-phenyl-* (9.6), benzo[b]thiophene, 6-methyl-* (8.7), benzothiazole (6.5), octane (6.2), nonane (3.2), 2-butene, (z)* (2.7).

*indicates tentatively identified compound (TIC) with a GC/MS peak match quality of less than 85 percent.

Table 11. (continued)

Reference	Scenario	Chemicals/particulates measured
TRC, 2009	Two outdoor playing fields made of new generation artificial turf containing recycled crumb rubber infill;	VOCs, sVOCs and metals: 8 VOCs and 1 metal were detected at the following highest concentrations (in μg/m^3): acetone (51), ethanol (22), methylene chloride (9), 2-butanone (MEK) (3), chloroform (2.9), toluene (2.7), n-hexane (2.1), chromium (1.4), chloromethane (1.1); seven tentatively identified compounds

Reference	Scenario	Chemicals/particulates measured
	one grass field for comparison. One artificial turf field was less than three years old, the other was less than one year old. Air sampling was during the summer with temperatures from 79 to 94°F, sampling performed at three feet above the surface, 4-6 air samples collected from above each field. Two air samples collected from upwind of each field to measure ambient background.	(TICs) included isobutane, pentane, 2-methyl-1,3-butadiene (a.k.a., isoprene), 2-methylbutane. PAHs: none detected. Phthalates: none detected. $PM_{2.5}$ and PM_{10}: both classes of particulates detected by real-time monitoring at 3 to 50 µg/m^3, similar concentrations over fields and upwind of fields.

Chemical concentrations in the air above the fields were compared to health-based screening levels, assuming continuous, lifetime exposures for athletes using the fields. These assumptions overestimate the risks, since athletes do not spend their entire lives on these fields. Non-cancer health effects were evaluated by calculating hazard quotients using the highest on-field concentrations. Most hazard quotients were very low, indicating a very low risk of non-cancer health effects. The highest ranged from 0.1 to 0.6 for the compounds 1,3-pentadiene, 1,4-pentadiene, (E)-1,3-pentadiene and 2-methyl-1,3-butadiene. Hazard quotients of less than one suggest that non-cancer health effects are unlikely.

Eight potential chemicals of concern were evaluated for their cancer risks based on their highest on-field air concentrations. The highest excess lifetime cancer risk was 4×10^{-5} for 1,3-pentadiene (using the cancer potency of 1,3-butadiene as a surrogate). However, the concentration of 1,3-pentadiene in the air upwind of the field corresponded to a 2×10^{-5} cancer risk. Thus, it was judged that the cancer risks posed by this chemical due to its occurrence in field air and ambient air were similar. Other potential carcinogens were either below the air concentration associated with the 10^{-6} cancer risk level or occurred in only one of eight field samples (as TICs). The report concluded that these chemical exposures did not constitute a serious public health problem, and posed small risks of either cancer or non-cancer health effects.

For the particulate matter size classes of $PM_{2.5}$ and PM_{10}, real-time monitoring of one field showed no meaningful differences between the air concentrations over the field compared to upwind of the field. Technical problems were encountered in real-time monitoring of the second field. These data suggest these fields are not a source of $PM_{2.5}$ or PM_{10}. Samples collected by wipe sampling and vacuuming both fields were analyzed by microscopy. Rubber particles were in the millimeter range. Particles small enough to be inhaled, in the 5-7 micrometer range, were crustal minerals such as quartz and calcite. Rubber particles were not in the respirable range. Both the wipe data and the air monitoring data indicate that recycled crumb rubber infill in new generation artificial turf fields is not a significant source of $PM_{2.5}$ or PM_{10}.

TRC is an engineering and consulting firm which performed a study of artificial turf fields for the New York City Department of Health and Mental Hygiene (TRC, 2009). The study included air sampling from above and upwind of the same two artificial turf fields that were sampled for the New York State (2009) study. A single grass field was also sampled for comparison. Eight VOCs and one metal were detected in the air over the artificial turf fields. Three of the VOCs (2-butanone, chloroform, and n-hexane) were not detected in any of the upwind samples or over the grass field. In addition, seven TICs were detected, with four being specific to the artificial turf (isobutane, pentane, 2-methyl-1,3-butadiene, 2-methylbutane).

Monitoring of the air over and upwind of the artificial turf fields for $PM_{2.5}$ yielded the same concentration range. $PM_{2.5}$ concentrations ranged between 3 and 50 $\mu g/m^3$ for both.

Comparing the target list chemicals detected over the artificial turf fields to those detected in the upwind samples or over the grass field, three were specific to the on-field samples: 2-butanone, n-hexane and chloroform. The concentrations of the first two chemicals were well below the corresponding New York State short-term and annual air guideline levels. Therefore, the chemicals were not considered for risk assessment. While the chloroform concentration was above the annual guideline level, the chemical was not considered for risk assessment because its presence over the single artificial turf field was thought to have resulted from drift from a nearby swimming pool commonly treated with chlorine. From among the four TICs that were specific to the artificial turf fields, three were well below their corresponding guideline values. The fourth, isoprene, does not have a guideline value. However, since it was detected in only one air sample as a TIC, and it was not detected when a bulk sample of crumb rubber was analyzed in the laboratory, it was not considered for risk assessment. Thus, a formal risk assessment was not performed for any chemical detected by air sampling. The report concluded that health effects were unlikely to result from the types of inhalation exposures expected to occur at these artificial turf fields.

Comparing studies

Table 12. Comparison of the chemical concentrations measured in air above artificial turf fields in the studies by Dye et al. (2006) and New York State (2009)

Chemical	Concentration in Dye et al. (2006) ($\mu g/m^3$)[1]	Concentration in NY State report (2009) ($\mu g/m^3$)[1]	[Dye]/[NY State]
Toluene	85	1.6	53
Benzothiazole	31.7	6.5	5
p- and m-Xylene	25.5	0.8	32
Acetone	15.3	0.6	26
o-Xylene	13.1	0.3	44
4-Methyl-2-pentanone	12.7	1.2	11
Ethylbenzene	6.7	0.3	22

[1]Highest value reported

Table 12 compares the concentrations of seven VOCs detected in air samples from above indoor and outdoor artificial turf fields. From among the 20 chemicals detected at the highest levels by Dye et al. (2006) (see Table 1), these seven were also detected by New York State (2009) (see Table 11). The concentrations can be compared to determine if the indoor study measured consistently higher concentrations compared to the outdoor study. The last column in Table 12 shows that the concentrations of these seven VOCs were from 5- to 53-fold higher in the air over indoor fields compared to outdoor fields. Therefore, as discussed in this report, using the indoor values from Dye et al. (2006) to calculate health risks overestimates the risks athletes face from inhaling the air above outdoor artificial turf fields containing crumb rubber infill.

Similar to the chemical concentrations discussed above, the concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) were somewhat higher for the indoor study by Dye et al. (2006). The indoor study detected $PM_{2.5}$ and PM_{10} concentrations as high as 18.8 and 40.1 $\mu g/m^3$, respectively. Ambient, background levels of particulates were not measured. Therefore, it was not possible to determine whether the particulates were released by the turf or were already present in the ambient, outdoor air. The outdoor studies by New York State (2009) and TRC (2009) did not detect these particulates above ambient, background levels (about 15 and 3-50 $\mu g/m^3$, respectively). The indoor study used a chemical marker for tire rubber (N-cyclohexyl-2-

benzothiazolamine) to quantify the rubber in the particulate matter. Rubber comprised from 23 to 50 percent of the $PM_{2.5}$ or PM_{10}. Using microscopy, the New York State (2009) study ruled out rubber as the source of the microscopic particles in the 5-7 micrometer range. Considering all three studies together, it appears that $PM_{2.5}$ and PM_{10} were at background levels in the air over outdoor artificial turf fields, but may have been present at above-background concentrations in the air above indoor fields.

Table 13 below shows a comparison of the chemicals detected in the air above the same two artificial turf fields that comprised the studies by New York State (2009) and TRC (2009). These are the eight chemicals that were specific to the air above artificial turf in the TRC (2009) study. Sampling for both of these studies was performed at the end of August and beginning of September 2008. The chemical concentrations were consistently higher in the New York State (2009) study, ranging from 1.7-fold to 85-fold higher. The reasons for these differences are unknown. These variable results highlight the difficulties faced in obtaining consistent results from potential point sources of outdoor air pollution. Despite this variability, both studies found that the chemical concentrations they measured were unlikely to produce adverse health effects in persons using these fields.

Table 13. Comparison of the chemical concentrations measured in air above the same two artificial turf fields in the studies by New York State (2009) and TRC (2009)

Chemical	Concentration in NY State report (2009) ($\mu g/m^3$)[1]	Concentration in TRC report (2009) ($\mu g/m^3$)[1]	[TRC]/[NY State]
2-Butanone (MEK)	-	3.0	-
Acetone	0.6	51.0	85
Chloroform	0.2	2.9	15
Chloromethane	0.1	1.1	11
Ethanol	-	22.0	-
n-Hexane	0.4	2.1	5
Methylene chloride	3.0	9.0	3
Toluene	1.6	2.7	1.7
Isobutane*	-	2.4	-
Pentane*	0.5	11.8	24
Isoprene (a.k.a., 2-methyl-1,3-butadiene)*	0.9	2.8	3
2-Methylbutane*	0.7	3.0	4

[1]Highest value reported, - not reported, * TIC

Conclusions

- The New York State (2009) report describes the most comprehensive study performed to date on the new generation of artificial turf containing recycled crumb rubber infill. Air sampling above two fields measured VOCs, sVOCs, PM_{10} and $PM_{2.5}$.

- A total of 65 chemicals were identified in the air above a four-year-old field and 85 over a one-year-old field. Many of these were detected at similar concentrations in the air samples taken upwind of the fields.
- Most of the chemicals detected were tentatively identified compounds (TICs), as identified by their GC/MS peaks, with match qualities of less than 85 percent of the peaks. Therefore, these were considered "unknown" chemicals and not evaluated for health effects.
- $PM_{2.5}$ and PM_{10} levels were the same over one field and upwind of the field, suggesting the fields are not sources of PM release.
- Chemicals of potential concern were selected and evaluated for cancer and non-cancer health effects based on their measured air concentrations and assuming continuous, lifetime inhalation by athletes using the fields. These latter two assumptions tend to overestimate the health risks.
- Hazard quotients were all less than one, indicating a low risk of non-cancer health effects. Excess, lifetime cancer risks were either below the 10^{-6} risk level, were similar for the upwind and on-field samples, or the chemical was only detected in one of eight on-field samples. Therefore, the report concluded that these fields do not constitute a serious public health problem since the risks of health effects are low.
- The study by TRC (2009), monitoring the same two artificial turf fields as the New York State (2009) study, also concluded that health effects were unlikely to result from the types of chemical inhalation exposures expected to occur to athletes using these fields.
- The concentrations of chemicals in the air over indoor fields (Dye et al., 2006) were from 5- to 53-fold higher than their concentrations over outdoor fields (New York State, 2009). This demonstrates that using data from indoor fields to calculate the health risks from outdoor fields overestimates those risks.

Data Gaps (some of which are being addressed in the current OEHHA study of artificial turf)

- Only two artificial turf fields were evaluated in the New York State (2009) study. The same two fields comprised the TRC (2009) study. Testing additional fields for the release of chemicals and particulate matter is warranted.
- Testing fields of different ages and at different temperatures would help determine how those variables affect chemical and particulate release. In particular, fields near the end of their useful lifetime should be evaluated.
- More air samples from upwind of the fields should be collected on the same days as field samples to determine if chemicals measured over the fields are also present at similar concentrations in the ambient air.
- The air above fields was not tested for airborne metals. The previously reported finding of lead in dust sampled from some artificial turf fields indicates a potential for lead and other metals to become suspended in the air and possibly inhaled. Testing field air samples for metals is warranted.
- To estimate inhalation exposures it was assumed that athletes used the artificial turf fields continuously over their entire lifetimes. This overestimates the health risks. Data covering the time athletes spend on these fields would allow more accurate exposure and risk calculations and result in reduced risk estimates.

- In the study by New York State (2009), the relatively large number of TICs with peak match qualities below 85 percent indicates that these fields release many unidentified VOCs and sVOCs ("unknowns"). Some of these were at μg/m^3 levels (Table 11). It is likely that the health risks posed by these chemicals, if any, will not be known for the foreseeable future. The presence of a relatively large number of unidentified organic chemicals in the air over these fields is a potential health risk that cannot be evaluated at present.

References

53. Dye, C., Bjerke, A., Schmidbauer, N. and Mano, S. (2006) Measurement of air pollution in indoor artificial turf halls. Norwegian Pollution Control Authority, Norwegian Institute for Air Research, Report No. NILU OR 03/2006, TA No. TA-2148/2006.
54. New York State (2009) An assessment of chemical leaching, releases to air and temperature at crumb-rubber infilled synthetic turf fields. New York State Department of Environmental Conservation and New York State Department of Health, May 2009.
55. TRC (2009) Air quality survey of synthetic turf fields containing crumb rubber infill. TRC, Windsor, Connecticut, prepared for New York City Department of Health and Mental Hygiene, March 2009.

What Do the Experts Say?

As the popularity of synthetic turf escalates, so does scrutiny about its usage. That's why we actively collect research and studies from independent, third-party organization about synthetic turf and its components. Review the latest thinking below from outside groups and our association.

Synthetic Turf Council - Media Alerts, News Releases and Position Statements

Official Position Statements - Federal or State Agencies, Sports Authorities, Academic Organizations

Current and Independent Research, Technical and Academic Papers:

- Environmental and Health Risk
- Staph / MRSA
- Risk of Injury
- General Information
- Other Relevant Studies

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- Synthetic Turf 360°
- Case Studies and Testimonials
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- Research and Latest Thinking
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- Photos of Synthetic Turf Uses

Current and Independent Research, Technical Academic Papers

Environmental and Health Risk

"Safety Study of Artificial Turf Containing Crumb Rubber Infill Made from Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface" Full study. Summary presentation by OEHHA and Cal/EPA.
California Office of Environmental Health Hazard Assessment (OEHHA)
Pesticide and Environmental Toxicology Branch
Funded by the Department of Resources Recycling and Recovery (CalRecycle)
October 2010

Conclusions: No public health concerns were identified regarding the inhalation of volatile organic compounds (VOCs) or particulates (PM2.5) above artificial turf;
Artificial turf harbored fewer bacteria (including MRSA and other Staphylococci) than natural turf;

The rate of skin abrasions per 1,000 player hours was two- to three-fold higher on artificial turf compared to natural turf;
The sum of these latter two effects on the skin infection rate for athletes competing on artificial turf relative to natural turf cannot be predicted from these data alone.

"An Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields"
University of Connecticut Health Center
The Connecticut Agricultural Experiment Station
Department of Public Health
Connecticut Department of Environmental Protection
July 2010

The headline from the July 30, 2010 News Release from the Connecticut Department of Public Health announced, "Result of State Artificial Turf Fields Study: No Elevated Health Risk." Comprising separate reports from the four state agencies listed above, the Final Report presents the results of an extensive study into the health and environmental risks associated with outdoor and indoor synthetic turf fields containing crumb rubber infill. "This study presents good news regarding the safety of outdoor artificial turf fields," stated Department of Public Health Commissioner Dr. J. Robert Galvin. The above link is to the Overall Executive Summary, which includes links to the News Release, the four separate reports from the state agencies, and the report by the Peer Review Committee from The Connecticut Academy of Science and Engineering.

"Review of the Impacts of Crumb Rubber in Artificial Turf Applications"
University of California, Berkeley, February 2010
Laboratory for Manufacturing and Sustainability
Prepared for: The Corporation for Manufacturing Excellence (Manex)

"The research conducted by Manex and Berkeley is among the most comprehensive reports to date, reviewing and assessing existing studies from the past 12 years, as well as containing independent analysis. The conclusions of this study validate key findings from other recent studies, demonstrating the materials are both cost-effective and safe." From Manex/UC Berkeley Press Release posted April 5, 2010. Click here for full Press Release.

"A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds"
U.S. Environmental Protection Agency, November 2009

This study and statements of safety by the U.S. EPA of synthetic turf fields and playgrounds containing crumb rubber from recycled tires complements the study and statement of safety by the CPSC in 2008 (see below). In its Press Release, the EPA summarized its findings, including the following:

- The levels of particulate matter, metals, and volatile organice compound concentrations in the air samples above the synthetic turf were similar to background levels;
- All air concentrations of particulate matter and lead were well below levels of concern;
- Zinc, which is a known additive in tires,...was found to be below levels of concern.

See December 10, 2009 EPA Press Release, "Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces"

"Chemicals and Particulates in the Air Above the New Generation of Artificial Turf Playing Fields, and Artificial Turf as a Risk Factor for Infection by Methicillin-Resistant Staphylcoccus Aureus (MRSA)"
Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, July 2009

There is a negligible human health risk from inhaling the air above synthetic turf, and, though data gaps exist, it is "unlikely that the new generation of artificial turf is itself a source of MRSA...." (Significantly the OEHHA did not review the January 2009 results of the study into the lifespan of staph on grass and synthetic turf sponsored by the STC and the Pennsylvania Turfgrass Council - see below.) The OEHHA summary of the results is posted on its website. The full report includes an important Addendum that references reports by the New York State Department of Environmental Conservation and Department of Health (May 2009) and the New York City Department of Health and Mental Hygiene (March 2009) - see below.

"An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb-Rubber Infilled Synthetic Fields"
New York State Department of Environmental Conservation and New York State Department of Health, May 2009

In its Press Release, the NYSDEC announced that this new comprehensive study concludes that crumb rubber infilled synthetic fields "poses no significant environmental threat to air or water quality and poses no significant health concerns."

"Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill"
TRC, March 2009. Prepared for NY City Department of Health and Mental Hygiene

"In summary, an analysis of the air in the breathing zones of children above synthetic turf fields do not show appreciable impacts from COPCs [Contaminants of Potential Concern] contained in the crumb rubber. Therefore, a risk assessment was not warranted from the inhalation route of exposure." Of 69 VOCs, 17 PAHs, including Benzothiazole, 10 metals, and a range of particulate matter tested, the COPCs that were detected in the ambient air samples above the crumb rubber synthetic turf fields were found in similar concentrations in the air samples above the grass field and the background locations.

"CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On,"
U.S. Consumer Product Safety Commission, NEWS from CPSC, July 30, 2008

The CPSC staff conducted tests of synthetic turf products for analysis of total lead content and accessible lead. In the above News Release it concludes that, "young children are not at risk from exposure to lead in these fields."

For a summary of the analytical methods used and the test results, see "CPSC Staff Analysis and Assessment of Synthetic Turf 'Grass Blades"

"A Review of the Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill"
Prepared for New York City Department of Health and Mental Hygiene by TRC, May 2008

A comprehensive 180-page review of available scientific literature and research on synthetic turf with crumb rubber infill covering such topics as chemical composition and human health risks from crumb rubber infill, risks of physical injury, heat-related illness, staph, etc. A summary of the available research is also included.

"Review of the Human Health & Ecological Safety of Exposure to Recycled Tire Rubber found at Playgrounds and Synthetic Turf Fields"
Prepared for Rubber Manufacturers Association by ChemRisk, Inc., July 17, 2008

A report by an independent environmental firm on the human health and ecological risks from ground rubber in playgrounds and sports fields, and based on a thorough review of studies from advocates and opponents to the use of recycled tire materials.

"Environmental Effects of Synthetic Turf Athletics Fields"
Milone & MacBroom, December 2008

HEAT: On hot sunny days, surface temp of the fibers was 40-50 degrees hotter than ambient temp; air temp at 2' above surface or under cloud cover was near ambient. Crumb rubber was only a few degrees hotter than ambient. Watering the field had a short-term effect.

OFF-GASSING: EHHI identified certain compounds of concern in its very limited 2007 laboratory study of the chemicals contained in crumb rubber – benzothiazole, volatile nitrosamines, and 4-(tert-octyl) Phenol. MMI tested for these compounds in the air above the synthetic turf fields with crumb rubber infill at several locations. A "very low concentration" of benzothiazole was found at 1 of 2 fields -- the other compounds were not detected.

LEACHING: Testing done over 1 year period. Test for zinc, lead, selenium, and cadmium, and compared to lowest aquatic life criterion for each element. Only zinc detected, and then well below water quality standard.

"Follow-up Study of the Environmental Aspects of Rubber Infill, A Laboratory study (perform weathering tests) and a field study, rubber crumb from car tyres as infill on artificial turf"
INTRON, commissioned by two tyre associations, and supervised by the National Institute for Public Health and the Environment and by the Ministry of Housing, Spatial Planning and the Environment in the Netherlands, April 2008

"The impact of weathering of the rubber crumb for the technical lifetime of an artificial turf field (approx. 10 to 15 years) does not cause the leaching of zinc from the rubber crumb...to exceed the threshold values..."

Environmental and Health Evaluation of the Use of Elastomer Granulates (Virgin and from Used Tyres) as Filling in Third-Generation Artificial Turf"
Author: Dr. Robert Moretto (EEDEMS) 1
ADEME/ALIAPUR/FIELDTURF TARKETT 2007
Scientific long-term study for French organizations

Study of quality of water passing through SBR, TPE and EPDM granules, and of gases emitted by the sports fields. No impact from these materials on water resources; no effect on health from inhaling VOC and aldehydes emitted by materials in close, poorly ventilated indoor facility or outdoors; ecotoxicologically, no impact on the environment. Extensive bibliography.

"Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products"
Office of Environmental Health Hazard Assessment of California EPA. Januarv 2007

Evaluation of toxicity due to ingestion based on existing literature - risk is well below de minimus level considered an acceptable cancer risk.

Evaluation of toxicity due to ingestion based on gastric digestion simulation - same as above.

Evaluation of toxicity due to chronic hand-to-surface-to-mouth activity - low risk of adverse noncancer health effects. Slightly higher than de minimus level for chronic ingestion of chrysene, but low enough to be considered an acceptable cancer risk.

Skin sensitization - no sensitization observed.

Evaluating the potential for damage to the local environment and ecology - soil samples under a playground surface burned in a fire contained levels of metals, VOCs, PAHs, dioxins and furans at or below background, suggesting low risk. Air above the burn site was judged by the U.S. EPA as posing no health risk. Concentrated leachate from tire shreds produced in a lab was toxic to several organisms, but a rain event would not likely produce leachate in such concentrations to cause toxicity to these organisms. Shredded tires used above the ground water table produced no toxicity in sentinel species.

Staph / MRSA

"Survival of Staphylococcus aureus on Synthetic Turf"
By Andy McNitt, Ph.D., Associate Professor of Soil Science, Penn State University
December 2008. A research project funded by the Synthetic Turf Council and the Pennsylvania Turfgrass Council.

A study to examine the survival of S. aureus on infilled synthetic turf systems and natural turfgrass under different environmental conditions and to evaluate the effectiveness of various control agents applied to the synthetic turf.

S. aureus survived for as long on natural turfgrass as it did on synthetic turf systems in both indoor and outdoor settings. S. aureus lived longest indoors, but can be effectively treated with commercially available antimicrobial treatments as well as detergents. Outdoors S. aureus has a very low rate of survival, particularly when exposed to UV light and higher temperatures.

"Environmental Management of Staph and MRSA in Community Settings"
Centers for Disease Control and Prevention, July 2008

"A Survey of Microbial Populations in Infilled Synthetic Turf Fields"
By Andy McNitt, Ph.D., Associate of Professor of Soil Science, Penn State University, and Dianne Petrunak, M.S., and Thomas Serensits, M.S.
June 2007

A survey to determine the microbial population of several crumb rubber infilled synthetic turf systems and natural turfgrass fields.

Official Statement on Community-Acrquired MRSA Infections (CA-MRSA)
National Athletic Trainers' Association, March 1, 2005

Risk of Injury

"Epidemiology of Patellar Tendinopathy in Elite Male Soccer Players"
Hagglund, M., PT, PhD; Zwerver, J., MD, PhD; Ekstrand, J., MD, PhD
American Journal of Sports Medicine, June 2011, 0363546511408877

Patellar tendinopathy is a relatively mild but fairly common condition among elite soccer players, and the recurrence rate is high.

This study investigated the epidemiology of patellar tendinopathy in 2,229 elite male soccer players from 51 European elite soccer clubs playing on natural grass and synthetic turf between 2001 and 2009.Objective: To compare the risk for acute injuries between natural grass (NG) and third-generation artificial turf (3GAT) in male professional football.

Conclusion: "Exposure to artificial turf did not increase the prevalence or incidence of injury."

"Risk of injury on third generation artificial turf in Norwegian professional football"
Bjørneboe J, Bahr R, Andersen TE (2010)
British Journal of Sports Medicine, 44: 794-798.

Methods: All injuries sustained by players with a first-team contract were recorded by the medical staff of each club, from the 2004 throughout the 2007 season. An injury was registered if the player was unable to take fully part in football activity or match play.

Results: A total of 668 match injuries, 526 on grass and 142 on artificial turf, were recorded. The overall acute match injury incidence was 17.1 (95% CI 15.8 to 18.4) per 1000 match hours; 17.0 (95% CI 15.6 to 18.5) on grass and 17.6 (95% CI 14.7 to 20.5) on artificial turf. Correspondingly, the incidence for training injuries was 1.8 (95% CI 1.6 to 2.0); 1.8 (95% CI 1.5 to 2.0) on grass and 1.9 (95% CI 1.5 to 2.2) on artificial turf respectively. No significant difference was observed in injury location, type or severity between turf types.

Conclusion: No significant differences were detected in injury rate or pattern between 3GAT and NG in Norwegian male professional football.

"Comparison of injuries sustained on artificial turf and grass by male and female elite football players"
Ekstrand J, Hägglund M, Fuler CW (2010)
Scandinavian Journal of Medicine and Science in Sports, DOI: 10.1111/j.1600-0838.2010.01118.x

The objective of this study was to compare incidences and patterns of injury for female and male elite teams when playing football on artificial turf and grass. Twenty teams (15 male, 5 female) playing home matches on third-generation artificial turf were followed prospectively; their injury risk when playing on artificial turf pitches was compared with the risk when playing on grass. Individual exposure, injuries (time loss) and injury severity were recorded by the team medical staff. In total, 2105 injuries were recorded during 246 000 h of exposure to football. Seventy-one percent of the injuries were traumatic and 29% overuse injuries. There were no significant differences in the nature of overuse injuries recorded on artificial turf and grass for either men or women. The incidence (injuries/1000 player-hours) of acute (traumatic) injuries did not differ significantly between artificial turf and grass, for men (match 22.4 v 21.7; RR 1.0 (95% CI 0.9–1.2); training 3.5 v 3.5; RR 1.0 (0.8–1.2)) or women [match 14.9 v 12.5; RR 1.2 (0.8–1.8); training 2.9 v 2.8; RR 1.0 (0.6–1.7)]. During matches, men were less likely to sustain a quadriceps strain (P=0.031) and more likely to sustain an ankle sprain (P=0.040) on artificial turf.

"Injury risk on artificial turf and grass in youth tournament football"
Soligard T, Bahr R, Andersen TE (2010)
Scandinavian Journal of Medicine and Science in Sports, DOI: 10.1111/j.1600-0838.2010.01174.x

The aim of this prospective cohort study was to investigate the risk of acute injuries among youth male and female footballers playing on third-generation artificial turf compared with grass. Over 60000 players 13–19 years of age were followed in four consecutive Norway Cup tournaments from 2005 to 2008. Injuries were recorded prospectively by the team coaches throughout each tournament. The overall incidence of injuries was 39.2 (SD: 0.8) per 1000 match hours; 34.2 (SD: 2.4) on artificial turf and 39.7 (SD: 0.8) on grass. After adjusting for the potential confounders age and gender, there was no difference in the overall risk of injury [odds ratio (OR): 0.93 (0.77–1.12), P=0.44] or in the risk of time loss injury [OR: 1.05 (0.68–1.61), P=0.82] between artificial turf and grass. However, there was a lower risk of ankle injuries [OR: 0.59 (0.40–0.88), P=0.008], and a higher risk of back and spine [OR: 1.92 (1.10–3.36), P=0.021] and shoulder and collarbone injuries [OR: 2.32 (1.01–5.31), P=0.049], on artificial turf compared with on grass. In conclusion, there was no difference in the overall risk of acute injury in youth footballers playing on third-generation artificial turf compared with grass.

"Very Positive Medical Research on Artificial Turf"

Turf Roots Magazine 01, pp. 8-10
www.fifa.com

A report of medical research conducted by FIFA's Medical Assessment and Research Centre (F-MARC) comparing injuries sustained at the FIFA U-17 tournament in Peru, which was played entirely on "football turf" (synthetic turf) with the injuries sustained at previous U-17 tournaments, which were played mainly on well-manicured grass. "The research showed that there was very little difference in the incidence, nature and causes of injuries observed during those games played on artificial turf compared with those played on grass."

"Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study"
J Ekstrand, T Timpka, M Hagglund
British Journal of Sports Medicine 2006; ***40****:975-980*

Objective: "To compare injury risk in elite football [soccer] played on artificial turf compared with natural grass."

Conclusion: "No evidence of a greater risk of injury was found when football was played on artificial turf compared with natural grass. The higher incidence of ankle sprain on artificial turf warrants further attention, although this result should be interpreted with caution as the number of ankle sprains was low."

