



Health Impact Assessment of the Use of Artificial Turf in Toronto

April 2015

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Abbreviations and Acronyms

ACL	Anterior cruciate ligament
ASTM	American Society of Testing and Materials
CA-MRSA	Community associated MRSA
CDC	Centers for Disease Control and Prevention, US
COPC	Contaminants of potential concern
CPSC	Consumer Product Safety Commission, US
EPA	Environmental Protection Agency, US
GIS	Geographical Information System
GHG	Green house gas
HEIA	Health Equity Impact Assessment
HIA	Health Impact Assessment
KemI	Swedish Chemicals Agency
MRSA	Methicillin-resistant <i>staphylococcus aureus</i>
OEHHA	Office of Environmental Health Hazard Assessment, California
PAH	Polycyclic aromatic hydrocarbons
PGMC	Planning and Growth Management Committee
PF&R	Parks, Forestry and Recreation
SBRr	Styrene-butadiene recycled rubber
SVOC	Semi-volatile organic compound
TBI	Traumatic brain injury
TCDSB	Toronto Catholic District School Board
TDSB	Toronto District School Board
TPH	Toronto Public Health
UHI	Urban Heat Island
VOC	Volatile organic compound
WHO	World Health Organization

EXECUTIVE SUMMARY

Introduction

For a number of years, Toronto Public Health has been responding to requests by internal and external stakeholders on the health and safety of artificial turf products. This health impact assessment (HIA) was undertaken to gain a more complete understanding of the health concerns related to the use of artificial turf in Toronto given its increasing use. This HIA focuses on the use of third generation artificial turf in sports fields and play spaces, which is now the most common type in use, and examines the impacts on the social and environmental determinants of health and their associated effects on health. A proposal to install artificial turf may result in a change of use patterns on the field or the installation of structures. While these associated changes may have community impacts, they are not the focus of the HIA.

Background on Artificial Turf in Toronto

Artificial turf is being widely promoted by the industry as a cost-efficient, maintenance-free, and environmentally-friendly product that can replace natural grass on a variety of surfaces. Third generation systems, which are widely used today, improve upon abrasive and less shock-absorbing variants found in earlier generations. Typically, they are comprised of a mat of evenly-spaced fibres, filled with small rubber granules or a mixture of rubber granules, sand or other material, and sometimes with a shock pad for added safety. Manufacturers are evolving their product, in part, to address concerns related to heat, toxicity and injury.

In Toronto, the use of artificial turf surfaces is becoming increasingly common on sports fields, and the trend is spreading to schools, child-care facilities, parks, streets, home lawns and commercial areas. To date, the Toronto District School Board (TDSB) and the Toronto Catholic School Board (TCDSB) have installed artificial turf on the properties of 18 elementary and four high schools and plan to install artificial turf on the properties of 19 additional schools. Toronto's Park, Forestry and Recreation (PF&R) Division maintains over 14 artificial sports fields and has a plan to install four additional artificial turf sports fields over the next few years. Artificial turf is also being used by Business Improvement Areas (BIAs) and the City's Urban Forestry Unit as a groundcover option in Toronto streetscapes.

Toronto residents and organizations in other jurisdictions have raised concerns regarding the potential effects of artificial turf on human health and the environment, with the recycled tire infill material being one of the main sources of concern. Many studies have been conducted by universities, government agencies, sports federations, and manufacturers of artificial turf to assess the toxicological risks associated with artificial turf materials. Other studies have examined the impact of artificial turf on: the rate and types of injuries among users; the absorption of heat; and storm-water management.

The 2014 Provincial Policy Statement directs municipalities to address climate change mitigation and adaption, including maximizing the use of vegetation and pervious surfaces. Toronto addresses this through the Toronto Green Standard and zoning bylaw, which limit the use of hard surfaces, including artificial turf, on properties in the city and encourage natural landscaping to reduce the urban heat island impacts of development. Currently, artificial turf is treated as a "non-roof hardscape" in the Toronto

Green Standard, grouping it together with other surfaces that display heat-retaining properties which are known to contribute to local urban heat island effects.

Health Impact Assessment (HIA) Methodology

Health impact assessment is a systematic, objective process, recognized by the World Health Organization, which reviews how a proposed policy, program or initiative impacts the different environmental and social determinants of health. Among others, an HIA may look at determinants like air quality, water quality, physical activity, social inclusion and disability. It uses the best available evidence gathered from research, stakeholders and the community to assess the likely impacts (both positive and negative) of a proposal on the health and wellbeing of people as well as the distribution of these impacts on different sub-populations. It also makes recommendations on how a proposal might be amended to promote positive impacts and/or reducing negative impacts, including the inequitable distribution of these impacts.

An HIA Working Group made up of representatives from Toronto Public Health, Children Services, City Planning, Environment and Energy, Parks, Forestry and Recreation, and Toronto Water, was formed. Toronto Public Health's HIA tool was adapted and used to identify potential health and environmental impacts associated with the use of artificial turf that would be addressed in the assessment. The Working Group agreed that the HIA would begin with an assessment of artificial sports fields (e.g. indoor and outdoor recreational and professional sports pitches) and play spaces (e.g. school and park playgrounds, child-care centres). As the findings of this HIA are also relevant to residential and commercial landscaping and other uses, reference would also be made to these uses as appropriate. Given the variety of artificial turf systems, the assessment would primarily assess the impacts of third generation systems with a crumb rubber infill and compare these with natural grass or other surface materials.

The assessment was informed by a review of peer-reviewed and grey literature and targeted consultations. Key informants included staff from some Toronto schools and school boards, playground design experts, and other municipalities with experience using artificial turf.

Summary of Findings

The results of this HIA are organized under five social and environmental determinants of health which have been grouped into three categories: natural environmental factors; built environment and lifestyle factors; and equity and access factors. Factors having the potential for greatest positive or negative impact on health and the environment are highlighted below. The data available are predominantly on third generation artificial turf sports fields. The assessment therefore focuses on this use, though the findings are also relevant to children's play spaces, residential and commercial landscaping uses.

Natural Environmental Factors

Evidence of Harm

- Artificial turf is made of several heat-retaining materials which can significantly increase field surface temperatures, substantially increase air temperatures near fields, and potentially contribute to the urban heat island effect in surrounding neighbourhoods. This contributes to increased health risk during hot weather events.

- Increased surface and air temperatures created by artificial turf fields can increase the risk of heat-related illnesses and injuries among users during heat waves, particularly among young children who are more sensitive to extreme heat. Young children and athletes are especially susceptible to heat-related illness such as dehydration, heat exhaustion and heat stroke while exercising in hot conditions.
- Traditional artificial turf systems, designed with subsurface drain pipe systems, can increase storm water run-off, contributing to water quality concerns and increase flooding risks after heavy rainfall or snow melts; these events are expected to increase in Toronto with climate change.
- Hazardous substances from the crumb rubber can leach into surface or ground water; these releases are below levels of concern to human health. More research is needed to assess the potential impact on the health of aquatic ecosystems from the release of zinc and a few other substances that may be found in artificial turf. Pesticides and fertilizers used in the maintenance of natural turf may also contaminate surface and ground water.
- Artificial turf surfaces do not provide the ecological or biodiversity benefits of natural turf. This is expected to negatively affect nearby trees, other vegetation and reduce the capacity of the ground to absorb rainfall or snow melt, increase flooding risks.
- Natural grass fields serve as important "carbon sinks" removing carbon dioxide from the atmosphere; while the carbon foot print of artificial turf varies depending on the materials used and design, artificial turf fields release carbon into the atmosphere during their manufacturing, transportation, installation, maintenance and end-of-life disposal stages.

Evidence of Benefit

- Evidence suggests that artificial turf fields need less water for their maintenance, which is an advantage in areas with potential water shortages.

Neutral or Inconclusive

- Based upon a review of the available evidence, third generation artificial turf is not expected to result in exposure to toxic substances at levels that pose a significant risk to human health provided it is properly installed and maintained and users follow good hygienic practices (for example washing hands, avoiding eating on artificial turf and supervision of young children to ensure they do not eat the infill material).
- There is insufficient evidence related to the allergenic potential of latex in crumb rubber; more study is required to address uncertainty in exposure estimates for lead, other metals, polyaromatic hydrocarbons and other substances; and further research is needed to more fully understand the potential impact of low-level exposure to carbon nanotubes. These risks can be minimized through the use of standard hygienic practices.

Built Environment and Lifestyle Factors

Evidence of Harm

- While artificial turf may offer opportunities to improve athletic programming or revitalize barren spaces, they can displace natural green space which is also important to health and the development of children.
- There is evidence that artificial turf may increase the risk of skin abrasions which can in turn facilitate infections.
- In general, artificial turf lacks the natural biodegrading properties of natural surfaces, making it more susceptible to unsanitary conditions for users.
- Although the impacts of artificial turf are expected to vary from community to community, where artificial turf fields intensify the use of the field for organized sports, negative impacts on quality of community life may occur.

Evidence of Benefit

- Artificial sports fields provide more total available hours of usage than current natural fields and can extend playing seasons.
- Artificial turf has the potential to acting as a barrier between the surface and underlying contaminated soil which may facilitate re-development of contaminated sites for recreational purposes; this could increase opportunities for physical activity.

Neutral or Inconclusive

- While sports fields with artificial turf are often used for structured sports for more hours per year, the impact of such installations on overall levels of physical activity in a community is not known.
- Research suggests that artificial turf and natural grass have comparable rates of injury with differences in injury patterns.
- Parks and playgrounds with a diversity of well-maintained natural features are also important for children's health.

Equity and Access Factors

Evidence of Benefit

- Artificial turf fields have the potential to enhance health equity in Toronto by providing opportunities for outdoor recreation within low-income, high-density neighbourhoods where there is inadequate access to quality recreational space.
- Artificial turf field can provide playing surfaces that can be used by persons using mobility aids.

Neutral or Inconclusive

- Installation of artificial turf surfaces is often accompanied by a change in use patterns, which may negatively impact certain groups; however, measures can be put in place to reduce negative impacts on community access and disadvantaged communities.

