Weston & Sampson

427 Main Street, Suite 400, Worcester, MA 01608
Tel: 508.762.1676

MEMORANDUM

TO: Peter Rice, Dan Hartrey

FROM: Michael Moonan

DATE: November 1, 2016

SUBJECT: Synthetic Turf Infills for Route 33 Recreation Field Project

---

Weston & Sampson has evaluated various types of infill options for synthetic turf fields in conjunction with our design of the synthetic turf field at the Route 33 recreation site. The information that follows provides a comprehensive analysis of each option.

The following list summarizes the types of synthetic turf infill alternatives that have been reviewed. More detailed definitions of the infill types are provided in Appendix A and Appendix B.

Crumb Rubber
Coated Crumb Rubber
EPDM
TPE
Nike Grind
Sand (Silica)
Coated Silica Sand
EcoMax
CoolPlay
Cork & Coconut Fibers (GreenPlay)
Cork (Purefill)
Coconut Fibers (GeoFill)
Coconut Husk, Rice Husk, & Cork (Infill-Pro Geo)

The infill system is one of the most important components in synthetic turf field design and construction. It is the basis for the safety and performance level of the turf system. The material provides the appropriate cushioning to absorb impact and it plays a significant role in determining the G-max rating of a field. A G-max rating is a measurement based on the G-force (or gravitational force) of shock absorbed during impact. This factor can have a large effect on the injury rate for players using a particular field. The infill system also offers traction for players to cut, plant and release (essential parts of sport) just like they would on natural grass. The infill market is becoming more complex with new products being introduced at a rapid rate. The infill materials that are most proven and tested over the years are crumb rubber and sand infill blended mix. In addition to providing a proper G-max rating to reduce the risk of concussions, traction and release performance attributes are essential in order to prevent lower limb injuries. Crumb rubber infill has been proven to provide the closest performance compared to natural grass as it relates to G-max and traction and release performance without the use of a shock pad.

Over the last several years, crumb rubber has fallen under scrutiny because of the chemical properties of the material. Some claims indicate that exposure to crumb rubber has caused cancer in some athletes, specifically children. Studies have shown that crumb rubber infill poses no

greater health risks than playing on a grass field. Despite these studies, concerns in some communities are at a high level. In response to these concerns, the synthetic turf industry developed an organic material infill option.

General observations about organic material infill include:

- Organic material infills have promising factors such as the ability to cool the surface temperature, faster/slower ball roll depending on the sport, and the ability to be recycled, either back into the earth or reused on future initiatives.
- Various organic material infills also need to be irrigated in order to maintain ideal moisture content. Most of the organic material infills require a shock pad to achieve the minimum G-max rating which increases cost and decreases performance factors.

There have been more than 75 studies examining the inherent characteristics of artificial turf and crumb rubber over the last decade by governmental institutions like the EPA, academic institutions such as University of California, Berkeley and Hofstra University and reputable laboratories and environmental engineering firms such as Labosport and Teter Engineering. The testing and analysis has spanned the globe and considered fields of different ages and in different temperatures. Results have been benchmarked against stringent health and safety standards such as the 2013 European Union toy standard, the U.S. ASTM toy standard, EPA standards for soils and painted surfaces and California's Proposition 65 which protects state drinking water from chemical contaminates.

Any material used in recreational playing field construction, whether it is organic or synthetic requires testing to ensure its safety. Properly specified, clean and tested crumb rubber from a reputable source is considered safe for consumer use.

Studies have further indicated that the levels of measurable elements are well within governing environmental standards as listed above. Therefore, it has been concluded that the use of crumb rubber poses no additional health risks when compared to the use of natural turf. Over a decade of data clearly shows that artificial turf fields with crumb rubber are as clean or cleaner than typical surface soils, reduce injuries to players, do not have pesticides and fertilizers, conserve water, and offer significantly more playing time. Considering player safety and proven products, crumb rubber infill is the best alternative for this project. A bibliography of these studies and letters addressing this matter are provided in Appendix B.

APPENDIX A:

TYPES OF INFILL

With so many choices, it is important to understand the difference between the various infill types and materials. Listed below are the most commonly used infill types.

***Crumb Rubber*:** Crumb Rubber is derived from car and truck tires that are ground up and recycled. Two types of crumb rubber infill exist: Ambient and Cryogenic. Together these make up the most widely used infill in the synthetic sports field and landscape market. Crumb rubber infill is substantially metal free, and according to the STC (Synthetic Turf Council) Guidelines for crumb rubber infill, should not contain liberated fiber in an amount that exceeds .01% of the total weight of crumb rubber, or .6 lbs. per ton. Although numerous studies have proven crumb rubber to be non - toxic to the field users, many safety concerns have risen in the media.

***Coated Rubber Infill*:** Both ambient and cryogenic rubber can be coated with colorants, sealers, or anti-microbial substances if desired. Coated rubber provides additional aesthetic appeal, reduction of dust by products during the manufacturing process and complete encapsulation of the rubber particle.

***EPDM Infill*:** EPDM (Ethylene Propylene Diene Monomer) is a polymer elastomer with high resistance to abrasion and wear and will not change its solid form under high temperatures. Typical EPDM colors are green and tan. EPDM has proven its durability as an infill product in all types of climates. Its excellent elasticity properties and resistance to atmospheric and chemical agents provide a stable, high performance infill product.