"Risk of injury on artificial turf and natural grass in young female football [soccer] players"
Kathrin Steffen, Thor Einar Andersen, Roald Bahr
British Journal of Sports Medicine 2007; ***41****:i33-i37*
http://bjsm.bmj.com

Objective: "To investigate the risk of injury on artificial turf compared with natural grass among young female football [soccer] players."

Conclusion: "In the present study among young female football [soccer] players, the overall risk of acute injury was similar between artificial turf and natural grass."

"Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players"
Colin W Fuller, Randall W Dick, Jill Corlette, Rosemary Schmalz
British Journal of Sports Medicine 2007; ***41*** *(Supplement 1):i20-i26*
(Part 1: match injuries)
British Journal of Sports Medicine 2007; ***41*** *(Supplement 1):i27-i32*
(Part 2: training injuries)
Abstracts available at http://bjsm.bmj.com

Abstracts available at http://bjsm.bmj.com

Objective: "To compare the incidence, nature, severity and cause of match injuries (Part 1) and training injuries (Part 2) sustained on grass and new generation turf by male and female footballers."

Methods: The National Collegiate Athletic Association Injury Surveillance System was used for a two-season (August to December) prospective study of American college and university football teams (2005 season: men 52 teams, women 64 teams; 2006 season: men 54 teams, women 72 teams).

Conclusion of both Part 1 and Part 2: There were no major differences in the incidence, severity, nature or cause of match injuries or training injuries sustained on new generation artificial turf and grass by either male or female players.

General Information

"Evaluation of Playing Surface Characteristics of Various In-Filled Systems"
By Andy McNitt, Associate Professor of Soil Science, Penn State University, and Dianne Petrunak
December 2006

Table of Contents reflects the scope of the research:

The research:

- Introduction and Objectives
- Construction of Experimental Area
- Characterization of Infill Systems
- Simulated Foot Traffic and Grooming
- Surface Hardness (G-Max)
- Infill Media and Underlying Pad
- Traction
- Abrasion
- Microbial Populations in Synthetic Turf
- Temperature and Color
- Summary and Considerations

F. Other Relevant Studies

"Evaluation of Potential Environmental Risks Associated with Installing Synthetic Turf Fields on Bainbridge Island"
D. Michael Johns, Ph.D., Windward Environmental LLC, Seattle, WA, February 2008

Review of available scientific literature and publications in order to provide an assessment about potential risks to the environment from zinc and chemicals contained in crumb rubber infill. "...water that percolates through turf fields with tire crumb is not toxic..."

"Initial Evaluation of Potential Human Health Risks Associated with Playing on Synthetic Turf Fields on Bainbridge Island"
D. Michael Johns, Ph.D., Windward Environmental LLC, Seattle, WA, January 2008

Review of available scientific literature and publications in order to provide an assessment about potential risks of human health to children and teenagers and the risks to the environment from precipitation runoff.

"Ambient Air Sampling for PAH's, Comsewogue High School Football Field"
"Ambient Air Sampling for PAH's, Schreiber High School Football Field"
Broderick & Associates, Inc., October 2007

In response to a news report that the above fields had three cancer-causing chemicals that were in excess of state (NY) safety levels, this independent environmental consulting and testing firm tested the fields to determine the potential routes of exposure for athletes, coaches, etc. using these fields. Broderick & Associates concluded that the potential for exposure to PAH's (sometimes referred to as an exposure to out-gassing or off-gassing of chemicals from crumb rubber infill) is "minimal or insignificant."

"Rubber - Its Implications to Environmental Health"
A FIFA presentation, Dr. Eric Harrison, Zurich, June 2007

Presentation on the chemical composition of SBR rubber and its health and environmental risks. Summary of relevant studies, and comments about the risks of SBR rubber relative to risks already present in the environment.

"Twenty Questions [and Answers] on Rubber Granulate"
Dr. Bryan B. Willoughby, March 2007
Prepared for the Sports and Play Construction Association (SAPCA)

Q & A summary in layman's terms. Published in conjunction with British Standards Institute and SAPCA.

"Environmental and Health Risks of Rubber Infill, rubber crumb from car tyres as infill on artificial turf"
INTRON, commissioned by two tyre associations, and supervised by the National Institute for Public Health and the Environment and by the Ministry of Housing, Spatial Planning and the Environment in

the Netherlands, January 2007

"Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contract we conclude that there is not a significant health risk due to the presence of rubber infill...from used car tyres."

"Synthetic Turf Sports Fields and the Environment"
Written to Westford Township (Mass) by John Amato, P.E., STC Certified Independent Consultant, 2007

Excellent and practical discussion on synthetic vs. natural turf.

"Rubber - Its Implications to Environmental Health (Hydrocarbon Rubbers)"
Dr. Bryan Willouby, Independent Consultant in Polymer Chemistry, 2006
Presented by Synthetic Turf Council at its November 2006 Annual Membership Meeting

Presentation of chemical analysis of SBR rubber, and the likelihood that leachate containing PAHs, benzene, phthalates and alkyphenols, and zinc present a health or environmental hazard. Zinc presents a localized environmental risk, but all other risks judged insignificant.

"Assessing the Health and Environmental Impact from the Use of End-of-Life Tire Rubber Crumb as Artificial Turf in Sports Arenas"
D.A. Birkholz, Director, Research & Development, ALS Laboratory Group, Edmonton, Alberta, October 18-20, 2006

Overview of various health and environmental questions, including exposure to carcinogenic PAHs, amines, and N-nitrosamines from skin contact and ingestion of toxic chemicals, leaching of toxic chemicals, releasing of toxic chemicals and particulates with use.

"Artificial turf pitches - an assessment of the health risks for football players and the environment" - A Summary
Norwegian Institute of Public Health, Oslo, October 2006
Presentation by Dr. Christine Bjorge at the ISSS Technical Meeting 2006 in Dresden

See above. No elevated human health risk from use of indoor synthetic turf halls, from VOCs (more study needed), from benzene, from PAHs. Environmental risk is local. Perhaps risks from latex rubber, but not enough research.

"PAHs and Other Organics in Tyres - Origins and Potential for Release"

Release

Dr. Bryan G. Willoughby, Independent Consultant in Polymer Chemistry, June 23, 2006

Summary of exposure risks from inhalation, leachates, and skin contact.

"Artificial turf pitches - an assessment of the health risks for football players"
Norwegian Institute of Public Health and Radium Hospital, Oslo, January 2006

Nine exposure scenarios - inhalation, skin, and oral exposures to adults, juniors, older children and children.

"Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds"
Detlef A. Birkholtz, Enviro-Test Laboratories, Edmonton, Alberta, Canada
Kathy L. Belton, Alberta Centre for Injury Control and Research, Edmonton, Alberta, Canada
Tee L. Guidotti, Department of Public Health Sciences, University of Alberta, Edmonton, Alberta, Canada
Journal of the Air & Waste Management Association, July 2003

Oral ingestion - low hazard
Inhalation of toxic vapors - inconsequential and negligible
Dermal exposure - low overall hazard
Cancer hazard through ingestion - small amounts will not result in unacceptable hazard
Species - specific lethality from leachate - moderate toxic risk, but not significant

FOR IMMEDIATE RELEASE

CONTACT: Troy Squires
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(800) 723-8873

LAWRENCE UNIFIED SCHOOL DISTRICT SELECTS GAMEDAY GRASS™ 3D FROM ASTROTURF® FOR EIGHT NEW ATHLETIC FIELDS

Lawrence and Free State High School Get New, Advanced Synthetic Turf Systems

RALEIGH, NC. (March 18, 2009) – Lawrence Unified School District (USD) selected GameDay Grass™ 3D by AstroTurf®, one of the most advanced synthetic turf products, featuring best-in-class performance benefits, and characteristics that closely mimic the look and feel of natural grass, for eight district athletic fields. Installation of the new synthetic turf football, soccer, baseball and softball fields at Lawrence High School and Free State High School, is underway by AstroTurf®. In addition to the renovation of the athletic fields, AstroTurf® will install its XPLODE™ polyurethane competition track system and new tennis courts at Lawrence High School this summer.

For district officials, the decision to select GameDay Grass™ 3D from AstroTurf® was simple.

"There were a number of factors that proved GameDay Grass™ 3D was the best product for Lawrence USD," said Tom Bracciano, division director of operations and facility planning. "The proprietary Root Zone® aiding with traction, Sustain™ all rubber infill eliminating sand that hardens over time and scientific data on player performance and safety made it clear GameDay Grass™ 3D from AstroTurf® was the best choice for our high schools and community."

The eco-friendly benefits and AstroTurf®'s "green" manufacturing initiatives also came into play for the environmental conscious town. The new synthetic turf fields remove the need for fertilizers, pesticides and herbicides and cut down on pollution resulting from gasoline-powered motors.

"We take great pride in having the opportunity to work with Lawrence Public Schools to provide innovative, durable and safe playing surfaces for the athletes and community groups to use," said GSV CEO Jon Pritchett. "Lawrence made it clear they wanted nothing but the best for all the new sports venues and we are proud they selected the GameDay Grass™ 3D system by AstroTurf®."

AstroTurf® is the approved synthetic turf and athletic supplier of the U.S Communities Government Purchasing Alliance™, a nonprofit organization that helps government agencies, school districts (K-12), higher education, and other nonprofits reduce the cost of purchased goods by pooling the purchasing power of public agencies nationwide. As a registered participant of U.S. Communities, Lawrence USD benefited from the variety and quality of products and services offered by AstroTurf®.

Work on the new football fields at each high school has wrapped up and installation of the turf for the baseball fields is in progress. All remaining elements of the project including the construction and installation of the track system and tennis courts will be completed this summer.

--more--

About AstroTurf®

The iconic AstroTurf® brand offers advanced, state-of-the-art, multi-sport and specialized synthetic turf systems with proprietary engineered technologies, leveraging the industry's only vertically integrated manufacturing system. The relaunch of AstroTurf®, including the enlistment of football legend Archie Manning as ambassador for the brand, has positioned it again as the leading innovator in the synthetic turf industry, with a growing number of high schools, colleges, professional sports teams and municipalities selecting AstroTurf®-branded products for their premium quality, technical superiority and safety. AstroTurf® is a registered trademark of Textile Management Associates, Inc.

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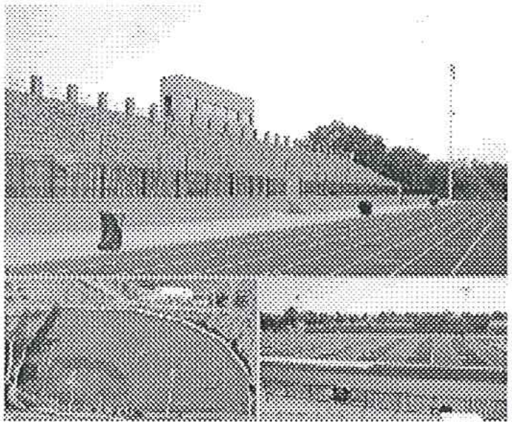


LAWRENCE HIGH SCHOOL SPORTS VENUES

Lawrence, Kansas

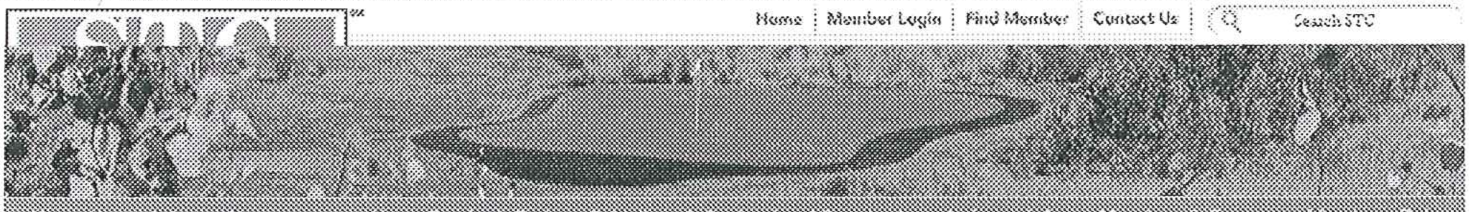
As an outgrowth of the 2007 PLAY Feasibility Study, which evaluated the adequacy of playing fields in the City of Lawrence, USD 497, in 2008, undertook a significant improvement project to upgrade the playing fields at both Lawrence high schools. Phase I of the project improved the conditions at eight sports fields at three different District locations. Landplan Engineering provided project coordination, design, construction documentation, and construction observation/inspection for all projects. Landplan designed the various venues utilizing first-of-their-kind structures, with designs that harken back to stadiums of old, but with delivered costs below equivalent aluminum bleacher facilities.

Free State High School had existing football field/track, soccer field, baseball field, softball field and tennis courts. As lead consultant, Landplan coordinated efforts to provide new synthetic turf surface on all fields and lighting for the football and soccer fields and tennis courts. Grandstands with seating for 4,000 and storage beneath were developed for the football field.

The Lawrence High School site had existing football field/track and eight tennis courts. Landplan Engineering worked with the School District to develop a new synthetic turf football field/track, softball field and soccer field. Lighting was added to all sports fields. Grandstands with seating for 4,000 and storage beneath were developed for the football field. The existing tennis courts were converted to new parking (350 stalls); an additional 600 stalls were also placed at the Lawrence High School site.

The third site, the location of the Lawrence Virtual School, had an existing area that was used for soccer practice and 45 parking stalls. Landplan developed plans that provided a full-size synthetic turf baseball field with lights and seating for 200 people and eight tennis courts with lights and seating for 200 people, along with 150 parking stalls and underground stormwater detention.

Landplan Engineering, P.A.
Lawrence, Kansas; Kansas City, Missouri; The Woodlands, Texas; Columbus, Ohio; Farmington Hills, Michigan



Case Studies and Testimonials

See the Impact Synthetic Turf Has on Schools and Communities:

Athletic Fields

- Wister Elementary School - Philadelphia, PA
- Kiowa County High School - Greensburg, KS
- William Dick School - Philadelphia, PA
- Tri-Valley High School - Dresden, OH
- Salesian High School - Richmond, California
- Junction City High School - Junction City, Kansas
- Germantown High School - Philadelphia, Pennsylvania
- Old Dominion University – Norfolk, Virginia

Playgrounds & Parks

- City of Lakeland Parks & Recreation Department (Common Ground Park) - Lakeland, FL
- City of Wauwatosa - Wauwatosa, WI
- Geneva Area Recreational, Educational, Athletic Trust (GaREAT)
- West Hollywood Sports Complex – Hollywood, Florida

Landscape

- Hawaii Canines For Independence – Maui, Hawaii
- Mandarin Oriental Hotel – New York, New York
- Twentynine Palms Marine Corps Base – Mojave Desert Region, Twentynine Palms, California

Related Links

- About Synthetic Turf
- Synthetic Turf 360°
- Case Studies and Testimonials
- Synthetic Turf FAQ's
- Research and Latest Thinking
- Synthetic Turf Video
- Guidance for Athletic Directors
- Independent Guidance
- Photos of Synthetic Turf Uses

Athletic Fields Case Study: Wister Elementary School, Philadelphia, PA

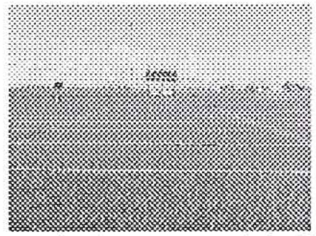
2010 Grand Prize Winner of the Search for the Real Field of Dreams

John Wister Elementary School is located in the heart of Philadelphia, in an economically challenged area plagued by gunshots and murder that lacked safe play places. Like many city schools, there is no grassy area on the school yard and no field nearby for the children to play. As a result, Wister was a bare yard, void of life. Students were often hurt when trying to play football or gymnastic stunts and trips to the nurse were constant. With nothing to do, students often ended up fighting with each other for menial reasons and mostly due to boredom. The new field has had an immediate positive effect on everyone – the school, the students and the surrounding community. It has provided an incentive for students to not only come to school but to arrive on time to play on the turf. There is no more fighting because students have so much to do. Students are much more respectful of each other and automatically break themselves into groups to play in different areas simultaneously. The field provides the closest thing to grass that many of these children see day to day. It allows students to exert energy and release their frustration which helps to prepare them for the rest of their academic day. This once barren field is a place of opportunity, where students take ownership and pride in their schoolyard. Read Full Story

Athletic Fields Case Study: Kiowa County High School,

Greensburg, KS

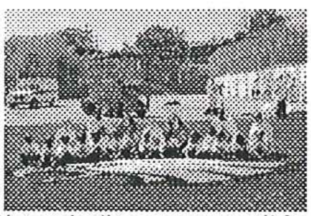
2010 Grand Prize Winner of the Search for the Real Field of Dreams



On May 4, 2007, an EF-5 tornado obliterated 95% of Greensburg, Kansas. The schools and facilities were a total loss. All that was left of its football stadium was the field itself, and its surface was riddled with holes, gouges, and debris. Gone were the bleachers, the concession area, the lights, the goalposts and the fencing. Despite enormous challenges, school started in August of 2007, as previously planned. Trying to decide where to practice and where to play were issues that continually plagued administrators. For two years, competing at home was out of the question. While the school was very appreciative of neighboring towns that shared their sports facilities, small towns count on home games to build community pride and bring all ages together for a common goal. With so much loss, townspeople desperately needed a place to rally. Galvanized by this goal, a dream began to form in the minds of our school leaders: the dream of having not only a "home" field again, but the only synthetic 8-man turf in the state of Kansas. School administration, construction crews and everyone in town worked around the clock to finish before their home opener on September 4, 2009. Today the school proudly hosts sports competitions and the community youth football league uses it for their Saturday games. It truly shows what can happen when people dare to dream big. Read Full Story

Athletic Fields Case Study: William Dick School, Philadelphia, PA

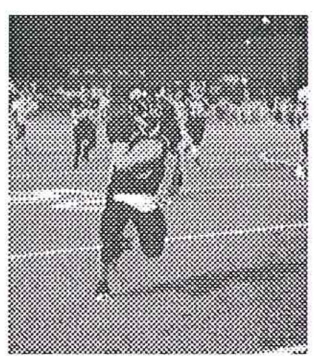
2010 Top Winner of the Search for the Real Field of Dreams (Athletic Fields Category)



Ranging in age from five to 13, the students at William Dick School in Philadelphia arrive from homes with a poverty rate of over 90%. The empty school yard was filled with almost a full city block of broken concrete. When the Philadelphia Eagles Youth Partnership asked students what their dreams were for the school year, the children overwhelmingly said they wanted "grass."They longed to be able to play their games on a safer surface when they had recess and came to play – during school, weekends, evenings and summer vacation. Since planting grass wasn't feasible, a synthetic turf field was installed in the far corner of the schoolyard in June 2007. The goal was to offer these children an area where students and the community could come to play football, tag and other games without worry of skinned knees or even worse injuries that had been seen so many times before. Opportunities for students to play against staff in games as well as physical education activities on the turf became part of the everyday experience. When students wanted more space to play, a local synthetic turf company sponsored a reading challenge at the school to make this happen. The field helps the school raise the bar with students academically and provide incentives for good behavior. It has also lead to strong social responsibility, as parents and neighbors monitor and keep the play area in great share during after-hours recreation. Read Full Story

Athletic Fields Case Study: Tri-Valley High School, Dresden, OH

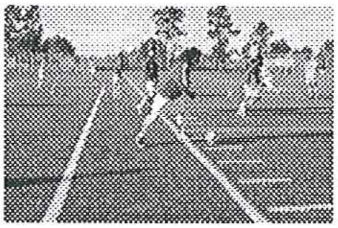
2010 National Finalist of the Search for the Real Field of Dreams (Athletic Fields Category)



The small town of Dresden, Ohio prospered for many years because of the Longaberger basket company. But In the last ten years, that prosperity has turned to despair as Longaberger has to cut its workforce from 8,000 to just over 1,000. Unemployment in our county is nearly 16% compared to the state average of 10%. The town needed a shot of adrenaline, something to rally around and be proud of again – Tri-Valley High School's football program. The program had begun to build with three winning seasons, but now the game field was in bad shape after overuse and severe drainage issues. It constantly drew the ire of opposing coaches because they feared their athletes would get injured as a result of the field conditions. At the end of 2008, we decided to build on the momentum created by the football program and propose the field turf project to our school and community. Six months later we had our new synthetic turf field and everything has changed. Our student athletes have all reaped the benefits of such a great surface. The football team is now able to play and practice on a perfect surface every day. From soccer and band in the fall, to baseball, softball and track in the spring, our turf gets used on a daily basis. The drainage problems that were so prevalent on our old field are now non-existent. Every Friday night in the fall, townspeople forget about their problems and share in the thrill of success that our completed project has provided. This year, they watched Tri-Valley Football complete a perfect 5-0 home record on the new synthetic turf field. Read Full Story

Athletic Fields Case Study: Salesian High School, Richmond, California

2009 Grand Prize Winner of the Search for the Real Field of Dreams



In a true story of David vs. Goliath, the football team at Salesian High School in Richmond, California went from the brink of closure to defeating an "unbeatable" team with players twice its size. It was Salesian's first game on their brand new synthetic turf field – a field that is now being hailed the Grand Prize Winner of the Search for the Real Field of Dreams. Salesian High School unveiled its field for the varsity football Homecoming game in 2007. They were up against a school with three times as many students and an offensive line that looked like an NFL team. Nearly 1,000 fans packed the stands as Salesian High School defeated its opponent 40-37. The headline in the next day's newspaper read, 'David Slays Goliath.'

Located in a city with one of the country's highest murder rates, the students at Salesian High focused their efforts on academics – the school boasts a graduation rate near 100 percent. And although 70 percent of students are involved in athletics, the conditions of their grass field were so poor that the soccer and football teams were on a three-year notice to be shut down. That all changed when the school raised funds to install a synthetic turf field. Salesian's inspirational story stood out among the winning entries selected by an independent panel of judges as winners of the STC 2009 Search for the Real Field of Dreams. Read Full Story

Athletic Fields Case Study: Junction City High School, Junction City, Kansas

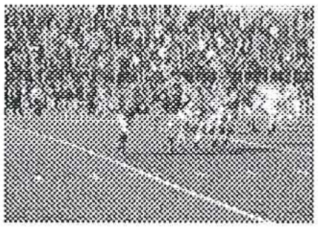
2009 First Runner-Up of the Search for the Real Field of Dreams

The varsity football team at Junction City High School squashed a 40 year dry spell and won the 2008 State Championship after replacing its run-down playing field with synthetic turf. The school's inspirational story has now helped it win First-Runner Up in the 2009 Search for the Real Field of Dreams. Located in the small military town of Junction City, Kan., the old field could only be used once or twice a week. Now the new synthetic turf field is used nearly every day, all year round. The school's award-winning band now has a place to practice, the soccer team has a place to play home games and the "Ultimate Blue" Frisbee team is able to use the fields, too. From a fundraiser flag football game hosted by area firefighters to a "Tribute to Our Troops" night recognizing military members and their families, the field at Junction City High School has truly helped bring the entire community together. Read Full Story

Athletic Fields Case Study: Germantown High School,

Philadelphia, Pennsylvania

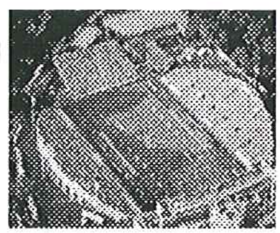
2009 National Finalist of the Search for the Real Field of Dreams



Benjamin L. Johnston Memorial Field is one of five "super sites" that serve Philadelphia high school athletics. Germantown High School runs the facility, which provides athletic field space for schools that lacked on-premises outdoor space, a typical problem in urban settings. Overuse had turned the field into a desolate eyesore which became a complete quagmire during rain. Then the Local Initiatives Support Corporation in Philadelphia helped arrange for a $200,000 grant from the NFL's Grassroots program as part of a major renovation project. The Philadelphia Eagles and School District of Philadelphia also came together to give area's youth a better place to play. Together, these efforts lead to the install of a synthetic turf field that has transformed the community. It hosts football, soccer, field hockey and track teams from more than 10 local schools, and most mornings over 100 people are exercising n the field before the school day even begins. Student athletes take care of the field, raking leaves, washing the neighbor's sidewalks and painting the fencing. Recognized as a national finalist in the 2009 Search for the Real Field of Dreams, the field is now a place that creates healthy minds, healthy bodies and opportunities for a bright future. Read Full Story

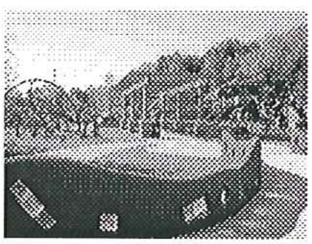
Athletic Field Case Study: Old Dominion University - Norfolk, Virginia

After 70 years of hibernation, Old Dominion University decided to build a football program with a new synthetic turf field. The project meant a lot to this tight-knit community, who took their time to do things right. They faced challenges ranging from raising funds and dealing with weather problems to the sheer magnitude of the construction project. But the team prevailed and began their inaugural season in September 2009. All of their extra play and practice time on the synthetic turf field made a big difference – the football team finished with a 9-2 record, the best record ever for a first year program in NCAA history.



Public Parks Case Study: City of Lakeland Parks & Recreation Department (Common Ground Park), Lakeland, FL

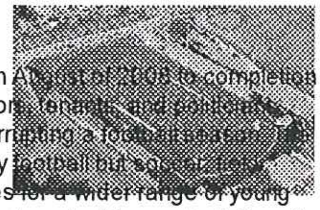
2010 Top Winner of the Search for the Real Field of Dreams (Community Parks and Fields Category)



Experts have found that encouraging social interactive play builds physical, emotional, social and cognitive development for children. With this in mind, the City of Lakeland Parks & Recreation Department in Florida opened Common Ground in 2009, its first inclusive playground featuring unique play experiences for children of varying physical and cognitive abilities. The park features over 25,000 square feet of synthetic turf play zones to connect barrier free play elements and edging to ensure kids remain as safe as possible. In the shape of a butterfly, Common Ground provides play opportunity for all kids including over 17,000 children with physical and cognitive challenges in the Lakeland community. Thousands of volunteers donated their time and fundraised for four years to make it a reality. Community partnerships and collaborations collected over $1.8 million dollars to fund Common Ground. All four Lakeland Rotary Clubs sponsored community runs. Butterflies in Flight, a public art project, raised awareness and dollars. State, county and municipal government matched funds with grants and in kind support. Common Ground is truly a community dream come true. Read Full Story

Public Parks Case Study: City of Wauwatosa, Wauwatosa, WI

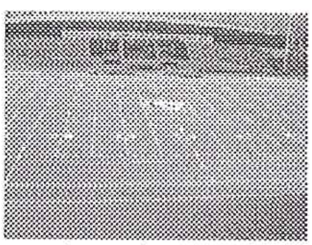
2010 National Finalist of the Search for the Real Field of Dreams (Community Parks and Fields Category)



Wauwatosa's new athletic field is located in Hart Park, which is owned and maintained by the City. The previous football field was a clay-based natural turf field, which deteriorated from overuse by five high schools and one semi professional football team. Between the loss of major tenants and constant construction, the park was being used less and less by residents. Something had to be done to demonstrate the City's commitment to the park as a destination and a positive contributor to the quality of life. The Hart Park field and athletic complex represented a true cooperative effort. From its inception in August of 2008 to completion in September of 2009, City staff, consultants, general contractors, sub contractors, tenants, and politicians collaborated closely to complete this project in less than 12 months without interrupting a football season. The results have been amazing. The synthetic field has generated interest in not only football but soccer, field hockey, lacrosse, and rugby as well. It provides new and expanded opportunities for a wider range of young athletes. Since 2009 the semi pro league has contracted to return and one of its tenants, Marquette University High School, completed an undefeated football season culminating in the state Division I championship. It will now be the home field for a NCAA Division III college lacrosse team and serve as the local site for the Regional USA Field Hockey Futures Program, which is the primary feeder program for the Olympics. Field rental requests have increased exponentially because the surface can withstand much more frequent use than the old natural turf field. With all these changes, Hart Park is a testament to what can be accomplished when a community pulls together toward a common goal. Read Full Story

Public Parks Case Study: Geneva Area Recreational, Educational, Athletic Trust (GaREAT), Geneva, OH

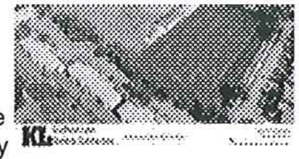
2010 National Finalist of the Search for the Real Field of Dreams (Community Parks and Fields Category)



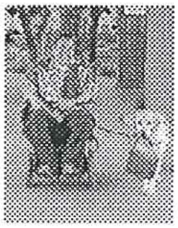
Geneva Area Recreational, Educational, Athletic Trust (GaREAT) is a non-profit corporation created to focus both energy and funding towards creating a world-class multipurpose facility. The GaREAT Sports Complex, announced in May 2008, sits on a 175-acre campus in Geneva, Ohio about 50 miles east of Cleveland. Focused on serving members from all ages and a variety of athletic abilities, the complex has three turf fields that can be used for football, soccer, lacrosse, baseball and softball. It's impact has been tremendous in the Northeast Ohio region, giving athletes and locals a place to work-out, train and compete year-long. It promotes public wellness with senior walking routes to regional competitions. Nationally recognized teams now have the chance to practice full field to help their game while local teams can compete and train in an environment that was not available before. Throughout their first year of opening, the facility has helped many teams from Ohio, Michigan, Indiana, Pennsylvania and New York train and compete. The GaREAT Sports Complex looks forward to creating more success stories in the future. Read Full Story

Public Parks Case Study: West Hollywood Sports Complex – Hollywood, Florida

The West Hollywood Sports Complex in Hollywood, Florida provides services to the community in an area with limited recreational facilities. In renovating their 30 year old complex, they selected synthetic turf for the new community center's two year old complex, they selected synthetic turf for the new community center's two playing fields – one for softball and baseball games, and the other for soccer and football. Switching away from natural grass yielded immediate cost savings and environmental benefits. The complex now saves $80,000/year in maintenance fees. They conserve eight million gallons of water annually and have eliminated the need for mowing, fertilization, pest control and returfing of wear areas. Now nearby residents have access to premier playing surfaces on a daily, year round basis.