Table 1: Summary of health impacts associated with artificial turf compared to natural surfaces

Determinants of Health	Environmental and Health Impacts
Environmental Factors	
Urban heat island	Has the potential to increase air temperature in nearby neighbourhoods, which could increase the risk of heat-related illnesses during hot weather.
Heat-related illness and injuries	Significantly increases temperature of surface and above surface, which increases the risk of heat-related illnesses and injuries among field users, especially children, during hot weather.
Contaminants in air, dust and water	Adverse health effects unlikely although good hygienic practices are required to reduce user exposure to contaminants in dust associated with rubber infill. Potentially adverse impact on aquatic ecosystems from contaminants in leachate over the long-term.
Historically contaminated sites	Can act as a barrier to underlying contaminated soil on a contaminated site and allow the installation of a playing field that can increase opportunities for physical activity.
Storm water runoff	Increases the risk of localized flooding during extreme weather events which are expected to become more common with climate change.
Carbon sink	Reduces carbon sinks, which increases net releases of greenhouse gases that contribute to climate change.
Built Environment and Lifestyle Factors	
Physical activity	Increases the number of hours during which fields are available and is expected to favour structured recreational activity; the impact on overall activity level in the community is not known, however.
Injuries	Artificial turf and natural grass have comparable rates of injury, although there are some differences in injury patterns.
Access to natural green space	Artificial turf can displace natural green space which is also important to health and the development of children.
Neighbourhood impacts	Increased field time for structured recreation can increase traffic, lighting, parking and noise concerns for nearby residents.

Determinants of Health	Environmental and Health Impacts
Equity and Access Factors	
Public access to recreation	Has the potential to enhance access to outdoor recreation facilities among low-income, high-density neighbourhoods that are currently under-served. Installation of artificial turf surfaces is often accompanied by a change in use patterns, which may negatively impact certain groups; measures can be put in place to reduce negative impacts on community access and disadvantaged communities.
Access for people with disabilities	Has the potential to enhance access to recreation facilities for people using mobility aids such as wheelchairs.

Limitations

The continuing evolution and the large variation in design and characteristics of natural fields and artificial turf systems make it difficult to accurately compare between impacts of natural and artificial systems. Available literature on rubberized surfacing is limited and makes it difficult to draw definitive conclusions about impacts on human health from the use of such materials in children's playground surfaces or running tracks. Literature on injuries is largely limited to the impacts on professional athletes and short-term observations. There are also limited data on potential exposures to certain contaminants that can be found in components of artificial turf systems.

Conclusions

Artificial turf surfaces were first developed for use in sports fields. They are being used in other recreation spaces in schools, childcare facilities, and parks, and increasingly for landscaping along streets, on residential properties and in commercial areas.

The design of artificial turf surfaces and the materials used in them have changed over time to address earlier concerns related to environmental impacts, heat, injuries, and exposure to toxic substances. As the technology continues to evolve it is possible that this will reduce their negative environmental and health impacts even further.

Artificial turf surfaces become much hotter than natural grass, which can be a risk for blisters, burns or heat stress during hot weather. Unlike natural grass which has evaporative cooling properties, artificial turf is made of several heat-retaining materials which can significantly increase field surface temperatures, substantially increase air temperatures near fields, and thus contribute to the urban heat island effect in surrounding neighbourhoods. This increases the risk of heat-related health impacts during hot weather events. Widespread use of artificial turf would make Toronto less resilient to extreme weather events and increase adverse health impacts associated with these events.

While injury patterns differ among natural grass surfaces and different designs of artificial turf surfaces, the available evidence suggests that overall, playing on third generation artificial turf does not result in a higher risk of injury than playing on natural grass.

Available evidence does not indicate that playing on third generation artificial turf will result in exposure to contaminants at levels that pose a significant risk to human health provided it is properly installed and maintained and users follow simple hygienic practices (for example, washing hands, avoiding eating on the artificial field, and removing dust from shoes and clothing before going indoors). While there are still some uncertainties regarding impacts from exposure to some substances found in artificial turf (carbon nanotubes, lead and other metals, latex, some metals, and polyaromatic hydrocarbons, for example), standard hygienic measures will minimize any of these risks. Under such conditions, and in the cases where use of natural turf is not possible or practical, the benefits from increased physical activity on fields are expected to outweigh the risks from exposure to toxic substances.

Overall the main concerns relating to the use of artificial turf are linked to climate change mitigation and adaptation. Widespread use of artificial turf would make Toronto less resilient to extreme weather events and increase adverse health impacts associated with these events. Natural surfaces are important features of an urban landscape. They provide valuable environmental services by helping to cool the air, absorb rain water and remove carbon dioxide from the atmosphere. The 2014 Provincial Policy Statement directs municipalities to address climate change mitigation and adaptation, including maximizing the use of vegetation and pervious surfaces. Toronto addresses this through the Toronto Green Standard and zoning bylaw, which limit the use of hard surfaces, including artificial turf, on properties in the city and encourage natural landscaping to reduce the urban heat island impacts of development.

Natural surfaces contribute to increased resilience to extreme weather events and reduce the risk of heat-related health impacts. In certain cases artificial turf can offer the prospect of increased activity levels and could be appropriate in areas which would otherwise not be available as an active space for a community. Installations of artificial turf sports fields may allow for playing fields in areas where natural turf cannot be maintained due to intensity of use or characteristic of the site and enable the use of contaminated lands for sporting facilities. City Planning, Parks, Forestry and Recreation, and other relevant City Divisions could review their practices and guidelines to ensure that when artificial turf is used, it provides an overall benefit to Toronto.

Recommendations

- a) Consider the installation of artificial turf only in situations where the conditions on the site and the high use of the space would prevent the maintenance of a healthy natural turf.
- b) Future proposals to install artificial turf include mitigation strategies that specifically address health concerns relating to:
 - i. Lack of availability of accessible green space, opportunities to increase vegetation in the surrounding neighbourhood and factors related to biodiversity and ecosystem health;
 - ii. Creation of urban heat islands;
 - iii. Water capture, drainage, maintenance and sanitation.

- c) Prevent heat-related health impacts by providing shade and drinking water, and prohibit the use of the field when artificial turf surfaces become very hot such as during heat alert and extreme heat alert days.
- d) Ensure proper ventilation in indoor artificial turf facilities.
- e) Post messages on outdoor artificial fields to remind users of the potential for heat-related injuries on hot days and of the use of good hygienic practices, including:
 - i. Washing hands after playing on artificial turf;
 - ii. Supervision of small children to ensure they do not eat the infill material;
 - iii. Avoiding eating on the artificial turf;
 - iv. Avoiding tracking infill material into the school or home (shaking visible rubber pellets off, or providing shoe/equipment cleaning areas before exiting the field);
 - v. Protecting exposed skin from direct contact with the turf during hot weather events;
 - vi. Cleaning and disinfecting affected areas and covering abrasions as soon as possible.
- f) Use alternative infill materials that have fewer toxic contaminants and/or less solar absorption on new installations, rather than crumb rubber infill made from recycled tires, whenever possible.
- g) Adopt protocols for selecting and purchasing artificial turf systems that address concerns regarding chemical content, heat absorption, and other environmental and health and safety factors;
- h) Ensure that maintenance protocols are followed and procedure in place to inspect, test, and replace any existing synthetic turf as it ages or deteriorates.

1 Project Overview

As the use of artificial turf is becoming more common, various divisions and external stakeholders, such as the Toronto District School Board, have asked Toronto Public Health to comment on potential health impacts of its use at various times.

City Planning requested TPH to provide guidance on the potential health and environmental risks of replacing natural grass with artificial turf. To assess the positive and negative health impacts associated with the use of artificial turf, TPH conducted a Health Impact Assessment (HIA). The aim of the HIA was to explore potential impacts using a broad range of evidence and to identify strategies to safeguard health, maximize opportunities for health equity, and mitigate any potential health and environmental risks.

This HIA focuses on the use of third generation artificial turf in sports fields and play spaces examining the impacts on the social and environmental determinants of health and their associated effects on health. Proposals to install artificial turf may often result in a change of use patterns on the field or the installation of structures. While these associated changes may have community impacts, they are not the focus of the HIA.

Context

Artificial turf is already in use in Toronto in a variety of settings and applications and the City, school boards and other organizations have plans for future installations. Some current uses of artificial turf in Toronto include:

- Indoor and outdoor sports fields (recreational and professional sports pitches i.e. soccer, football, cricket, lawn bowling greens, indoor golf ranges)
- Play spaces (school and park playgrounds, childcare centres)
- Residential and commercial landscaping (home and building lawns, rooftops, decks, patios, balconies, around swimming pools, pet areas)
- Streetscapes (roadway medians, sidewalks, bases of street trees)
- Public spaces (temporary installations, road shows)

The 2014 Provincial Policy Statement directs municipalities to address climate change mitigation and adaption, including maximizing the use of vegetation and pervious surfaces. Toronto addresses this through the Toronto Green Standard and zoning bylaw, which limit the use of hard surfaces, including artificial turf, on properties in the city and encourage natural landscaping to reduce the urban heat island impacts of development. Currently, artificial turf is treated as a "non-roof hardscape" in the Toronto Green Standard, grouping it together with other surfaces that display heat-retaining properties which are known to contribute to local urban heat island effects.

Concerns have been raised about potential health impacts of this growing use of artificial turf as well as the materials used in them, especially to vulnerable user groups such as young children in schools and childcare facilities. As such, this HIA considers risk mitigation strategies for situations where artificial turf is already installed and for future installations.

The Toronto school board face demands to provide safe, year-round accessible sports fields for their student population and the surrounding community. Toronto's increasing population, and its demand for

recreation space, is challenging the ability of school boards to provide and maintain natural playing surfaces. In some recent instances private sector businesses have paid to install artificial turf playing surfaces in exchange for commercial use of the space outside of school hours. Concerns have been raised related to both the impacts of the surface type and the loss of community access to the space.