***TPE Infill*:** Thermoplastic elastomer (TPE) infill is non-toxic, heavy metal free, available in a variety of colors that resist fading, very long lasting, and 100% recyclable and reusable as infill when the field is replaced. TPE infill, when utilizing virgin-based resins, will offer consistent performance and excellent g-max over a wide temperature range.

***Sand (Silica) Infill*:** Pure silica sand is one of the original infilling materials utilized in synthetic turf. This product is a natural infill that is non-toxic, chemically stable and fracture resistant. Silica sand infills are typically tan, off-tan or white in color and - depending upon plant location - may be round or sub-round in particle shape. As a natural product there is no possibility of heavy metals, and the dust/turbidity rating is less than 100. It can be used in conjunction with many other infills on the market to provide a safe and more realistic playing surface. The round shape plays an integral part in the synthetic turf system. It is important that silica sand have a high purity (greater than 90%) to resist crushing and absorption of bacteria and other field contaminants. Silica sand can either be coated with different materials or as a standalone product or can be used to firm up in combination with traditional crumb rubber infill systems.

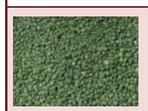
***Coated Silica Sand Infill*:** This class of infill consists of coated, high-purity silica sand with either a soft or rigid coating specifically engineered for synthetic turf. These coatings are either elastomeric or acrylic in nature (non-toxic) and form a bond with the sand grain sealing it from bacteria to provide superior performance and durability over the life of a field. Coated sand is available in various sizes to meet the application's needs. Depending on the amount and type of infill, coated sands can either be used with or without a pad and are available in various colors. All of the coatings listed are non-toxic and are bonded to the quartz grain for superior performance and

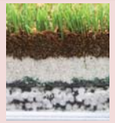
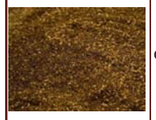
durability over the life of your field. These materials are typically used as a homogenous infill which provides both ballast and shock absorbing qualities to a synthetic turf application.

Organic Infill: There are several organic infills available in the North American market, all utilizing different organic components, such as natural cork and/or ground fibers from the outside shell of the coconut. These infill materials require additional padding under the turf to ensure safety of the players and a fairly rigorous maintenance regimen to ensure the materials remain properly distributed. Some synthetic turf companies will not allow the use of these products because they are not as reliable as other alternatives and reduce player satisfaction. At the end of its life cycle it can be recycled directly into the environment.