Landscape Case Study: Hawaii Canines for Independence – Maui, Hawaii

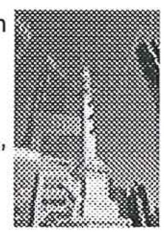


Hawaii Canines for Independence (HCI) is a charitable organization that provides disabled residents with specially trained dogs that give them the freedom and confidence to live more independent lives. When they needed more green space to train their assistance dogs, a leading industry provider donated a 3,000 square foot artificial grass system. Now HCI volunteers spend less time cleaning and maintaining the grounds and more time training dogs.

"Our new artificial lawn helps keep the dogs and the facility clean and the yard will be better for people in wheelchairs to use when practicing with their dogs," said Mo Maurer, founder and owner of HCI. "We are so thankful to have this big improvement."

Landscape Case Study: Mandarin Oriental Hotel – New York, New York

"Every inch matters," is a term most New Yorkers have grown accustomed to. With limited room that costs a small fortune, using space efficiently is a must. The Mandarin Oriental Hotel understands this concept well. They installed a beautiful, 38th floor terrace yoga deck with an artificial grass system to maximize its outdoor space. Now hotel visitors have the opportunity to take pleasure in a lush green space overlooking the city. They're not the only ones. Other hotels, residential rooftops and parking decks in the bustling Big Apple are being covered in state-of-the-art synthetic grass products.



Landscape Case Study: Twentynine Palms Marine Corps Base – Mojave Desert Region; Twentynine Palms, California

Located in the desert region of the Mojave Desert, conserving water at Twentynine Palms is a must. The world's largest Marine Corps base recently installed 12,000 square feet of state-of-the-art synthetic grass to help suppress water usage. That move allows them to save an average of 600,000 gallons of water per year - enough to fill 20 large swimming pools!

Now when military personnel and their families visit the amphitheatre and dog park areas, they can enjoy a lush, great looking green space year round. Synthetic grass also eliminates the need for fertilizers and pesticides which pollute the environment. It is softer and more inviting than hard surfaces and is non-allergenic, creating a safe area for children and pets.

STC
Synthetic Turf Council

NEWS RELEASE

DATE: May 31, 2011

MEDIA CONTACT: Shira Miller/678-392-1785
Shira@shiramiller.com

Synthetic Turf Becomes Latest Celebrity Trend

A-Listers and Landmarks Conserve Water While Beautifying Grounds

(Atlanta, Ga.) – The term "celebrity trend" typically conjures up images of $5,000 handbags, private airplanes or dancing on a reality show. But the latest A-Lister must-have is actually coming right out of their backyards. A growing number of celebrities like Jessica Alba, Kristen Bell and David Basche are going green by turning to synthetic turf for their landscape needs.

"I chose synthetic grass for Jessica Alba's backyard doggie oasis and use it at clients' homes as often as possible," said Kari Whitman, celebrity designer. "The eco-friendly synthetic turf looks so realistic and stands up to pet messes, wear and tear. I also love that it eliminates the need for pesticides and fertilizers, making your yard healthier for you and your pets. Plus it saves water and some cities will even give you a rebate on your utility bill. It's a win-win."

Synthetic turf is also helping landmarks and pop culture icons beautify landscape while saving water. In contrast to its famed "grotto" and legendary parties, the synthetic grass at the Playboy Mansion looks serene. The Pixie Hollow Fairy Garden at Epcot's International Flower & Garden Festival featured a lush, realistic synthetic grass lawn, which was accessible for wheelchairs and walking braces, and easily withstood the event's heavy foot traffic. Disney World and Disneyland also feature synthetic turf in designated areas throughout their resorts.

Synthetic turf for landscape and recreation is one of the fastest growing segments of the market. Able to be installed in places where grass can't grow or be effectively maintained, its numerous applications include residential, commercial and municipal landscape; airport grounds; pet parks; playgrounds and rooftops. The Southern Nevada Water Authority estimates that every square foot of natural grass replaced saves 55 gallons of water per year.

About the Synthetic Turf Council

Based in Atlanta, the Synthetic Turf Council was founded in 2003 to promote the industry and to assist buyers and end users with the selection, use and maintenance of synthetic turf systems in sports field, golf, municipal parks, airports, landscape and residential applications. The organization is also a resource for current, credible, and independent research on the safety and environmental impact of synthetic turf. Membership includes builders, landscape architects, testing labs, maintenance providers, manufacturers, suppliers, installation contractors, infill material suppliers and other specialty service companies. For more information, visit www.syntheticturfcouncil.org.

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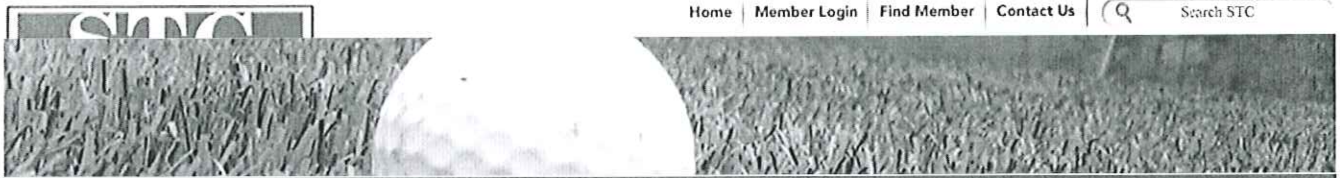

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"Our players love playing on the artificial turf surface. The change has been extremely beneficial to Tennessee Tech, the football program and to the student athlete experience. When we have a field that can maintain all that wear and tear, that's what is beneficial for a long-term financial investment."

Mark Wilson
Athletic Director, Tennessee Tech

About Synthetic Turf

These days, synthetic turf seems to be everywhere. More than 5,500 athletic sports fields are currently in use throughout the United States. Millions of students have new opportunities to practice and play on a sports field that can always be counted upon. It has helped teams go from worst to first, intensified school pride and brought together entire communities.

Thousands of homes, businesses, golf courses, municipalities, playgrounds and public spaces have also turned to synthetic grass. This lush, attractive landscape solution requires minimal resources and maintenance while saving millions of gallons of water each year.

The positive environmental impact of synthetic turf is tremendous. Billions of gallons of water are conserved annually. Potentially harmful pesticides and fertilizers are eliminated, while emissions from gas-powered maintenance equipment is significantly reduced.

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Grass without limits.

Playground Artificial Turf

Pixie Hollow Fairy Garden comes alive with synthetic Turf

Epcot International Flower & Garden Festival showcases ForeverLawn

March 2, 2011 (Albuquerque, NM) -- The Epcot International Flower & Garden Festival opens today at Walt Disney World in Orlando, Fla. The spring special event offers many surprises for visitors such as Disney character topiaries, a colorful array of flowers, and live music events, but guests may be most surprised to learn that the lush, green grass beneath their feet may be fake.

The Pixie Hollow Fairy Garden features a gorgeous green lawn, but like most attractions at the theme park, this grass is not what it seems. The playground's artificial turf is an incredibly realistic synthetic grass offering from ForeverLawn and DuPont that is not only accessible to wheelchairs and braces, but is also a beautiful, durable landscaping solution that can withstand the festival's heavy foot traffic.

If walking on this playground artificial turf isn't enough, the park also offers a playground where guests can roll, tumble, and play on it. Part of an overall safety system called Playground Grass, the playground artificial turf is safe for children to play on and safety rated to fall heights of 12 feet, so children lucky enough to visit the park can play safely.

ForeverLawn calls their Playground Grass product "the new generation of playground safety surfacing." A soft, accessible surface, Playground Grass provides children of all abilities the opportunity to play. Even children with allergies can romp on the playground's artificial grass, since the non-organic surface does not harbor allergens or insects.

This marks the fifth year that ForeverLawn's playground artificial grass has been part of the festival. The turf originally appeared in a DuPont display in 2007, and continues to draw amazement and attention from guests. "People ask us all the time if the grass is real," said Jim Davis, product portfolio manager, DuPont Landscape Systems. According to Davis, visitors at the display would bend down to touch the grass to make sure it is, in fact, artificial. "They don't believe us when we tell them it's artificial," he said.

More information about Playground Grass can be found at playgroundgrass.com. Visitors to the Epcot International Flower &

Garden Festival can experience the unique playground artificial turf for themselves from March 2 through May 15, 2011.

About ForeverLawn

ForeverLawn provides innovative synthetic grass products to create better landscapes worldwide. In areas where real grass is difficult to grow or maintain—due to high traffic or poor conditions—ForeverLawn offers a realistic alternative that is beautiful, functional, and durable. In addition to its landscape lines, ForeverLawn also offers specialty products including K9Grass, SportsGrass, Playground Grass, GolfGreens, and SplashGrass.

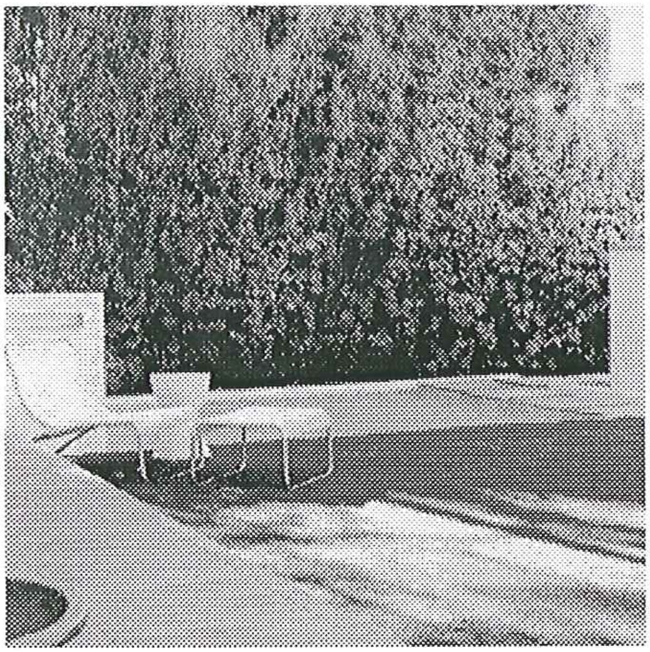
ForeverLawn—Grass without limits. foreverlawn.com

Sunset

« Return to Should you fake the lawn?

Should you fake the lawn?

Get the pros and cons of synthetic grass and other low-care alternatives



Architect Tom Schaller installed a modern dipping pool in his Venice, CA, front yard. He envisioned lawn to complete the design. But Schaller didn't want to consume that much water. So he installed fake turf and got the look without the guilt. More in our blog

Tom Schaller

Lawns and the alternatives
Traditional lawn, synthetic lawn, native grasses, and drought-tolerant blends — the pros and cons

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How to lose the lawn
Beautiful, easy-care alternatives to turf grass

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Save water and $
Here's how to lessen your water footprint, save cash, and still have a beautiful yard

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By Maile Meloy

There's just something beautiful and comforting about mown grass. Whether you're throwing a ball, lying in the shade on a hot day, or sitting outside on a warm night, a green lawn is a pleasure.

Writer Wallace Stegner, having grown up in dry, wild Saskatchewan, Canada, first saw a lawn at age 11 in Montana. "I stooped down and touched its cool nap in awe and unbelief. I think I held my breath — I had not known that people anywhere lived with such grace."

Lawns are also an environmental nightmare if you live in a dry climate, and Stegner did try hard to remind people of the natural aridity of the West. I live in Los Angeles, where millions of gallons of drinkable water are dumped into lawns every day, year-round.

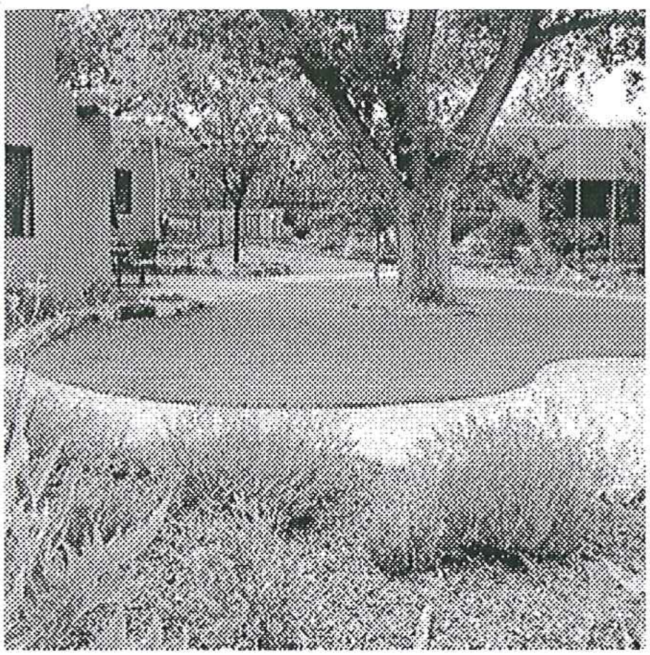
Compare: Lawns and the alternatives

Each of the hundreds of thousands of gas-powered push mowers that whine away, cutting that lushly watered grass, puts 11 times more pollution into the air every hour than a car. The leaf blowers — illegal in many areas but widely used anyway — are just as bad. The carbon footprint of L.A.'s lawns is enormous.

And then there's the constant, nerve-racking noise from all those mowers and blowers, on different lawns, on different days.

For a while, my husband and I dealt with the problem by not watering our lawn. Call it default xeriscaping: If you don't water, you miraculously don't have to mow. But it's not pretty. The weeds start to take over, and people stop picking up after their dogs, figuring that you don't really care. We did care about the grass — we just didn't want it to grow.

Then we went to a party at the house of a landscape designer who watered, she said, for only eight minutes a week, and did her own gardening, with no mowing. This was real xeriscaping: She had succulents, and drought-tolerant trees, and pink-flowering


This example is from the home of Nate Downey and Melissa McDonald of Santa Fe, NM. They are very aware of water scarcity but wanted a soft surface for their sons to play on. Artificial turf under their big Siberian elm was their solution. More in the garden blog
Sharon Cohoon


Real grass: soft, pretty, and thirsty
Leigh Beisch

Lawns and the alternatives
Traditional lawn, synthetic lawn, native grasses, and drought-tolerant blends — the pros and cons

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How to lose the lawn
Beautiful, easy-care alternatives to turf grass

cactus, and Mexican beach pebbles — and two stunning green rectangles of perfect lawn in the back. "The grass," another guest whispered to me. "It's not real."

"It's not?" I asked. It looked gorgeously real.

"Touch it," she said.

I did, and it was true: The grass was fake.

It wasn't Astroturf, exactly, but long, smooth blades of grass that looked exactly like real grass but happened to be plastic. It had been laid down like a carpet, over prepared ground. She hosed it off sometimes, and it drained itself. It wasn't cheap, but given that she didn't have to mow, water, reseed, or fertilize, it would pay for itself in eight years. And then there was the peace of mind, the quiet, and the conservation of water. We had a solution.

Next: The backlash

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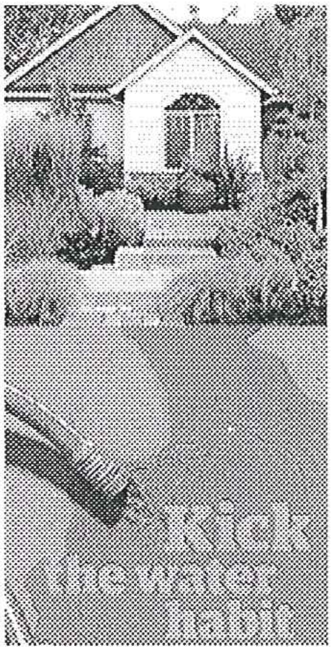

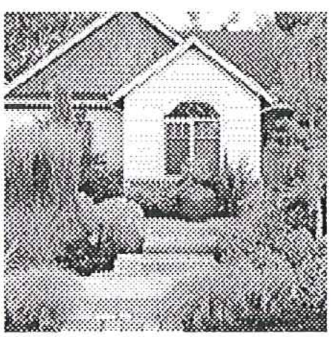

What we weren't prepared for was the backlash. We told a friend our plan, and she was horrified. It wasn't natural, she said. It was weird. A house should be surrounded by living things, not plastic. We should let what naturally grew there grow. But what naturally grows in my Southern California yard is scratchy stuff that snakes and lizards like to live in. Kids don't like to play on it, and our neighbors would run us out.

So we put in the plastic lawn. First the installers had to take out our pathetic weedy grass — no regrets there — and put down sand, so nothing would grow up from below. Then they compressed the sand, which is loud; we told ourselves we were doing all our noise polluting at once.

More: Kick the water habit

They rolled out the lawn in sheets, so cleverly that it's impossible to see the seams or the darts at the corners. It looks like we just put in the world's most pristine sod. My husband's brother came over soon after it was finished, and called me from his cell phone. He said, "I'm standing outside, but I'm not sure if I have the right house. It has this incredibly beautiful lawn." He was unconvinced that two people so lackadaisical about landscaping could grow such perfect grass. And he was right, of course.

My father has remained skeptical about the whole idea. He admits that it looks beautiful, but he can't get over the sound. The grass makes a plastic rustle that makes him laugh out loud. I'm told that if you hose it down, that sound goes away, but then you wouldn't be saving water. And the truth is, my father burns so many hours and so much gasoline mowing his lawns in Montana that he has no earthly right to laugh at a whispery rustle.

Have a fake lawn? Post a photo

You can get synthetic lawn that's late-summer long, or putting-green short, or somewhere in between. You can get dark green or light green, depending on the kind of grass that grows near you. You can even choose the color of the springy underlayer. Ours has variegated strands — some dark, some light — and looks especially real.

The best part? No pouring clean water into the grass. No burning gasoline to mow it. No fertilizer running into the sea.

People will stop and stare, and say how magnificent your lawn is. And you don't have to tell anyone it's fake. I always do, in the same way I blurt out that the dress I've been complimented on cost $19. But you can just let people think you have a very green thumb, and a silent, invisible mower. You can act like a girl in a real designer dress, and just say thank you.

More: Lawns and the alternatives

Maile Meloy | *From the* July 2009 Issue

The Limpkin

Newsletter of the
Space Coast Audubon Society of Brevard County, Florida

History of the American Lawn

By Cameron Donaldson

Reprinted with permission from the Guide for Real Florida Gardeners, a free publication for homeowners, available at your local native nursery or Florida Native Plant Society chapter, or by calling Just Cause Media, 321-951-2210.

Some scientists believe that humans may be genetically encoded with a need to surround ourselves with low-growing turf grass. Tens of thousands of years ago in Africa, our ancestors stayed fit by chasing and being chased by big wild animals. The African savannas, large areas of low grasses, enabled human hunters to easily stalk their prey and spot predators at a distance.

Historians, however, believe that the human desire for lawns came about much later, in 17th century Europe, when the ruling royals flaunted their wealth by surrounding themselves with lawns. Lawns did a great job of showing off castles and manor homes. They also let the neighbors know that the lawn owner was so wealthy that he could afford to use the land as a playground, rather than a source of food. Thus, the lawn became a status symbol.

In the United States, early colonists were far too busy to be bothered with something as time-consuming and useless as a lawn. Their yards were cottage gardens planted with edible and medicinal plants and surrounded by paths and storage areas of hard-packed dirt, swept clean daily. And so it remained until enough wealth and leisure time was accumulated to start decorating the yard and creating play areas. Naturally our immigrant ancestors brought with them their Old World ideas-and Old World plants.

By the mid 1800s, the desire to emulate upper-crust Europe was in full swing. Literate Americans began to see magazine articles and books touting the lawn as essential for beautiful homes. At first, only the wealthy could afford the labor provided by hired staff to maintain lawns. Of course, this further cemented the idea of lawn as a status symbol. The push mower came on the scene in 1870 and suddenly almost any property owner who wanted to could have a lawn.

Seizing on this opportunity to push forward an "improved" lifestyle and supporting industry, the Garden Clubs of America, U.S. Department of Agriculture, and U.S. Golf Association jointly spread the gospel of grass

throughout the country in the early 1900s. Contests were held to reward lawn owners. Garden writers focused on the neighborly desire to conform and acquire status. Lawns became not just an aesthetic issue but a moral imperative.

With ever-improving technology, gas-powered lawnmowers came on the scene and after World War II, chemical weapons manufacturers turned their attention to the lawn and the formidable perceived enemy: insects. Warehouses of potent chemicals turned into fertilizer and pesticide products. This came at the perfect time for the postwar boom era, when Americans everywhere became suburbanites and felt they needed lawns.

Fortunately for all of us, scientists like Rachel Carson (author of Silent Spring) came along to explain the danger that such chemicals presented to all life, including ours, and the modern environmental movement was born. Scientists and activists battled to institute legal protections for public health and welfare and continue to do so today. Thanks to their efforts, many homeowners already want to reduce or eliminate the use of chemicals in their home. Now we're beginning to recognize the need to reduce or eliminate lawns!

Read more on your own:

- The Landscaping Revolution, Garden with Mother Nature Not Against Her, Andy Wasowski, Contemporary Books, Contemporary Gardener Series, Chicago, 2000.
- The Lawn: A History of an American Obsession, Virginia Scott Jenkins, Smithsonian Institution Press, Washington D.C., 1994.
- Redesigning the American Lawn: a Search for Environmental Harmony, F. Herbert Bormann, Diana Balmori, and Gordon T. Geballe, Yale University Press, 1993.

Online:

- http://magazine.audubon.org/backyard/backyard0105.html
- http://www.primalseeds.org/lawns.htm
- http://www.traditionalgardening.com/Spring97/lawnbody.htm
- A number of interesting reference links are provided by AFNN member All Native Garden Center & Plant Nursery at: http://www.nolawn.com/moreaboutnolawns.html

News

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Synthetic Turf Installed in North America Conserves More Than Three Billion Gallons of Water,Eliminates Nearly a Billion Pounds

02/01/2011
Synthetic Turf Council

While millions of people, businesses, schools and homeowners use synthetic turf for landscape and play, one of its major beneficiaries is the environment. As of 2011, the estimated total amount of synthetic turf installed in North America annually conserves more than three billion gallons of water, significantly reduces smog emissions and eliminates close to a billion pounds of harmful fertilizers and pesticides. The industry has also recycled more than 105 million used tires.

"Synthetic turf has made a very positive impact on the environment," said Rick Doyle, President of the Synthetic Turf Council. "The synthetic turf industry continues to innovate to enhance synthetic turf's numerous eco-friendly benefits that empower users to reduce their carbon footprint."

Significant Environmental Impact

* Conserves over three billion gallons of water. Water is one of our most precious resources. More than 6,000 synthetic turf fields are currently being used in the United States, with each full-sized field saving between 500,000 to 1,000,000 gallons plus of water each year. During 2010, that meant at least three billion gallons of water, and perhaps as much as six billion or more, was saved through the use of synthetic turf fields.

* Eliminates the need to water lawns. According to the U.S. Environmental Protection Agency (EPA), over one-third of residential water is used for lawn irrigation nationwide, totaling more than 4 billion gallons of water a day. The Southern Nevada Water Authority also estimates that every square foot of grass replaced with synthetic turf saves an additional 55 gallons of water per year. Therefore, an average lawn of 1,800 square feet will save 99,000 gallons of water a year if landscaped with synthetic turf – about 70% of a homeowner's water bill, or up to $500.

* Eradicates the use of almost a billion pounds of pesticides and fertilizers. The EPA has identified runoff of toxic pesticides and fertilizers as a principal cause of water pollution. In Florida alone, the EPA estimates that about 1,000 miles of rivers and streams, 350,000 acres of lakes and 900 square miles of estuaries are impaired by runoff of pesticides and fertilizers. Synthetic turf eliminates the need for nearly a billion pounds of harmful pesticides, fertilizers, fungicides and herbicides which are used to maintain grass.

* Keeps more than 105 million used tires out of landfills. Most of the synthetic turf sports fields and landscape applications in use incorporate crumb rubber infill recycled from used tires, keeping more than 105 million used tires out of landfills.

* Depending on field usage, synthetic turf can lower consumption of energy, raw materials and solid waste generation. BASF Corporation performed an Eco-Efficiency Analysis measuring environmental and economical impacts of synthetic turf athletic fields with professionally installed and maintained grass alternatives. According to BASF, among the major findings of the study was that the average life cycle costs over 20 years of a natural grass field are 15 percent higher than the synthetic turf alternatives, even when factoring in a replacement synthetic turf field during that time. Released in November 2010, the life cycle assessment found that with typical field usage, synthetic turf had a lower consumption of energy, raw materials and solid waste generation than natural grass fields. BASF's eco-efficiency analysis is an award-winning and strategic tool, based on the ISO 14040 standard for lifecycle analysis, which quantifies the sustainability of products or processes.

* Prevents smog and noxious emissions. According to the EPA, lawn mowers are a significant source of pollution that impairs lung function, inhibits plant growth, and is a key ingredient of smog. A gas-powered push mower emits as much hourly pollution as 11 cars, and a riding mower emits as much as 34 cars. In addition, the EPA estimates that over 17 million gallons of gas and oil are spilled each year from refueling lawn equipment; that is more oil than was spilled by the Exxon Valdez.

* Reduces grass clippings. The EPA estimated in 2002 that 12% of what goes into landfills is yard waste. During the summer months, clippings can account for nearly half of a community's waste. Switching to synthetic turf reduces this significant source of environmental pollution.

Schools, parks, businesses, municipalities, homeowners, golf courses and others using synthetic turf can receive Leadership in Energy and Environmental Design (LEED) credits for Water Efficient Landscaping, Stormwater Design, Recycled Content and Rapidly Renewable Materials from the U.S. Green Building Council. Many synthetic turf companies have also created products that are 100% recyclable. 'Green' options also exist for recycling, reusing and disposing of infill and the synthetic turf itself. The industry is working hard to develop further eco-friendly end-of-life disposal solutions.

About the Synthetic Turf Council

Based in Atlanta, the Synthetic Turf Council was founded in 2003 to promote the industry and to assist buyers and end users with the selection, use and maintenance of synthetic turf systems in sports field, golf, municipal parks, airports, landscape and residential applications. The organization is also a resource for current, credible, and independent research on the safety and environmental impact of synthetic turf. Membership includes builders, landscape architects, testing labs, maintenance providers, manufacturers, suppliers, installation contractors, infill material suppliers and other specialty service companies. For more information, visit **www.syntheticturfcouncil.org**.

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New turf surface at Roy Kidd Stadium near completion - 07/20/2009

New OP soccer complex gets national tournament - 06/16/2009

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Stadium on schedule: Future home of the Crushers set to open June 2 - 04/30/2009

Weather is tough opponent for spring sports - 04/22/2009

All Pro Freight Stadium Uncovered - 04/13/2009

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Men work non-stop on All Pro Freight Stadium for Crushers' home opener - 03/11/2009

Hawks ready for season to start Sunday - 02/10/2009

Practice time: Lehigh laxers set to begin season - 01/16/2009

TigerTurf Takes the Field - 10/20/2008

TCNJ's football triumphs on Homecoming, 24-7 - 10/18/2008

Heisman Winner Mike Rozier to Participate in TCNJ Homecoming - 10/17/2008

Heisman Winner Mike Rozier to Appear at North Allegheny High School Dedication - 10/16/2008

Texas Sports Builders Tabbed with ASBA Award - 10/16/2008

Former Area of Tragedy Turned into "Green" Recreational Area with TigerTurf EnviroField - 10/16/2008

Royse City High School's New TigerTurf Is "Number One Field" in Texas - 10/09/2008

Legendary All-Star Game Inaugurates Bradford High's New TigerTurf - 09/22/2008

Spring-Ford set to debut turf field - 09/19/2008

Stadium welcomes new turf - 09/10/2008

Edwardsville opens new field in style - 09/10/2008

Women's Soccer Opens New Finnesey Field with 3-0 Win Over Saint Peter's - 09/05/2008

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Global Synthetic Turf Manufacturer - TigerTurf - Bringing State-of-the-Art Manufacturing Facility to Americas - 03/20/2007

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July 15, 2011

Jerry Brown vetoes artificial turf bill backed by conservationists

Gov. **Jerry Brown** has vetoed legislation that would have required homeowners associations to let people replace their lawns with artificial turf, the governor's office announced today.

Senate Bill 759, by Sen. **Ted Lieu**, D-Torrance, was supported by water conservationists and passed by the Legislature with some bipartisan support. It would have prohibited associations, which often govern the aesthetics of a neighborhood, from banning artificial turf.

"A decision to choose synthetic turf over natural vegetation is best left to individual homeowners associations, not mandated by state law," the Democratic governor said in his veto message.

Lieu fired a testy Twitter message or two at Brown last month after the governor vetoed the first budget passed by Democratic lawmakers. But Lieu said this afternoon that he didn't think the veto was in retribution.

"It does appear to me that Jerry Brown is looking at each bill on its merits and then making his decision," he said.