1.1 The Health Impact Assessment (HIA) Process

HIA Framework

An HIA is a systematic, objective process, recognized by the World Health Organization. It uses the best available evidence gathered from research, stakeholders and the community to assess the likely impacts (both positive and negative) of a proposal on the health and wellbeing of different groups in the population. It also makes recommendations for how the project, policy or practice might be amended to maximize positive health impacts or to reduce any negative impacts. Toronto Public Health initially developed an HIA framework in 2008.¹ The framework has since been modified to better align with the Ministry of Health and Long Term Care's approach to Health Equity Impact Assessments.

Stakeholder Input and Consultation

Gathering views from community and expert stakeholders helps to understand the issues from a local and experiential perspective. An HIA Working Group made up of representatives from Toronto Public Health, Children Services, City Planning, Environment and Energy, Parks, Forestry and Recreation, and Toronto Water, was formed. To better understand the concerns of the community, and to scope the assessment, consultations were held with a range of stakeholders with expertise in the use of artificial turf in Toronto (See Appendix 1 for list of stakeholder groups that were consulted).

To assist TPH in defining the parameters of the assessment a half-day stakeholder workshop was held on January 29, 2014 to scope the HIA. Details of the outcome of this meeting, including the list of participants, are found in Appendix 2. A second meeting was held to review the preliminary findings and discuss next steps. Comments were also received on the draft report and incorporated.

Determining the Scope of the HIA

Based on the input obtained from consultations with stakeholders, certain uses of artificial turf in Toronto were prioritized and parameters for study were identified. At the suggestion of the stakeholder group, this HIA focuses on sports fields and children's play spaces. As the findings of this HIA are also relevant to residential and commercial landscaping and other uses reference is also made to these uses as appropriate. Table 2 below summarizes the parameters considered during this HIA, along with the rationale for each.

¹ Toronto Public Health, 2008. TPH Health Impact Assessment Framework Final Draft Report. Prepared by Jacques Whitford for Toronto Public Health. Available at: http://www1.toronto.ca/City%20of%20Toronto/Toronto%20Public%20Health/Healthy%20Public%20Policy/PDF%20Reports%20Repository/draft_hia_framework.pdf

Table 2: Considerations for the HIA

Parameter	Scope for this HIA	Rationale
Applications or uses of artificial turf	Indoor and outdoor sports fields (recreational and professional pitches i.e. soccer, football, cricket, lawn bowling greens, golf ranges) Play spaces (school and park playgrounds and child-care centres)	Community concern has been mostly around exposure to toxic chemicals to children in play areas and on sports fields. Stakeholders recommended that TPH address other uses such as landscaping at a later stage
Type of artificial turf	Third generation, infilled turf systems (also consider 4th generation turf, where research is available).	Older carpet-style turf has been generally replaced with third generation turf. Most environmental and health concerns raised are about crumb rubber, which is the most common infill material found in artificial turf in Toronto.
Comparison	Natural grass or other surface alternatives such as rubberized or paved surfaces (where research is available).	Artificial turf is designed to mimic natural grass. In most cases, artificial turf is used to replace natural grass surfaces.
Population focus	Focus on age-related groups (e.g. preschoolers (0-5), school age children (0-18), older adults), persons with mobility concerns, low income or economically disadvantaged groups.	Equity considerations should be integrated into the HIA. Young children, older adults and people with disabilities are potentially vulnerable group of users. Since overall people living on low-income have poorer health, the potential impact on access to facilities that promote physical activity is important. Professional athletes and persons who install or maintain artificial turf fields may be affected, but these impacts are occupational in nature and thus outside the scope of the HIA.

Health and Environmental Impacts to Assess

This HIA on artificial turf in sports fields and play spaces examines a wide range of environmental, human health and community concerns. Given that this HIA is not based on a specific proposal, not all of the concerns identified during consultations with stakeholders may be relevant for a particular site. For instance, the greater permitting of these fields could have neighbourhood-level impacts such as

increased traffic volumes, increased noise, and reduced access to public space. These impacts are not directly related to the type of surface and will vary greatly depending on the specific characteristics of the site where the installation of the turf is being proposed; therefore these are not the primary focus of the HIA. Health equity is an important value for TPH; therefore various aspects that could have an impact on access to recreation as well as impacts on health are discussed. Table 3a and 3b below highlight the results of the scoping phase for the HIA (more details are available in Appendix 2)

Table 3a: Concerns and Potential Impacts to be considered in the HIA

Determinant Pathway	Potential Impacts/Outcomes to consider
Environmental Factors	<ul style="list-style-type: none"> • Exposure to toxic contaminants by inhalation, ingestion and skin contact, including indoor applications, and particularly among children • Heat-related stress among users of field particularly for children • Climate change impacts including heat-related health impacts due to the urban heat island effect and greenhouse gas emissions • Risks of flooding due to storm water run-off • Use of water, pesticides and fertilizers and the leaching of contaminants to water • Impact on soil quality and water availability for nearby trees and other vegetation
Built Environment & Lifestyle Factors	<ul style="list-style-type: none"> • Physical activity, including implications for neighbourhoods where turf cannot be established or maintained • Risk of injuries • Risk of abrasions and infections from bacteria, algae and other biological materials • Maintenance and sanitation related issues • Loss of natural green space (childhood development, learning opportunities, diverse play opportunities, social cohesion, mental health)
Social and Economic & Equity & Access Factors	<ul style="list-style-type: none"> • Impacts on disadvantaged populations (for example low income, racialized groups) including access to recreational opportunities and heat-related impacts among those who are already susceptible to heat (children, elderly and those with pre-existing health conditions) are therefore included

Table 3b: Concerns and Potential Impacts excluded from the HIA

Determinant Pathway	Potential Impacts/Outcomes to consider
Environmental Factors	<ul style="list-style-type: none"> • Noise: Natural greenspaces are known to attenuate ambient noise. Artificial turf systems are more reflective and thus can increase ambient noise levels when compared to natural surfaces. There are insufficient data on the health significance of this difference. The characteristics of the neighbourhood surrounding the field also influence the degree to which noise will have a negative impact on the community. These concerns are better addressed during the planning, design, and management of the field. • Light: Materials used in artificial turf are more reflective than grass. When the fields are lit to allow night-time playing, this could result in an overall increase in the brightness of the area around the field. There are insufficient data on the health significance of this difference; the characteristics of the neighbourhood surrounding the field also influence the degree to which light will have a negative impact on the community. These concerns are better addressed during the planning, design, and management of the field.
Built Environment & Lifestyle Factors	<ul style="list-style-type: none"> • Traffic impacts: When an artificial turf installation increases the amount of time a field is in use and the type of games played, there could be an increase in traffic. This impact is related to the use of the field rather than the type of turf; the impact will also vary greatly depending on the location of the field. These concerns are better addressed during the planning, design, and management of the field.
Social and Economic & Equity & Access Factors	<ul style="list-style-type: none"> • Cost of installation: While cost, especially life-cycle cost, is an important aspect to consider when deciding whether to install artificial turf, this is not directly related to health.

Gathering the Evidence

Based on the four main determinants of health - environmental factors, built environment factors, lifestyle factors, and equity factors - research questions were developed to guide the assessment. The research questions were developed in an iterative manner - informed first by the workshop with City stakeholders and then refined or expanded, as further evidence was obtained. Table 4 includes examples of the research questions used to guide the assessment.

Table 4: Assessment Questions Identified by Scoping Exercise

(1) What are the environmental impacts of third/fourth generation artificial turf compared to natural grass when used in sports fields and play spaces?	(2) What are the human health impacts of third/fourth generation artificial turf compared to natural grass when used in sports fields and play spaces?	(3) What are the social/community impacts of third/fourth generation artificial turf compared to natural grass?
<p>Does artificial turf adversely contribute to urban heat island? Does the drainage from artificial turf infilled with tire rubber crumb contribute to toxic runoff? Do third/fourth generation artificial turf systems compromise the health of surrounding vegetation either through ecotoxicity or water deprivation? Considering manufacturing, transportation, installation, maintenance and disposal, does artificial turf have a larger carbon footprint compared to grass fields?</p>	<p>Does artificial turf, including the rubber particles and other hazardous constituents, pose either a short- or long-term health risk for field users? Do particular routes of exposure to hazardous constituents pose higher human health risks? Is third/fourth generation artificial turf associated with increased musculoskeletal injury risk versus natural grass? If so, what are the incidence, nature and mechanisms of injury on artificial turf? Is third/fourth generation artificial turf associated with increased non-musculoskeletal injury risk (e.g. abrasions, infections, heat stress) versus natural grass? Compared to natural grass, what is the impact of artificial turf on physical activity?</p>	<p>Compared to natural green space, what is the impact of artificial turf on: Childhood development and education (ecoliteracy) Mental/psychological well-being family/community cohesion Access and proximity to play spaces for low-income groups, people with restricted mobility Community impacts such as traffic, noise, behaviour, etc.</p>

This HIA employed mixed research methods, including a literature review, secondary data analysis, and targeted consultations. The peer-reviewed and grey literature was used to assess the best available evidence for each of the potential health impacts. To help understand the extent and distribution of the use of artificial turf in Toronto, TPH identified the number of existing and proposed installations of artificial turf in Toronto via internet searches, secondary data, and a survey from Parks, Forestry and Recreation and data from the school board.

1.2 Background on Surface Materials

A number of different types of surfaces have been deployed for use in park and school playgrounds and fields.

Natural Grass

Since the beginning of organized sports, natural grass has been viewed as the "standard" field surface (Dragoo & Braun, 2010). The construction of natural playing surfaces has varied from site to site and the nature of sporting activity, but has generally been developed on original soil, fill sites with imported soil, or in some exceptional cases, old landfill or drainage sites (Government of Western Australia, 2011b).

In recent years, there has been an increasing demand for natural grass species with improved drought and wear tolerance, and which have good recovery rates. In some cases, this has emerged from specific requirements for individual sporting codes or simply, the need to meet demands placed by the high intensity use of natural playing areas. More information about the different varieties of natural grass species, their characteristics and maintenance requirements, can be found in a report released by the Government of Western Australia (2011b) entitled, *Natural grass v synthetic turf - Study report*.