Appendix B - Rt. 33 Recreation Field, Portsmouth, NH

Synthetic Turf Infill Options

	Infill Type	Examples	Material Description	Facts and Advantages	Disadvantages	Life Span	Maintenance	End of Life Cycle	Cost / S.F. *Carpet and infill system only	Irrigation System	Estimated Rt. 33 Field Synthetic Turf Cost (Soccer Field - 89,805 s.f.) * Carpet, infill, shock pad (if required) and irrigation system (if required) only.	Annual Maintenance Cost
	**Crumb Rubber Infill**	1. Gillette Stadium, MA 2. Hoover High School, CA 3. Ames High School, IA	Crumb rubber infill is derived from recycled tires. There are two types: Ambient and Cryogenic. Ambient crumb rubber is created through a process where the tires are kept at room temperature during the crumbling process. Cryogenic crumb rubber is created by freezing the tires prior to granulation. This process avoids heat degradation. Crumb rubber infill is the most widely used infill material for synthetic sports fields.	This is currently the most inexpensive and widely used infill material on the market. Crumb rubber is metal free and does not contain liberated fibers in an amount that exceeds .01% of the total weight of the crumb rubber. The metal and liberated fibers are materials used in the tire manufacturing process. According to the Sports Turf Council (STC) crumb rubber meets the European Union EN 73-1 Standards which are the standards for compliance of chemicals in children's toys. Most used, tested and proven infill in the industry.	Although numerous studies have proven crumb rubber to be non - toxic to the field users, many safety concerns have risen in the media. Because of its black colour SBR has high surface temperatures caused by sunlight.Crumb rubber gives off odors at high temperatures and can not be recycled, only re-used.	Life of the carpet	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be reused (not recycled) ex: Field infill, asphalt, acoustic barriers, ADA compliant playground surfacing, natural turf soil amendments, etc.	$4.00 - $4.50	Not required	$404,123	$5,000 - $10,000 (Plus 300 hours of labor)
	**Coated Crumb Rubber Infill**	1. Mary E. Grogan Community Park, CA 2. Randall Island Sport Complex, NY 3. Buckingham Browne & Nichols School, MA	Both the ambient and cryogenic rubber can be coated with colorants, sealers, and anti-microbial substances. Similar to crumb rubber infill, coated crumb rubber also does not contain metal and lose fibers used during the tire manufacturing process as well meets the EN 73-1 standards.	Coated crumb rubber provides additional aesthetics appeal, reduction of dust by product during the manufacturing process and complete encapsulation of the rubber particle.	High cost, same chemical make-up as SBR rubber, and limited availability.	Life of the carpet	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Select products can be recovered, cleaned and recoated for reuse as infill. Can also be recycled into rubberized asphalt or molded products.	$4.75 - $5.25	Not required	$471,476	$5,000 - $10,000 (Plus 300 hours of labor)
	**EPDM Infill**	1. Los Prados Park, CA	EPDM (Ethylene Propylene Diene Monomer) is a polymer elastomer with high resistance to abrasion and wear. Available in a variety of colors and has similar physical characteristics to crumb rubber infill.	EPDM has proven its durability as an infill product in all types of climates. Its excellent elasticity properties and resistance to atmospheric and chemical agents provide a stable, high performance infill product.	Over time EPDM can harden because the cross-linking reaction used to make the product continues. This has a negative impact on playing characteristics and can affect the fibre characteristics.Recycling is not possible.	8-10 years	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be reused as infill and recycled into new infill or other products.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	Not required	$628,635	$5,000 - $10,000 (Plus 300 hours of labor)
	**TPE Infill**	1. Sprague School, MA	Thermo Plastic Elastomer (TPE) infill is a non-toxic elastomer, available in variety of colors, very long lasting and 100% recyclable and reusable as infill when the field is replaced. TPE has a similar feeling as it relates to play characteristics to crumb rubber.	TPE infill, when used with virgin-based resins, will offer consistent performance and excellent g-max over a wide temperature range. It is used in combination with a shock pad.	High cost, must use proven, proprietary formulas for quality, and limited availability. Has been known to get sticky in hot climates in proper formula is not used.	8-10 years	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be reused as infill and recycled into new infill or other products.	$7.50 - $7.75 (Includes $2.00 Shock Pad)	Not required	$6,959,888	$5,000 - $10,000 (Plus 300 hours of labor)
	**Nike Grind**	1. Lincoln High School, OR 2. Lafayette Park, CA 3. Glassel Park, CA	Nike Grind includes three types of raw materials made from recycled athletic shoes and manufacturing byproducts: rubber from the outsole, foam from the midsole and fabric from the upper. These materials are ground up and used by select companies in sport and playground surfaces, as well as in numerous Nike apparel, footwear and equipment products.	Nike Grind Reduces water consumption by hundreds of thousands of gallons each year over natural grass fields. It's optimized construction is rigorously tested for impact performance, and is virtually odorless and won't mark balls, shoes or players.Nike Grind can use a lighter color profile to reflect sunlight and generate 10–15-percent less heat build up, helping to sustain athletic performance.	It take 50,000 - 75,000 pairs of shoes to make a full size soccer field, which limits that availablity of this prodect. The demand tends to be higher then can be supplied, making annual infill replacement difficult and unreliable.	10 years of play at 40 hours a week.	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be reused (not recycled) ex: Field infill, asphalt, acoustic barriers, ADA compliant playground surfacing, natural turf soil amendments, etc.	$5.75 - $6.00	Not required	$538,830	$5,000 - $10,000 (Plus 300 hours of labor)
	**Sand (Silica)**	Used as a ballast in all rubber systems	Pure silica sand is one of the original infill materials utilized in synthetic turf system. This product is a natural infill that is non-toxic chemically stable and fracture resistant. Typically tan or white in color. As a natural product there is no heavy material within the silica. It is important the silica have a high purity (greater than 90%) to resist deterioration and absorption of bacteria.	It can be used in conjunction with many other infills on the market to provide safe and more realistic playing surface. Silica can be mixed with rubber products. Silica sand can either be coated with different materials as a standalone product or can be used to firm up a combination of traditional infill systems. It is used in combination with a shock pad.	The relative hardness of the material is very high, high abrasive quality, high cost due to required shock pad, high transportation costs due to weight, and more infill needed due to small particle size and heavy compaction.	Life of carpet	- Grooming per 100 hours - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be reused as infill on new field, in landscape installations, and for natural turf soil amendments.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	Not required	$628,635	$5,000 - $10,000 (Plus 300 hours of labor)
	**Coated Silica Sand Infill**	1. Newburyport High School, MA 2. South Windsor High School, CT	This class of infill consists of coated, high-purity silica sand with either a soft or rigid coating specifically engineered for synthetic turf. These coatings are either elastomeric or acrylic in nature (non-toxic) and form a bond with the sand grain sealing it from bacteria to provide superior performance and durability. Coated sand is available in various sizes.	This material is typically used in a homogenous infill which provides both ballast and shock absorbing qualities in combination with a shock pad.	The relative hardness of the material is very high, high cost due to required shock pad, high transportation costs due to weight, and more infill needed due to small particle size and heavy compaction.	16 year maximum	- Grooming per 100 hours - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be returned to select manufacturers to be cleaned and recoated. Can also be reused as top dressing on natural turf fields.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	Not required	$628,635	$5,000 - $10,000 (Plus 300 hours of labor)
	**EcoMax**	1. Bellarmin College Preparatory , CA	This infill is comprised of an extruded composite of recycled turf and thermoplastic elastomer (TPE). The EcoMax granules deliver a new, impact absorbing infill that offers safe and comfortable performance.	EcoMax offers great playability characteristics (plays close to high end cryogenic rubber/sand infill system), good compression/compaction characteristics, slight heat reduction, and is Tested rigorously for mechanical wear and weathering.	High cost, limited availability, and limited installation and long term use history.	8 years	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be returned to select manufacturers to be cleaned and recycled. Can also be reused as infill in synthetic turf field.	$7.00 - $7.50 (Includes $2.00 Shock Pad)	Not required	$673,538	$5,000 - $10,000 (Plus 300 hours of labor)
	**CoolPlay**	1. University of Tulsa, OK 2. Saratoga High School, CA 3. University of Maryland, MD	FieldTurf's exclusive and innovative Extruded Cork Composite (ECC) top dressing allows the CoolPlay system to deliver the same behavior and overall stability as FieldTurf's Elite system fields found in the world's most famous stadiums. CoolPlay takes nothing away from performance... exept the heat.	The special ECC top dressing could replace the top layer of crumb rubber on the three-layer infill system - which is proven to offer better performance and safety. The ECC granule is durable, shock absorbing and absorbs far less heat than other alternatives. No irrigation needed. CoolPlay has higher resiliency than other organics.	Still uses crumb rubber in the infill system which comes with all of the same concerns as having a regular crumb rubber infill and the top cork layer will breakdown over time.	8 years	- Grooming per 100 hours of play - Replace 10% of infill every 2-3 years - Decompaction 2 times a year - Annual G-MAX Monitoring	Can be used to topdress natural turf fields.	$4.75 - $5.00	Not required	$449,025	$12,000 - $18,000