PHOTO CREDIT: *Artificial turf at Granite Park, January 22, 2007. Florence Low / Sacramento Bee file photo*

Categories: Bills (2011-2012 session) , Gov. Jerry Brown

Posted by **David Siders**
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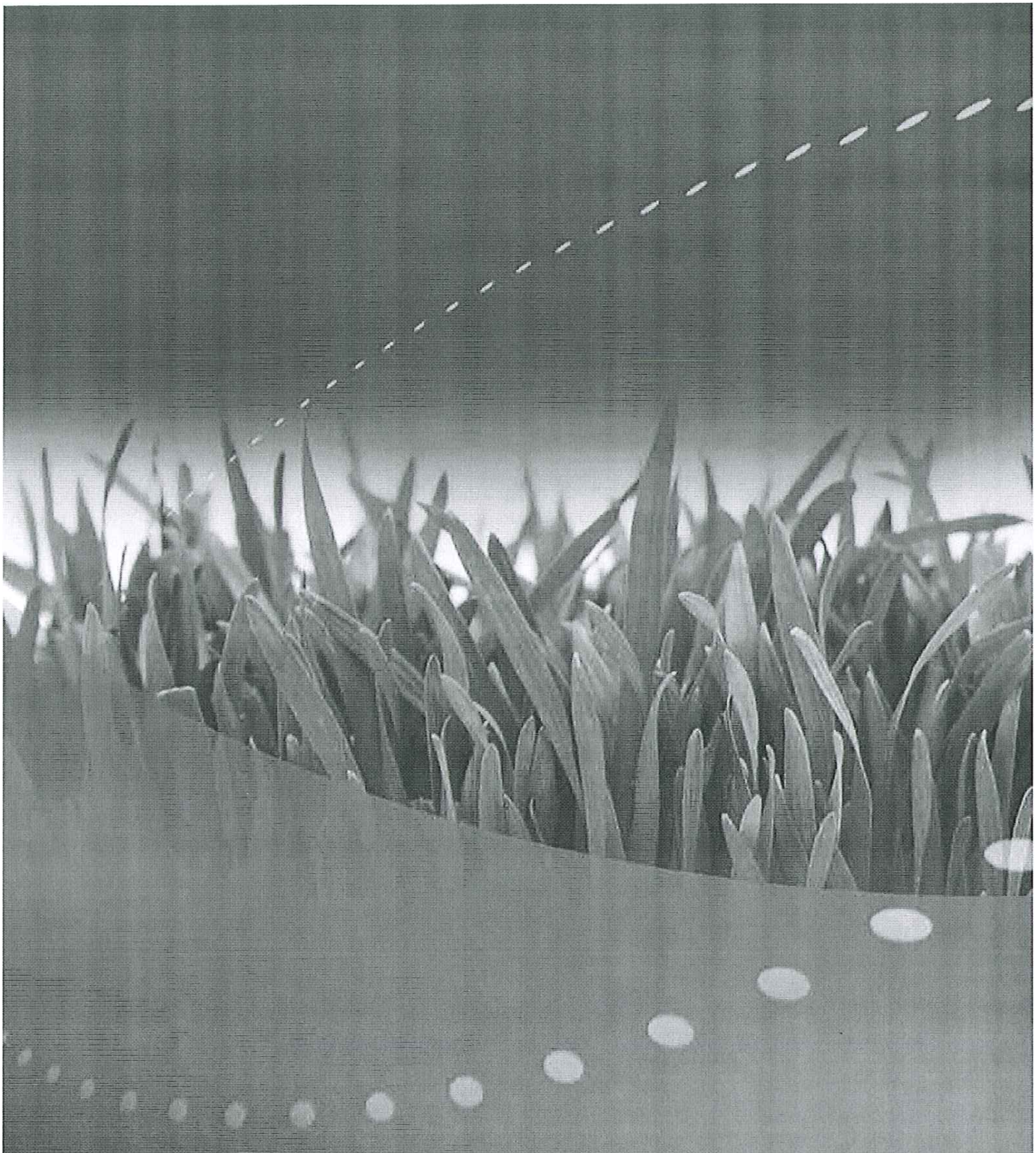
Synthetic Turf 360°

A Guide for Today's Synthetic Turf



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2011

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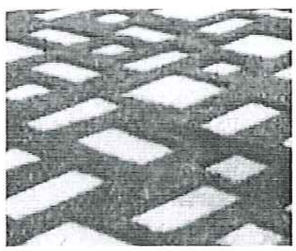


Why Synthetic Turf?

There are many reasons why synthetic turf has become so popular.

A heightened sense of environmental awareness prompts interest in its ability to conserve billions of gallons of water each year. Increased user requirements and intense competition have given rise to a new generation of synthetic turf systems that replicate the look and playability of natural, lush grass.

Athletes enjoy significantly more playing time without the need for resource-intensive maintenance. Homeowners, businesses, parks, municipalities and government entities use synthetic grass as an attractive landscape solution that saves time, money and water.

The Synthetic Turf Council (STC) created this guide to showcase the numerous uses and benefits of synthetic turf. It features information about athletic fields and the growing landscape and recreation category, which includes parks, playgrounds, homes, businesses, golf courses and more.

If you would like to learn more, we invite you to visit www.syntheticturfcouncil.org.
Thanks for your interest in synthetic turf!

Athletic Fields

Popular, versatile solution

At the beginning of 2011, more than 6,000 synthetic turf fields were being used in North America by a growing number of high school and collegiate athletes playing and practicing football, soccer, hockey, baseball, rugby, lacrosse and many other sports.

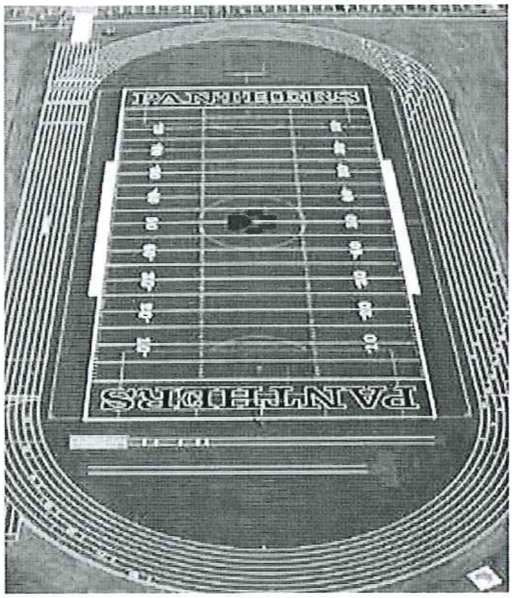
About half of all NFL teams currently play their games on synthetic turf and, since 2003, over 70 FIFA U-17 and U-20 World Cup matches have been played on synthetic turf soccer fields.

STC

Significant environmental benefits

Depending on the region of the country, one full-size synthetic turf sports field saves 500,000 to 1,000,000 gallons of water each year. During 2010, between 3 billion and 6 billion gallons of water were conserved through its use. According to the EPA, the average American family of four uses 400 gallons of water a day.[1] Therefore, a savings of 3 billion to 6 billion gallons of water equates to the annual water usage of over 20,000 to 40,000 average American families of four.

For a multi-use field in Texas, where there is little rain, the water savings is much greater. School officials with the El Paso Independent School District stated that their 10 new synthetic turf sports fields will save more than 80 million gallons of water every year, or 8 million gallons of water per field.



The estimated amount of synthetic turf currently installed has eliminated the need for nearly a billion pounds of harmful pesticides and fertilizers, which has significant health and environmental implications.

Example:

In a July 7, 2007, article entitled "Grass Warfare," the Wall Street Journal states, "The pesticides used in lawn-care products found on shelves nationwide are considered legal by government standards. But broader research on health risks from such chemicals has prompted general warnings. The EPA, which regulates pesticide use, notes on its own website that kids are at greater peril from pesticides because their internal organs and immune systems are developing." [2]

According to the North Carolina Department of Environment and Natural Resources polluted storm water run-off is the No. 1 cause of water pollution in their state, with common examples including over-fertilizing lawns and excessive pesticide use.[3]

The EPA has identified run-off of toxic pesticides and fertilizers as a principal cause of water pollution. According to that federal agency, approximately 375,000 acres of lakes, 1,900 miles of rivers and streams and 550 square miles of estuaries in Florida are known to be impaired by nutrient pollution, a primary source of which is excess fertilizer.[4]

[1] WaterSense, an EPA publication, www.epa.gov/watersense/pubs/indoor.html
[2] Gwendolyn Bounds, "Grass Warfare" (Wall Street Journal, July 7, 2007)
[3] Stormwater FAQs (North Carolina Department of Environment and Natural Resources website)
[4] Public Q&A Index – Florida (EPA website)

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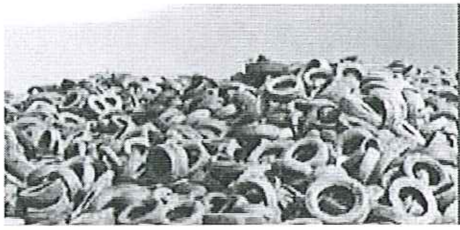


Most of the 6,000-plus synthetic turf sports fields in use today use crumb rubber infill recycled from used tires, keeping more than 105 million tires out of landfills.

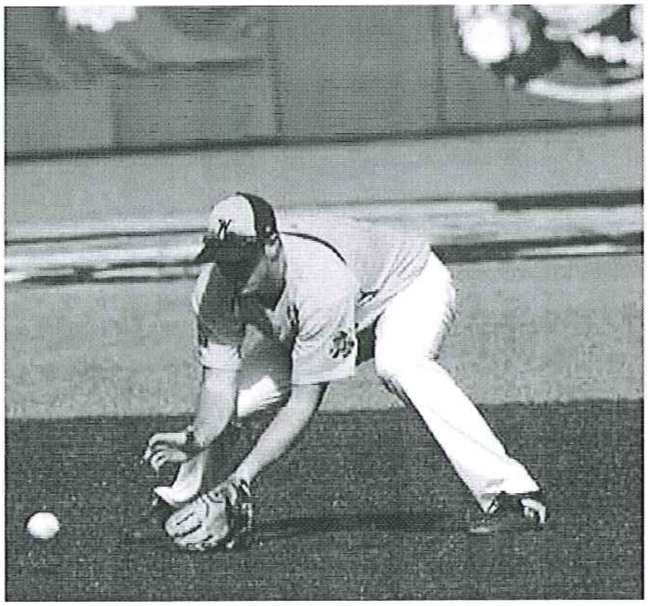
Synthetic turf helps reduce noxious emissions.

According to the EPA, "lawn mowers emit high levels of carbon monoxide, a poisonous gas, as well as hydrocarbons and nitrogen oxides that contribute to the formation of ground level ozone, a noxious pollutant that impairs lung function, inhibits plant growth and is a key ingredient of smog."[5] The EPA also reports that a push mower emits as much pollution in one hour as 11 cars and a riding mower emits as much as 34 cars.[6]

In 2010, a BASF Corporation Eco-Efficiency Analysis, which compared synthetic turf athletic fields with professionally installed and maintained grass alternatives, concluded that synthetic turf can lower consumption of energy and raw materials and generation of solid waste depending on field usage. BASF also found that the average life-cycle costs over 20 years of a natural grass field are 15 percent higher than the synthetic turf alternatives.

A synthetic turf company and STC member has forged a recycling partnership with Yellowstone National Park to divert nearly 300 million plastic bottles from landfills each year. The plastic bottles will be recycled into select synthetic turf products and backing for carpet.

Using synthetic turf can help environmentally conscious builders and specifiers with LEED® (Leadership in Energy and Environmental Design) project certification from the U.S. Green Building Council in the areas of Water Efficient Landscaping, Recycled Content, Rapidly Renewable Material and Innovation in Design.



"With synthetic turf, we use a lot less water. It used to be 3 million gallons of water each year with regular grass and now we probably use a tenth of that amount."

— Bob Sube, Director of Facilities and Construction, Fillmore Unified School District, California

[5] Your Yard and Clean Air, EPA Office of Mobile Sources. (Fact Sheet OMS-19, May 1996)
[6] Small Engine Rule to Bring Big Emissions Cuts. (EPA News Release, April 17, 2007)

Increased playing time and safety

Synthetic turf can be utilized around 3,000 hours per year with no "rest" required, more than three times that of natural grass. This creates increased practice and play time as well as the valuable flexibility to use your field for other events. The opportunity to be active and participate in sports is critical for the fitness, mental health, self-esteem and leadership development of youth.

It is a smart solution for playing fields that have become unsafe from overuse or severe climatic conditions. A grass field simply cannot remain lush and resilient if it is used more than three to four days a week, in the rain, or during months when grass doesn't grow. Rain-outs are eliminated since highly permeable synthetic turf quickly drains excess water off the field.

Made with resilient materials for safety, synthetic turf sports fields provide a uniform and consistent playing surface.

Traction, rotation and slip resistance, surface abrasion and stability meet the rigorous requirements of the most respected sports leagues and federations. Some of the published studies of the comparative safety of synthetic turf include:

- A 2004 NCAA study among schools nationwide comparing injury rates between natural and synthetic turf; the injury rate during practice was 4.4% on natural turf, and 3.5% on synthetic turf.
- An analysis by FIFA's Medical Assessment and Research Centre of the incidence and severity of injuries sustained on grass and synthetic turf during two FIFA U-17 World Championships. According to FIFA, "The research showed that there was very little difference in the incidence, nature and causes of injuries observed during games played on artificial turf compared with those played on grass."[7]
- Three 2010 long-term studies published by researchers from Norway and Sweden comparing acute injuries on synthetic turf and grass. The studies examined the type, location and severity of injuries sustained by hundreds of players during thousands of hours of matches and training over a four-to-five-year period. Many types of acute injuries to men and women soccer players, particularly knee injury, ankle sprain, muscle strains, concussions, MCL tears and fractures were evaluated. The researchers concluded that the injury risk of playing on artificial turf is no greater than playing on natural grass.[8]

These studies and many more, including the FIFA comparative results of its exhaustive research, are posted on the Synthetic Turf Council's website under Research & Latest Thinking.

[7] "Very Positive Medical Research on Artificial Turf" (Turf Roots Magazine 01, pp. 8-10, FIFA)

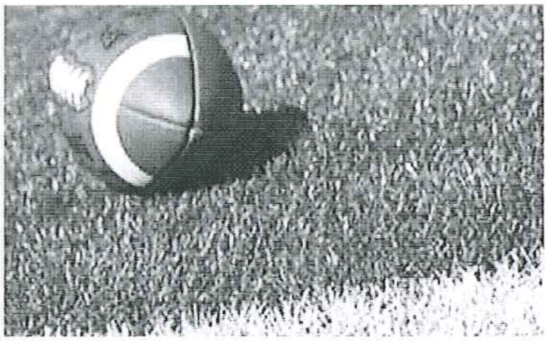
[8] Bjorneboe J, Bahr R, Andersen TE (2010) Risk of injury on third generation artificial turf in Norwegian professional football. British Journal of Sports Medicine 44: 794-798.

Ekstrand J, Hagglund M, Fuller CW (2010) Comparison of injuries sustained on artificial turf and grass by male and female elite football players. Scandinavian Journal of Medicine and Science in Sports. DOI: 10.1111/j.1600-0838.2010.01118.x

Soligard T, Bahr R, Andersen TE (2010) Injury risk on artificial turf and grass in youth tournament football. Scandinavian Journal of Medicine and Science in Sports. DOI: 10.1111/j.1600-0838.2010.01174.x

Cost-effectiveness

According to Cory Jenner, a landscape architecture professional in Syracuse, N.Y., the cost of installing and maintaining a synthetic turf sports field over a 20-year period (including one replacement field) is over three times less expensive per event than the cost of a grass field over the same period of time. This is because many more events can be held on a synthetic turf sports field. This cost-per-event advantage is validated by other authorities and field owners.



Because synthetic turf can withstand so much wear and tear, many schools rent their fields to local sports teams and organizations to bring in extra funding. At Cincinnati's Turpin High School, the field is rented 80 percent of the evenings between January and October — raising $40,000/year for the last two years from rental fees.

"The synthetic field completely revolutionized our sports program. We now have a multi-dimensional facility with activities scheduled year-round, nearly around the clock. Along with football, Newman Field now hosts an incredible range of activities — intramural sports, lacrosse sports, lacrosse playoffs, soccer leagues, local high school events, such as sports camps, cheerleading competitions and much more."

— Rob Coleman, Athletic Director, Whittier College, California

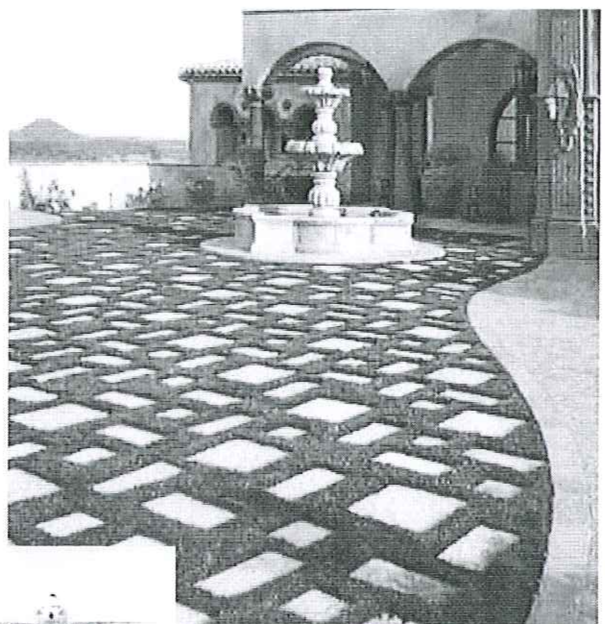
Landscape and Recreation

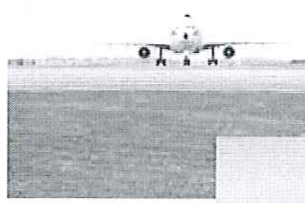
Various applications

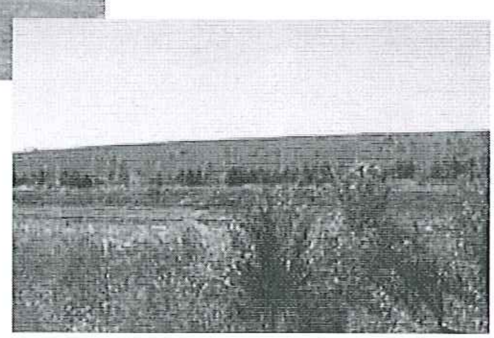
Beautifully landscaped synthetic turf can often be installed in places where grass can't grow or be effectively maintained.

Applications include:

- Airport grounds
- Businesses/commercial developments
- Golf courses
- Highway medians
- Homes/residential communities
- Municipalities
- Parklands
- Pet parks
- Playgrounds
- Rooftops
- Tennis courts
- Closed landfills







Closed Landfill

Eco-friendly solution

From Disneyland and the Wynn Hotel to the Twentynine Palms Marine Corps Base and your neighbor's yard, thousands of homes, businesses, golf courses and public spaces have turned to synthetic grass to provide a lush, attractive landscape solution that requires minimal resources and maintenance.

Water conservation is a necessity. In March 2011, Wharton published a report about the growing scarcity of water. It references a prediction by the 2030 Water Resources Group that by 2030 global water requirements will be "a full 40 percent above the current accessible, reliable supply." Further, less than 3 percent of all available water is fresh and drinkable. Underground aquifers hold almost all the potable water available in liquid form, and their rate of depletion more than doubled between 1960 and 2000.[9] Yet, the EPA states that nationwide landscape irrigation is estimated to account for almost one-third of all residential water use, totaling more than 7 billion gallons per day.[10]

Synthetic turf promotes greater utilization of land, as you can do more with the same space surfaced with synthetic turf than with natural grass. Rooftops once deemed unusable for high-rises and residential buildings can now feature inviting green areas. Hotels that had to restrict the use of the lawns for parties and events can now schedule as many functions as they can book.

The Southern Nevada Water Authority estimates that every square foot of natural grass replaced saves 55 gallons of water per year.[11] If an average lawn is 1,800 square feet, then Las Vegas homeowners with synthetic turf could save 99,000 gallons of water each year or about $400 annually. In Atlanta, homeowners could save $715 a year, not including much higher sewer charges.

In its report, "Municipal Solid Waste in the United States, 2009 Facts and Figures," the EPA estimates that 33.2 million tons of yard trimmings were generated in 2009, the third largest component of Municipal Solid Waste in landfills.[12] As yard trimmings decompose, they generate methane gas, an explosive greenhouse gas and acidic leachate.[13]

A June 2008 National Public Radio report called "Water-Thirsty Golf Courses Need to Go Green" reported "Audubon International estimates that the average American golf course uses 312,000 gallons of water per day. In a place like Palm Springs, where 57 golf courses challenge the desert, each course eats up a million gallons a day. That is, each course each day in Palm Springs consumes as much water as an American family of four uses in four years."[14]

Impermeable synthetic turf is being used as an economical and environmentally effective solution for the closure of landfills, mine spoils and hazardous sites. Among the many reasons: it provides a perennially green landscape cover; dramatically reduces construction and long-term maintenance costs; improves stability; prevents erosion; controls gas and odor; and reduces leachate.

"The inclusion of synthetic grass in our landscape has proven to be a smart choice for the resort and Mother Earth. Since the conversion, we are able to accommodate increased capacity and utilize a greater percentage of grassy areas, while providing an enhanced event experience, without damaging the grass. This year, there will be 8 million gallons of water conserved and our new synthetic lawn allows us to eliminate the use of fertilizers, pesticides and herbicides on ground in close proximity to the beach."

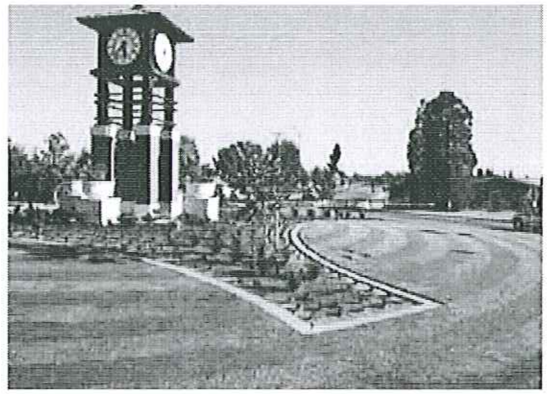
— Rodrigo A. Carrillo, Project Manager, Fontainebleau Hotel, Miami Beach, Fla.

[9] "Valuing Water: How Can Businesses Manage the Coming Scarcity?" (Wharton School of the University of Pennsylvania, March 2011)
[10] Outdoor Water Use in the United States, (EPA 832-F-06-005, August 2008)
[11] Water Smart Landscapes Rebate (Southern Nevada Water Authority website)
[12] "Municipal Solid Waste in the United States, 2009 Facts and Figures," (EPA Office of Solid Waste, EPA530-R-10-012, December 2010)
[13] Frequent Questions about Yard Trimmings, (EPA website, December 2010)
[14] Frank Deford, "Water-Thirsty Golf Courses Need to Go Green," (National Public Radio, June 11, 2008)

Saves money

A growing number of tax credits and rebates are available since synthetic turf conserves water. For example, the Central Basin Municipal Water District in California reports that Golden State Water Company customers replacing their irrigated areas with synthetic turf can save $1 per square foot, up to a $1,000 rebate.

Many public spaces, from government grounds and highway medians to airport entrances, are turning to synthetic grass for appealing, water-saving landscape solutions that reduce operating and maintenance expenditures.



Rooftop Garden

Promotes accessibility

Play areas are among the public spaces covered by the Americans with Disabilities Act. The 2010 Standards for Accessible Design (Sections 240, 1008) addresses play areas designed, constructed and altered for children ages 2 and over in a variety of settings, including parks, schools, childcare facilities, shopping centers and public gathering areas. According to the standards, "the surfaces that are universally accessible and go beyond ADA to be actually usable for children with disabilities include artificial grass with rubber underneath. The benefit of these surfaces besides the accessibility is the maintenance. You do not need to do daily maintenance to ensure that safety is maintained."[15]

Making recreation for the disabled as inclusive as possible is a growing priority. "Inclusive recreation is one of the fastest growing needs in more and more parks and recreation agencies across the United States," said Elizabeth Kessler, 2009-2010 National Recreation and Park Association president, during the 11th annual National Institute on Recreation Inclusion conference in November 2010.

Synthetic turf creates more recreation opportunities for people with disabilities and physical challenges. Wheelchairs roll easily and crutches won't sink into park and landscape surfaces, like those used by the Miracle League nationwide to help youth with physical disabilities play baseball.

Many retirement communities use extensive amounts of synthetic turf for landscaping to assist residents with mobility challenges. People using wheelchairs, canes or walkers can easily move across the turf. Because they are easy to maintain, synthetic turf surfaces also offer seniors the beauty of a decorative lawn without the expense, labor and time of weekly yard work during much of the year.

"Our new artificial lawn helps keep the dogs and the facility clean and the yard will be better for people in wheelchairs to use when practicing with their dogs. We are so thankful to have this big improvement."

— Mo Maurer, founder and owner of Hawaii Canines for Independence

[15] Fact Sheet: Adoption of the 2010 Standards for Accessible Design (ADA website)

Promotes safety and security

Local communities need accessible, versatile play surfaces for its youth and people of all ages. Parks and playgrounds that use synthetic turf allow kids to be active year-round on safe and resilient sports surfaces.

With synthetic turf, kids and parents don't have to worry about mildew and bacteria from wet mulch, allergies associated with natural grasses or other potential health irritants.

Owners of second homes that landscape with synthetic turf don't need a lawn maintenance crew that may be tempted by a vacant home.

"In 2009 the City of Lakeland opened Common Ground, our first inclusive playground featuring unique play experiences for children of varying physical and cognitive abilities. We utilized synthetic turf to cover over 25,000 square feet of play zones to connect our barrier free play elements. The surface creates the natural looking green environment so critical to our design, provides barrier free safety fall zones that protect our children, drains almost instantly even after a tropical torrential rain and it remains cooler than other safety surface options. Maximizing our children's outdoor play time, Common Ground is a community dream come true."

— Pam Page, Assistant Director of Parks & Recreation, City of Lakeland Parks & Recreation Department, Lakeland, Fla.

Common Ground Park, Lakeland, Florida

Community and lifestyle enhancement

By making continuous and safe play possible, synthetic turf promotes a healthy lifestyle, which enhances community well-being. It also helps increase childhood fitness, an important objective of the "Let's Move!" program championed by First Lady Michelle Obama, and the NFL's "Play 60" campaign.

Synthetic grass creates low-maintenance, pet-friendly lawns that keep man's best friend safe and healthy while controlling odors.

Homeowners remove the headaches of ongoing lawn care, adding more leisure time back into their already busy lives.

Synthetic turf can come in many colors, like the orange, blue and yellow grass at the Sunflower Preschool Playground at Barnett Family Park in Lakeland, Florida.

Pixie Hollow Fairy Garden, 2011 Epcot International Flower and Garden Festival, Disney World, Orlando, Florida

Ready to get started with synthetic turf?
Visit our Online Buyers Guide and Member Directory at www.syntheticturfcouncil.org.

www.SyntheticTurfCouncil.org

www.syntheticturfcouncil.org

>*HEALTHY NEIGHBORHOODS*

GOING THE EXTRA YARD

introduction by ***jennifer bogo***

Barbecues and picnics, freeze tag and laughter. The yard is a place where neighbors gather, kids play, and pets frolic. It's where you go to read on a warm afternoon, or catch fireflies in the cool of the evening. The first piece of nature as you walk out your door. Or is it?

Yards have long been considered places where wilderness is not so much cultivated as tamed. Places of gadgets and gizmos--sprinklers, sprayers, seeders, shears. With Japanese beetles to be fought and dandelions to stifle, products like Weed-a-Bomb and the Flame Gun soon filled out the arsenal. Pre-made lawns could be bought and unfurled like sheets on a bed of suburbia, and mowed without even having to set foot on the ground.

Advertisements whetted Americans' appetites for golf-course-like greens. Scotts Weedfree Seed and Turf Builder in 1944 promised a "carpet of sparkling green turf [that] will be the pride of the family and the envy of the neighborhood." In 1959 the Porter-Cable Machine Company encouraged buyers to hop on its Yard Master mower and "watch the crowds gather." To many, lawns represented status that could be sowed. Today they cover more U.S. land--25 million acres--than any single crop.

"They have proven to be a very expensive ecologic and economic symbol," points out Bret Rappaport, the director of Wild Ones, a nonprofit organization that encourages landscaping with native plants as an alternative to the vast swaths of monoculture widespread today. "An exotic landscape requires life support," he says. "One has to alter the environment for it to survive. And life support isn't cheap--it requires pesticides, fertilizers, and water." In fact, a typical U.S. lawn, one-third of an acre in size, receives as much as 10 pounds of pesticides, 20 pounds of fertilizer, and 170,000 gallons of water annually. What's more, in a year a homeowner could spend the equivalent of a 40-hour workweek simply mowing that lawn (producing pollution equal to that created by driving a car 14,000 miles) and hundreds of dollars caring for it.

Natural landscaping, on the other hand, harmonizes a yard's plant life with the greater ecological community--the species already adapted to the local climate--while eliminating the need for costly maintenance. Whereas nitrogen and phosphorous fertilizers, along with chemical herbicides and pesticides, easily run off conventional lawns and into water sources, the varying root lengths of native plants actually reduce this "non-point-source pollution" by anchoring soil and absorbing water. Natives also attract a variety of local wildlife and provide respite for millions of migrating birds

What You Can Do

If you'd like a copy of the "Audubon Guide for a Healthy Yard and Beyond," or if you have a natural landscaping story to share, send an e-mail to Audubon At Home.