Engineered Shredded Wood (Mulch) and Granitic Sand

Since 2001, granitic sand and engineered shredded wood became the recommended protective surfacing materials for park and school playgrounds. This material is not commonly used for sports field surfacing. Granitic sand has been determined to have greater play value and provides better impact attenuation than shredded wood. However, some of the negative aspects of sand are that it can be blown or tracked to adjacent areas and indoors. Shredded wood is a more accessible surface, but it is known to decompose very quickly, requiring regular refilling (Evergreen, 2009).

Rubberized Surfacing

Recycled tires are being used increasingly as a primary component of children's playground surfaces and running tracks, as they have the potential to reduce fall-related injuries among children. Exposure patterns can differ according to whether the crumb rubber is loose or compressed into a solid form. Generally, recycled tires in playground surfaces take one of three forms:

- As uncompressed tire shreds or crumb comprising a rakeable surface;
- As rubber tire shreds that are poured-in-place and hardened into a compressed surface; and
- As tiles molded in the factory from tire shreds, which are then transported to the playground and locked or glued into place, forming a compressed surface.

Artificial Turf

Artificial turf was first developed in the U.S. in the 1960s. One of the first uses of artificial turf was in the Houston Astrodome stadium following the failure of natural grass to grow under the stadium's translucent roof. First generation artificial turf systems (marketed thereafter as 'AstroTurf') consisted of a mat of very short and densely woven fibres, with a cushion backing. For most of the next decade,

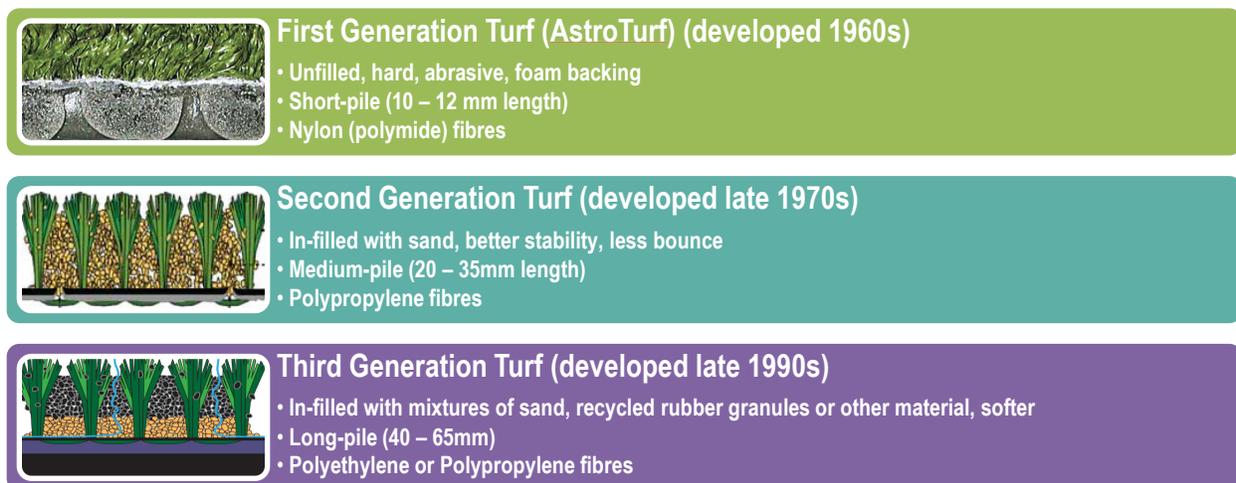
complaints emerged from professional athletes about injuries on these fields. As a result of their densely packed nylon-based fibres, these fields were not much more than green indoor/outdoor carpets capable of causing friction burns and other injuries. Many stadiums that installed turf during this period, reverted back to natural grass.

By the late 1970s many design improvements had been made to address concerns about injuries and contaminants found in surface material. These second generation artificial turf systems were composed of a mat of longer, less densely-spaced synthetic fibres woven into a canvas backing and filled with a thin layer of sand. Sports pitches had improved to the point where a second generation turf was used for the field hockey tournament at the 1976 Olympic Games in Montreal (Beausoleil, Price, & Muller, 2009). Technological improvements continued into the 1990s when significant changes were seen with the introduction of third generation turf systems.

Third generation systems, which are still widely used today, are composed of a mat of longer and even less densely-spaced fibres, filled with small rubber granules or a mixture of rubber granules, sand or other material, and sometimes with a shock pad for added safety. The increase in variations, infill types and ever-evolving component technologies has made it difficult to identify a standard norm for third generation systems. Manufacturers are evolving their product, in part, to address concerns related to heat, toxicity and injury. This type of product evolution appears to entail a balancing of different priorities. For instance a third generation system may address potential heat and toxicity issues by using sand in place of crumb rubber, thereby also exposing users to increased risk of abrasion injuries.

These third generation turf systems are widely popular for soccer and American football applications worldwide and are increasingly being seen for cricket and multi-sport usages (State Government of Victoria, 2011). Figure 1 below provides a summary of the main characteristics of artificial turf generations.

Figure 1. Summary of Developments in Artificial Turf



Adapted from: (State Government of Victoria, 2011)

There continue to be changes in the design of artificial turf systems. Newer systems referred to as "fourth generation" do not require any infill for the fibres to remain upright and are made to meet specialised sporting demands.

Materials in Artificial Turf

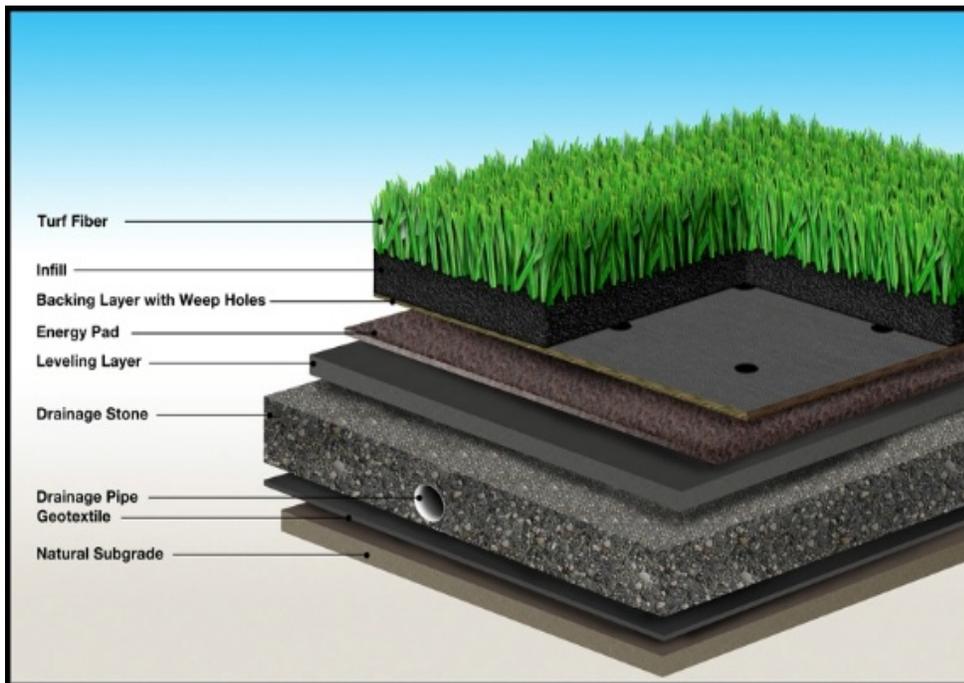
Unlike the coarse, short-pile nylon fibres in first generation artificial turf, the fibres in second and third generation turfs are generally made of softer and plastics including polyethylene or polypropylene. The earlier issues related to the dyes used in the nylon fibres were no longer an issue with these new plastic fibres. They are engineered to simulate natural grass blades and to provide greater stability to the infill materials (Beausoleil et al., 2009). The materials used as the base for the mat layer are generally polyester or polypropylene, partially reinforced with fibreglass. The fibres are held in place by a second base made of latex or polyurethane (Kolitzus, 2007).

Although there are various infill materials – including sand and cork materials - the main infill material used in third generation systems is made of rubber derived mostly from recycled tires (SBRr – styrene-butadiene recycled rubber) (Kolitzus, 2007). A large artificial sports field can use approximately 27, 000 recycled tires (Huber, 2006). Sand infill materials are typically made of silica. The silica can be coated with elastomer or acrylic coatings to reduce the likelihood of bacteria accumulation. The shock pad used underneath artificial turf can also be made from reused materials such as running shoe soles (Government of Western Australia, 2011b).

Construction and Design of Artificial Turf

Figure 2 below shows the general construction of a conventional artificial sports surface. Once the dirt surface is shaped, it is compacted and a geotextile fabric is pinned over the complete surface. Next, the base structure of the field is created using rock material. If the field is designed with a piped drainage system, this layer may have built-in drainage pipes. If a shock pad is included, this will be added immediately after the base layer. The artificial turf surface with a perforated backing layer will be applied to this base. Then, depending on the type of infill materials used, silica sand and granulated rubber may be applied.

