Artificial Turf Fields
A Literature Review and Recommendations
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Introduction

During the two decades following the introduction of artificial turf to athletic fields in the mid-60s (famously in Houston's Astrodome in 1966), the popularity of the new material grew. Only in the late-80s were the merits of synthetic playing surfaces first questioned seriously. The earliest complaints were voiced by players concerned with what they claimed to be a higher rate of injury associated with the artificial fields. More recently, a host of concerns have surfaced regarding the environmental and human health effects caused by the artificial materials from which turf is constructed.[1]

The aim of this report is to present as coherent a view as possible with respect to these effects in order to formulate recommendations regarding the use of artificial turf. Most of the information has been synthesized from academic journal articles and municipal agency publications. Information in this report was located using Internet searches and sources listed on the advocacy site synturf.org.

Summary:

Artificial turf fields may be made in one of several ways, but they are commonly composed of plastic fibers woven into a plastic mesh backing. The fibers are usually supplemented by an in-fill material, which is frequently composed of pellets made from recycled automobile tires, called "crumb rubber". Other in-fill materials are sometimes mixed with or may even replace crumb rubber. A great deal of the health-related controversy surrounding artificial turf has centered on crumb rubber.[2]

The composition of crumb rubber includes a wide array of synthetic organic chemicals, some of which can out-gas or leach from the material. In addition to these chemicals, crumb rubber may contain high levels of zinc, and possibly other metals such as arsenic, cadmium, chromium, lead or selenium.[3]

While concern has been raised regarding the presence of all of these substances, which have been found to be harmful at certain concentrations to human and environmental health, the substance that has been most widely linked to adverse environmental effects is zinc. Runoff from synthetic playing surfaces can result in zinc concentrations in surface water high enough to kill marine life.[4] Most studies have found that other chemicals become sufficiently diluted before entering surface water so as not to pose a serious risk.

1 Luz, 2008

2 "Additional Artificial Turf Issues," 2008

3 Ibid.

4 Graham, 2008.

The other main concerns among the literature stem from the presence of microorganisms on the artificial surfaces, lead in the plastic fibers, and the tendency of synthetic turf to become much hotter than natural grass.

The literature review below lends itself to the recommendation that natural grass fields be utilized rather than synthetic turf. Although the environmental and human health effects associated with artificial turf have not been demonstrated conclusively, enough evidence of harmful effects exists to warrant application of the Precautionary Principle.

Benefits of Synthetic Turf:

Artificial fields offer some benefits over natural grass that are environmental and financial in nature. They require no mowing, fertilizers, or pesticides, and are resistant to wear and tear due to heavy sporting use.[5] They include long-lasting painted lines for sporting fields, guarantee a uniform playing surface in all weather conditions, can be snow plowed using rubber fittings, and can be fitted with drainage systems to prevent flooding.[*] The ability of synthetic fields to be used year-round has resulted in increased usage within school districts.[6] They do not require watering for maintenance, but some fields are watered for cooling on hot days. The International Hockey Federation actually requires that all artificial field hockey surfaces be saturated prior to practices or games to ensure better traction and bounce.[7]

Disadvantages of Synthetic Turf:

Environmental Health

Little research has been conducted to determine crumb rubber's environmental impacts as a source of physical pollution in the form of debris. There is anecdotal evidence, however, that the pellets can be easily conveyed to water bodies through storm drains, and studies on plastic pellets show that debris of equivalent size can be ingested by marine organisms. The National Oceanic and Atmospheric Administration notes that this can cause blockages of the esophagus, introduce toxins to the animal's system, and induce an artificial sense of satiation that can deplete energy reserves.[8]

The New Jersey Department of Health and Senior Services found crumb rubber to include volatile organic chemicals such as toluene, benzene, and aldehydes, and other organic chemicals such as phthalates and polycyclic aromatic compounds. A study by the Connecticut Agricultural Experiment Station reported out-gassing and leaching of benzothiazole, butylated hydroxyanisole, n-hexadecane, and 4-(t-octyl) phenol from crumb rubber.[9] A report by INTRON, a Dutch building materials service company, also

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5 "Synthetic Turf Products."

* Specific information regarding drainage systems and the possibility of filtration was not available.

6 "Benefits of Synthetic Turf." DLH Architecture.