For information about landscaping with natives, contact Wild Ones, which was started in 1980 and now educates its 3,000 members through 40 local chapters, a handbook, and a national publication. Call Wild Ones at 877-394-9453.

that, in turn, disperse seeds, pollinate plants, and keep insect populations in check.

"Anybody can do this in their own backyard," says Diana Balmori, coauthor of *Redesigning the American Lawn: A Search for Environmental Harmony.* "It's not rocket science." Start by reducing the amount of lawn itself, she suggests, and replace it with a more diverse plant community. Then layer what you plant, since different heights provide shelter for different insects and birds. Whenever possible, use grasses and plants that are native to your area--and thus adept at growing in boggy, steep, or exposed spots. This vegetation should need no more water than rain and snow provide.

You can feed grassy areas by mixing the seeds with clover, which as it's cut becomes a natural source of nitrogen, or by applying organic fertilizers such as lawn clippings and compost. "All of these things are common sense, and they can be found in the same nursery that's pushing monoculture," Balmori says.

"People want to make a difference at home, in the communities where they live," says Noel Gerson, vice-president of Audubon At Home, a national program that was recently launched to support this transformation. "And they want the information to do that." Like the people profiled here, residents of Tampa, San Antonio, and Seattle don't have to look far to find hands anxious to help them on the path to a healthier yard. Audubon chapters in these cities spread the message of natural landscaping through programs that teach the nuts and bolts of conserving water, cutting down on chemical use, and providing wildlife habitat. While more examples exist, these three prove that conservation can be easy wherever you live, and it can be accomplished one yard at a time.

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tampa, florida, by ***jeff klinkenberg***

WASTING NO WATER

What You Can Do

Floridian Charner Reese (left) uses native species such as Chickasaw plum and muhly grass (below) in place of a water-thirsty grass lawn. Native plants are less energy-intensive while imparting a regional look.

If you're wondering where to buy native plants in the Tampa area, the local

Audu

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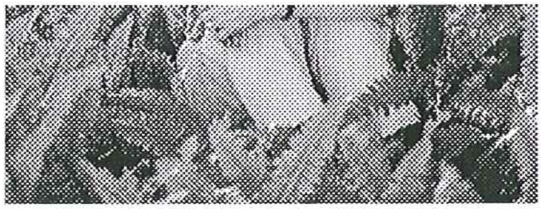

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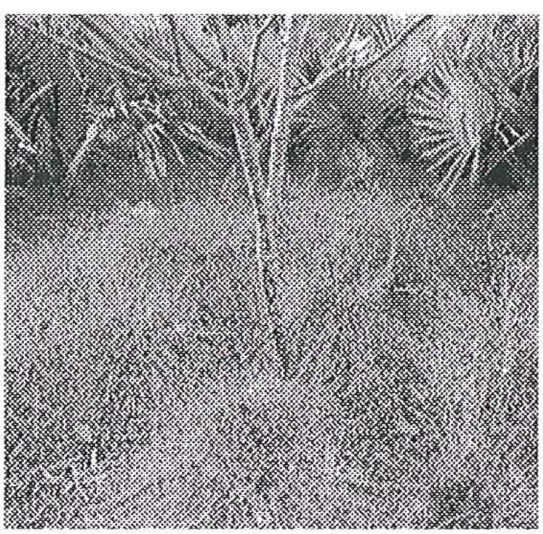
Audubon chapter serves as a clearinghouse of materials for breaking the St. Augustine grass habit. Call Tampa Audubon at 813-983-0258, or e-mail tampa.audubon@verizon.net.

1. "Let's go get rid of some grass," says Charner Reese, grabbing a hoe and marching toward a lawn that should be wilting with fright. Her sacrilege is taking place in a Florida suburb where most folks worship--and water--their lawns. Reese, an environmental planner, and her husband, Tom, an environmental lawyer, are different from their neighbors. During the past decade they have removed their greedy lawn inch by inch and replaced it with native vegetation that's far less thirsty and much kinder to wildlife.

Pines, palmettos, cypresses, Chickasaw plums, and cabbage palms are slowly taking over their Tampa yard. Under the trees is a riot of wildflower pinks, reds, and yellows.

A green tree frog watches near the American beauty berry; a mockingbird sings from the red cedar. Yes, those are flamingos perched beneath the magnolia. They're plastic, of course. The Reeses may dislike traditional landscapes, but they are Floridians, after all.

And like most Floridians, they know how to push a lawn mower. They are simply loath to do it. "My vision for my yard is not to have any lawn at all," says Charner, who moved to Florida as a child and received a master's degree in botany from the University of Florida in 1979. It's not unfair to call her an earth mother, with her skin brown from the sun and her arms and back strong from toting bags of wood chips. She flinches when she hears her neighbors' leaf blowers.



"When my lawn turns brown I do nothing," she says. "When it rains again it usually turns green. But if it doesn't, I just get rid of it and plant a native." She swings her hoe again and executes a small patch of St. Augustine, the found-in-every-yard grass species known for its appetite for water and pesticides.

Years ago the Reeses would have been declared

© Burke Uzzle

un-American. In fact, Tom Reese once defended a homeowner who defied a landscape ordinance in coastal Florida by refusing to have a real lawn. Tom managed to keep the man from becoming a scofflaw, and the ordinance became extinct. But the dark ages haven't entirely disappeared. In the drought-plagued Tampa region, the average citizen uses 132 gallons of water a day--about half of it in the yard. The Southwest Florida Water Management District now encourages area residents to replace grass with native vegetation, and Tampa's Audubon chapter conducts "healthy habitat" monthly seminars to help homeowners learn how.

"It's like fighting the American Dream," says Ged Caddick, president of Tampa Audubon, who points out that many local communities are still deed-restricted, which means residents are required to maintain that perfect field of green. "But examples like the Reeses," he says, "show that a yard that doesn't require a lot of water or chemicals can look nice, that it can be aesthetically pleasing and easy to maintain."

"It was pretty easy," Charner Reese agrees. First she and Tom made a diagram of their yard. Then they decided what they wanted to plant and headed for a nursery that sells only Florida natives. Although over the years the Reeses have spent about $400 on nearly three dozen plant species, they're sure they have more than paid for their new landscaping with a lower water bill.

"We don't even have a sprinkler," Charner says. She waters only by hand and only after she has put a new plant into the ground. Once a native is established, she says, it usually does fine. Even her grass thrives. Of course, her new variety, muhly grass, is a native. "I found a baby black snake under a patch of it," says Charner, who values snakes so much she even tossed a rubber serpent in a hedge for good luck.

Alas, the workman who arrived to fix an awning must have been startled. He chopped off the rubber snake's head. After the Reeses teach their city to value native landscaping, perhaps they can mount a public relations campaign on behalf of snakes.

Jeff Klinkenberg *is the author of two essay collections on Florida history and culture.*

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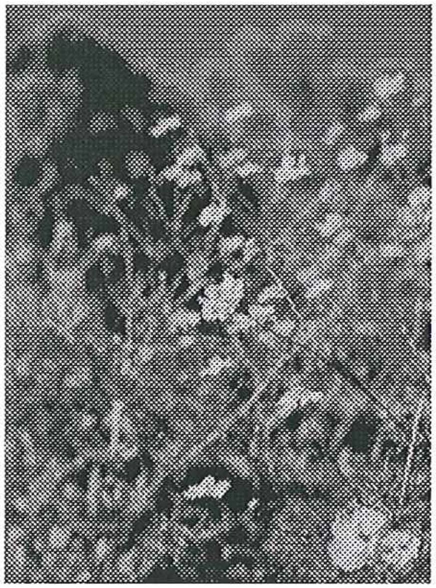
san antonio, texas, by ***kelly bender***

CUTTING OUT CHEMICALS

rocks. In the spring, purple martins swoop and swirl in feeding frenzies. "Dragonflies are everywhere," Marjie says, "and they're so good about eating the mosquitoes."


© Brent Humphreys

Marjie is convinced that none of this would be possible if she and her husband used harsh chemical pesticides. "Hummingbirds need the little mites they find in flowers," she says, "and songbirds have to have insect protein when they feed their nestlings in the summer." All native insects, from the lovely butterflies to the lowly aphids, are subject to natural predators, but Marjie has yet to experience a plague of any particular species. And as for a safer fertilizer? "A little fish emulsion goes a long way," she says, her hazel eyes twinkling.

The Christophers' yard is a place of harmony, where humans work with nature instead of against it. Now neighbors who once scoffed ask for their advice, which Marjie, a member of the Bexar Audubon Society and a

volunteer with the Texas Master Naturalists, is eager to give. "She knows her plants well and has learned quite a bit about environmentally friendly pest control," affirms Patty Leslie Pasztor of Bexar Audubon, who plans to include a stop at the Christopher yard in a spring "wildscaping" workshop the chapter is staging. "Marjie is really willing to share her garden and knowledge with others."

That becomes obvious with one look at her landscaping, which spills out onto the utility easement adjacent to the backyard. The area has become a place where neighborhood adults gather to talk and trade plant cuttings and seeds, and where neighborhood children play among the shrubs, grasses, and flowers. Though her own roots are planted firmly in the Texas soil, Marjie looks across her homemade Eden and sighs, "It's like being a million miles away."

Kelly Bender, *a wildlife biologist, recently coauthored a book on gardening for wildlife.*

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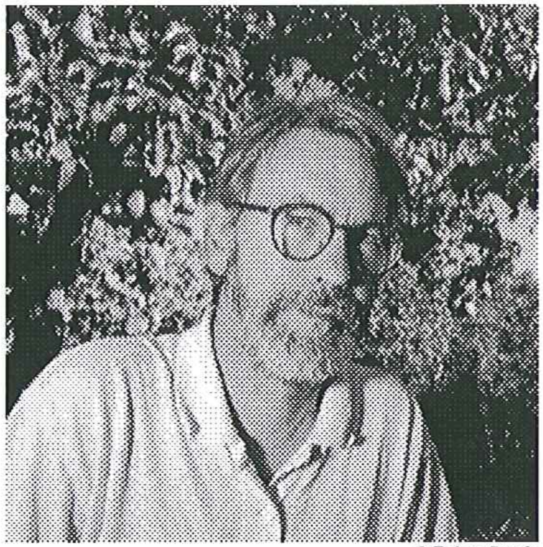
seattle, washington, by ***claire hagen dole***

WOOING THE WILDLIFE

Audubon
3/2002

WOOING THE WILDLIFE



© Brian Smale

3. It's easy to miss Don Norman's driveway, on a quiet street in northern Seattle. It seems to disappear into a lush landscape of cedar, vine maple, and snowberry. Follow it past a tall stand of Pacific wax myrtle, the leafy branches swaying with the movement of seed-gobbling warblers, and you'll come to an opening in the trees, where Norman's modest house sits next to a manmade pond ringed by ferns. Nearby, a downy woodpecker drums against a Douglas fir snag that is riddled with ragged holes--the nesting sites of northern flickers and chickadees.

Standing quietly in the clearing, Norman slips binoculars over an unruly thatch of brown hair. He is watching a golden-crowned sparrow peck at leaf litter. As a wildlife toxicologist who bands and studies migratory birds, he has seen this individual before. "This bird is trap-happy," he says. "I've caught and examined it several times in the past week, and it's definitely gaining weight for winter."

Other bird sightings on his half-acre lot practically leap off the pages of his carefully kept notebook: a ruby-crowned kinglet that spent the winter, three fox sparrows that made their debut this year. Then there was the Costa's hummingbird--the second ever sighted in Washington--that found the yellow blooms on Norman's broccoli so appealing that it stayed for two weeks, attracting a steady stream of local birders. More than 70 species of birds have landed in his yard since he began his tally in 1980.

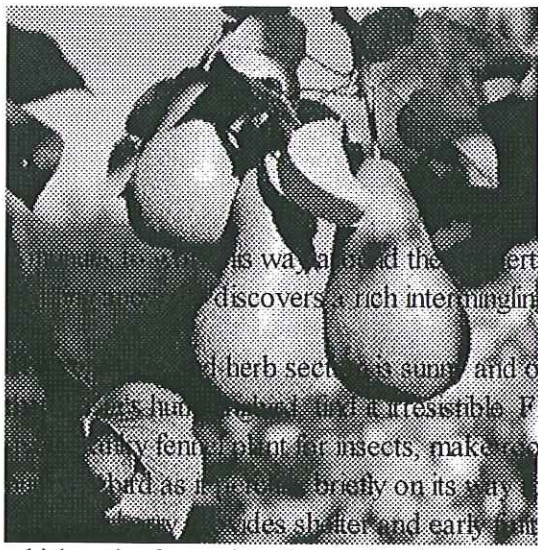
Norman, a member of the Seattle Audubon Society's conservation committee, opens up his yard to other visitors, too--anyone who is interested in the chapter's Gardening for Life program and wants to see the concept in action. "Don accepts that it takes time to transform a yard into real habitat," says Lauren Braden, program director. "It's easy to get overwhelmed by the idea, but there are very simple things that will make a yard more friendly and healthy to wildlife."

"The part of Gardening for Life that really hit home with me was the idea of leaving things alone--not cleaning up in fall, not trying to have a perfect

What You Can Do

Don Norman (left) has watched many a contented waxwing feast on the native serviceberry along the back of his garden. The Bosc pear tree (below), which Norman planted for his own snacking, is a variety adapted to the local climate, so besides being pest-resistant, it rarely loses fruit to a late cold snap.

Just ask Seattle Audubon if you'd like a copy of a booklet full of other regional tips, or if you'd like a Gardening for Life workshop brought to your Seattle neighborhood. Call 206-523-8243, extension 14, or e-mail laurenb@seattleaudubon.org of leaving things alone - not cleaning up in fall, not trying to have a perfect yard," says Norman. He leaves piles of brush and garden clippings for Bewick's wrens to pick over in winter, as well as a swath of uncut grass where towhees can forage undisturbed. The seeds of overwintering mustards are so enthusiastically devoured by finches and siskins that he now plants extra mustard.



Norman didn't always visualize his yard as one seamless wildlife habitat. When he moved in, two decades ago, he was faced by an overgrown tangle of Himalayan blackberry and holly. He planned a landscape of varied uses: an organic vegetable garden with fruit trees and vines, and a wildlife garden of native trees and shrubs. But as he [illegible] his way around the [illegible]erty, removing invasives and [illegible] discovers a rich intermingling of the two gardens.

[illegible] herb sec[illegible] is sunny and open, and many birds, like [illegible] hum[illegible] find it irresistible. Flocks of bushtits, working [illegible] fen[illegible] for insects, make room for an Anna's [illegible]bird as it [illegible] briefly on its way to the porch feeder. A border [illegible]des shelter and early [illegible] for robins and waxwings, which make forays into the garden for insects. Along the garden's perimeter, Norman is planting more native shrubs, such as snowberry and red-flowering currant, to extend the wildlife space. In a recently cleared spot, he extends the food garden by adding raspberry canes.

And if a few of Norman's berries make a meal for a flicker? Given the rewards of habitat gardening, he is more than willing to share.

Claire Hagen Dole *was the publisher of* Butterfly Gardeners' Quarterly *for seven years.*

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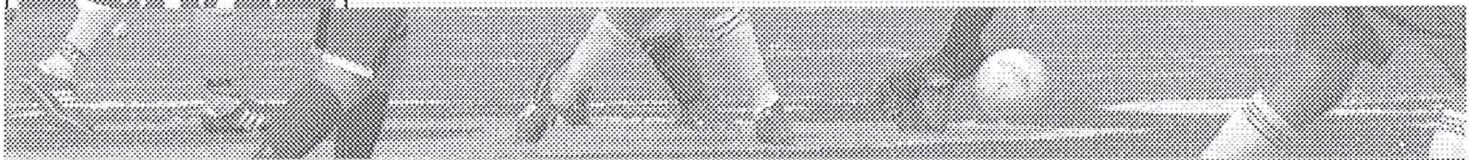
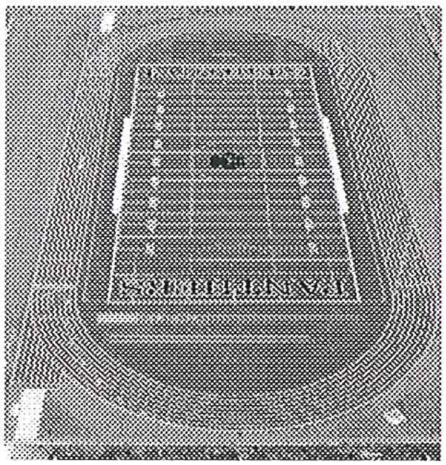
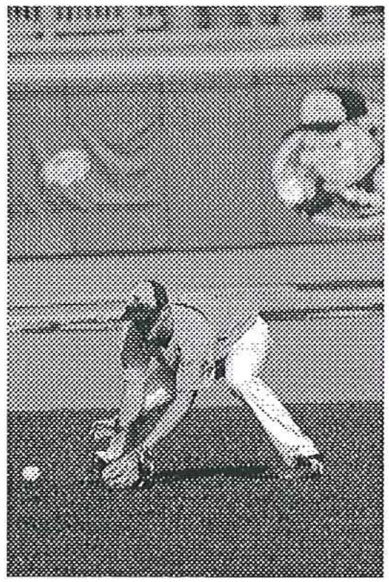


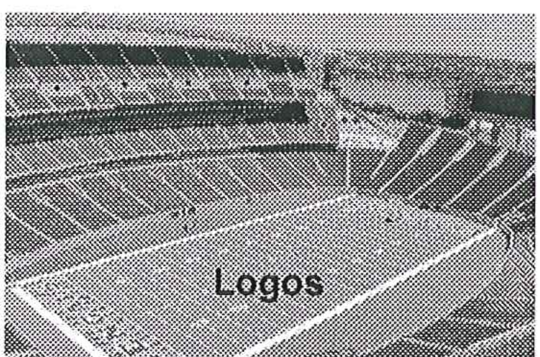
Photos of Synthetic Turf Uses



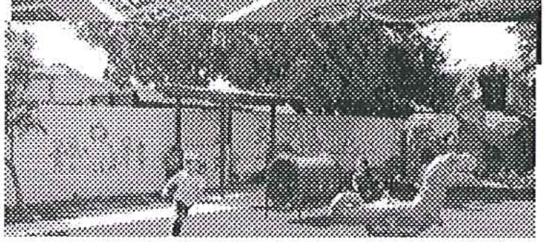
Sports Fields

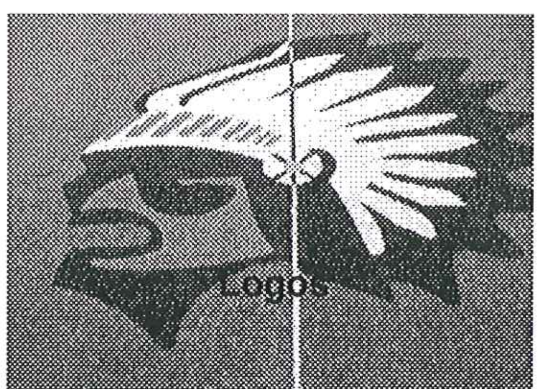


Sports Fields



Logos





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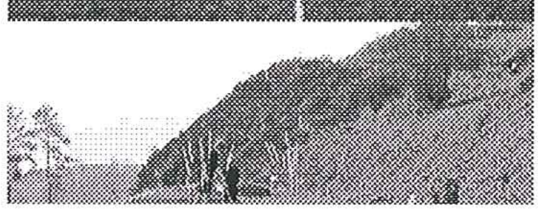

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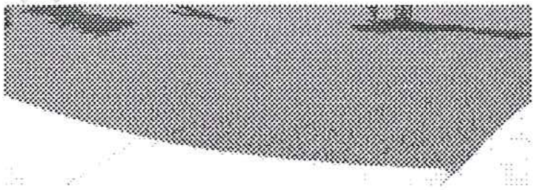
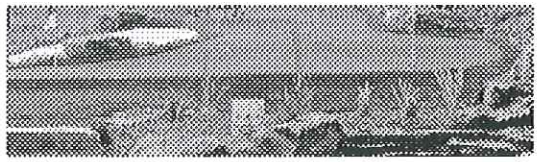
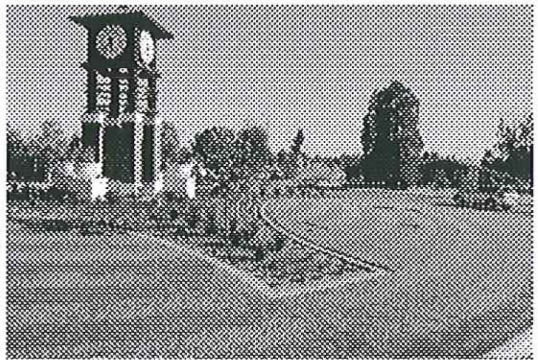


Playgrounds



Golf

Landscape



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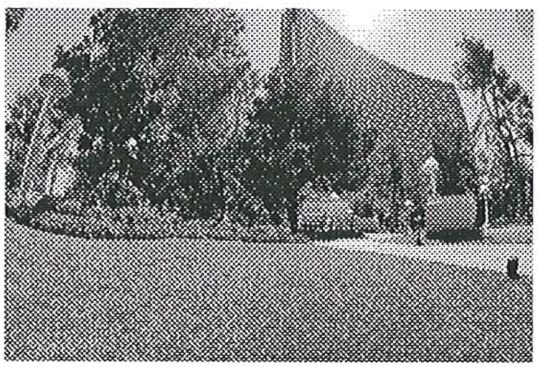

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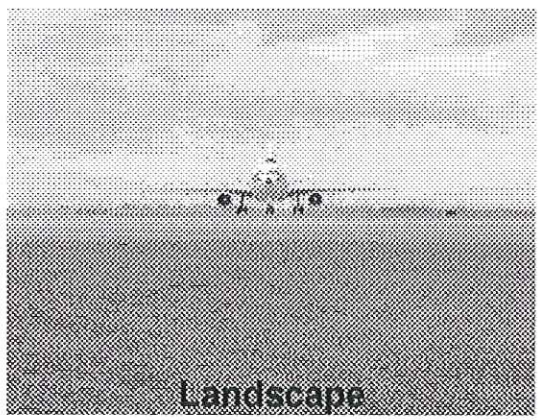

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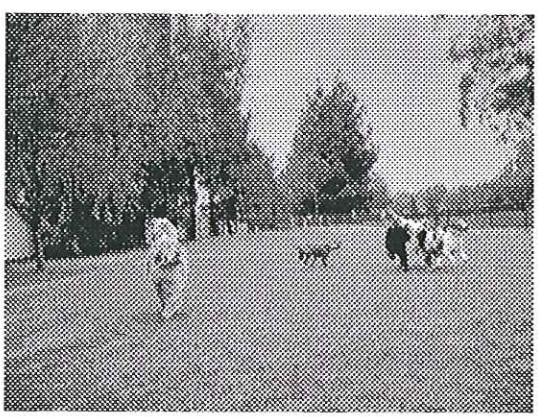
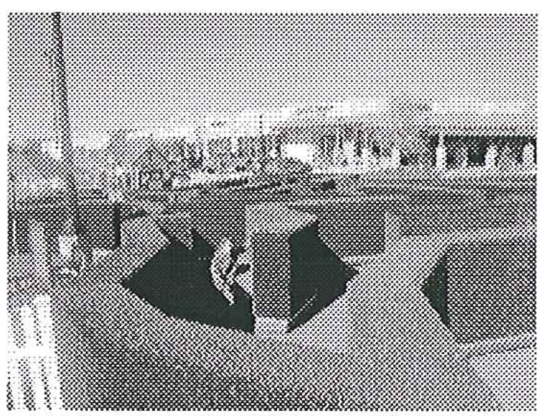


Pet Turf



Community Maze


GrassForever.com


GrassForever.com

Environ Health Perspect. 2008 March; 116(3): A116–A122. PMCID: PMC2265067

Environews
Focus

Synthetic Turf: Health DebateTakes Root

Luz Claudio

In Little League dugouts, community parks, professional athletic organizations, and international soccer leagues, on college campuses and neighborhood playgrounds, even in residential yards, the question being asked is "grass or plastic?" The debate is over synthetic turf, used to blanket lawns, park spaces, and athletic fields where children and adults relax and play; the questions are whether synthetic turf is safe for human and environmental health, and whether its advantages outweigh those of natural grass. Despite or perhaps because of the fact that it is too early to definitively answer those questions, the debate is fierce.

New York City, which buys the largest amount of synthetic turf of any U.S. municipality, held a hearing 13 December 20007 on the use of synthetic turf in city parks. There is a clear need for open space in the city. The 28,700 acres of land constituting some 4,000 parks are distributed unevenly throughout the city. "Many districts have no green parks, not even one," said Helen Sears, a city council member representing the Jackson Heights neighborhood, during the hearing.

New York City Department of Parks & Recreation commissioner Adrian Benepe wants to address the need for parks and athletic fields by installing not only natural grass fields and lawns but also synthetic turf. "With quality recreational facilities—which means, in some cases, synthetic turf fields—we will be able to better confront this issue," he says. In New York City, he points out, at least 35 synthetic turf fields are or will be a replacement for asphalt surfaces.

Others oppose the move toward synthetic turf. "Grassroots organizations have been working hard to have pesticide use reduced or banned in places where it is unnecessary," says Tanya Murphy, a board member of Healthy Child, Healthy World, an advocacy organization. "Now we're going from the frying pan and into the fire when replacing grass with synthetic turf."

The debate leaves many on the fence. Orlando Gil, an assistant research scientist at New York University and soccer coach, is weighing both alternatives: "We want children to play outside, exercise, and play sports, but with pesticides and fertilizers in grass and chemicals in artificial turf, I don't know which to choose."

Indeed, a dearth of research on the nonoccupational human health effects of exposure to the constituents of synthetic turf hampers the ability to make that choice with any degree of confidence. On the basis of limited toxicity data, some reports have concluded the health risks are minimal. Most agree, however, that far more research is needed before the question can be definitively answered. In the 13 December 2007 issue of *Rachel's Democracy and Health News*, William Crain of the City College of New York Psychology Department and Junfeng Zhang of the University of Medicine & Dentistry of New Jersey School of Public Health called conclusions of minimal risk "premature."

A Turf History

During the 1950s, the Ford Foundation studied ways to incorporate physical fitness into the lives of young people, particularly in cities where outdoor play areas were scarce. Ford joined Monsanto Industries to create an artificial surface on which children could play sports. In 1964 the first artificial playing surface was marketed under the name Chemgrass.

Meanwhile, the first domed stadium was being built in Houston, Texas. The Astrodome, with its retractable translucent plastic ceiling, let in enough sunshine to maintain a natural grass field. But after the first baseball season, it was clear there was a problem. The plastic panes produced a glare that made it difficult for players to see the ball. This problem was solved by painting the panes black—but then the grass began to die from lack of sunlight. By the beginning of the second season, the Astros were playing on dead grass and painted dirt. At this time, production of Chemgrass was limited, but what little was available was installed in the Astrodome. By the end of the 1966 season, the material had been renamed AstroTurf. The green nylon carpet was a success.

The popularity of AstroTurf grew steadily during the 1970s and 1980s, with most of its use in professional sports arenas. However, a backlash began to unfold when players started to complain about the surfacing. The English Football Association banned synthetic turf in 1988, mainly because of complaints from athletes that it was harder than grass and caused more injuries. Similar concerns were growing in the United States. A poll conducted by the National Football League Players Association in 1995 showed that more than 93% of players believed playing on artificial surfaces increased their chances of injury. This sentiment was famously expressed by baseball player Dick Allen: "If a horse won't eat it, I don't want to play on it."

The movement against AstroTurf gained traction, and many ballparks were converted to natural grass during the 1990s. One example was Giants Stadium in New Jersey, which had used AstroTurf since its construction in 1976. The stadium was refitted with a system of 6,000 removable trays of natural grass. Even the new stadium in Houston, built to replace the original Astrodome, was surfaced with grass.

In this story of grass, the balance is tilting once more against the natural kind. Natural grass, under some circumstances, cannot consistently withstand the demands of sports where a lot of running is involved. Parallel to this back-and-forth controversy over which is best have come new developments in the manufacture of synthetic turf. Several companies, including the makers of the original AstroTurf, have come on the market with new playing surfaces.

FieldTurf, for example, is made of a blended polyethylene–polypropylene material woven to simulate blades of grass. The "grass" is held upright and given some cushioning by adding a layer of infill made of recycled tires, rubber particles 3 mm in diameter or smaller. This crumb rubber infill is sometimes mixed with silica sand. Many stadiums that switched to grass from AstroTurf have since switched back to FieldTurf-style synthetic turf.

Figures from the Synthetic Turf Council, a trade organization based in Atlanta, show that 10 years ago there were 7 new-generation fields installed in the United States. Today there are 3,500. Says Geoffrey Croft, president of the nonprofit New York City Parks Advocates, which promotes public funding and increased park services, "There are millions of square feet of synthetic turf already installed on fields around the country, and not one environmental impact statement has been issued."

Human Health Questions

Given the relatively recent development of new-generation synthetic turf, there are unanswered questions regarding its potential effects on health and the environment, with the rubber infill one of the main sources of concern. The crumbs become airborne and can be breathed in and tracked into homes on clothes and athletic gear. There are also questions about dermal and ingestional exposures, and about ecosystem effects.