Figure 2. General construction and layers of third generation artificial turf



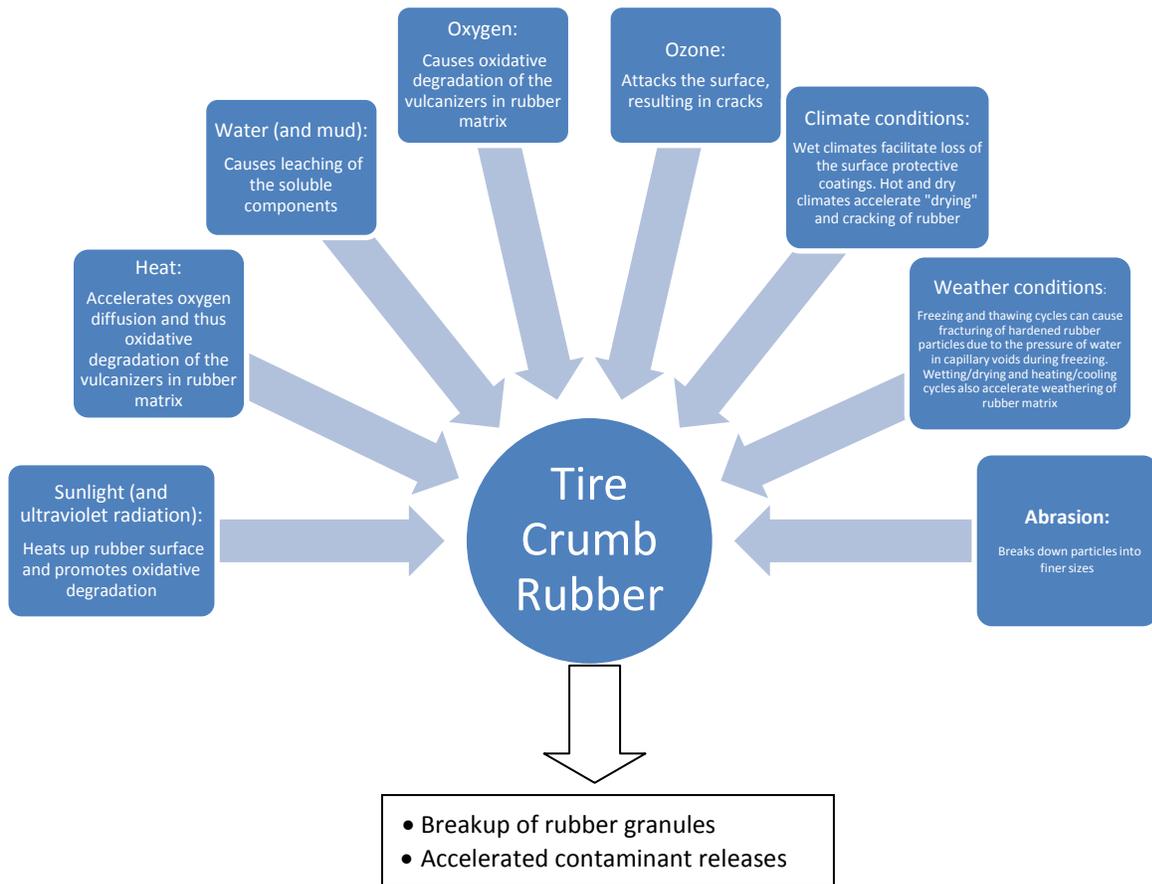
Source: <http://www.syntheticurfCouncil.org/?page=FAQs>

The technology of artificial sports surfaces has grown in recent years to allow for multiple variations in design to meet customer needs and intended sports or recreational uses. For instance, designs for younger age groups may have added shock absorbance pads to improve cushioning and secondary grass fibres to reduce the amount of infill material that kicks back onto a player. There are also designs with no crumb rubber to eliminate material risks to very young players (e.g., risk of toddler eating the crumb rubber balls).

Breakdown of Artificial Turf Materials

Under normal conditions, tire rubber degrades slowly. However, exposure to oxygen, ozone, heat, sunlight and liquids can all result in changes to the physical and chemical makeup of crumb rubber and thereby impact the rate of release and type of contaminants released from the degraded rubber matrix (Cheng et al., 2014) (see Figure 3 below). Rubber crumb produced from recycled tires (versus virgin rubber) is also more susceptible to environmental factors leading to aging of rubber (i.e. cracking, splitting, oxidizing and overall deterioration). The high surface-to-volume ratio of crumb rubber also makes it more vulnerable to oxygen and ozone attack and physical degradation through regular wear. As a result, the release of contaminants into air and the leaching of heavy metals and contaminants into water are expected to be greater than from full-sized tires.

Figure 3. Major environmental factors affecting the degradation of tire rubber crumb in artificial turf



Adapted from: (Cheng et al., 2014)

1.3 Use of Artificial Turf in Toronto

1.3.1 Overview of Current Use on Playgrounds and Sports Fields in Toronto

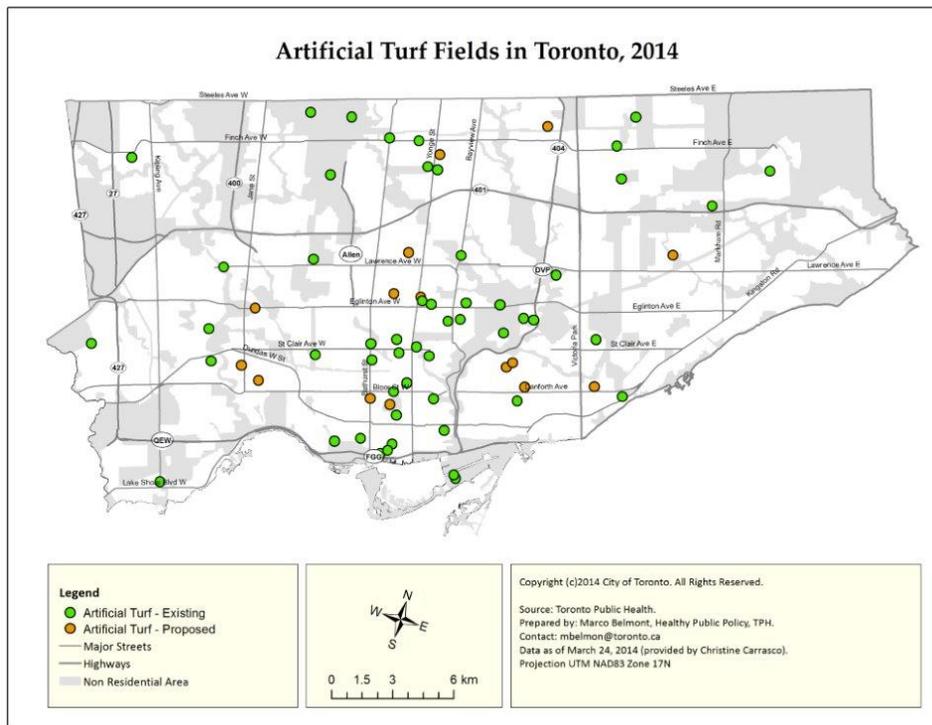
There is no inventory of artificial turf surfaces in Toronto. It is therefore not possible to estimate the full extent of use of this surface material. Table 5 summarizes the data currently available to TPH and includes City-owned locations, educational institutions and other sport facilities. The table provides a snapshot of the range of groups currently using artificial turf for sports field and play space purposes and how these numbers are expected to rise in the near future. Locations of these fields are shown in Figure 4.

Table 5: Number of existing and proposed locations of artificial turf in Toronto²

Land Owner	Existing locations	Proposed locations
City of Toronto	22	4
TDSB	18	10
TCDSB	4	9
Private schools and universities	4	1
Other (private sports fields)	6	-
TOTAL	54	24

² Numbers reflect unique locations where artificial turf has been installed, not the number of applications of artificial turf, as one location may have more than one field, play space, etc. The number of proposed installations may also be greater, as the figures reflect known sites, not installations that have been approved in Capital plans.

Figure 4: Existing and Proposed Locations with Artificial Turf in Toronto



Parks, Forestry and Recreation (PF&R) currently owns over 21 locations where artificial turf has been installed in sports fields, lawn bowling greens, cricket pitches or play spaces. In some cases, the sports fields are leased and maintained by other parties, as is the case for Allan Lamport Stadium, which is leased to and maintained by MLSE (Maple Leafs Sports and Entertainment) during the indoor (winter) season. At least four more artificial turf sports fields are scheduled to be installed in Toronto by PF&R between 2014 and 2017. PF&R’s capital plan includes provisions for the installation of one or more artificial field once every two years (City of Toronto, 2013b).

Children's Services recently replaced natural grass with artificial turf at the Metro Hall Child Care Centre. The artificial turf present at the site does not contain rubber crumb infill (personal communication). At present, the actual numbers of children's playgrounds in Toronto with artificial turf are unknown. However, it has become common practice when installing new play structures, to replace sand pits with a rubber surface or artificial turf. These materials are believed to provide children more protection from fall related injuries. Artificial turf is also perceived to require less maintenance and upkeep.

Schools Boards, Private Schools and Universities

To date, the Toronto District School Board (TDSB) has installed artificial turf in 15 elementary schools and 3 secondary schools and additional installations are proposed for ten (9 elementary, 1 secondary) additional schools over the next five years (TDSB, 2013). The Toronto Catholic District School Board (TCDSB) has installed artificial turf in one high school and three elementary schools. It also shares two

artificial turf fields with the City of Toronto, both of which are in high schools. City staff are also aware of four artificial fields that have been installed in three private schools in the City and the University of Toronto's Varsity Centre. Two outdoor artificial fields at the University of Toronto's backfield campus have recently been built in preparation for the Pan Am and Parapan Am Games in 2015.

Other Locations

An internet search identified six other locations in Toronto where artificial turf has been installed as sports fields. One of these locations is the "The Hanger". Located at Downsview Park, this property is owned by the Canada Lands Company (CLC), a federal commercial Crown corporation. City staff understand that there are three outdoor fields (one of which is domed in the winter) and one building with artificial turf at this location. The remaining five locations are owned and managed by private companies and include: Toronto Soccerplex, SoccerWorld Polson Pier, Toronto City Sports Centre, Metro Golf Dome and the Rogers Centre.

2.3.2 Overview of Other Uses in Toronto

Artificial turf is increasingly being used for residential and commercial landscaping purposes. These applications include lawn areas, pet areas, rooftops, patio decks, parkettes, public right-of-ways and streetscapes. It is fast gaining popularity because it is durable, and does not require weeding, fertilizing, cutting or watering.

Business Improvement Areas and the City's Urban Forestry Branch have installed artificial turf on tree plantings for street-level applications. Artificial turf has also been used on road median containers and in-ground tree covers.