	Infill Type	Examples	Material Description	Facts and Advantages	Disadvantages	Life Span	Maintenance	End of Life Cycle	Cost / S.F. *Carpet and infill system only	Irrigation System	Estimated Rt. 33 Field Synthetic Turf Cost (Soccer Field - 89,805 s.f.) * Carpet, infill, shock pad (if required) and irrigation system (if required) only.	Annual Maintenance Cost
	**ZeoFill**	1. Jesuit High School, CA 2. John Ferraro Athletic Fields, CA 3. Van Nuys - Sherman Oaks Complex, CA	Zeolites are naturally occurring minerals found in specific types of sedimentary rocks. Due to their natural absorbent/adsorbent qualities, zeolites have been used for many different applications. The use of ZeoFill was of particular interest to the synthetic grass industry since it is certified organic and therefore poses no safety concerns.	ZeoFill provides a cooler surface, less pungent rubber smell, no harmful silica sand dust which increase chances of silicosis and helps clean waste water run-off.	The Synthetic Turf industry has adopted zeolite as an alternative infill but most companies don't realize the potential harm if they use the wrong type of zeolite. Also due to the relative hardness of ZeoFill, a shock pad is required.	8 years	- Grooming per 100 hours - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be re-used as a soil amendment, cat litter or even storm water filtration	$6.25 - $6.50 (Includes $2.00 Shock Pad)	Not required	$583,733	$5,000 - $10,000 (Plus 300 hours of labor)
	**Cork & Coconut Fibers (GreenPlay)**	1. St. Timothy's School, MD	A select, high tensile strength coconut fiber matrix blended with ground virgin cork. No chemicals are added and it comes in a variety of browns and earth tone colors.	This environmentally sustainable, highly permeable,100% recyclable infill has proven to reduce turf temperatures up to 65 degrees, reduce G-Max levels, increase foot stability and reduce energy restitution with proven durability for the life of the field. These materials have a natural resistance to mold & fungus. Irrigation and a shock pad are required.	Requires irrigation to avoid hardening, requires annual additional infill, unproven longterm performance, increased cost per square foot, and higher maintenance costs.	8 years	- Grooming per 100 hours of play - Replace 10% of infill every 2-3 years - Decompaction 2 times a year - Annual G-MAX Monitoring - Monitor moisture content twice a week	Top layer (40%) can be reused as infill, the remaining 60% can be used to topdress a natural turf field.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	$40,000.00	$668,635	$12,000 - $18,000 (Does not include cost of water. 12,000 gallons twice a week is the recommended average)
	**Cork (PureFill)**	1. Santa Flavia- Palermo, Italy 2. SV Wateringseveld- The Netherlands 3. Signal Iduna Park- Dortmund, Germany	Cork infill is a natural infill that is 100% environment friendly and non-toxic. It is an organic, recyclable and sustainable product that is harvested from the cork oak tree every nine years, without harming the trees.	Cork is considered an unalterable and unperishable material. It has a low thermal conductivity due to its natural structure which will reduce the surface temperature significantly. The suberin component of cork is anti-microbial and anti-allergenic and will repel pests, mold, and prevent the cork from rotting. No water is required, but a shock pad is necessary.	Moderate resiliance, low density allows materials to float, cling to fibers with static charge, may require irrigation to remove static charge, and limited availability.	8 years	- Groom after heavy rain - Replace 10% of infill every 2-3 years - Decompaction 3 times a year/ every 4-6 weeks - Annual G-MAX Monitoring	Can be used to topdress natural turf fields or recycled directly into the environment.	$6.25 - $7.50 (Includes $2.00 Shock Pad)	Not required	$673,538	$14,000 - $20,000
	**Coconut Fibers (GeoFill)**	1. Google Corporate Campus Soccer Field, CA 2. Pleasantville High School and Middle School Fields, NY	Coconut fibers allows for clean water runoff, is 100% recyclable and is naturally resistant to mold and fungus. These fiber's unique organic properties, gives the entire system synthetic grass an amazing touch of naturalness	Coconut fibers are layered with sand and a shock pad to provide a stable surface that prevent infill shifts and flyouts. Naturally cooler because the composition of the fibers holds moister and is resistant to mold and fungus. This infill system will require irrigation and annual top dressing and decompaction.	Requires irrigation to avoid hardening, requires annual top dressing and decompaction, unproven longterm performance, increased cost per square foot, and higher maintenance costs.	8 years	- Grooming per 100 hours of play - Replace 10% of infill every 2-3 years - Decompaction 2 times a year - Annual G-MAX Monitoring - Monitor moisture content twice a week	Can be used to topdress natural turf fields or recycled directly into the environment.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	$40,000.00	$668,635	$12,000 - $18,000 (Does not include cost of water. 12,000 gallons twice a week is the recommended average)
	**Coconut Husk, Rice Husk and Cork (Infill-Pro Geo)**	1. The Fessenden School, MA 2. Virginia Soccer Training Center, VA 3. Highlands Field, CA	This unique natural infill is composed by selected organic fibres that guarantee better technical and sporting performances, provide better conditions for athletes, the environment and safety. Provides a natural grass-like look	Excellent UV resistance Due to the fibre nature and the plant origin, it has a high UV resistance making deterioration very slow over a very long time. This infill can be recycled for agricultural use therefore when the artificial turf comes to the end of its life, it is easy and economical to remove.	Requires irrigation to avoid hardening, requires annual additional infill, unproven longterm performance, increased cost per square foot, and higher maintenance costs.	8 years	- Grooming per 100 hours of play - Replace 10% of infill every 2-3 years - Decompaction 2 times a year - Annual G-MAX Monitoring - Monitor moisture content twice a week	Can be used to topdress natural turf fields or recycled directly into the environment.	$6.75 - $7.00 (Includes $2.00 Shock Pad)	$40,000.00	$668,635	$14,000 - $20,000 (Does not include cost of water. 12,000 gallons twice a week is the recommended average)
	**Walnut Shells (SafeShell)**	1. Baseball Field, Cincinnati, OH	Safeshell is made of 100% USA grown walnut shells.Safeshell teamed up with a leading biotechnology firm to develop a unique process that virtually eliminates residual protein allergens which remain on the shell after processing. SafeShell is a blend of Black and English walnut shells. Black walnut shells are more rounded than English walnut shells. The result of this proprietary mix is the perfect balance of firm, fast and player friendly.	Safeshell excels at evaporative cooling. Safeshell absorbs water with minimal expansion and then releases it slowly over time to help keep surfaces from heating up too quickly. Even dry, Safeshell plays cooler than crumb rubber. Safeshell is made from one of the hardest nut shells on the planet. It doesn't float and plays the same wet or dry. 100% organic.	Safeshell is a made from walnut shells because they are the hardest nut in the world. The trade-off is the abrasion factor.Also SafeShell has only been around for a little over two years so there is limited installation and long term use history.	Life of carpet	- Grooming per 100 hours - Decompaction every 3-4 years - Top dressing every 2-3 years - Annual G-MAX monitoring	Can be used to topdress natural turf fields or recycled directly into the environment.	$6.50 - $6.75 (Includes $2.00 Shock Pad)	Not required	$606,184	$5,000 - $10,000 (Plus 300 hours of labor)