For athletes, the little black rubber pellets may seem little more than a nuisance. Others express more concern, especially when it comes to children's exposure to the infill. Patti Wood, executive director of the nonprofit Grassroots Environmental Education, argues, "This crumb rubber is a material that cannot be legally disposed of in landfills or ocean-dumped because of its toxicity. Why on earth should we let our children play on it?"

Recycled crumb rubber contains a number of chemicals that are known or suspected to cause health effects. The most common types of synthetic rubber used in tires are composed of ethylene–propylene and styrene–butadiene combined with vulcanizing agents, fillers, plasticizers, and antioxidants in different quantities, depending on the manufacturer. Tire rubber also contains polyaromatic hydrocarbons (PAHs), phthalates, and volatile organic compounds (VOCs).

According to the Rubber Manufacturers Association, only 8 states have no restrictions on placing tires in landfills. Most of these restrictions have to do with preventing pest problems and tire fires, which release toxicants such as arsenic, cadmium, lead, nickel, PAHs, and VOCs.

Some studies suggest that the same chemicals that can be released profusely during a tire fire may also be released slowly during deterioration of crumb rubber. For instance, researchers at the Norwegian Institute of Public Health presented a report at the 2006 meeting of the International Association for Sports Surface Sciences on turf-related chemicals in indoor stadiums. The report, *Artificial Turf Pitches: An Assessment of the Health Risks for Football Players*, showed that VOCs from rubber infill can be aerosolized into respirable form during sports play. The authors calculated health risk assuming the use of recycled rubber granulate, which releases the lowest amounts of these chemicals of any type of rubber infill.

The report concluded that, given current knowledge, the use of synthetic turf indoors does not cause any elevated health risk, even in vulnerable populations such as children. However, the report continues, "It should also be noted that little or no toxicological information is available for many of the volatile organic compounds which have been demonstrated as being present in the air in the [indoor stadiums]. . . . [Furthermore], not all organic compounds in the [stadium] air have been identified." In particular the report called for more information regarding the development of asthma and airway allergies in response to exposure to the latex in many tires.

Similarly, the California Office of Environmental Health Hazard Assessment (OEHHA), in the January 2007 report *Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products*, concluded that 49 chemicals could be released from tire crumbs. Based on an experiment simulating gastric digestion, the OEHHA calculated a cancer risk of 1.2 in 10 million assuming a one-time ingestion over a lifetime—well below the 1 in 1 million *di minimis* risk threshold. In a hand-wipe experiment, the OEHHA calculated an increased cancer risk of 2.9 in 1 million for ingestion of chrysene (a suspected human carcinogen found in tire rubber) via hand-to-mouth contact with crumb rubber infill. This estimate assumed regular playground use for the first 12 years of life and was termed by the authors to be "slightly higher" than the *di minimis* level.

In the summer of 2007, Environment and Human Health, Inc. (EHHI), a nonprofit organization headquartered in North Haven, Connecticut, commissioned a study from the Connecticut Agricultural Experiment Station to determine whether toxic compounds from crumb rubber could be released into air or water. The report *Artificial Turf* describes identifying 25 chemical species with 72–99% certainty using mass spectrometry–gas chromatography. Among those definitively confirmed were the irritants benzothiazole and *n*-hexadecane; butylated hydroxyanisole, a carcinogen and suspected endocrine disruptor; and 4-(*t*-octyl) phenol, a corrosive that can be injurious to mucous membranes.

The Synthetic Turf Council said in a statement issued on 13 December 2007 that "Claims of toxicity [in the EHHI report] are based on extreme laboratory testing such as the use of solvents and high temperatures to generate pollutants." But the EHHI stands by its studies. *Artifical Turf* author David Brown, EHHI's director of public health toxicology, says, "It is clear the recycled rubber crumbs are not inert, nor is a high temperature or severe solvent extraction needed to release metals, volatile, or semi-volatile organic compounds." Brown asserts that the laboratory tests approximate conditions that can be found on the field, and that no solvent besides water was used.

According to Brown, the basic barrier to accurately assessing the safety of recycled tire rubber is the high variability in tire construction and the lack of chemical characterization of the crumb rubber. "Very few samples have been tested," he says. "There is no study with sufficient sample sizes to determine the potential hazard." He adds, "Since new tires contain vastly different amounts of the toxic materials, based on the intended use, it is impossible to ensure players or gardeners and others that their personal exposure is within safe limits."

Another debated health issue is that of injuries. Several studies published in a supplement to the August 2007 issue of the *British Journal of Sports Medicine* reported no differences in the incidence, severity, nature, or cause of injuries in soccer teams who played on grass versus new-generation synthetic turf. However, injuries may depend on the type of sport being played. A five-year prospective study of football injuries among high school teams published 1 October 2004 in *The American Journal of Sports Medicine* showed that there were about 10% more injuries when games were played on synthetic turf than when played on grass surfaces. Conversely, the risk of serious head and knee injuries was greater on grass fields.

Injuries lead to another concern: infection with methicillin-resistant *Staphylococcus aureus* (MRSA), which is thought to spread especially easily among athletes because of repeated skin-to-skin contact, frequency of cuts and abrasions, and sharing of locker room space and equipment. A study conducted by the Centers for Disease Control and Prevention and published in the 3 February 2005 issue of the *New England Journal of Medicine* showed that, although synthetic turf itself did not appear to harbor MRSA, the greater number of turf burns caused by the abrasive friction of this type of surface increased the probability of MRSA infection, especially among professional athletes playing on hard surfaces.

There is, however, some evidence to suggest that synthetic turf may harbor more bacteria. For example, an industry study sponsored by Sprinturf, a maker of synthetic turf, found that infill containing a sand/rubber mixture had 50,000 times higher levels of bacteria than infill made of rubber alone. To address this, the company markets synthetic turf that is "sand-free" as a safer alternative and offers sanitation for those fields already installed.

Proper maintenance of synthetic turf requires that the fields be sanitized to remove bodily fluids and animal droppings; manufacturers market sanitizing products for this purpose. According to *Synthetic Turf Sports Fields: A Construction and Maintenance Manual*, published in 2006 by the American Sports Builders Association, some synthetic turf owners disinfect their fields as often as twice a month, with more frequent cleanings for sideline areas, where contaminants concentrate.

Different Shades of Green

Cultivated natural grass carries plenty of environmental baggage. According to "Water Management on Turfgrass," a paper on the Texas A&M University Cooperative Extension website (http://plantanswers.tamu.edu/), natural grass sports fields can require up to 1.5 million gallons of water per acre per year. The frequent mowing

[illegible]
said Joel Forman, medical director of the Pediatric Environmental Health Specialty Unit at Mount Sinai School of Medicine, speaking at a 6 December 2007 symposium on the issue.

Many physical properties of synthetic turf—including its dark pigments, low-density mass, and lack of ability to vaporize water and cool the surrounding air—make it particularly efficient at increasing its temperature when exposed to the sun. This is not only a hazard for users, but also can contribute to the "heat island effect," in which cities become hotter than surrounding areas because of heat absorbed by dark man-made surfaces such as roofs and asphalt. From many site visits to both black roofs and synthetic turf fields, Gaffin has concluded that the fields rival black roofs in their elevated surface temperatures.

Although it is often argued that one of the advantages of synthetic turf is that it does not need irrigation, some installations must be watered to control the excessive heat. Benepe stated in public hearings that water misters may have to be installed in some fields to help remedy the heat problem. According to Gaffin, synthetic turf is so efficient at absorbing sunlight, that cooling with water is only temporarily effective. "After a short while of watering, I expect the temperature should rebound and the surface become intolerably hot again," he says.

In addition to heat control, the International Hockey Federation requires that college teams saturate synthetic turf fields before each practice and game to increase traction, according to an article in the 19 October 2007 Raleigh (North Carolina) *News & Observer*. The article, which examined why local universities were watering their synthetic turf fields in the midst of severe ongoing drought in the U.S. Southeast, noted that Duke University received a business exemption to water the fields provided overall campus water consumption decreased by 30%.

The EHHI study addressed the question of whether synthetic turf fields can contribute to increased water contamination from rain or from spraying or misting. The study found that 25 different chemical species and 4 metals (zinc, selenium, lead, and cadmium) could be released into water from rubber infill. Moreover, because synthetic turf is unable to absorb or filter rain-water, chemicals filter directly into storm drains and into the municipal sewer system without the beneficial filtration that live vegetation provides. Benepe and others agree this can be an issue that New York City would need to address, as water runoff from synthetic turf fields could overwhelm storm drains, thus contributing to the estimated 27 billion gallons of raw sewage and stormwater that discharge from 460 combined sewer overflows into New York Harbor each year.

Finally, what happens to synthetic turf fields when they are no longer usable? Industry estimates that synthetic turf fields have a lifespan of 10 to 12 years, whereupon the material must be disposed of appropriately. Rick Doyle, president of the Synthetic Turf Council, says the infill could be cleaned and reused; put to another purpose, such as for rubber asphalt; incinerated; used in place of soil to separate landfill layers; or otherwise recycled. Typically, however, it is landfilled.

Alternatives

One of the benefits of synthetic turf is that it can serve as a way to reuse old tires, a real problem given the 1 billion–plus tires that are sold every year. Doyle says the synthetic turf industry currently recycles one-twelfth of the 300 million auto tires that are withdrawn from use each year. The average soccer field can contain crumb rubber made from 27,000 tires at a density of about 4 to 15 pounds of infill per square foot.

Europe has launched an aggressive tire recovery campaign in which tires that meet quality criteria can be retreaded and reused. End-of-life tires that cannot be reused are recycled for other uses including some industrial energy-generating applications, the production of rubberized pavement, and recycling into materials for the car industry (in addition to some use in producing synthetic turf). In western Europe, recovery rates of used tires have increased from 65% in 2001 to almost 90% in 2005.

Whereas end-of-life tires add tons of waste a year for disposal in many areas, in Europe they are turning into a potentially lucrative secondary raw material. "There are increasingly numerous applications," says Serge Palard, head of the end-of-life tire recovery department at Michelin, one of the largest tire manufacturers in the world. "In some countries where we did not know what to do with end-of-life tires a few years ago, now we do not have enough to meet the demand of all the reprocessors."

In accordance with the European Union's recently implemented REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulations, which will require more testing of industrial chemicals, companies such as Michelin are working to reduce the use of harmful chemicals in tires in order to facilitate recycling into other products.

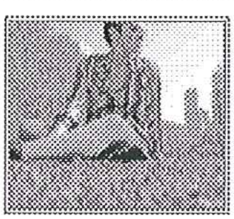
European companies are also finding innovative ways to address concerns regarding recycled tire infill in synthetic turf. In Italy, for example, there is an effort to market synthetic turf fields that feature infill made of a new thermoplastic material that is thought to be nontoxic. Mondo, a manufacturer of floor surfaces, produces Ecofill, a patented polyolefin-based granule used in synthetic turf. According to the company, this material disperses heat more efficiently; is highly shock absorbent; does not contain polyvinyl chloride, chlorine, plasticizers, heavy metals, or other harmful chemicals; and is 100% recyclable.

Another alternative is infill made from plant-derived materials. Synthetic turf manufacturer Limonta Sport produces Geo Safe Play, an infill made from coconut husks and cork. Company spokesperson Domenic Carapella says, "There are certainly alternatives to crumb rubber. There is no longer a reason to sacrifice the playing quality and more importantly the health of children [playing on synthetic turf]."

Why can't the alternative to bad grass fields simply be well-maintained grass fields, asks Croft. Certain varieties of turf grasses have been bred for resistance to stress, ability to withstand trampling and low water conditions, and other characteristics that make them appropriate for athletic field use.

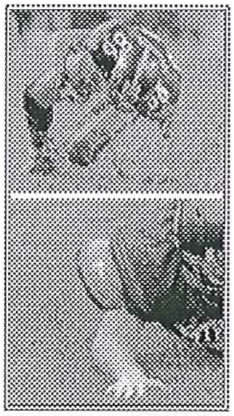
But according to Doyle, increased maintenance is not the answer. "More maintenance cannot overcome overusage of a natural grass sports field," he says. "And overusage of a natural grass sports field or usage during a rainstorm or in months of dormancy will produce an unsafe playing surface." Adds Benepe, "Even the wealthiest professional sports teams and Ivy League universities have concluded that grass fields are a losing proposition for intense-use sports such as football or soccer. . . .There is also the reality that natural turf fields used for high-intensity sports must be replaced every few years, unless you severely restrict use."

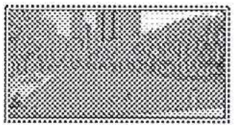
For now, New York State Assembly-members Steve Englebright, William Colton, and David Koon have proposed legislation to impose a six-month moratorium on the installation of synthetic turf until the state health and conservation departments have better studied the pros and cons of natural and synthetic grass. Said Englebright in a 5 November 2007 statement, "Before we take risks with our children's health and drinking water quality, we need to make sure that the uncertainties . . . are fully investigated."



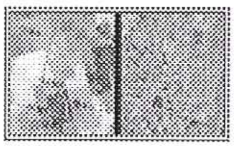
Synthetic turf field at Cadman Plaza Park, Brooklyn, New York

Weighing costs and benefits

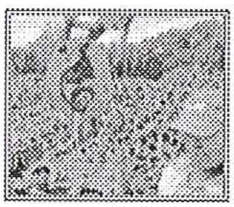




Moratorium introduced



Thermal effect



Growing demand

RECEIVED

AUG 22 2011

City County Planning Office
Lawrence, Kansas

August 22, 2011

To: Chair and Members of the Lawrence/Douglas County Metropolitan Planning Commission

Re: ITEM NO. 11 TEXT AMENDMENT TO CITY OF LAWRENCE DEVELOPMENT CODE; CHP20; SYNTHETIC TURF AS LANDSCAPING MATERIAL

First we commend the Planning Staff for its excellent and comprehensive report on the use of artificial turf. The report is well documented and clearly has been thoroughly researched on the limited number of permitted uses of artificial turf as a landscape material.

Furthermore, the Jayhawk Audubon Society believes that the staff recommendation for denial of the amendment request has been thoroughly analyzed and we agree that the request for the use of artificial turf in this application is not appropriate. For all the reasons that staff has enumerated, artificial turf appears to have significantly more negative effects on the environment than the few potential benefits it may have.

We ask you to deny the request.

Thank you for your consideration of these comments.

Sincerely,

Gary E Anderson

Gary Anderson, President

Jayhawk Audubon Society

PO Box 3741

Lawrence, KS 66046-3741

League of Women Voters of Lawrence-Douglas County
P.O. Box 1072, Lawrence, Kansas 66044

RECEIVED
AUG 22 2011
City County Planning Office
Lawrence, Kansas

August 21, 2011

Mr. Richard Hird, Chairman
Members
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
Lawrence, Kansas 66044

RE: AGENDA ITEM NO. 6: TA-4-6-11, A TEXT AMENDMENT TO THE CITY OF LAWRENCE DEVELOPMENT CODE; SYNTHETIC TURF AS LANDSCAPING MATERIAL (MKM)

Dear Chairman Hird and Planning Commissioners:

Please see the attached letter that we sent to you for your June 19, 2011 Planning Commission meeting regarding the use of synthetic turf in landscaping—Agenda Item No. 6 in this current Agenda. In our June letter we commended the staff for their report on its use and their recommendation for denial.

We reiterate our position, and have two other points to mention against the use of artificial turf.

(1) Because of its heat absorption and reflection, in order to avoid that effect, it needs water for cooling, negating the argument that it saves water.

(2) Depending on its location, the heat island effect that it produces is likely to increase energy use for air conditioning, in contrast to the cooling effect of natural vegetation for landscaping materials.

Again we thank the staff for their recommendation for denial of this proposed text amendment, and hope that you will not recommend approval of TA 4-6-11.

Sincerely yours,

Alan Black

Caleb Morse
Member of the Board

Alan Black, Chairman
Land Use Committee

Attachment

ATTACHMENT

League of Women Voters of Lawrence-Douglas County
P.O. Box 1072, Lawrence, Kansas 66044

June 19, 2011

Mr. Charles Blaser, Chairman
Members
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
Lawrence, Kansas 66044

RE. ITEM NO. 11: TEXT AMENDMENT TO CITY OF LAWRENCE DEVELOPMENT CODE; CHAPTER 20; SYNTHETIC TURF AS LANDSCAPING MATERIAL (MKM)

Dear Chairman Blaser and Planning Commissioners:

We would like to thank the Staff for providing the valuable background information on the use of artificial turf. We especially appreciate staff recommendation of denial for its use in landscaping, and in its place the use of "low maintenance (natural) landscaping."

The reference material, as did the Staff Report, made clear the important reasons why this material should not be substituted for natural vegetation as groundcover. When it is so important to save energy, conserve our soil and protect the environment from pollution, the use of artificial turf for landscaping is not only counterproductive, but also environmentally damaging. As one of our members pointed out, artificial turf doesn't even save water because the other portions of the landscaping such as trees and shrubs must still be watered.

Thank you for your valuable information and negative recommendation on the use of artificial turf in landscaping.

Sincerely yours,

Caleb Morse
Member of the Board

Alan Black

Alan Black, Chairman
Land Use Committee

LWV6-19-11pcAgenda Item 11 Artif.turf LTR 2.wpd

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(1911-1998)

GLEE S. SMITH, JR.
OF COUNSEL

Jane M. Eldredge
Email: jeldredge@barberemerson.com

August 19, 2011

VIA E-MAIL

Mr. Richard W. Hird, Chair
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
6 East 6th Street
Lawrence, KS 66044

Re: Item 6 Synthetic Turf

Dear Mr. Hird:

We represent the applicant who requested the initiation of the text amendment. We appreciate the deferrals that you have provided to us. We have reviewed the June 22, 2011 Staff Report. We researched the current literature on artificial turf and Melissa Vancrum, a graduate student in law and urban planning, summarized that research in a Memorandum dated July 21, 2011.

Ms. Vancrum's research was presented to the Planning Staff on July 22, 2011 along with all of the supporting research documents. At the request of staff we also provided the memo and documentation electronically. Attached to this letter please find the Vancrum July 21, 2011 memo as Exhibit A. The staff has all of the supporting research documents in hard copy as well as electronically if you would like any of it.

Ms. Vancrum also reviewed the landscaping ordinances of 37 communities in this state and others. The communities in Arizona, California, Florida and Texas have had the most experience with permitting and regulating artificial turf. The communities in Colorado, Kansas and Nebraska generally have ordinances that are "silent" as to whether artificial turf is permitted as a landscaping material, which means the ordinances do not provide that artificial turf is permitted or prohibited. In most of the other Kansas communities where artificial turf has been requested, it has been permitted except in Salina where the subject landscape plan did not meet the minimum number of live plants. In other cases where there has been no request, the zoning official has said it would be permitted because it was not explicitly prevented. Ms. Vancrum's Other Community Comparison chart is attached as Exhibit B.

While we were disappointed that neither the Planning Staff, nor the Planning Commission was interested in a study session of artificial turf, we retained the two national experts on synthetic turf, Rusty Abell and Joseph W. DiGeronimo, to review and evaluate the evolving nature of the quality and use of artificial turf. They will both be present at the August 24, 2011 Planning Commission meeting. Their résumes are attached as Exhibits C and D respectively.

At our request Tim Bracciano, the facility director for Lawrence Public Schools, will be available at the Planning Commission meeting to report on our school district's selection of artificial turf for our athletic fields and their experience with it to date.

Lastly, we have prepared a letter reviewing and analyzing the legal requirements that must be followed in consideration of the requested text amendments. Please see Exhibit E. We submit that text amendments to the Lawrence Development Code are necessary to address the changing conditions in the evolution of artificial turf on athletic fields and landscaping and to address some apparent inconsistencies in the Development Code.

Thank you for your consideration. If there is any additional information that we may provide, please do not hesitate to contact us.

Sincerely,

BARBER EMERSON, L.C.

Jane M. Eldredge

Jane M. Eldredge

JME:dkh
Enclosures
cc: Planning Commission
Scott McCullough
Mary Miller

MEMORANDUM

To: Jane Eldredge
From: Melissa Vancrum
Re: Artificial Turf use as Landscaping in Lawrence
Date: July 21, 2011

The Lawrence Development Code appears to prohibit the use of artificial turf as part of any landscaping plan except as an alternative compliance element. However, many other localities encourage the use of artificial turf in landscaped areas and offer rebates for installing it and reducing water usage. Horizon 2020 encourages sustainable landscaping and a sustainable physical environment. Such goals include the use of artificial turf in many other circumstances.

Artificial turf has evolved dramatically in the last decade in safety, environmental friendliness, attractiveness, and durability. It has reserved LEED points in a number of projects. Artificial turf today can be indistinguishable from natural grass without close inspection. In addition, it can support Lawrence's goal of sustainability through decreased water consumption, pesticide and herbicide runoff, emissions from mowers, and grass clipping waste. The natural grass lawn is not sustainable and several alternatives need to be evaluated. Perhaps a focused study session would be helpful to more clearly analyze today's artificial turf products and determine if they should become a beneficial option of the local landscape.

The Natural Grass Lawn

The manicured grass lawn is a status symbol of the wealthy borrowed from European manor houses.[1] It is not "natural". It is highly cultivated. The grass lawn

[1] Donaldson, Cameron, History of the American Lawn, The Limpkin: Newsletter of the Spacecoast Audubon Society of Brevard County Florida.

proliferated in the U.S. after World War II as suburbia exploded. Americans previously used their yards primarily for growing food.

The natural grass yard is anything but natural. "[A] typical U.S. lawn, one-third of an acre in size, receives as much as 10 pounds of pesticides, 20 pounds of fertilizer, and 170,000 gallons of water annually. What's more, in a year a homeowner could spend the equivalent of a 40-hour workweek simply mowing that lawn (producing pollution equal to that created by driving a car 14,000 miles) and hundreds of dollars caring for it."[2] In the effort to cultivate a sustainable environment, it is difficult to support the natural grass lawn. However, many alternatives exist, including artificial turf.

Use

Artificial turf has evolved considerably since it was introduced in the 1960's for sports fields. Today artificial turf is used in parks, upscale residential yards, commercial developments, and golf courses. Its use is now widespread in professional sports and continually expanding for kids' athletic fields, including those of the Lawrence Unified School District. In recent years, artificial turf has become popular in celebrities' yards.[3] Walt Disney World, Disneyland and Epcot Center utilize artificial grass in some of their landscaping.[4] New York City uses the turf in some parks, and California agencies use it for some building landscaping.[5]

Appearance

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[2] Bogo, Jennifer, Going the Extra Yard, Audubon Magazine, March 2002.
[3] Synthetic Turf Becomes Latest Celebrity Trend, A-Listers and Landmarks Conserve Water While Beautifying Grounds" Synthetic Turf Council, May 31, 2001.
[4] Id.
[5] See California utillitClaudio, Luz, Synthetic Turf: Health Debate Takes Root, Environmental Health Perspectives, March 2008,

One reason for the widespread adoption of artificial grass is the improvement in look. Artificial turf can be selected in different shades of green with variegated strands and even the look of dead thatch mixed within the green blades. [6] Artificial turf also comes in different lengths to mimic the look of different types of natural grass even up close.

Health and Environmental Impacts

Use of artificial turf in select applications provides a significant benefit in the form of a large reduction in water consumption and allergens. Artificial turf may require occasional cleaning with water to remove dust and debris. This consumption is minimal compared to the needs of natural grass. Water is used on artificial turf athletic fields to cool the surface and provide traction before games. However, this would be unnecessary for landscaping purposes. Artificial turf also reduces allergens such as pollen in the environment. Crumb rubber from recycled tires often provides a sublayer for the artificial turf which makes the surface of the turf softer. Concerns have been raised about the irritation to latex allergy suffers due to the crumb rubber infill used in some artificial turf installations. However, levels of latex in tires are much lower than in latex gloves and other consumer products. To date no study has confirmed an issue of latex allergens released from artificial turf.[7]

Scientific studies are in disagreement over the potential for environmental harm from artificial turf. A CDC report identified lead dust on decaying old artificial turf

[6] Synthetic Turf Council, http://www.syntheticturfcouncil.org/.
[7] *See, e.g.*, Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.

fields as a potential health issue.[8] While old artificial turf may contain high lead content, the grass produced today must meet strict lead standards.[9] The industry has done this in part by utilizing organic pigments. The Synthetic Turf Council has agreed to further restrict lead content by complying with stringent lead standards proposed for children's products.[10] In 2008, the Consumer Product Safety Commission released a report that concluded that young children are not at risk of lead exposure from artificial turf in athletic fields.[11] In addition, an EPA study found that lead from recycled tires was not a concern in artificial athletic fields and playgrounds.[12]

Other potential issues including zinc continue to be studied. The EPA found levels in of zinc in the air and surface to be below levels considered harmful at athletic fields and playgrounds using recycled tires.[13] A 2008 study found levels of zinc in stormwater collected from artificial athletic field drainage systems to be below the Connecticut water quality standard.[14] Other chemicals such as lead, selenium and cadium were not detected in the drainage.[15] While some studies have found elevated zinc levels, risk to humans is minimal as most zinc is absorbed into soil and does not dissolve in water.[16] In addition, zinc is not very toxic to humans so the danger is mostly to aquatic

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[8] Artificial Turf, Centers for Disease Control and Prevention, http://www.cdc.gov/nceh/lead/tips/artificialturf.htm
[9] Good News about Lead Problems in Artificial Turf, Center for Environmental Health, Fall 2010 Newsletter, http://www.ceh.org/component/content/article/454.
[10] STC's Voluntary Commitment, Synthetic Turf Council, http://www.syntheticturfcouncil.org.
[11] CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On, News from CPSC, U.S. Consumer Product Safety Commission, July 30, 2008.
[12] Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces, United States Environmental Protection Agency, December 10, 2009.
[13] Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces, United States Environmental Protection Agency, December 10, 2009.
[14] Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.
[15] Id.
[16] Artificial Turf Field Investigation in Connecticut, Final Report, University of Connecticut Health Center, Section of Occupational and Environmental Medicine, 21 July 27, 2010.

and plant life. The California Environmental Protection Agency released a report based on two New York studies of air quality showing that exposure was "unlikely to produce adverse health effects in persons using these fields."[17] "Extensive research has pointed to the conclusion that these fields result in little, if any, exposure to toxic substances."[18]

Some studies have indicated concern with elevated temperature on artificial athletic field surfaces. The surface temperature of the synthetic grass blades has been recorded upwards of 150 degrees on sunny days. However, in temperatures recorded at 5 feet above the surface is dramatically lower and in some cases shows little difference in temperature.[19] Also, athletic fields consist of a large expanse of unshaded open space. Landscaping includes smaller patches of artificial grass shaded by trees and buildings which will reduce temperatures.

Summary

Other cities have found artificial turf to be a beneficial part of their landscape encouraging it with rebates and laws and using it in city parks and building landscaping. California even passed a law banning Home Owner's Associations from prohibiting the use of artificial turf in landscaping.[20] It was recently vetoed by the governor who said the

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[17] Chemicals and particulates in the air above the new generation of artificial turf playing fields, and artificial turf as a risk factor for infection by methicillin-resistant Staphgylococcus areus (MRSA) Literature review and data gap idenfication, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, July 2009.

[18] Review of the Impacts of Crumb Rubber in Artificial Turf Applications, Rachel Simon, University of California, Berkeley, Laboratory for Manufacturing and Sustainability, College of Engineering & Manex Consulting, February 2010.

[19] Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields, Milone & MacBroom, December 2008.

[20] *See* Cal. S.B. 759 (2011).

decision was better left up to the associations.[21] New York Parks and California utilities have taken advantage of the benefits of artificial grass.

Use of artificial grass may provide a sustainable alternative to natural grass in landscaping in Lawrence. Artificial turf reduces water use, pesticides, herbicides, emissions, grass clipping waste. Lead use has been dramatically reduced through industry efforts such as using organic pigmentation. There does not appear to be a clear threat to human health through release of zinc or other chemicals though studies continue. In addition, artificial turf can provide an attractive look as it is used for upscale homes, building landscaping, and even Disney World.

Recommendation

In a study session to which USD #497 officials who have installed and used artificial turf athletic fields would be invited, Lawrence can better determine whether to permit artificial turf use in landscaping as most other communities have and as the local school district has chosen for children to play on.

[21] Jerry Brown vetoes artificial turf bill backed by conservationists, Capitol Alert, The Sacramento Bee, July 15, 2011.

State	Community	Artificial Turf Allowed?	Requests to Use Artificial Turf?
Arizona	Buckeye	Permitted wherever grass allowed	
	Surprise	Permitted, protected	
California	Beverly Hills	Silent but permitted in places	
	Fullerton	Permitted, regulated *	
	Garden Grove	Permitted, regulated *	
	Glendale	Permitted, regulated	
	La Palma	Permitted, regulated *	
	Laguna Hills	Permitted, regulated *	
	Orange	Permitted, regulated *	
	Santa Ana	Permitted, regulated*	
	Santa Cruz	Silent but permitted	
	Stanton	Permitted, regulated *	
Colorado	Englewood	Permits, 70% live plants *	
	Ft. Collins	Silent	
	Greeley	Silent	
Florida	Clearwater	Directed staff to revise ordinance to allow 7/23/11	
	Punta Gorda	Permitted as special exception	
Kansas	Fairway	Silent	No requests
	Greensburg	Silent but permitted	No requests
	Hays	Silent	
	Johnson County	Silent	
	Kansas City	Silent	No requests
	Leavenworth	Silent	
	Leawood	Silent	No requests
	Manhattan	Silent	No requests
	Mission	Silent	
	Mission Hills	Silent	One request, approved for backyard putting green
	Olathe	Silent	No requests
	Overland Park	Silent, "nothing preventing"	No requests
	Prairie Village	Silent	
	Roeland Park	Silent	
	Salina	Silent	One request, denied because didn't meet live plant minimum
	Shawnee	Silent	
	Topeka	Silent	No requests
Nebraska	Omaha	Silent	
Texas	Austin	Silent	
	El Paso	Permitted with alternate compliance	

* See staff report for ordinance language

City Ordinance Language on Artificial Turf

Surprise, AZ

Sec. 58-596. - Artificial or synthetic turf.
Any person(s) or association(s) is prohibited from imposing private covenants, conditions, restrictions, deed clauses or other agreements between the parties, which prevents person(s) from utilizing artificial or synthetic turf as an alternative to any landscape. Artificial or synthetic turf shall be allowed on all surfaces where landscape can be applied.