In Toronto, pre-cut rolls of artificial turf are available for purchase in home improvement stores. The cost of this kind of pre-cut product is \$4.50 per square foot, which does not include the cost of installation and additional building materials such as the sub-base aggregate and sand infill. Artificial turf can also be special ordered through a turf dealer and prices range between \$8 and \$16 a square foot installed depending on the size of the area and the product selected.³

Artificial turf for home use is marketed as a family friendly product that can be used virtually anywhere, including in children's play areas and pet areas. It is also pitched as a durable and a product that is easy to clean and maintain. Some artificial turf products also claim to be LEED (Leadership in Energy and Environmental Design) certified, allowing users and builders to contribute LEED points in the areas of Water Efficient Landscaping, Recycled Content, Rapidly Renewable Material and Innovation in Design.

³ Harvey, Ian. (2011, February 9). Artificial turf: The green, green grass of home. The Star. http://www.thestar.com/life/homes/decor/2011/02/09/artificial_turf_the_green_green_grass_of_home.html (Accessed 12 January, 2015)

2 Health Impact Assessment Findings

2.1 Environmental Factors

2.1.1 Urban Heat Island effect

Two main concerns were expressed by community and expert stakeholders related to the heat-retaining properties of artificial turf: its potential to contribute to local "urban heat island" effects; and its potential to exacerbate heat-related illnesses among artificial turf users. The latter is examined under the section on the built environment.

Climate change is a permanent change in weather patterns over time that will have an impact on human health and the environment. With climate change, Toronto is expected to experience more frequent severe weather events such as heat waves, heavy rainfall or snowfall, and severe storms (City of Toronto, 2013a). Prolonged periods of extreme heat have been linked to increased prevalence of heat-related illnesses and mortality. These effects will likely be greater in urban areas where urban health island effects exacerbate temperature increases that result from climate change.

Climate adaptation and mitigation measures include increasing vegetation to act as carbon sinks for greenhouse gases and reduce the urban heat-island effect, decreasing impervious surface materials to increase water infiltration, and reducing the use of ground surface materials that have high heat retention. Using artificial turf as a replacement for natural ground cover goes against these measures.

Summary of Evidence

Unlike natural grass which has evaporative cooling properties, artificial turf is made up of heat-retaining materials which contribute to elevated surface temperatures. The surface temperature of exposed artificial turf increases with solar radiation load, as opposed to air temperature (Devitt, Baghzouz, Bird, & Young, 2007). Several studies have compared average surface temperatures of artificial turf with different outdoor surfaces under various conditions (see Table 6). The information shows that the surface temperature of artificial turf can be greater than natural grass and on some occasions higher than for paved surfaces. In the most extreme case, artificial fields exhibited surface temperatures that were up to 38°C higher than those on natural turf, along with increased ambient temperatures (Adamson et al., 2007; McNitt & Petrunak, 2007). Evidence suggests that the grass fibres and the crumb rubber infill are the most heat-absorbent components (Devitt et al., 2007). Time of day (amount and angle of sunlight) (Devitt et al., 2007), wind, and cloud cover also influence the surface temperature of artificial turf.

There have been only a few studies examining the thermal properties of artificial turf in relation to the urban heat island effect. Those studies indicate that artificial turf has very low solar albedo, meaning that the sunlight is absorbed, which increases the temperature of the field surface (Aoki, 2009). Spectral reflectance measurements indicate that green coloured artificial turf reflects less than 10% of incoming radiation (Devitt et al., 2007). Another study found that artificial turf had the lowest albedo of all of the

urban surface materials examined (see Table 7), reflecting only 8% of incoming radiation (Yaghoobian, Kleissl, & Krayenhoff, 2009). Using an offline convection model, the same study also found that replacing grass with artificial turf adds 2.3 kilowatt hours per square metre per day of heat to the atmosphere, which could result in increases in air temperatures in urban areas by up to 4 °C (Yaghoobian et al., 2009).

Table 6: Surface Temperature Recordings (in degrees Celsius)-Different Outdoor Surfaces

Source	Location	Air temp (°C)	Natural grass	Artificial turf (black infill)	Artificial turf (white infill)	Soil	Asphalt	Concrete
(C. F. Williams & Pulley, 2002)	Provo, Utah	27.5	25.7	47.2	-	36.8	43.1	-
(Devitt et al., 2007).	Las Vegas, Nevada	44.5 max	38*	76	66.4	59*	60.9	-
(Adamson, 2007)	Columbia, Missouri	36.7	40.6	78.3	-	-	-	-
(Aoki, 2009)	Japan	11 am summer	42.2	67	-	-	-	-
(Aoki, 2009)	Japan	11 am winter	11.5	19.6	-	-	-	-
(Penn State Center for Sports Surface Research, 2012)	University Park, Pennsylvania	24.4 avg. (clear, sunny)	-	73	-	-	-	-
(Penn State Center for Sports Surface Research, 2012)	University Park, Pennsylvania	25 avg. (clear, sunny, breezy)	-	65	-	-	-	-
(Penn State Center for Sports Surface Research, 2012)	University Park, Pennsylvania	34 avg. (hazy, breezy, hot)	-	61	-	-	-	-
(TDSB, 2013)	Toronto, Ontario	30 avg. (direct sun)	36	64	-	-	55	46
(TDSB, 2013)	Toronto, Ontario	30 avg. (shade)	22	30	-	-	34	22

*Estimated from graph, as exact temperature was not reported

Table 7: Albedo Properties of Selected Surface Materials

Property	Natural grass	Artificial turf	Asphalt	Concrete
Albedo	0.26	0.08	0.18	0.35

Source: (Yaghoobian et al., 2009).

Consequently, artificial turf fields can be expected to create micro-climates.⁴ A recent report from the City of Windsor (De Carolis, 2012), which compared thermal images of a natural grass field in 2005 to images taken after the installation artificial turf on the field in 2010, found that local surface temperatures increased by approximately 7°C degrees with installation of the artificial turf (De Carolis, 2012). As this example illustrates, sites with artificial turf experience hotter micro-climate conditions. While the contribution of a single artificial turf field to overall urban heat island effect across the whole city is likely to be small (Denly, Rutkowski, & Vetrano, 2008) it is desirable to minimize overall proportion of heat retaining surfaces in the city to decrease the adverse health impact related to urban heat island effects.

Heat Vulnerability

Toronto Public Health has closely examined issues related to heat vulnerability in Toronto (Toronto Public Health, 2011). Vulnerability to heat is defined as a combination of exposure to heat and sensitivity to heat. Heat exposure is defined by the heat in the environment, the likelihood that a person will encounter that heat, and the length of time to which they are subject to those conditions. Heat sensitivity is defined as the decreased ability to cope with hot weather, because of physiological, medical, behavioural, and/or social factors. For example, children are more sensitive to heat because their bodies do not regulate their body temperatures as well as the bodies of healthy adults. Sensitivity to heat also arises from people's personal circumstances. For example, people who live on low incomes may not have access to air conditioning or recreational spaces to get relief from the heat.

When comparing natural grass surfaces and artificial turf in relation to heat vulnerability, it is important to note that natural grass and other types of green space in a neighbourhood can reduce exposure to heat, while artificial turf surfaces can increase exposure. TPH has identified areas of Toronto that are more vulnerable to heat. Any artificial turf surfaces in these areas would increase local heat exposure and therefore heat vulnerability.

To assess if existing artificial turf fields in Toronto are located in more heat vulnerable neighbourhoods, a spatial analysis was done for the 57 locations that use artificial turf. No correlation was found, meaning that artificial turf facilities are not predominantly located in areas of either low or high mean surface temperature.

⁴ Micro-climate refers to a climate that holds over a very small area. Micro-climates are usually modifications of the main background climate altered by features in the landscape and built environment.

Potential Mitigating Strategies

Several studies have examined the strategies that could be used to mitigate the hot surface and temperatures associated with artificial turf. Watering has been shown to rapidly drop surface temperatures, but this cooling effect has been found to be short-lived (McNitt & Petrunak, 2007; Serensits, McNitt, & Petrunak, 2011). Other strategies such as covering the surface with a tarpaulin or mixing the infill with calcined clay have not been effective at reducing surface temperatures beyond three hours (Serensits et al., 2011). One study found that surface temperatures can be reduced slightly by painting black crumb rubber white (Devitt et al., 2007). Another study, which examined various turf fibres, infill colours, and products marketed as "heat-resistant", found that none produced a substantial reduction in surface temperatures compared to the standard green fibre black infill systems (Penn State Center for Sports Surface Research, 2012).

While the heat-retaining characteristics of artificial turf cannot be mitigated unless product technologies evolve, strategies can be put in place to mitigate the heat risks presented to users of the fields. Several municipalities, including the City of Windsor, have proposed thermal comfort strategies in parks (Blanchard, 2013) and recommended the inclusion of shade structures in artificial turf field design plans (De Carolis, 2012). Planning tools could be used to guide decision-making on the location of future fields to protect residents from urban heat island effects that may be associated with them. For example, the City of Windsor has used mapping tools to identify areas in the City where artificial turf development should be avoided because the urban temperatures are already elevated (De Carolis, 2012). The Toronto Green Standard (City of Toronto, 2014) and zoning bylaw restrict the proportion of a property that can be made of hard surfaces (such as pavement and artificial turf) and encourages the use of natural landscaping, including green roofs, to reduce heat gain and surface water runoff. The Toronto Shade Policy (City of Toronto, 2007) and Guidelines (City of Toronto, 2010) encourage the provision of shade in parks and other public spaces.

Conclusions

Unlike natural grass which has evaporative cooling properties, artificial turf is made of several heat-retaining materials which can significantly increase field surface temperatures, substantially increase air temperatures near fields, and thus contribute to the urban heat island effect in surrounding neighbourhoods.

Options to Reduce Risk

- 1) When considering new proposals for artificial sports fields, assess the impact that the field will have on the urban heat island effect as part of the decision-making framework and consider the coolest surface option available.
- 2) Avoid the installation of artificial turf in areas of the City that have been identified as vulnerable to heat unless there are clear benefits to vulnerable populations from increased physical activity and opportunities for recreation.
- 3) Until cooler product technologies are available, mitigate the heat-related health and environmental impacts of artificial turf by planting vegetation around the field, installing built and natural shade structures, and providing water features such as misting posts and drinking fountains.