APPENDIX C:

BIBLIOGRAPHY OF STUDIES AND LETTERS.

INDEPENDENT RESEARCH AND REPORTS ON CRUMB RUBBER INFILL (1998-2014)

as outlined by the synthetic turf council – www.syntheticturfcouncil.org

Tabor Academy – Synthetic Turf Athletic Field Evaluation
CDM Smith, March 13, 2014

- The objective of this study was to evaluate the potential water quality impacts of the synthetic turf field at Tabor Academy in Marion, MA.
- Conclusion: "...stormwater runoff from the athletic field is not a source of pollutants/contaminants that would pose a threat to the harbor."

Artificial turf football fields: environmental and mutagenicity assessment
Schilirò, T1, et al., Arch Environ Contam Toxicol, 2013

- The aim of the present study was to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM10 and PM2.5) and related polycyclic aromatic hydrocarbons (PAHs), aromatic hydrocarbons (BTXs), and mutagenicity of organic extracts from PM10 and PM2.5.
- Both organic extract mutagenicity values were comparable with the organic extract mutagenicity reported in the literature for urban sites.
- On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city.

Bioaccessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers
Environmental and Occupational Health Sciences Institute, Robert Wood Johnson Medical School, 170 Frelinghuysen Road, Piscataway, NJ, 2013

- "The SVOCs identified based on library matches of their mass spectra were not present in toxicological databases evaluated and many are ubiquitous part of consumer products. Similarly, the metal concentrations measured in field samples indicate that the risk would be de minimus among all populations expected to use artificial turf fields."

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 Cardno ChemRisk, Inc., August 1, 2013

- 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.

Artificial turf football fields: environmental and mutagenicity assessment
Department of Public Health and Microbiology, University of Torino, Italy, 2012

Crumb Infill and Turf Characterization for Trace Elements and Organic Materials
Dr. Paul J. Lioy and Dr. Clifford Weisel, Environmental and Occupational Health Sciences Institute, Robert Wood Johnson Medical School, October 31, 2011, Submitted to NJDEP

An Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields University of Connecticut Health Center
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 (see below).