Glendale, CA

30.31.010 – Regulations for the ROS, R1 and RIR Zones. The following regulations shall apply in the ROS, R1R and R1 zones. A. All street setback areas shall be landscaped with plant materials or a combination of plant materials and permeable surfaces and shall be permanently maintained in a neat and orderly manner. Nonliving materials may be used as ground cover including but not limited to: wood chips, bark, decorative rock, and stone. Plant materials shall compose a majority (more than 50%) of the street setback areas, exclusive of permitted driveways. Other than permitted hardscape, all areas not planted shall be covered (top dressed) with materials such as wood chips or approved alternative. Top dressing beneath tree canopies shall be to the satisfaction of the Director of Planning, and shall be calculated as area of live plant material. Permeable surface allows the movement of water through the surface material and include materials such as pavers, decomposed granite or grasscrete. Permeable surfaces are encouraged wherever possible in lieu of impermeable hardscape.

B. In the ROS and R1R zones artificial turf shall not be permitted. C. In the R1 zone, artificial turf may be used when not visible from the public street immediately adjacent to the property. Artificial turf shall be calculated toward the total lot area requirement for landscaping, but shall not be calculated toward the live plant material requirement. Additionally, artificial turf shall not be permitted beneath tree canopies. D. A minimum of forty (40) percent of the total lot area shall be permanently landscaped open space. Decorative design elements such as swimming pools, spas, fountains, sculptures, planters, rock gardens or other similar elements may be permitted where they are integral parts of a landscape plan composed of a majority (more than 50%) of live plant materials. Neither the interior nor the street setback areas shall be completely paved or covered with gravel. Any live plant material or permeable surface located in a required driveway shall not count toward required landscaping.

30.31.020 –Regulations for all Multi-family, Commercial, Industrial, and Mixed Use Zones, the CE Zone and the PS Overlay Zone A. The following regulations shall apply in the R-3050, R-2250, R-1650, R-1250, C1, C2, C3, CPD, CR, IND, IMU-R, SFMU and CE zones, and the PS Overlay Zone 6. Artificial Turf. Artificial turf shall not be used when visible from the public street immediately adjacent to the property.

Greeley, CO

18.44.070 General landscape standards for all properties (k) Required landscaping. (1) At least fifty percent (50%) of any required yard, excluding driveway and walkway to the front door, shall contain live plantings. (2) At least fifty percent (50%) of any parkway or right-of-way planting area, excluding driveways and public sidewalks, shall contain live plantings. (3) All yards not covered by an approved building, driveway, walkway or other permanent structure shall be landscaped. (4) Areas visible from a public right-of-way or adjacent property are required to be landscaped in accord with the provisions of this Chapter. Yards not visible from the right-of-way or adjacent property must be kept free from weeds and shall not be bare dirt.

Landscape area shall mean the area of required open space, according to the zoning district provisions in which the property is located, that is not allowed to be covered by buildings, paving or other impervious surface, whether within a lot, outlot or tract or within a public right-of-way, and shall not include any legally established area for storage or outdoor display.

Definitions of lawn and turf expressly do not include artificial turf.

Ft. Collins, CO

3.2.1 Landscaping and Tree Protection (2) Landscape Area Treatment. Landscape areas shall include all areas on the site that are not covered by buildings, structures, paving or impervious surface. Landscape areas shall consist only of landscaping. The selection and location of turf, ground cover (including shrubs, grasses, perennials, flowerbeds and slope retention), and pedestrian paving and other landscaping elements shall be used to prevent erosion and meet the functional and visual purposes such as defining spaces, accommodating and directing circulation patterns, managing visibility, attracting attention to building entrances and other focal points, and visually integrating buildings with the landscape area and with each other.

Landscaping shall mean any combination of living plants such as trees, shrubs, plants, vegetative ground cover or turf grasses, and may include structural features such as walkways, fences, benches, works of art, reflective pools, fountains or the like. Landscaping shall also include irrigation systems, mulches, topsoil use, soil preparation, revegetation or the preservation, protection and replacement of existing trees.

*Note: Pushes xeriscape, notes that xeriscape does not include artificial turf.

Punta Gorda, FL

The use of artificial turf may be considered by application for a Special Exception pursuant to Chapter 26, Section 16.8, as an alternative to grass and ground cover.

(1) The application for the Special Exception to allow the use of artificial turf must include the following information:

a. Two copies of a detailed, signed and sealed site survey of the property that is less than one year old that indicates the location of existing trees and shrubs and all other improvements on the property.

b. Two copies of the landscape plot plan indicating the proposed location of the artificial turf and other landscape materials. Setbacks to the seawall will be required to be shown for any trees, large shrubs, curbing, areas of rock beds or boulder type landscape material that is planned. All landscape plans must meet minimum standards as denoted in this Article.

c. If the property is zoned commercial or multi-family, a copy of an approved Southwest Florida Water Management District Permit shall be included in the permit application.

d. Evidence that the artificial turf proposed will have a minimum tufted weight of 56 ounces per square foot, be a natural green in color, and have a minimum 8 year warranty. A sample of the turf proposed that meets these standards shall be submitted with the Special Exception application including a copy of the manufacturers' specifications and warranty information.

e. Evidence that all artificial turf installations will have a minimum permeability of 30 inches per hour per square yard and provide anchoring information as to the size and location of anchors to ensure the turf will withstand the effects of wind.

f. Consideration of the percentage of living plant materials versus percentage of artificial turf proposed for any property shall be part of the review process. Evidence that living plant material will be drought tolerant and consist of 50 percent Florida native species including shrubs, vines, trees and ground covers.

(2) Any Special Exception granted to allow artificial turf shall include the following conditions:

a. Precautions for installation around existing trees shall be monitored and may be restricted to ensure tree roots are not damaged with the installation of the base material.

b. Rubber, sand and any other weighting or infill material is prohibited.

c. If artificial turf is planned to be installed next to the seawall, the artificial turf shall be pinned or staked behind the seawall. Nothing shall be attached directly to or placed on the seawall or seawall cap.

d. A copy of the Special Exception and conditions thereof shall be recorded in the Public Records of Charlotte County so that any subsequent purchaser will be on notice regarding the special rules relating to the artificial turf.

e. A landscape inspection shall be conducted after the installation of the artificial turf to ensure all living plant materials conform to the provided landscape plot plan and meet the drought tolerant and native species requirements.

f. If artificial turf is to be installed in the City right-of-way, a separate right-of-way permit must be obtained prior to commencing work.

g. Artificial turf shall be maintained in a green fadeless condition and shall be maintained free of dirt, mud, stains, weeds, debris, tears, holes and impressions, as determined by Code Compliance. All edges of the artificial turf shall not be loose and must be maintained with appropriate edging or stakes.

h. Artificial turf must be replaced if it falls into disrepair with fading or holes or loose areas, as determined by Code Compliance. Replacement shall be completed within 60 days of notification by Code Compliance.

i. If maintenance is required on the City right-of-way, or utility easement, it shall be the responsibility of the property owner to remove, replace and repair, at the owner's expense, any artificial turf that has been placed in the right-of-way or utility easement within 60 days.

j. If maintenance is required on the seawall and/or seawall cap, it shall be the responsibility of the property owner to remove, replace and repair, at the owner's expense, any artificial turf that has been placed in the rear yard of the property abutting the seawall within 60 days.

k. The City of Punta Gorda shall not be held liable for any damage to any artificial turf or other items placed within the right-or-way, within six feet of the seawall or within any area covering City utilities.

Fairway, KS

15-4-3.204 Required Landscape Material A. General Requirements. All land areas which are to be unpaved or not covered by buildings, parking areas, or other structures shall be brought to finished grade and planted with turf or native grass or other appropriate ground cover. In addition to the minimum number of trees required to be planted by this Part, an appropriate number or amount of shrubs, ground cover and/or turf area plantings shall be included in each project, to be determined by the design criteria for the project relating to visual safety, species and landscape function. When business uses are adjacent to residential property, the minimum tree and planting requirements shall be planted within the ten (10) feet of the setback area immediately adjacent to the residential property.

Greensburg, KS

7.4 Sustainable Landscaping A.Sustainable landscaping is encouraged. Raingardens, landscaped detention facilities, bio-swales, xeriscaping, and other such features (installed with Best Management Practices) may replace the detailed requirements. B.In all instances, stormwater runoff shall be directed from parking areas to landscaped areas (see Article 6, Low Impact Development). C.Suitable ground cover in landscape areas includes pervious materials such as larger rock, mulch, and the like.

From: Christy Pyatt [mailto:bldgclerk@greensburgks.org]
Sent: Friday, August 05, 2011 3:57 PM
To: Law Clerk 2
Subject: RE: Land Development Code

I checked with our zoning advisor. Artificial turf would be permitted as landscaping in Greensburg.

Christy Pyatt
City of Greensburg
Building Clerk
Municipal Court Clerk

Hays, KS

Sec. 71-1180. Other landscape standards. The following additional landscape standards shall also apply: (4) Required landscaped area shall consist of a minimum of 60 percent in ground surface covered by living plant materials or turf grass. The remaining 40 percent may be covered with bark, wood chips, rock, brick, stone or other similar nonliving materials; provided that an effective weed barrier is installed. (5) All land area not covered by landscaping, paved parking, drives and walkways, and structures shall be seeded with perennial grass and regularly mowed and maintained in a proper appearance.

Johnson County, KS

Section 3. DEFINITIONS OF BASIC TERMS: "Landscaping" The bringing of the soil surface to a smooth finished grade, installing trees, shrubs, ground cover or mulch of decorative stone or wood chips or similar materials to soften building lines, provide shade and generally enhance the appearance of the premises and produce an aesthetically pleasing effect

Kansas City, KS

Division 10 Landscape and Screening Sec. 27-696. - Definitions. Ground cover means landscape materials or living, or low-growing plants other than turf grass, installed in such a manner so as to provide a continuous cover on the ground surface.
Landscape materials means living plants, such as trees, shrubs, vines, ground cover, flowers and grass turf. It may include such nonliving features as stone, sand, bark and brick pavers (excluding pavement), and structural or decorative features such as fountains, pools, earthen berms or mounds, walls, fencing, benches, lighting, etc.
Sec. 27-699. - General requirements and guidelines.
(a) Landscaping. (1)The area between the curb of a public street and the property line shall be brought to finish grade and planted in grass. In no case may this area be paved or covered with materials other than grass or an appropriate ground cover, except at approved driveways that shall be paved. Approved street trees may also be planted.
(2) All areas not covered by buildings, paved area, or other acceptably improved areas shall be landscaped with such landscaping continuously maintained.

Leavenworth, KS

ArticleVIII. LANDSCAPINGANDSCREENING Section 8.04 Required Landscaping 1. Required Landscaping: A 20 - foot strip of landscaping shall be provided along the perimeter property line of all multifamily, commercial, and industrial development sites except for approved points of pedestrian or
vehicle access. Site perimeter landscaping shall be planted pursuant to the requirements for a 20 - foot buffer. ArticleXVIII. DEFINITION Landscape Material: Living material such as trees, shrubs, ground cover/vines, turf grasses, and non - living
material such as: rocks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), and/or other items of a decorative or embellishment nature such as fountains, pools, walls, fencing, sculpture, etc

Leawood, KS

16-4-7.3 Landscaping Requirements-Other Districts 6. Landscaped open space shall consist of a minimum of 60% living materials, the remaining areas may consist of non-living materials such as bark, wood chips, decorative rock or stone or other similar materials.

16-4-7.4 Installation and Maintenance of Landscaping and Screening
Lawn grass shall be maintained on all areas not covered by other landscaping, parking, drives, buildings, or similar structures. Existing yards shall be maintained with grass or other approved ground cover.

Manhattan, KS

ARTICLE IV DISTRICT REGULATIONS 4-112. M-FRO. Multi-Family Redevelopment Overlay District
(F) Compatibility Standards (1) Site Design Standards. (f)Building and Foundation Landscaping: Building and foundation
plantings, consisting of shrubs and bushes, shall be provided to accent and enhance residential buildings, and to soften the appearance of street-facing walls and/or fences. (g) Green Space: A minimum of fifteen (15) percent of the site shall
be maintained as green space, consisting of lawns and other living plant materials. In addition to lawns, front yard areas along streets shall include a minimum of one (1) shade tree of two and one-half (2 1/2) caliper size for every fifty (50) feet of street frontage.

Mission, KS

SECTION 405.020: DEFINITIONS GROUND COVER: Landscaping materials or living low-growing plant, other than turf grass, installed in such a manner so as to form a continuous cover over the ground surface. LANDSCAPE MATERIAL: Consists of such living material as trees, shrubs, ground cover/vines, turf grasses and non-living material such as rocks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement) and/or other items of a decorative or embellishment nature such as fountains, pools, walls, fencing, sculpture, etc. SECTION 415.060: GENERAL CONDITIONS AND PLAN REQUIREMENTS In addition to the minimum number of trees to be planted as set forth in Section 415.090, the appropriate number or amounts of shrubs, ground cover and/or turf area plantings that shall be included within each project shall be determined by the design criteria within each project as established by the City Planning Commission as they relate to visual safety, species used and landscape function.

Mission Hills, KS

5-149 Powers. The ARB [Architectural Review Board] may within its power approve or deny a building permit application and in approving an application may attach such requirements and conditions as it deems appropriate under the circumstances, including but not limited to: G. Landscaping requirements which may include requiring new trees, shrubs, or other landscaping or replacing existing trees, shrubs or other landscaping.

Olathe, KS

18.62.020 General Requirements and Interpretations All land areas as approved by a final site development plan and issued a building permit, which are not to be paved or covered by buildings shall be brought to finished grade and planted with turf, native grasses, or other appropriate ground covers.

18.06.290 "Ground cover" means landscape materials, or living low-growing plants other than turf grass, installed in such a manner so as to form a continuous cover over the ground surface.

Overland Park, KS

18.110.290 Ground cover "Ground cover" means landscape materials, or living low-growing plants other than turf grass, installed in such a manner so as to form a continuous cover over the ground surface.
18.110.345 Landscape material "Landscape material" means such living materials as trees, shrubs, ground cover, vines, turf grasses, and non-living materials such as rocks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), and other items of a decorative or embellishment nature such as fountains, pools, walls, fencing, sculpture, etc.
18.450.030 General requirements All land areas which are to be unpaved or not covered by buildings shall be brought to finished grade and planted with turf or native grass or other appropriate ground cover. In addition to the minimum number of trees required to be planted by this Chapter, an appropriate number or amount of shrubs, ground cover and/or turf area plantings shall be included within each project, to be determined by the design criteria for the project relating to visual safety, species and landscape function.

Per Mark in Planning & Development Department, there is "nothing preventing" artificial turf use in the Code.

Prairie Village, KS

Sec. 27-696. - Definitions Ground cover means landscape materials or living, or low-growing plants other than turf grass, installed in such a manner so as to provide a continuous cover on the ground surface.
Landscape materials means living plants, such as trees, shrubs, vines, ground cover, flowers and grass turf. It may include such nonliving features as stone, sand, bark and brick pavers (excluding pavement), and structural or decorative features such as fountains, pools, earthen berms or mounds, walls, fencing, benches, lighting, etc.

Roeland Park, KS

ARTICLE 10. LANDSCAPING AND SCREENING 16-1003. GENERAL REQUIREMENTS. All land areas which are too be unpaved or not covered by buildings shall be brought to finish grade and planted with turf or native grass or other appropriate ground cover. In addition to the minimum number of trees required to be planted by this Chapter, appropriate number or amount of shrubs, ground cover and/or turf each plantings shall be included within each project, to be determined by the design criteria for the project relating to visual safety, species and landscape function.

Salina, KS

(3) Definitions. For the purpose of this section, the following words and terms as used herein are defined to mean the following: a. Landscape material: Shall consist of such living material as trees, shrubs, ground cover/vines, turf grasses, and nonliving material such as: rocks, pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), and/or other items of a decorative or embellishment nature such as: fountains, pools, walls, fencing, sculpture, etc. e. Ground cover: Landscape materials, or living low-growing plants other than agricultural crops and turf grass, installed in such a manner so as to form a continuous cover over the ground surface.

(5) Required landscaping for front yards c. The following design standards shall apply to required landscaping and trees in front yards: Shrubs, ground cover and other landscape plantings shall be selected from the Recommended Xeriscape Plant List for Salina. Comparable plantings may also be selected with the approval and consent of the City Forester and the Zoning Administrator, if the proposed plantings are demonstrated to meet the City of Salina's objective of providing attractive landscapes with minimal water usage. (8) Other landscape standards. The following additional landscape standards shall also apply: d. Required landscaped area shall consist of a minimum of sixty (60) percent in ground surface covered by living plant materials from the Recommended Xeriscape Plant List for Salina turf grass. The remaining forty (40) percent may be covered with bark, wood chips, rock, bricks, stone or similar nonliving materials provided an effective weed barrier is installed. e. All land area not covered by landscaping, paved parking, drives and walkways, and structures shall be seeded with warm sea

Shawnee, KS

17.57.015 Definitions. C. "Ground cover" shall mean landscape materials, or living low-growing plants other than turf grass, that is installed in such a manner so as to form a continuous cover over the ground surface.

E. "Landscape material" shall mean living plants such as trees, shrubs, ground cover/vines, and turf grasses; and nonliving material such as: rocks, pebbles, sand, bark, mulch, edging, brick pavers, earthen mounds (excluding pavement); and/or other items of a decorative or embellishment nature such as: fountains, benches, pools, walls, fencing, sculpture, geo-block drives, etc. 17.57.020 General Conditions.A. A landscape plan shall be submitted in support of a site plan, preliminary development plan for commercial, office, institutional, and multi-family residential developments, or and preliminary plats or final plats when a preliminary plat is not required, for single family residential subdivisions with tracts and/or lots abutting designated major streets for substantial new construction. All land areas which are not to be paved or covered by buildings shall be brought to finished grade and planted with turf or native grass or otl

Omaha, NE

Sec. 55-714. - Definitions. b) Landscaped area: That area within the boundaries of a given lot consisting primarily of plant material, including but not limited to grass, trees, shrubs, flowers, vines, groundcover, and other organic plant materials; or grass paver masonry units installed such that the appearance of the area is primarily landscaped. Inorganic materials such as brick, stone or aggregate may be used within landscaped areas, provided that such material comprises no more than 35 percent of the area of the required landscaped area. Flat concrete or asphalt, other than walkways five feet or less in width, may not be used within a required landscaped area.

Topeka, KS

Chapter 18.235 LANDSCAPE REQUIREMENTS 18.235.120 Size and quality requirements. (d) Grass shall be planted in such a manner as to completely cover all exposed soil after one full growing season. (e) No bare ground shall be left exposed. Grass or other groundcover or mulch, such as pine straw or tree bark, shall cover all bare ground.

Austin, TX

§ 25-2-1003 GENERAL REQUIREMENTS. (A) In this article, landscape yard means the area of a lot between the street right-of-way and a line that coincides with the front wall of the building and extends from the building corners to the side property lines. (B) At least 20 percent of the area of the landscape yard of a lot must be landscaped area. (D) A required landscaped area may include planters, brick, stone, natural forms, water forms, aggregate, and other landscape features, if inorganic materials do not predominate over the plants. Smooth concrete or asphalt may not be included in a required landscaped area.

El Paso, TX

18.46.140 - Alternative compliance. Artificial turf with a permeable base used in parkways and narrow areas 33' or less in any dimension, including all areas of the parkway.

Rusty Abell

Member - Partner
Director – Field Operations / Technical Advisor

Educational Background:

Texas Tech University, Lubbock, Texas. Chemistry

Professional Experience:

Directs the field operations and oversees numerous project superintendents on various athletic facility construction sites, both designed by us as well as others. Also serves as Technical Advisor for Sports Turf Design, Construction, Manufacture, Installation and Sports Field Functions. Has a strong background in the artificial turf and synthetic grass industry in turf manufacturing, development, and state of the art installation techniques of the various turf systems. Also has unmatched experience in the development of new millenium technologies for a variety of shock layer systems, field drainage systems, vertical to horizontal drainage applications, engineered rock base profiles, track and field layout and construction, as well as synthetic turf field design and installation for a variety of sport preferences. Also has a vast knowledge of turf maintenance, testing, repair, removal and total replacement. Has thirty-seven years of self employed experience in all facets of sports facilities construction, as a contractor, a technical consultant and an expert with turf life and usage applications.

Additional Professional Experience:

- Sport Rec Recreational Surfaces, Lubbock, Texas. Self employed 1974 thru present.
- DMA Sports Design Group, LLC. — Member-Partner
- ISA – Sport USA — Partner
FIFA Certified field testing, analysis
- NFL – National Football League — Certified testing and field analysis
- DMA Sports – Sturbridge, MA
1999 – present — Technical Advisor
Construction Management
- Sprinturf, Inc. – Wayne, PA
2002 - 2004 — Technical Advisor
Project Manager

- Quest Sports - Muncie, IN — Technical Consultant
  2000 - 2002 — Technical Advisor

- Valley Crest Sports – Calabasas, CA. — National Manager- Sports Turf Division
  1996 – 1999 — Technical Advisor – Sports Turf

- Sportfield, Inc. – Dallas, TX — Technical Consultant
  1996 – 2001 — Project Manager

- U.S. Indoor Golf, Inc. – San Francisco,. — Director and Advisory Board Member
  1986 – present

- Tour True Turf Technologies – San Francisco — Technical Consultant
  1986 – present

Professional Associations:

- Sports Turf Managers Association, 1997, 1998, 2009,2010,2011
- National Golf Foundation – Technical Advisor
- United Sates Tennis Court and Track Builders Association (USTC&TBA)
  Board of Directors - 9 years
  President – Track Division - 2 terms
  Chairman – Track Book Committee
  Track Construction Manual – Volume I & II, Co-author
  Chairman – Ethics Committee
  Chairman – Field Events Construction Committee
  Chairman – Awards Committee
  - Speaker – "One on One Conference with Experts in Sports Complex Construction" for Tennis Industry Magazine at the Atlanta Super Show.
- STC (Synthetic Turf Council)
- STA (Synthetic Turf Association)
- ASGI (Association of Synthetic Grass Installers)
  Board of Directors
- National Football League – Turf Consultant and field performance testing

Awards:

- Track of the Year (1988) USTC&TBA
- Distinguished Service Award (1987, 1989, 1990, 1991) USTC&TBA
- Grand Masters Award for Marketing and Achievement – PGA

Inventor / Manufacturer:

- Tour True Turf Technology

- Tour True adjustable golf cup replacement system
- Tour True Turf installation processes
- Tour True hydraulic undulation process
- Non compactable base and top dress systems for synthetic grass turf infill

Co-Inventor:

- "Jog Fog" – Presidential jogging track surface system
- Presidential HRX – Resilient tennis court surface system
- Dynamic Base – Synthetic simulated root zone shock absorption system
- Co-developer – NFL strategic field testing concept

Technical Consultant / Installer – (brief high profile list)

- National Football League – Turf Consultant
- The White House – Complete new tennis facility – Bush 41 Administration
- The White House – Truman Balcony, re-floor – Bush 41 Administration
- The White House – Horseshoe Landing Areas – Bush 41 Administration
- The White House – Construct new dedicated basketball court – Bush 41 Administration
- The White House – Construct Presidential golf green – Bush 41 Administration
- The White House – Presidential Situation Room Ceiling, re-floor – Clinton Administration
- The White House – Presidential jogging track, design-construction – Clinton Administration
- The White House – Presidential tennis court resurfacing – Clinton/Bush 43 transition
- The White House – Truman Balcony – resurface – Obama Administration
- Texas Stadium Corporation – Maintenance-technical advisor (1994-2003)
- Texas Stadium Corporation – New football field – design, install, technical advisor
- University of Colorado – Four new football fields – SportGrass
- Arizona State University – New artificial turf football
- PacBell Ballpark – New Baseball stadium (S.F.)
- Tennessee Titans – New football practice fields
- Southern Methodist University – New football stadium, SportGrass
- Seattle Seahawks – New football stadium
- Tarleton State University – Football
- University of California Monterey Bay – Baseball/softball fields
- City of Moreno Valley, CA – 320,000 sq. ft. synthetic turf soccer complex
- City of Los Angeles, CA – Synthetic turf soccer fields
- West LA College – New synthetic football/soccer field
- William Jewell College – New football stadium
- Monterrey, Mexico – New professional baseball stadium – synthetic grass
- London, England – New professional soccer/rugby complex – synthetic grass
- Titleist Golf Corporation – Research Center, Tour True
- Callaway Golf Corporation – Research Center, Tour True
- Ely Callaway – residence, Tour True

- Mt. Fugi, Japan – Mt. Fugi Golf Club, Tour True
- Chelsea Piers Golf Complex – Pier 59, Manhattan Island, NY., Tour True
- Coors Beer Family – residence, Tour True
- Tom Smothers Family – residence, Tour True
- Jack Nicholson Family – residence, Tour True
- Paul Azinger – PGA professional, Tour True
- Steve Elkington – PGA professional, Tour True
- Steve Pate – PGA professional, Tour True
- Larry Mize – PGA professional, Tour True
- Asao Aoki – PGA professional, Tour True
- Hank Haney – PGA professional, Hank Haney Golf Ranch, Tour True
- Michael Jordon – NBA professional, Tour True

And Numerous Others

Joseph W. DiGeronimo

DMA/DiGeronimo-Mikula Associates, LLC
PO Box 524
Sturbridge, Massachusetts 01566
Tel: (508) 347-5184
Fax: (508) 347-5911

MAIN OFFICE:

DI GERONIMO ASSOCIATES, LTD.
Sturbridge, MA

PROFESSIONAL CERTIFICATION

International Synthetic Turf Council (STC)
2004-Present STC – Certified Independent Professional
Association of Synthetic Grass Installers (ASGi)
United States Tennis Court and Track Builders Association:
1979-1993 C.T.C.B. - Certified Tennis Court Builder
1981-1993 C.T.B. - Certified Track Builder

EDUCATION

University of Detroit
Civil Engineering, 1970-1973

St. Peter's College, NJ
Pre-Engineering Science, 1969-1970

Wm. L. Dickinson High School, 1968
Jersey City, NJ

APPOINTMENTS

Certified, Synthetic Turf Council, 2004-2010
Certified Instructor, Association of Synthetic Grass Installers (ASGI) 2009-Present
Chairman, U.S. Tennis Court and Track Builders Assoc., 1987-1990.
Chairman, Technical Committee and Specs, USTC&TBA, 1979-1989.
Technical Consultant/Director, USTC&TBA, 1984-1987.
Member, U.S. Tennis Association Facilities Committee, 1984-1987.
Technical Director, International Association of Sport Surface
Sciences (I.S.S.S.), 1985-1989.
Consultant for Tennis and Golf Facilities at The White House (Bush Adm.)
Consultant for Tennis Facility at Camp David (Bush Adm.)
1996 Altanta Olympics - Design and Consultant for Synthetic Turf Field Hockey and Tracks
Consultant for Jogging Track at The White House (Clinton Adm.)
Speaker for the National Golf Foundation Seminars
Board of Directors - Jeremy Worrell Foundation (2006-Present)
ASTM F08 Subcommittee on Bat Speed

MEMBERSHIPS

Inrternational Synthetic Turf Council (STC), Mr. Richard Doyle III
Association of Synthetic Grass Installers (ASGI), Ms. Ann Costa, Pres.
United States Tennis Association (USTA). Reference: Miles DuMont
International Assoc. for Sport Surface Science (ISSS).
American Standards of Testing Materials (ASTM).
Construction Specification Institute (CSI).
United States Athletic Facilities Council (USAFC).
U.S. Tennis Court and Track Builders Association (USTC&TBA).
National Golf Foundation (NGF). Reference: Angelo Pularmo, Exec. V.P.
National Football Foundation/College Hall of Fame
Vince Lombardi Foundation
Jeremy Worrell Foundation

PUBLICATIONS

Author of First Edition - Track Construction Manual for USTC&TBA and NFSHSA.
Contributor to Second Edition - Track Construction Manual for USTC&TBA
Author of Standard 400 Meter Track Layout for NFSHSA
Guideline Specifications for the Construction of Tennis
Courts and Running Tracks for USTC&TBA
Tennis Industry Magazine:
- "Bird Baths"
- "A Moment with Joe DiGeronimo""The President's Court"
- "Tennis Construction of the '90's"
- " Underground Watering for Soft Courts"

Athletic Business Magazine:
- "The Do's and Don't's of Athletic Facility Construction
- "What's in a Surface"
- "Everything You Wanted to Know About Tennis Surfaces"
- "Tennis Court Construction of the 90's"
- "How to Choose a Track System"
- "Synthetic Surfaces for Tennis"

National Parks Maintenance Magazine:
- "Winterizing Your Tennis Courts"
- "A Court Fit for a President"

Guideline Specifications for Track and Tennis Courts for USTC&TBA and USTA.