2.1.2 Heat-Related Illness and Injuries

Artificial turf fields exhibit higher surface temperatures than natural grass surfaces. Early research conducted on first and second generation turf suggested that increased surface temperatures associated with artificial turf had an impact on the heat load experienced by users (Buskirk, McLaughlin, & Loomis, 1971) (Kandelin, Krahenbuhl, & Schacht, 1976). There are no published reports pertaining to heat-related illnesses such as heat cramps, heat exhaustion, heat stroke or dehydration experienced by users of third generation artificial turf users. However, given the surface temperatures associated with them, it can be assumed that field users would be at increased risk of negative heat-related health impacts. There have been reports of players developing heat blisters on their feet after playing on artificial turf surfaces (Hummer, 2010; Sports Illustrated, 2007; Williams & Pulley, 2002).

The heat-related risks are expected to be greater among children playing on artificial turf because biologically children do not adapt as well as adults to a high climatic heat stress (95°F or 35°C) (Anderson et al., 2000). They have a greater surface area-to-body mass ratio than adults. They produce more heat than adults during physical activity. And they have a reduced ability to regulate their body temperatures (Denly et al., 2008). Young children also have a less developed "tough" layer on their skin than that of older children and adults, making them more vulnerable to burn-related injuries (Denly et al., 2008).

Potential Mitigation Strategies

Some jurisdictions have taken steps to mitigate potential heat-related illnesses related to the use of artificial turf. Given that injury to the skin can occur within ten minutes of exposure to artificial turf with temperatures greater than or equal to 50°C, some organizations have used this temperature as a maximum safe surface temperature (Brigham Young University, 2002). Other jurisdictions have implemented education strategies; advising parents and users of artificial turf of the potential for heat-related illness and how to recognize and prevent those symptoms (Denly et al., 2008).

Toronto schools and school boards indicate that while concerns have been raised about to heat-related illnesses and injuries among young children playing on artificial turf, to date, no cases of injury or illness have been reported by teachers, students or parents on fields currently in use. Supervising teachers and or sports coaches already adhere to School Board policies for outdoor play on heat alert days, regardless of the playing surface. School Board staff have indicated that, on the whole, engineered mulch is the preferred surfacing material in playground areas because of the heat-related concerns associated with artificial turf and rubberized surfaces.

Conclusions

Surface and air temperatures surrounding artificial turf can get significantly higher than ambient surface and air temperatures. These increased temperatures can increase the risk of heat-related illnesses and injuries among users. Young children and athletes are especially susceptible to heat-related illness such as dehydration, heat exhaustion and heat stroke while exercising in hot conditions.

Options to Reduce Risk

Owners and/or operators of artificial turf fields could adopt the following practices:

- 1) Incorporate thermal comfort strategies into turf plans for existing or proposed sites to reduce the risk of heat-related illnesses. For example, they can provide shaded areas, install water fountains, and increase nearby natural vegetation to help field users to stay cool and hydrated.
- 2) Develop and implement heat safety awareness programs. For example, they can install signage around fields advising field management staff, coaches, parents and field users on the potential for heat-related illnesses and injuries and how they can be prevented and/or treated.
- 3) Include a statement about the potential for heat-related illnesses and injuries in facility rental guidelines. This statement could indicate the potential risk involved with using the field under high heat conditions and inform external users of the conditions that may be unfavourable for play.
- 4) Restrict field access when surface temperatures exceed a threshold, such as during heat alert and extreme heat alert days, to avoid heat-related injuries.

2.1.3 Toxic Contaminants

The contaminants in artificial turf depend on the materials used. While manufacturers have made changes in the design of surfaces in response to concerns, questions continue to be raised, for example: what are the potential health effects from exposure to recycled tire infill material, or of plastic coatings on sand? The previous section briefly summarized the breakdown of rubber crumb in artificial turf and some of the contaminants of concern with respect to environmental impacts. This section reviews human health concerns and begins with an overview of the contaminants of concern and potential exposure pathways, followed by a summary of available research evidence and government positions on the potential toxicological risk of exposure to artificial turf. There is limited information on exposure to plastic coatings used in sand-based infill.

Contaminants and Human Exposure Pathways

Artificial turf contains several contaminants of potential concern for human health. In the past, the synthetic fibres (i.e. grass blades) of artificial turf have been associated high levels of metals, including lead. The levels of these substances in newer turf materials are generally lower. The infill component of third generation artificial turf often contains infill made from recycled tires which have been found to contain metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). The risk posed by contaminants in artificial turf depends on the rate at which they are released, the route of exposure and the amount of exposure and the bioavailability of the contaminant (Cheng et al., 2014).

Generally, users of the turf may come into contact with toxics in artificial turf via three routes of exposure: ingestion, inhalation, and contact with skin (dermal uptake). SVOCs and VOCs released from the crumb rubber and the fine particulates re-suspended from the field can be inhaled. The organic contaminants and heavy metals on the exterior surfaces of the fibre blades and rubber infill, as well as

the fine rubber granules, can stick to the skin and clothes upon contact. As a result, the users can also be exposed through dermal uptake and incidental ingestion (e.g., via hand-to-mouth activity).

Children, especially very young children, have many characteristics which make them uniquely vulnerable to the three routes of exposure described. Some of these characteristics include: breathing more air per kilogram of body weight than adults, more frequent hand-to-mouth behaviour, and having a less "tough" skin which potentially increasing their dermal uptake (Denly et al., 2008).

Health Risks

Many risk assessment studies have been conducted to characterize the human health risks of third generation artificial turf using crumb rubber infill via the three exposure pathways noted above. Although each of these assessments have been conducted using distinct assumptions and have evaluated different concentrations of contaminants, these assessments have concluded that the degree of exposure is likely to be too small to increase the risk to health. However, there continues to be some areas of uncertainty. A recent review (Cheng et al., 2014) has synthesized the evidence on the human health impacts of artificial turf.

Ingestion - With respect to the potential risk of intentional or incidental oral ingestion of crumb rubber found in the infill of third generation artificial turf fields, reviewed studies suggest no significant acute, cancer, or chronic adverse health effects in both short- and long-term exposure scenarios. With respect to hand-to-mouth contact, there is no indication of adverse health effects, even though this type of exposure is associated with a high degree of variability and uncertainty, as it is influenced by many factors including frequency of field-use, hand-to-surface contact, along with many other factors (Cheng et al., 2014).

Dermal absorption: With respect to exposure through the skin, studies have generally shown that exposures through the skin were too low to cause any health effects among children and adult users of artificial turf. A study that examined the urine samples of adult football players found that the uptake of PAHs via skin uptake was negligible and similar to the range of uptake from environmental sources and/or diet (van Rooij & Jongeneelen, 2010).

Inhalation: Exposure by inhalation has been a larger area of investigation given that physical activity results in accelerated inhalation rates, potentially making artificial turf users more vulnerable. Field monitoring has shown that the levels of PAHs and VOCs in the air above outdoor artificial turf fields were not high enough to warrant concern for human health. Health risk evaluations indicate that elevated health risk from inhalation exposure could occur for workers with a long history (>5 years) of installing artificial turf in confined and poorly ventilated spaces (Moretto, 2007). With adequate ventilation, the risk from indoor artificial turf was below levels of concern. Menichini and colleagues (2011) estimated that inhalation exposure to PAH from artificial turf over an intense 30-year activity (5 hours/day, 5 days/week, year round) could result in a negligible increase in risk.⁵

Overall, available evidence suggests that toxic constituents of artificial turf are not expected to result in exposure to contaminants at levels that pose a significant risk to human health provided it is properly

⁵ As defined by an excess lifetime cancer risk of one in one million, which is Toronto Public Health's health benchmark for carcinogens.

installed and maintained and users follow good hygienic practices. There are some gaps with respect to test methods for determining the types of contaminants in artificial turf and approaches for assessing and taking action on potential risks (Van Ulirsch et al., 2010). While there is still insufficient evidence to fully address concerns related to low-level exposures to some contaminants during childhood (Denly et al., 2008), the risk of allergic reactions to crumb rubber that contains latex, and the potential presence of carbon black nanoparticles⁶ and carbon nanotubes warrant the use of standard hygienic practices such as washing hands and avoiding eating on the artificial turf in order to minimize any risk to health. Table 8 provides a summary of conclusions on exposure to toxic contaminants from selected government agencies.

Table 8: Toxicological Risks Associated with Artificial Turf – Selected Government Agency Conclusions

USA	
New Jersey Department of Health and Senior Services (2008)	Recommended the closure of three sports fields because the concentrations of lead found in the nylon fibres in the first generation artificial turf and the dust in one of the fields were considered to be high. The initial tests were conducted on a limited number of playing fields. NJDHSS sampling of additional athletic fields and other related commercial products indicates that artificial turf made of nylon or nylon/polyethylene blend fibres contains levels of lead that pose a potential public health concern. Tests of artificial turf fields made with only polyethylene fibres (third generation turf) showed that these fields contained very low levels of lead.
Consumer Product Safety Commission (2008)	Tested artificial blades of grass for lead content. The results showed no case in which the estimated exposure for children playing on the field would exceed their recommended limit of 15 µg lead/day.
The New York City (NYC) Department of Health and Mental Hygiene (Denly et al., 2008)	Considers it to be unlikely that low levels of exposure to the various chemicals measured in artificial turf have any effects on the health of players. Tested nylon fibres from a number of artificial turfs, measuring the levels of lead in dust by surface area. Since the values found fell within the allowable limits for residential surfaces set by the U.S. EPA, it considered that fields could continue to be used in spite of the relatively high concentration of lead measured in the fibres themselves.

⁶ Carbon black is added to tires as reinforcement filler during production and can make up 30% or more of car tires. It has been classified as a possible carcinogen by the US EPA and by the International Agency for Research on Cancer.