Artificial Turf Field Investigation in Connecticut Final Report
Nancy Simcox, Anne Bracker, John Meyer, Section of Occupational and Environmental Medicine, University of Connecticut Heath Center, July 2010

DEP Artificial Turf Stormwater Study
University of Connecticut Health Center, The Connecticut Agricultural Experiment Station, the Department of Public Health and DEP, July 2010

Human Health Risk Assessment of Artificial Turf Fields Based upon Results from Five Fields in Connecticut
Connecticut Department of Public Health, Program in Environmental and Occupational Health Assessment, July 2010

Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields
Connecticut Academy of Science and Engineering, June 2010

2009 Study of Crumb Rubber Derived from Recycled Tires Final Report
Xiaolin Li, William Berger, Craig Musante, MaryJane Incorvia Mattina, Connecticut Agricultural Experiment Station, Department of Analytical Chemistry, May 2010

Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill
Joost G. M. van Rooij Æ, Frans J. Jongeneelen, International Archives of Occupational and Environmental Health, (2010) 83:105–110

- This study provides evidence that uptake of PAH of football players active on artificial grass fields with rubber crumb infill is minimal. If there is any exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet.

Review of the Impacts of Crumb Rubber in Artificial Turf Applications
Simon, Rachel, University of California, Berkeley, Laboratory for Manufacturing and Sustainability, February 2010
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."
- 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 safe, cost-effective, and responsible use for tire rubber.
  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.
- See April 5, 2010 Manex/UC Berkeley Press Release, Manex and UC Berkeley Issue Study on Recycled Rubber in Artificial Turf Applications

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

Office of Environmental Health and Hazard Assessment, Department of Resources Recycling and Recovery, Editor. 2010, State of California

- PM2.5 and associated elements (including lead and other heavy metals) were either below the level of detection or at similar concentrations above artificial turf athletic fields and upwind of the fields. No public health concern was identified.

A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds

National Exposure Research Laboratory Office of Research and Development U.S. Environmental Protection Agency, 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 organic 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

Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill

New York City Department of Health and Mental Hygiene, 2009

An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb-Rubber Infilled Synthetic Turf Fields

Lim, L. and R. Walker, New York State Department of Environmental Conservation and Department of Health, Editor, 2009

- Initial findings suggested that there was a low likelihood of risk to the environment or public health via drinking water from ground or surface water contamination.
- Further, the concentrations of VOCs and particulate matter detected above the surface of the fields did not exceed background levels, and thus do not suggest an increased risk from the installation of these fields.

Chemicals in Outdoor Artificial Turf: A health risk for users?

Beausoleil, Monique et. al, Public Health Branch, Montreal Health and Social Services Agency, June 2009

Zinc in Drainage Water Under Artificial Turf Fields with SBR

Hofstra, U., INTRON, March 2009

- On the basis of the new observations, we conclude that, after 7 years of use, zinc does not penetrate the underlays. This is consistent with the laboratory tests, in which it was calculated that zinc leaching will not occur until a period of 230 to 1800 years has elapsed2. It can also be concluded that the concentrations of zinc in the drainage water are not significantly higher than the concentrations in the rainwater.
- After 7 years, there is no evidence that the use of rubber infill poses a risk in terms of the leaching of zinc.

A Review of the Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill

Elizabeth Denly, Katarina Rutkowski, Karen M. Vetrano, Ph.D., TRC, Prepared for NYC Department of Health and Mental Hygiene, May 2008

- To date, eleven human health risk assessments were identified that evaluated exposure to the constituents in crumb rubber. Although each risk assessment was conducted using distinct

assumptions and evaluated different concentrations of COPCs (chemicals of potential concern) in crumb rubber, all had a similar conclusion: exposure to COPCs from the crumb rubber may occur, however, the degree of exposure is likely to be too small through ingestion, dermal or inhalation to increase the risk for any health effect. The risk assessments have been conducted primarily by state agencies, consultants, and industry groups.

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".

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..."

Evaluation of Playing Surface Characteristics of Various In-Filled Systems
McNitt, A.S., 2008 April 9, 2008

- Total microbial numbers were lower in synthetic turf systems when compared to natural grass fields. Staphylococcus aureus was not found on any of the playing surfaces.

Evaluation of the Environmental Effects of Synthetic Turf Athletic Fields
Bristol, S.G. and V.C. McDermott, Milone & MacBroom, Inc., 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 one 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.

Fact Sheet: Crumb-Rubber Infilled Synthetic Turf Athletic Fields
New York City Department of Health, August 2008

- Our review of the available information on crumb rubber and crumb rubber infilled turf fields indicates that ingestion, dermal or inhalation exposures to chemicals in or released from crumb rubber do not pose a significant public health concern.

Follow-up Study of the Environmental Aspects of Rubber Infill
Hofstra, U., INTRON, 2008

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.

Hazardous Chemicals in Synthetic Turf Materials and Their Bioaccessibility in Digestive Fluids
Zhang JJ, Han IK, Zhang L, Crain W. et. al, 2008

Rubber Crumb Health Risk Evaluation
Lamie, P. Memorandum to: Richard Reine, Director Concord Public Works, April 24. 2007 [cited 2008 4/28]

- There is little exposure to and thus little risk from PAHs or other chemicals associated with ground rubber used in artificial turf fields to the human population.