7 Blythe, 2007.

8 Ibid.

9 "Additional Artificial Turf Issues," 2008

describes the presence of nitrosamines, xylenes, and secondary amines.[10] (See Table 1 for the health hazards associated with these chemicals).

Table 1. Health Hazards Associated with Chemicals found in Crumb Rubber

Chemical	*Recognized Health Hazards*	*Suspected Health Hazards*
Toluene	Developmental toxicant;	Cardiovascular or blood toxicant; Gastrointestinal or liver toxicant; Immunotoxicant; Kidney toxicant; Neurotoxicant; Reproductive toxicant; Respiratory toxicant; Skin or sense organ toxicant
Benzene	Developmental toxicant; reproductive toxicant; carcinogen	Cardiovascular or blood toxicant; Endocrine toxicant; Gastrointestinal or liver toxicant; Immunotoxicant; Neurotoxicant; Respiratory toxicant; Skin or sense organ toxicant
Aldehydes	Inhalation or contact may irritate or burn skin and eyes; Inhalation, ingestion, or absorption through skin may be fatal	
Phthalates		Developmental toxicant; Endocrine toxicant; Reproductive toxicant
Polycyclic aromatic compounds		Carcinogen; Cardiovascular or blood toxicant; Gastrointestinal or liver toxicant; Reproductive toxicant; Respiratory toxicant; Skin or sense organ toxicant
Benzothiazole	Skin and eye irritation	
Butylated hydroxyanisole	Carcinogen	Endocrine toxicant; Gastrointestinal or liver toxicant; Immunotoxicant; Neurotoxicant; Respiratory toxicant; Skin or sense organ toxicant
N-Hexadecane	Flammable	
Nitrosamines		Skin or sense organ toxicant
Xylenes		Cardiovascular or blood toxicant; Developmental toxicant; Gastrointestinal or liver toxicant; Immunotoxicant; Kidney toxicant; Neurotoxicant; Reproductive toxicant; Respiratory toxicant; Skin or sense organ toxicant

Sources: "Chemical Profiles," Scorecard; CAMEO Chemicals

10 Hofstra, 2007.

The primary hazard associate with the chemicals found in tires is aquatic in nature. The INTRON report concludes that the emission of hazardous substances into air does not pose an environmental risk because only very limited amounts of volatile components were found. The only material that was found in significant concentrations was zinc, which leaches into ground and surface water.[11] (Zinc, one of the main additives used in tire manufacturing, is used to quicken the rubber vulcanizing process.[12])

INTRON's results were corroborated by a study conducted by Environment and Human Health, Inc., a private Connecticut-based organization.[13] A study by the Norwegian Institute for Water Research found the levels of alkylphenols to be too high as well.[14] Both of these studies emphasize, however, the fruitlessness of attempting to find consistent levels of any toxic chemical in crumb rubber because of the considerable variation in the concentrations of components between different types of car tires.

Braun Intertec, an engineering and environmental consultancy, conducted a literature review, which discovered that chemical exposures have been documented within the rubber fabrication and reclamation industries. Contaminants include volatile organic compounds and semi-volatile hydrocarbons. Additionally, toxic chemicals have been found to leach into groundwater at tire reclamation sites.[15]

The most significant means by which chemicals from synthetic turf impact the environment is by getting washed into water bodies by the rain. It is possible that synthetic turf reduces net runoff by obviating irrigation[16], but typical synthetic turf is impermeable and the chemicals that it releases filter directly into storm drains and into municipal sewer systems during runoff events. Additionally, runoff does not undergo the beneficial filtration process that live vegetation provides before reaching surface water.[17] Threats from leached chemicals are greater in freshwater, as toxicity has been shown to decrease as salinity increases.[18]

A study published by an industry association counters the notion that runoff poses a serious environmental risk, arguing that the precipitation that conveys the chemicals into water bodies also dilutes them, and that toxicity only persists for three months anyway.[19] This seems, however, to be the minority view among the literature.

Permeable artificial fields do exist, and are used to prevent flooding, but they do not eliminate the problem of storm water runoff, because they do not provide filtration before

11 Ibid.

12 Graham. 2008.

13 Brown, 2007.

14 Källqvist, 2005.

15 Olson, 2008.

16 "Conservation." Irvine Ranch Water District.