PATENTS

May 1996 - Registered Inventor U.S. Patent received for Rubber/Polyurethane Shock Pad System (Elastic Layer).
June 2001 - Synthetic Turf designed combination fibers

PROFESSIONAL EXPERIENCE

DMA/DI GERONIMO ASSOCIATES, LTD.
Sturbridge, MA - June 1975 to Present

Established independent office for Athletic Facility Design. Solely responsible for the design and development of plans and specifications for natural and synthetic sports surfaces.

D.A. has grown to a reputation of national recognition and is presently the leading consulting firm involved in more than 5 million square feet per year of sports surface construction.

I have designed or constructed over 900 tracks, 9,000 tennis courts and 300 natural turf football fields and 250 artificial turf fields nationally from 1973 to Present.

DI GERONIMO ASSOCIATES, LTD./Sturbridge, MA performs duties in engineering consultation, construction project management, and provides services for forensic engineering and expert witness testimony for litigation in the athletic construction industry. This office was retained by Presidential Sports Systems of Lubbock, Texas to design the track and artificial turf systems for the 1996 Olympics. This work was completed in August 1995.

Special Assignments during this period:

* 1983 to 1987 Establish Balsam in the US and research turf and track market.

* 1990 to 1994 Establish Martin Surfacing in the turf market. In charge of turf construction projects.

* 1989 to 1998 Remain as the sports facilities contractor for the White House. Work performed for President Bush and Clinton directly. Construction included a specially designed surface for tennis, synthetic golf green and jogging track on the south grounds.

* 1990 to 1998 Consulted with U.S. Indoor Golf on synthetic golf greens. Work included the design of the shock pad and turf system for Michael Jordan, Tom Smothers, Coors Beer Family, Chelsea Pier Golf Center (NYC), Callaway Golf Center and Titliest Research Center. In addition, was on site advisor at Mt. Fuji Country Club, Japan.

* 1996-1997 completed a consulting contract with the Sportfield and United States Sports Technology Group in Dallas, Texas. They were completing plans for the rehabilitation of the Texas Stadium artificial turf, home of the Dallas Cowboys.

- 1996-1999: Consulting for FieldTurf, synthetic grass systems. Projects included Ringgold H.S., PA, St. Benedict's soccer field, Chelsea Pier NYC soccer, Bergen Catholic H.S. football field.

ARCHITECTS DI GERONIMO, P.A.
Southfield, MI & Paramus, NJ - September 1979 to June 1986

Principal partner in charge of civil construction projects for the firm. Responsible for sports facility design for national program for the design of specialized track and field natural and synthetic surfaces.

During this period I consulted with Reslite and Tracklite track system assisting and designing asphalt mixtures for rubberized surfaces. Additionally, supervised installation of surface with various pavers throughout the USA.

The responsibility of marketing and presentation to clients for all related design commissions with emphases on sports facilities. Once the project was funded and construction contracts issued, I was responsible for the administration of this work and Representative to the Owner.

Architects DiGeronimo and DiGeronimo Associates maintain a continued joint-venture relation in sports facilities.

LEO CORPORATION
September 1976 to 1979

Project manager. Sports facility division. Project engineer.
Chiefly responsible for all sport facility construction projects. Established Company sports program and increased annual construction to twenty tracks. Annual construction of $14 million.

DOUGHERTY CONTRACTORS CORPORATION
Detroit, MI - May 1973 to September 1976

Project Engineer/Project Manager. Director of Field Operations. Corporate Vice President, Road Division. Survey and construction engineering. Project manager for the Sports Division for the leading builder of Track and Tennis facilities in the Midwest. Responsible for $7 million per year in athletic construction.

NEW JERSEY DEPARTMENT OF TRANSPORTATION
Newark, NJ - December 1970 to June 1971

Full-time co-operative engineer assigned to the Survey and Design Division.

As co-operative engineer, developed skills as survey party member, party chief. In preliminary roadway design and layout assisted in coordination with independent consulting team. Assisted in State review.

JERSEY CITY BOARD OF EDUCATION
Jersey City, NJ - May 1967 to December 1970

Assistant to the Clerk-of-the-Works for School Construction Program.

Primary responsibility to prepare and file Daily Job reports for various school construction projects. During this time I was involved in the construction of the new Ferris High School and Grammar School.

APPOINTMENTS:

1979-1987: Chairman, Technical and Specifications Committee for the USTC&TBA

1984-1990: Member, Facilities Committee for the United States Tennis Association

1985-1989: Member, USTA National Tennis Center (U.S. Open) sub-committee
1984-1987: Professional Director/Technical Consultant, Board of Directors-USTC&TBA

1985-1988: Technical Director (USA), Board of Directors of the International Federation of Sport Surface Sciences (I.S.S.S.)

1987-1990: National Chairman, United States Tennis Court and Track Builders Association (USTC&TBA)

1989-1991: Consultant for the White House Tennis Court

1989-1990: Consultant for Special Programs for Tennis Court Construction at Camp David

1990-1991: Member (Ex-Officio), Board of Directors - USTC&TBA

1990-1991: Chairman, Nominations and Personnel Committee for the USTC&TBA

1991-1993: ELECTED Member, Town of Sturbridge Parks and Recreation Commission

1996-1999 Appointed to the Vince Lombardi Foundation

1996-1998: National Football Foundation/College Hall of Fame (Bergen County Chapter)

2004-Present:Certified Independent Professional, Synthetic Turf Council

2006-Present:Board of Directors (Member)Jeremy Worrell Foundation

2009 - Present: Certified Instructor with the Association of Synthetic Grass Installers

2010 - Present: FIFA Certified Field Testing

2011 - Present: Appointed the official testing lab for the NFL

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MATTHEW D. RICHARDS*

*ADMITTED IN KANSAS AND MISSOURI

LINDA K. GUTIERREZ
MATTHEW S. GOUGH*
CATHERINE C. THEISEN
KRISTOPHER S. AMOS*
MATTHEW B. TODD
EDWARD H. TULLY

RICHARD A. BARBER
(1911-1998)

GLEE S. SMITH, JR.
OF COUNSEL

Jane M. Eldredge
Email: jeldredge@barberemerson.com

August 19, 2011

Mr. Richard W. Hird, Chair
Lawrence-Douglas County Metropolitan Planning Commission
City Hall
6 East 6th Street
Lawrence, KS 66044

Re: TA 4-6-11 Synthetic Turf as Landscaping Material

Dear Chairman Hird:

On behalf of the applicant we request that Sections 20-1003(b), 20-1009(e)(4) and 20-1701 of the City of Lawrence Land Development Code ("Development Code") be amended as requested in the April 18, 2011 request for initiation of a text amendment to permit the use of artificial turf.

We request that your consideration of this request follow Development Code Section 20-1302(f) which requires:

"**(f) Review and Decision-Making Criteria**
In reviewing and making decisions on proposed zoning text amendments, review bodies shall consider at least the following factors:

(1) whether the proposed text amendment corrects an error or inconsistency in the Development Code or meets the challenge of a changing condition; and

(2) whether the proposed text amendment is consistent with the Comprehensive Plan and the stated purpose of this Development Code (See Section 20-104)."

I. THE PROPOSED AMENDMENTS MEET THE CHALLENGE OF A CHANGING CONDITION.

A. Prior to the premature installation of artificial turf at Frontier Apartments, the City of Lawrence had routinely approved the use of synthetic turf in all of our playing fields at both high schools and at the Oread Hotel. The reluctance to approve artificial turf at the Frontier Apartments appears to be a changing condition that requires clarification. Perceived inconsistencies in the Development Code definitions and perceived inconsistencies in the interpretation of Article 10 may have contributed to this changing condition.

B. The staff interpretation of the definition of "Landscape Materials" appears to be a changing condition that requires clarification.

C. The evaluation of artificial turf products as materials that are environmentally friendly, that earn LEED credits for the reduction or elimination of the use of water, pesticides, fertilizers, and emissions and the decreased long-term maintenance costs of artificial turf are changing conditions that should be addressed.

II. THE PROPOSED AMENDMENTS ARE CONSISTENT WITH THE COMPREHENSIVE PLAN

A. The Comprehensive Plan is a policy guide that describes the community's vision for directing future land development. Horizon 2020, p. 1-1

B. The Overall Horizon 2020 Planning Goals balance public and private interests.

A. **"General Goal**

The overall community goal for planning is to provide, within the range of democratic and constitutional processes, for the optimum in public health, safety, convenience, general social and physical environment and individual opportunities for all the residents of the community, regardless of racial, ethnic, social or economic origin. It is the goal of the planning process to achieve a maximum of individual freedom, but public welfare must prevail. It is the intent to meet and safeguard individual rights and vested interests in a manner which will create the minimum disruption in individual freedoms and life values." Horizon 2020, p. 1-3

Artificial turf is an option available to owners of single family or duplex property who do not have to site plan any site improvements. Development Code, Section 20-1305(c)(1). It is not a threat to the public's health, safety or general welfare. It should be available to all land owners. Its use meets the policies of Horizon 2020 that encourage landscaping with reduced long-term maintenance costs, conservation of water, reduction of pesticides and fertilizers and reduction of emissions.

B. **"Sustainability**

> We will strive to ensure the sustainability of our physical environment, both natural and built, the health of our economy and the efficient and effective functioning of our community." Horizon 2020, p. 1-3

The use of artificial turf protects the environment by conserving water, reducing pesticides, fertilizers and emissions. Artificial turf increases the economic health of our community by requiring lower long-term maintenance costs. Artificial turf allows our society to enjoy a healthy and safe place to play and a pleasing setting for our homes and businesses.

C. Screening and Landscaping Policies of Horizon 2020 are contained in each separate land use chapter of Horizon 2020.

A. The land use chapters of Horizon 2020 are:

a. Residential - Chapter 5
  (a) Low Density Residential Land Use
  (b) Medium and Higher Density Residential Land Use
b. Commercial - Chapter 6
c. Industrial and Employment - Chapter 7

B. All four of the separate land use sections contain similar screening and landscape policies including the following:

> "c. Promote/encourage site design that uses existing vegetation, such as stands of mature trees, as natural buffers or focal points.

d. Encourage the use of high quality materials in the construction of screening and landscape areas to decrease long-term maintenance costs."
Horizon 2020, pp. 5-22, 5-28, 6-28 and 7-16 – 7-

17

C. "Landscape material" is defined in the Development Code to include both living and non-living elements. Development Code § 20-1701, p. 17-10

Horizon 2020 encourages both the use of mature trees and high quality landscape material. These two policies are neither inconsistent nor are they mutually exclusive. Whether the landscape material is living or non-living, it should be of high quality and should decrease long-term maintenance costs. Based on the documentation provided by the Planning Staff and that provided to the Planning Staff on July 22, 2011, it is an undisputed fact that the long-term maintenance costs of artificial turf is substantially less than that of live turf. When the Lawrence School District converted all of its playing fields to artificial turf, they estimated a significant annual decrease in maintenance costs.

D. Environmental Chapter 16 of Horizon 2020 expands on the overall Horizon 2020 goal of sustainability. Artificial turf is consistent with the chapter's emphasis on decreasing the use of water, reducing or eliminating emissions; and reducing our use of pesticides, fertilizers and herbicides.

1. The Overview of Chapter 16 recognizes that "land development is important to economic vitality." Horizon 2002, p. 16-1

Decreasing the cost of long-term maintenance of turf areas with the use of artificial turf improves the economic vitality of the community as well as improving the environment.

2. One important strategy of this chapter is to "establish effective incentives and regulations that promote sustainable and efficient management of environmental resources." Horizon 2020, p. 16-2

Reducing emissions promotes a sustainable management of the air we breathe. Reducing the use of pesticides, herbicides and fertilizers reduces long-term maintenance costs of turf which reduces the potentially negative impact of development.

3. An important issue in the Human and Built Environment Section of this chapter is sustainability which is defined as: "Creating a sustainable community protects and preserves the environment, natural and built for future generations. This can include minimizing negative impacts from development on the environment and promoting sustainable building and land use practices." Horizon 2020, p. 16-23

4. "Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable Development integrates the three pillars of environmental protection, economic development and social development in decision making." Horizon 2020, p. 16-23

> Policy 6.6 Promotes "the responsible use and conservation of energy, water and other natural resources." Horizon 2020, p. 16-25

Artificial turf conserves water, one of the most important natural resources. No being can live without it. .

> Policy 6.6(b) "Encourage water conservation...."
>
> Policy 6.6(c) "Provide education on the use of...other features which would reduce water consumption for landscaping."
>
> Policy 6.6(d) "Provide incentives for building and facility design which minimizes water usage...." Horizon 2020, p. 16-25

These policies emphasize the importance of the conservation of water in every way that we can and the importance of education about features, like artificial turf that conserve water.

5. An important issue in the Water Resources and Management Section is Water Quality including "Minimizing pollutants that can contaminate ground and surface water...."

   a. Policy 1.2(d) encourages continued alignment with the Kansas Water Plan. "Water conservation is essential for the effective management of water resources in Kansas to assure that a sufficient, long term supply of water is available for the beneficial uses of the people of the state." Kansas Water Office, Kansas Department of Agriculture, Kansas Water Plan, Vol. II. Water Conservation Policy and Institutional Framework, 1 (Jan. 2008). Horizon 2020, p. 16-5.

The Kansas Water Plan also emphasizes conservation of water. Artificial turf is consistent with the Kansas Water Plan.

b. Policy 1.2(d)(2) "Use fewer chemicals on lawn(s), gardens, fields and forests to protect water quality." Horizon 2020, p. 16-5.

Artificial turf requires no chemicals, thereby reducing the chemicals that can seep into our groundwater or runoff into our stormwater.

c. Policy 1.5(b) "Develop programs and regulations, such as pesticide-free park programs...to minimize pollutants leaching into underlying groundwater systems to help ensure the quality of our groundwater resources." Horizon 2020, p. 16-6

Artificial turf protects the groundwater by not requiring any chemicals. Some parts of our country use artificial turf in parks, at garden shows and other public spaces. It protects the groundwater and the stormwater by not requiring any chemical applications.

d. Policy 1.7(a) "Encourage minimal and appropriate use of fertilizers, pesticides and other chemicals to reduce stormwater pollutants." Horizon 2020, p. 16-7

Artificial turf reduces stormwater pollutants because it does not require the use of any fertilizers, pesticides or other chemicals.

6. The Air Resources and Management Section of this chapter focuses on air quality because "The quality of air impacts human, plant and animal health.

a. **Outdoor air pollution**. Minimizing pollutants is critical to maintaining outdoor air quality. Outdoor air pollution can lead to negative health impacts.

b. **Excessive greenhouse gases**. Reducing greenhouse gases is necessary to limit their negative impacts on the climate."
Horizon 2020, p. 16-18

Artificial turf minimizes pollutants such as pesticides, herbicides and fertilizers that effect outdoor air quality because it does not need any of them. Artificial turf reduces greenhouse gases because it never needs mowing. Artificial turf may reduce allergic reactions to pollens and weeks in living turf.

The relevant polices of this chapter that emphasize the need to improve air quality by reducing emissions are:

a. Policy 3.1 "Improve air quality through reduction in emissions from vehicle exhaust." Horizon 2020, p. 16-18

b. Policy 3.2 "Reduce emissions from vehicle exhaust."
Horizon 2020, p. 16-19

c. Policy 3.3 "Reduce emission of non-vehicular air toxics..."
Horizon 2020, p. 16-19

By not needing mowers, tractors, weed-eaters, or other mechanized equipment to maintain the artificial turf we reduce the emissions and greenhouse gases that would be present with live turf.

7. Waste Management Section of this Chapter

a. Policy 5.1 "Manage solid waste through a program that emphasizes the principles of Reduce, Reuse, and Recycle."
Horizon 2020, p. 16-22

Artificial turf may use recycled materials such as crumb rubber. Artificial turf does not generate yard waste that may be dumped in a land fill.

b. Policy 5.1(d) "encourage the expansion of the yard waste collection programs in order to minimize the use of land fills."
Horizon 2020, p. 16-22

Artificial turf generates no yard waste to be collected and taken away, thereby also reducing emissions from trash trucks. Some artificial turf may itself be recycled.

8. The Land Resources Management section of the chapter discusses

> "...Douglas County's various land resources which consist of rural woodlands and urban forests, native prairies and agricultural soils. These resources provide wildlife habitats, viewsheds, and open spaces, as well as serving as 'Green Infrastructure'...." Horizon 2020, p. 16-11
>
> Green infrastructure is "...our open space network...that minimizes the fragmentation of natural areas and benefits the community by protecting natural habitats, providing appropriate stormwater management, providing open-air recreation areas and providing sustainable development practices." Horizon 2020, p. 16-11

Green infrastructures are those that preserve the high quality agricultural soils, critical habitats for endangered species, wildlife habitats, native prairies, rural woodlands and urban forests. It is not consistent with urban development. It does not encourage development of any kind. The use of artificial turf is only appropriate on land that has or is developing to urban densities. Green infrastructures or open space networks may be appropriate for undeveloped land.

SUMMARY OF COMPLIANCE WITH HORIZON 2020

1. The Staff Memorandum of July 27, 2011 ("Memo") readily concedes that artificial turf complies with the goals and policies of:

A. Water conservation, since no irrigation is necessary for artificial turf; and

B. Reducing emissions because no regular mowing is necessary for artificial turf; and

C. Reducing or eliminating the use of pesticides, fertilizers and herbicides.

2. The Memo fails to recognize that the use of artificial turf complies with Horizon 2020 and its screening and landscaping policies found in each of the separate land use sections of chapters 5, 6 and 7. These polices of preserving mature trees and using high quality materials in landscaping and screening to decrease long-term maintenance costs are not in conflict. The staff's underlying assumption appears to be that either artificial turf can not be a "high quality material" or that "decreasing long-term maintenance" is not a worthy goal. Neither assumption is correct.

3. The Memo concludes that despite the consistency with the stated goals and policies of Horizon 2020, artificial turf "as a landscaping material is not in compliance with the recommendations in the Environment Chapter." Memo, p. 8.

However, the Memo does not provide a single reference to Horizon 2020 that discourages artificial turf. Instead the Memo offers an opinion of the merits of artificial turf, "as compared to low maintenance landscaping" and "traditional lawns." The request for a text amendment was not a request for a good, better, best sort of comparison, but merely a request to consider the proposed text amendment in accordance with the factors identified in Development Code § 20-1302(f). Artificial turf is not prohibited. It should be considered as one option to meet the policies and goals of Horizon 2020. Horizon 2020 encourages high quality landscape material to be used with any existing vegetation such as mature trees that can be preserved in a landscape plan.

III. DEVELOPMENT CODE

A. The proposed text amendments are consistent with the stated purpose of the Development Code which is found at Section 20-104 Purpose.

> "This Development Code is intended to implement the Lawrence/Douglas County Comprehensive Land Use Plan and other applicable plans adopted by the City Commission...in a manner that protects, enhances and promotes the **health, safety, and general welfare** of the citizens of Lawrence."

There is nothing in the comprehensive land use plan, Horizon 2020, that discourages artificial turf. When the Lawrence School District #497 designated artificial turf for their athletic fields, it was approved without comment or concern in three separate site plans. Horizon 2020 encourages high quality landscape material to be used with any existing vegetation such as mature trees that can be preserved in a landscape plan.

There was no prohibition against artificial turf or artificial plants in the Development Code's predecessor, The Lawrence Zoning Ordinance.

Such a prohibition was not recommended in the documentation from the consultant who assisted with the review and analysis of the Zoning Ordinance prior to the initial draft of the Development Code. The only documentation indicates that the Development Code should include all of the screening and landscape requirements in one place, rather than throughout the Development Code as they had been in the Zoning Ordinance.

Linda Finger, former planning director, was the staff person who handled the landscape portion of the Development Code. In an August 3, 2011 conversation she did not remember any discussion about artificial turf. She did remember adding the prohibition against artificial plants to the Development Code to discourage the use of artificial flowers and a front yard filled with rock mulch on Massachusetts Street.

B. The Development Code definition of **Landscape Material** includes both living and non-living elements:

"Section 20-1701

Landscape Material - Such **living material** as trees, shrubs, ground cover, vines, turf grasses, and **non-living material** such as: pebbles, sand, bark, brick pavers, earthen mounds (excluding pavement), and/or other items of a decorative or embellishing nature such as: fountains, pools, walls, fencing, sculpture, etc." Horizon 2020, p. 17-10

This definition indicates with the "etc." that the list of elements is not exhaustive. For the sake of clarity, "artificial turf" should be specified along with rocks, pebbles, sand, etc. rather than just implied.

C. Artificial turf exceeds grass in meeting the purpose of the Development Code Article 10 Landscape and Screening. The stated purposes of landscaping and screening that apply to turf, whether artificial or living are:

"Section 20-1001(a) **Purpose**

The regulations of this article are intended to:

(1) maintain the City's quality, heritage and character by enhancing its visual appearance through the use of landscaping;

(2) enhance environmental conditions by providing...air purification, oxygen regeneration, groundwater recharge, filtering of stormwater runoff...."

1. Visual Appearance

Although the terms "quality, heritage and character" are not defined terms in the Developmental Code, we know that "quality" does not mean artificial or living. As demonstrated in the many articles submitted by the staff and the applicant it is possible to have "high quality" living grass or artificial turf just as it is possible to have "poor quality" examples of each.

Our heritage is one of tents, sod houses and a dirt Massachusetts Street. We do not want to preserve this physical nineteen century heritage, but rather, if we are preserving our heritage of equal rights for all, support for entrepreneurial activities and respect for the environment; artificial turf surpasses living turf in that it reduces our consumption of the precious resource water; it eliminates the use of pollutants such as pesticides, herbicides and fertilizers into the air and into our groundwater and our stormwater runoff and thereby enhancing our environment by reducing or eliminating many of the negative effect of development.

Whether artificial turf enhances our visual appearance requires a subjective judgment of beauty. We submit that whether artificial or living, turf enhances our visual appearance if it is of high quality, properly installed and well maintained.

2. Environmental Conditions

Although artificial turf does not generate oxygen, it does not prevent the generation of oxygen by the trees, plants, shrubs and flowers that are part of a landscape plan. Artificial turf may heat up to higher temperatures than living turf, but it also cools down faster when it is shaded. The generation of heat is at the surface and not at the level of 4 feet to 5 feet above the surface level.

Artificial turf does a better job of reducing the use of water, eliminating pollutants and reducing the cost of long-term maintenance than living turf. It meets the general purpose of the Development Code and the specific purposes of Article 10 in more environmentally friendly ways than living turf.

Artificial turf has been approved by the Planning Staff and the City Commission on at least three separate occasions with the site plans approved for the athletic fields at Free State High School, the football field at Lawrence High School and the other athletic fields at Lawrence High School. Artificial turf has been administratively approved as an alternate compliance use for the Oread Hotel.

Current artificial turf systems enhance the city's visual appearance by providing a more uniform turf appearance in a more environmentally friendly way with lower long-term maintenance costs. Current artificial turf systems enhance environmental conditions by reducing the demand for water, by eliminating the negative effects of pollutants such as pesticides, herbicides and fertilizers that contaminate our air, our ground water and our streams through stormwater runoff.

D. The proposed text amendments "**protect, enhance and promote the health and safety of the citizens of Lawrence**" as required by Development Code Section 20-104.

1. The Staff Report of June 22, 2011 raises issues of heat, infection, latex allergy and chemical exposure based on a 2008 New York study that eliminated all of these concerns except heat. The study noted that artificial turf gets hotter than living grass and also cools off more quickly. Our local

experience with our high school activity fields and the Oread Hotel has not raised any heat related concerns even in this excessively hot summer.

2. The following additional studies have been provided to staff along with the July 21, 2011 memo from Melissa Vancrum to update the information about health and safety concerns associated with artificial turf:

a. July 30, 2008, U.S. Consumer Product Safety Commission release "CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On"

b. December 10, 2009, U.S. Environmental Protection Agency release, "Limited EPA Study Finds Low Level of Concern in Samples of Recycled Tires from Ballfield and Playground Surfaces"

c. The Synthetic Turf Council's Voluntary Commitment to remove all or most lead from the pigments used to color the synthetic turf and to comply with the proposed revised restrictions concerning lead in children's products.

d. April 2010 Munex and UC Berkeley Study on Recycled Rubber in Artificial Turf Applications

e. December 2008, "Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields by Milone & MacBroom, engineering, landscape architecture and environmental science. The summaries of the Milone & MacBrown studies included the following:

1. "**Summary**

The results of the temperature measurements obtained from the fields studied in Connecticut indicate that solar heating of the materials used in the construction of synthetic turf playing surfaces does occur and is most pronounced in the polyethylene and polypropylene fibers used to replicate natural grass. Maximum temperature of approximately 156° F were noted when the fields were exposed to direct sunlight for a prolonged period of time. Rapid cooling of the fibers was noted if the sunlight was interrupted or filtered by clouds. Significant cooling was also noted if water was applied to the synthetic fibers in quantities as low as one ounce per square foot. **The elevated temperatures noted for the fibers generally resulted in an air temperature increase of less than five degrees even during periods of calm to low winds.**

The rise in temperature of the synthetic fibers was significantly greater than the rise in temperature noted for the crumb rubber. Although a maximum temperature of 156° F was noted for the fibers, a maximum temperature of only 101° F, or approximately 16 degrees greater than the observed ambient air temperature, was noted for the crumb rubber."

2. "**Summary**

The evaluation of the stormwater drainage quality from synthetic turf athletic fields included the collection and analysis of eight water samples over a period of approximately one year from three different fields, the collection and analysis of samples of crumb rubber in-fill from the same three fields plus a sample of raw crumb rubber obtained from the manufacturer, and the evaluation of the effect of the stone base material on the pH of the drainage water. The results of the study indicate that the actual stormwater drainage from the fields allows for the complete survival of the test species *Daphnia pulex*. An analysis of the concentration of metals in the actual drainage water indicates that metals do not leach in amounts that would be considered a risk to aquatic life as compared to existing water quality standards. Analysis of the laboratory-based leaching potential of metals in accordance with acceptable EPA methods indicates that metals will leach from the crumb rubber but in concentration that are within ranges that could be expected to leach from native soil. Lastly, it can be concluded that the use of crushed basaltic stone as a base material in the construction of the athletic fields has a neutralizing effect on precipitation."

f. July 2009, study "Chemicals and particulates in the air above the new generation of artificial turf playing files, and artificial turf as a risk factor for infection by methicillin-resistant staphylococcus aureus (MRSA) literature review and data gap identification by the California Environmental Protection Agency Office of Environmental Health Hazard Assessment that concluded that there was not a serious public health concern.

g. "What Do the Experts Say," Synthetic Turf Council Survey of recent third party studies with

h. Announcements of synthetic turf on all Lawrence, Kansas high school athletic fields

I. Synthetic Turf Council 2010 Case Studies and Testimonials including awards for:

    1. Kiowa County High School in Greensburg, Kansas, and

    2. Junction City High School in Junction City, Kansas

j. Synthetic Turf Council, May 31, 2011 newsletter re synthetic turf as a celebrity trend.

k. Sunset Magazine article about the pros and cons of synthetic grass

l. History of the American Lawn

m. Summary of benefits of synthetic turf

There is no documented threat to the health or safety of our children who have played on our artificial athletic fields. There is no objective evidence of any health hazards with current high quality artificial turf.

E. The proposed text amendments meet the purpose of the Development Code, by clarifying the acceptance of artificial turf as a landscape material that will **protect, enhance and promote the general welfare of the citizens of Lawrence** as required by Section 20-104.

1. They specifically and clearly allow artificial turf not only in low density residential areas but also areas in high density residential, commercial and industrial areas.

2. They will allow the land owner to reduce the long-term maintenance costs of landscaping.

3. They will allow a turf that does not have the bugs, insects (including chiggers) that make their homes in live turf.

4. They will permit the reduction or elimination of the use of water.

5. They will allow the elimination of many pollutants such as pesticides and fertilizers that runoff live lawns protecting our groundwater and our stormwater.

IV. CONCLUSION

The proposed text amendments are necessary to address the challenge of changing conditions and to clarify some portions of the Development Code as well as to support consistency in the City's judgments about the acceptance of artificial turf as activity fields in our schools and to acknowledge the current state of development of artificial turf as an environmentally friendly product that decreases the long-term maintenance costs of turf and provides a more sustainable landscape material than may have been previously available.

V. Request Text Amendments

20-1003(e) In addition to required Shade Trees and Shrubs, landscape areas within the Interior of off-street Parking Areas shall be planted with turf which can be synthetic or natural, Ground Cover, Ornamental Trees, or Shrubs.

20-1009(b) No artificial plants or vegetation other than synthetic turf may be used to meet any standards of this section.

ADD TO DEV CODE 20-1009(e)(4) Synthetic turf areas shall be installed per the manufacturers specification as permanent lawns in Lawrence.

20-1701 - Landscaping: Such living material as trees, Shrubs, Ground Cover/vines, turf grasses, and non-living material such as: rocks, pebbles, sand, bark, brick pavers, earthen mound (excluding payment), synthetic turf and/or other items of a decorative or embellishing nature such as: fountains, pools, walls, fencing, sculpture, etc.

Thank you for your consideration.

Sincerely,

BARBER EMERSON, L.C.

Jane M. Eldredge

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JME:dkh