Synthetic Playfields Task Force Findings and Department Recommendations
San Francisco Recreation and Park Department, 2008

- SFE recognizes that human health risks are minimal from exposure to the crumb rubber infill used with synthetic turf products, according to the OEHHA study.

Environmental and health assessment of the use of elastomer granulates (virgin and from used tyres) as infilll in third-generation artificial turf
Dr. Robert Moretto, ADEME / ALIAPUR / FIELDTURF TARKETT, 2007

- According to current research, after a year's experimentation, the results on the 42 physicochemical parameters identified and on the ecotoxocological tests show that water passing through artificial turf using as filling either virgin TPE or EPDM or granulates resulting from the recycling of PUNR are not likely to affect water resources in the short and medium term.
- In conclusion to its study, the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial surfaces on pitches in outdoor situations present no actual cause for concern as regards human health.
- Worst case indoor VOC and aldehyde concentrations do not pose a health concern for adult or child athletes.

Environmental and Health Risks of Rubber Infill: Rubber crumb from car tyres as infill on artificial turf
Hofstra, U., INTRON, January 2007

- Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contact we conclude, that there is not a significant health risk due to the presence of rubber infill for football players an artificial turf pitch with rubber infill from used car tyres.

Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products
California Integrated Waste Management Board, 2007, Integrated Waste Management Board: Sacramento, CA

- Using the highest published levels of chemicals released by recycled tires, the likelihood for noncancer health effects was calculated for a one-time ingestion of ten grams of tire shreds by a typical three-year-old child; only exposure to zinc exceeded its health-based screening value (i.e. promulgated by a regulatory agency such as OEHHA or U.S. EPA). Overall, we consider it unlikely that a one-time ingestion of tire shreds would produce adverse health effects. Seven of the chemicals leaching from tire shreds in published studies were carcinogens, yielding a 1.2×10^{-7} (1.2 in ten million) increased cancer risk for the one-time ingestion described above. This risk is well below the *di minimis* level of 1×10^{-6} (one in one million), generally considered an acceptable cancer risk due to its small magnitude compared to the overall cancer rate (OEHHA, 2006).

Evaluation of health risks caused by skin contact with rubber granules used in synthetic turf pitches
Dr. Christa Hametner, Vienna, Dr. Hans Theodor Grunder, Berlin, 2007

- No significant health risks by either direct contact to rubber granules or by contact to rubber dust - with the exception of the risk of allergic reactions in indoor applications.

Leaching of zinc from rubber infill on artificial turf (football pitches)
Laboratory for Ecological Risk Assessment, 2007

- Human health risks posed by leaching of zinc are negligible as zinc concentrations in the water do not exceed drinking water standards. The risks of zinc to public health are of no concern: the human toxicity of zinc is low and WHO drinking water criteria are not exceeded.

Nitrosamines released from rubber crumb
van Bruggen, M., E.M. van Putten, and P.C.J.M. Janssen, 2007, RIVM: Bilthoven, the Netherlands

- Small quantities of nitrosamines emitted but not detectable in air; nitrosamine related health effects not likely.

Preliminary Assessment of the Toxicity from Exposure to Crumb Rubber: its use in Playgrounds and Artificial Turf Playing Fields
Thomas Ledoux, Ph.D., New Jersey Department of Environmental Protection, June 2007

- With the possible exception of allergic reactions among individuals sensitized to latex, rubber and related products, there was "no obvious toxicological concern" raised that crumb rubber in its intended outdoor use on playgrounds and playing fields would cause adverse health effects in the normal population.

Re: Ambient Air Sampling for PAH's, Schreiber High School Football Field (101 Campus Dr., Port Washington, NY 11050; Sampling Date: October 17, 2007)
Broderick, J.C., E. Vonderhorst, Editor, J.C. Broderick & Associates, Inc.: Port Washington, NY., 2007

An Assessment of Environmental Toxicity and Potential Contamination from Artificial Turf using Shredded or Crumb Rubber
Sullivan, J.P., Ardea Consulting: Woodland, CA. p. 1-43, 2006

Artificial turf pitches – An assessment of the health risks for football players
Norwegian Institute of Public Health and the Radium Hospital, 2006, Oslo. p. 1-34.

- Recycled rubber granulate contains many chemical substances which are potentially harmful to health. The concentrations of these substances are however extremely low, they are only leached from the rubber granulate in very small quantities and they are only present in low concentrations in the hall air.
- It has been concluded that exposure to benzene and PAHs in the quantities in which they have been measured in the halls will not cause any increased risk of cancer using the halls.
- Chemical substances are released in very low quantities; based on worst case assumptions, use of artificial turf halls does not pose elevated risk; more information needed on natural rubber allergens.

An Open Letter concerning the potential cancer risk from certain granulate infills from artificial turf
FIFA, Prof. Dr. Jiri Dvorak, July 2006

- "The majority of the studies have been on higher surface area particles and have concluded they are currently acceptable. Therefore the larger granules used in artificial turf will have even less potential for emissions. For example a study undertaken by the Danish Ministry of the Environment concluded that the health risk on children's playgrounds that contained both worn tyres and granulate rubber was insignificant. The available body of research does not substantiate the assumption that cancer resulting from exposure to SBR granulate infills in artificial turf could potentially occur."