17 Claudio, 2008.

18 Graham. 2008.

19 Birkholz, et. al, 2003.

runoff reaches surface water. The University of Virginia, for example, installed an artificial field that drains by infiltration to a permeable drain system located beneath the field. An environmental impact review published but the University's Office of Environmental Health and Safety determined that "the system is very permeable and drains by infiltration into the base and through the perforated underdrains." The collected water, however, is merely channeled toward a nearby body of water without being filtered.[20]

Human Health

Risk of Infection

Several studies have been carried out to test whether synthetic surfaces pose a greater risk of infection due to bacteria, fungi and other microorganisms than natural grass fields. Much of the research has focused on the ability of methicillin-resistant *Staphylococcus aureus* (MRSA) to survive and be transferred by the polyethylene blades of false grass.

Although there is some disagreement among the literature, most researchers seem to agree that artificial surfaces effectively harbor a range of microorganisms.[21] In-fills composed of a rubber/sand mixture, in particular, have been found to exhibit high levels of bacterial activity.[22]

Toxicological Effects

A wide array of positions comprises the debate over the severity of the toxicological effects associated with artificial turf. The positions are unified, however, by the limited amount of available toxicological data. The differing conclusions from this dearth of scientific information seem to be based on a sliding scale of willingness to utilize a substance with unverified effects.

The New Jersey Department of Environmental Protection Division of Science, Research and Technology conducted a literature review in June 2007 of health risk assessments related to crumb rubber on artificial turf fields. The review found little information concerning the environmental and human safety impacts of crumb rubber. It concluded that other than possible allergic reactions among people sensitized to latex, rubber and related products, there are no obvious toxicological issues associated with artificial fields.[23]

The French National Institute for Industrial Environment and Risks found that the volatile organic compounds emitted by artificial turf "give no cause for concern towards human health." The California Office of Environmental Health Hazard Assessment similarly reported that it is "…unlikely that a onetime ingestion of tire shreds would produce

20 Wenger & Sitler, 2004.

21 Orthman, 2006.

22 Claudio, 2008.

23 "Additional Artificial Turf Issues," 2008.

adverse [non-cancer] health effects," and that the risk of developing cancer from one-time exposure "…is well below the *de minimis* level of…one in one million…"[24]

The Norwegian Institute of Public Health conducted a risk assessment in 2006 and concluded that exposures to volatile and other synthetic organic chemicals does not pose an increased risk of adverse health effects, including allergy and cancer. The report did acknowledge, however, that odors and mucous membrane irritation could have temporary health impacts.[25]

Citing the above-mentioned study by the Connecticut Agricultural Experiment Station, Dr. Brown of Environment and Human Health, Inc. challenged the conclusions of previous health risk assessments. He argued that "…tire crumbs constitute a chemical exposure for humans and the environment…" and that "…health endpoints of concern are numerous, including acute [and chronic] irritation of the lungs, skin and eyes." "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." Therefore Brown recommended a "…moratorium on installing any new fields or playgrounds…" until potential exposures and health risks have been further assessed.[26]

Using even stronger language, KEMI – the Swedish Chemicals Inspectorate – advises discontinuing the use of recycled tires in artificial turf fields because the chemicals and metals that have been observed to leach out adversely affect human and environmental health.[27]

The U.S. Consumer Product Safety Commission conducted a study that found lead contained in the pigments that color synthetic grass blades. It concluded that the levels of lead are not harmful, but that children should wash their hands after playing on artificial fields.[28] This conclusion has been heavily criticized because Centers for Disease Control has not determined a benchmark level of exposure under which lead is not considered to be harmful. What it has written is that if enough is absorbed by the body, lead can cause neurological problems.[29] It should be emphasized, however, that as of yet, no cases of elevated blood lead levels in children have been linked to artificial turf on athletic fields anywhere in the US.[30]

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24 Ibid.

25 Ibid.

26 Brown, 2007.

27 Snöbohm & Rydén, 2008.

28 "CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On," 2008.

29 "Federal agencies at odds over artificial turf recommendations," 2008.

30 Ibid. In general, children less than 6 years old are more likely to be affected by lead than adults because of increased contact with lead sources in the environment, including lead-contaminated house dust and soil. Additionally, children absorb lead more easily and their developing nervous systems are more susceptible to the adverse health effects of lead including developmental delay and behavioral problems.

The New Jersey Department of Health and Senior Services found that fields made solely with polyethylene fibers contain very low levels of lead, but that turf made of nylon or nylon/polyethylene blend fibers contain high enough levels of lead to pose a potential public health threat. The risk for harmful exposure is low for new fields because lead is unlikely to escape from intact fibers, but as turf ages and weathers, lead gets released as dust that can be ingested or inhaled.[31]

The Connecticut Department of Public Health released a fact sheet that takes the middle ground in the debate over toxicological risks. The publication states that "based upon the current evidence, a public health risk appears unlikely. However, there is still uncertainty and additional investigation is warranted." The Department recommended "…consider[ing] these uncertainties as part of the array of issues evaluated when deciding whether to install artificial turf fields (e.g., cost, maintenance, public acceptability)."

Other Effects

Artificial turf surfaces are reported to have temperatures significantly higher that natural grass fields, increasing the risk of burns, dehydration and heat exhaustion in children. A researcher at the Center for Climate Systems Research at Columbia University found that synthetic turf fields can get up to 60°F hotter than grass, with surface temperatures reaching 160° during the summer.[32] Researchers at Brigham Young University found that synthetic fields sometimes reach 86.5°F higher than grass fields and that their temperatures can climb as high as 200°.[33] The town of Needham, MA devised a protocol with the installation of new artificial turf fields in 2009, which includes signs to warn the public of risks associated with turf activities on especially hot days, and which limits the amount of time that youth groups can spend using the fields.[34]

Although physical injury was the first health concern ever raised regarding artificial playing surfaces, the literature has still not reached a consensus around whether they in fact cause more injuries than natural grass surfaces. A study published in 2004 in *The American Journal of Sports Medicine* showed that about 10% more injuries befell high school football players using artificial fields than those using natural fields (although the risk of serious head and knee injuries was higher on grass fields). Several studies published in *British Journal of Sports Medicine*, however, showed no variance in the frequency or severity of injuries experienced on the two surfaces.[35] A factsheet that the New York State Department of Health published does not point to an elevated likelihood of physical injury when using either playing surface. It reports, though, that the abrasiveness of synthetic turf fibers may cause injuries such as abrasions or "turf burns".

31 "Potential Exposure to Lead in Artificial Turf," 2008.

32 Claudio, 2008.

33 Olson, 2008.

34 Ryan, 2009.

35 Olson, 2008.

Penn State University conducted a study that suggests synthetic turf made from nylon fibers is more abrasive than turf containing other types of fibers.[36]

Alternatives:

A number of alternatives to rubber in-fill made from recycled tires exist. However, third-party studies have not been carried out to test the health effects of these alternative materials. Mondo, a flooring manufacturer, produces a polyolefin-based granule that can replace crumb rubber. According to the company, their 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. Limonta Sport sells an infill made from natural coconut husks and cork.[37]

While these new materials may be less hazardous, they must overcome the fact that end-of-life tires currently glut the market and provide a cheap, steady source of in-fill. There is also a tremendous environmental benefit to recycling tires, as recycling avoids the need for the resources involved in producing replacement materials. The political push to recycle these tires adds incentive to convert them to in-fill and other artificial turf surfaces.[38] Strict regulations may be necessary to make safer materials more competitive.

Recommendations:

Although there is no clear consensus among the literature, natural fields are likelier more benign from both an environmental and a human health perspective than artificial fields. Adherence to the Precautionary Principle[39] is advisable in opting for natural fields.

If artificial turf is to be installed, the following steps are recommended to mitigate its negative impacts:

- A filtration system should be installed so that runoff may be treated, especially for zinc, before entering surface water.
- Storm drains should not be constructed on fields such that runoff events could carry crumb rubber toward water bodies. Measures such as curbing, installing grass buffers and minimizing surrounding impervious surfaces can be used to limit the risk of runoff finding its way to surface water or storm drains.
- Synthetic turf should be treated with disinfectant to prevent microbial infection. The disinfectant should be selected based on the degree to which it can get washed in surface water without harming the environment.

36 "Fact Sheet: Crumb-Rubber Infilled Synthetic Turf Athletic Fields," 2008.

37 Claudio, 2008.

38 Graham. 2008.

39 The Precautionary Principle dictates that when an activity threatens harm to human or environmental health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

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