Synthetic Turf from a Chemical Perspective - A status report
The Swedish Chemicals Inspectorate (Kemi), KEMIKALIENIMSPEKTIONEN Sundbyberg. p. 1-31, 2006

Measurement of non-exhaust particulate matter
Luhana, L., et al., 2004, Deliverable 8 of European Commission DG TrEn 5th Framework PARTICULATES Project

- In comparison to the indoor fields, 7.5 percent of PM10 at an urban Switzerland curb side sampling location was attributed to tire wear particles. The fraction of PM10 attributed to tire wear particles was 2 percent at an urban background site. The levels of PM10 attributable to ground rubber measured at

Norwegian fields appear to be similar in magnitude levels attributed in ambient air near roadways or tunnels. Typical ambient tire wear particle concentrations of PM10 or total suspended particulate are 2-5 µg/m3 for roadways and 10-20 µg/m3 for tunnels. Research to date has shown a highly variable distribution between fine (< 2.5 µm) and coarse (>7 µm) in airborne roadside tire wear particles.

Environmental Risk Assessment of Artificial Turf Systems
Kallqvist, T., Norwegian Institute for Water Research: Oslo. p. 1-19, 2005

Potential health and environmental effects linked to artificial turf systems – final report
Plesser, Thale S.W., Lund, J. Ole, Norwegian Building Research Institute, September 2004

- Rubber granules contain lead, cadmium, copper, mercury, zinc, PAHs, phthalates, 4- toctylphenol and isononylphenol.
- Concentration of lead, cadmium, copper and mercury in the rubber granules is below the Norwegian Pollution Control Authority's normative values for most sensitive land use and probably does not constitute an unacceptable environmental risk in the short or the long term.
- Concentrations of zinc and PAH in the recycled rubber granules exceed the Norwegian Pollution Control Authority's normative values for most sensitive land use. The concentrations of dibutylphthalate (DBP) and diisononylphthalate (DINP) exceed the PNEC values for terrestrial life.
- Concentration of isononylphenol is above the limits specified for cultivated land in the Canadian Environmental Quality Guidelines.
- Leachate from the recycled granulates contain zinc, polycyclic aromatic hydrocarbons (PAH), phthalates and phenols. The concentration of zinc indicates that the leachate water is placed in the Norwegian Pollution Control Authority's Environmental Quality Class V (very strongly polluted water), but is lower than the permissible zinc concentration in Canadian drinking water. The concentration of anthracene, fluoranthene, pyrene and nonylphenols exceed the limits for freshwater specified in the Canadian Environmental Quality Guidelines.
- The recycled rubber granulates give off a significant number of alkylated benzenes in gaseous form. Trichloromethane (sample 1) and cis-1,2-dichlorethene (sample 5) were also found.

Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds
Birkholz, D.A., K.L. Belton, and T.L. Guidotti, J. Air & Waste Management Association, July 2003

- "Genotoxicity testing of tire crumb samples following solvent extraction concluded that no DNA or chromosome-damaging chemicals were present. This suggests that ingestion of small amounts of tire crumb by small children will not result in an unacceptable hazard of contracting cancer."
- We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment.
- Extracts were not genotoxic and exposure potential in children deemed minimal; tire rubber at playgrounds does not pose a health hazard to children.
- An exposure assessment performed to address the potential health risks to children playing in facilities where tire crumb is used as ground cover concluded that there was little potential for an exposure sufficient to cause ad- verse health effects in children.

Child-Specific Exposure Factors Handbook
U.S. EPA, National Center for Environmental Assessment–Washington Office, September 2002

- Supplemental chronic risk estimates based on a child's typical incidental ingestion rate of 100 mg/day, as prescribed by the U.S. EPA's Child-Specific Exposure Factors Handbook, indicate that regular exposure (e.g., regular play on ground rubber filled athletic fields) to ground rubber for the length of one's childhood does not increase risk of cancer above levels considered by the state of California to be de minimus (i.e. a lifetime excess cancer risk of 10-6) or pose a likelihood of non-cancer effects (i.e. hazard index less than one).

Five Year Study of the Water Quality Effects of Tire Shreds Placed Above the Water Table
Humphrey, D.N. and E.K. Lynn, Department of Civil and Environmental Engineering, University of Maine, March 2001

- Tire shreds have a negligible impact on groundwater quality at neutral pH.

Emission Characteristics of VOCs from Athletic Tracks

Chang, F.H., et al., J Hazard Mater, 1999. 70(1-2): p. 1-20

- From 67 to 160 °F, the vapor pressure of benzothiazole increases by a factor of almost 40. However, based on a study of a synthetic rubber athletic track, total VOC emissions are estimated to increase by a factor of only 2 over the same range. No exposure estimates or risk calculations were determined based on results from this study. However, total VOC concentration at breathing height above the track was 0.39 µg/m3.

Environmental Impacts of Recycled Rubber in Light-Fill Applications

Liu, Helen S., et. al., Department of Plastics Engineering, University of Massachusetts Lowell, August 1998

- Recycled rubber derived from scrap tires is a safe recyclable material. Based on the evidence presented, the overwhelming conclusion is that it would be reasonable to recommend use of recycled scrap tires in civil engineering applications.