USA	
The New York City (NYC) Department of Parks & Recreation (2014)	<p>Based on elevated measurements of lead found in some city parks, indicates that it:</p> <ol style="list-style-type: none"> 1) Will use carpet-style or alternative infill materials on all new fields, rather than crumb rubber infill, 2) Implements NYC Health Department protocols to inspect, test, and replace any existing synthetic turf fields that may age or deteriorate, and 3) Implements the Health Department's recommendations on signage, procurement protocols and assessment of new technologies.
Centers for Disease Control and Prevention (2008, updated in 2013)	<p>Fields that are old, that are used frequently, and that are exposed to the weather break down into dust as the turf fibres are worn or demonstrate progressive signs of weathering, including fibres that are abraded, faded or broken. These factors should be considered when evaluating the potential for harmful lead exposures from a given field. CDC concludes that the risk for harmful lead exposure is low from new fields because the turf fibres are still intact and the lead is unlikely to be available for harmful exposures to occur. However, as the turf ages and weathers, and if there are elevated levels of lead in the fibres, this lead can be released in dust that could then be ingested or inhaled, and the risk for harmful exposure increases.</p>
Connecticut Department of Public Health (2007)	<p>Based on the data available, concludes that the public health risks associated with chemicals in artificial turf materials to be low. Sources of exposure not related to artificial turf materials to be more significant than those associated with artificial turf.</p>
California Environmental Protection Agency (2007)	<p>The Office of Environmental Health Hazard Assessment conducted an assessment of the health risks associated with SBRr aggregates under playground modules and found that the risk levels were below the levels generally considered acceptable.</p>
U.S. Environmental Protection Agency (2009)	<p>The EPA concluded that concentrations of PM₁₀, VOCs, metals and lead were below levels of concern; however, given the very limited nature of their study (i.e., limited number of components monitored, sites, and samples taken at each site) and the wide diversity of tire crumb material, they determined that it was not possible to generalize these findings without further sampling.</p>

USA	
California Department of Resources Recycling and Recovery (Vidair, 2010)	Particulates and associated elements (lead and other heavy metals) were either close to or below the level of detection above the artificial turf fields and upwind of the fields. Most air samples had VOC concentrations below the limit of detection. Fields with VOCs detected showed that exposures were below health-based screening levels, suggesting that adverse health effects were unlikely to occur. No correlation between concentrations of VOCs and surface temperature was found.
CANADA	
Montreal Health and Social Services Agency, Public Health Branch (Beausoleil et al., 2009)	Concluded that in light of all the information gleaned from the scientific literature, it appears that the health risks for players who use artificial turf are not significant and that it is completely safe to engage in sports activities on this type of outdoor field.
EUROPE	
Norwegian Institute of Public Health and Radium Hospital (2006)	The use of artificial turf (indoors in gymnasiums) with recycled rubber aggregates shows no evidence of posing a major health risk. As a precautionary measure, recommends that styrene-butadiene recycled rubber (SBRr) aggregates not be used in new indoor gymnasiums.
Swiss Federal Bureau of Public Health (2006)	Concluded that studies conducted in Sweden, Norway and Germany showed that playing on artificial turf with SBRr aggregates posed no particular health risks.
Swedish Chemicals Agency (KemI, 2006)	Recommended that aggregates from recycled tires not be used in the construction of new artificial turf fields. However, it considers that the SBRr aggregate in existing fields need not be replaced as long as it remains in good condition given the health and environmental risks associated with these materials are low.
AUSTRALIA	
Western Australia Department of Sport and Recreation, (2011b)	Concluded that 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.
Adapted from: (Beausoleil et al., 2009)	

Conclusions

Available evidence indicates that under ordinary circumstances, adverse health effects among adults and children are unlikely to occur as a result of exposure to artificial turf infilled with crumb rubber in both outdoor and indoor settings. Studies show that persons who would have relatively high exposures to rubber-infilled turf (workers and professional athletes) also do not have increased health risks. However, there are still some information gaps: the allergenic potential of latex in crumb rubber has not been thoroughly investigated; exposure to lead, other metals, carbon nanotubes, as well as other contaminants have not been fully evaluated in all types of turf systems; and the impact of low-level exposures during early childhood development is still uncertain.

Options to Reduce Risk

Health risks associated with artificial turf can be reduced or eliminated by following the following good practices:

- 1) Proper ventilation in indoor artificial turf facilities
- 2) Washing hands after playing on artificial turf
- 3) Supervising small children to ensure they do not eat the infill material
- 4) Not eating on the artificial turf
- 5) Preventing the tracking of infill material indoors (for example, shaking visible rubber pellets off or providing shoe/equipment cleaning areas before exiting the field)
- 6) Requiring the installation of artificial turf made with the least toxic materials when available
- 7) Adopt protocols for selecting and purchasing artificial turf infilled with rubber crumb. Such protocols could include requirements for suppliers and manufacturers to provide information on the chemical content of products, contaminant emissions overtime, and other material safety information;⁷
- 8) Ensure artificial turf in childcare settings or other play areas meets the limits for children's products as outlined in Health Canada's Consumer Products Containing Lead Regulation before purchase and installation; to minimize exposure to lead, prevent toddlers' direct exposure to artificial turf that does not meet these limits;⁸
- 9) Perform regular monitoring of contaminants; in order to account for risk at different stages throughout the lifecycle of an artificial turf field, sampling for lead content in artificial turf fibres is recommended at regular intervals (for guidance see Van Ulirsch et al., 2010).

⁷ The ASTM has issued Standard Specification for Total Lead Content in Synthetic Turf Fibres (ASTM F2765). The Synthetic Turf Industry has since voluntarily agreed to adhere to a standard of 100 mg/kg lead in turf fibres.

⁸ Health Canada's Consumer Products Containing Lead Regulation established 90 mg/kg as their lead limits for products that often include mouthing by small children under three years of age. (http://www.hc-sc.gc.ca/ahc-asc/media/nr-cp/_2010/2010_203fsb-eng.php)

2.1.4 Water Usage and Storm Water Management

Some of the environmental impacts of concern identified by stakeholders are related to water usage, storm water management and runoff water quality. These issues are important to health because they are often related to our exposure to harmful bacteria. The ability of our processes and infrastructure to function, particularly during extreme weather events, determines the likelihood of sewer back-up and overflow events, which may contain raw sewage, releasing harmful bacteria into homes, businesses and recreational areas, such as Lake Ontario (City of Toronto, 2013c). This section reviews water usage and storm water management, while the next section on environmental pollution reviews water quality issues in more detail. Water usage is particularly important in areas that experience regular restrictions to water use. In some communities the impact on ground and surface water quality can affect drinking water sources.

Water Usage - Summary of Evidence

Artificial turf is promoted by the industry as a "green" alternative to natural grass, with water conservation being portrayed as a key ecological benefit. In some jurisdictions, tax credits and rebates are being offered to residential and corporate users of artificial turf in light of its water conservation benefits (Synthetic Turf Council, 2014).

While artificial turf does not generally require irrigation, there are a few situations where artificial turf may require watering. For example, to improve playing conditions for sports such as field hockey; to clean the surface to meeting sanitation needs; and for temporary surface cooling. The water used for these purposes is usually less than the water needed to maintain natural grass (Simon, 2010). There are drought tolerant grass varieties that are amenable to heavy use; however, these varieties have not been compared with artificial turf with respect to their overall water needs.

In some cases, natural grass would need to be watered more often than an artificial turf field; however, the cooling benefits, improved aesthetics and psychological benefits may outweigh the cost of watering in a triple-bottom line analysis.

Storm Water Management - Summary of Evidence

Generally, natural surfaces absorb storm water better than impervious surfaces such as streets, parking lots, roofs and artificial turf. Natural grass fields can be designed to capture storm water runoff, and have an improved capability to improve water quality due to the filtering action of the soils used to grow the grass. Impervious surfaces reduce infiltration of precipitation through the soil which decreases groundwater recharge, stream base flow, and can deprives nearby trees and vegetation of water over the long term.

With changing climate the number of extreme weather events has increased in Toronto and this trend is expected to continue. The base of a traditional artificial turf system is typically designed with a six inch aggregate base with a subsurface drain pipe system that moves rainwater into a storm sewer. Horizontal designs similarly move water along the perimeter of the field into storm sewers.

This can increase storm water runoff, potentially overwhelming storm water management systems (TDSB, 2013) which lead to water quality concerns and flooding, making the area where the artificial turf is installed less resilient to the impact of climate change.

Mitigating Strategies

Currently in Toronto, the City's Wet Weather Flow Management Guidelines do not allow rain water to be piped directly into sewers. As such, organizations such as the TDSB and the TCDSB are in the process of exploring alternative designs for future installations of artificial turf to retain water onsite (TCDSB, 2014; TDSB, 2013). For recently installed artificial turf fields, the TDSB and the TCDSB have sought the advice of landscape architects to incorporate natural storm water management measures such as bioswales around artificial turf fields.

The harvesting of storm water for reuse has been a growing area of research and development (see Appendix 5). As a porous surface, artificial turf can be designed to allow storm water to pass through the turf layer and then be stored and or infiltrated into the subsurface or surrounding soil (New York City Department of Parks & Recreation, 2010). This has been done at the City of Waterloo's GreenLab pavilion at RIM Park. The outdoor sports facility has a green roof and an innovative water-harvesting system under its two artificial fields that stores rain to water the four natural fields (City of Waterloo, 2014). While such storm water management technology is possible for future fields, cost is a major barrier to implementation. The complexity of retrofitting existing infrastructure is also a major challenge.

Conclusions

Available research suggests that the use of artificial turf can reduce overall water use on sports fields. This can be a benefit in communities where water shortages are common. Unlike natural grass which has natural infiltration properties, traditional artificial turf systems, designed with a subsurface drain pipe system, can increase storm water run-off, contributing to water quality concerns and flooding. To ensure resilience under climate change it is important to design sports fields that use artificial turf surfaces in a way that maximizes water retention and infiltration on-site.

Options to Reduce Risk

- 1) Future installations of artificial turf fields should include drainage designs which detain and/or infiltrate water onsite. Some potential design options include infiltration trenches or bioswales around the perimeter of the field, including more water absorbent vegetation, or the construction of subsurface water-harvesting systems.

2.1.5 Water Contaminants and Aquatic Ecosystem

Aquatic ecosystem health is important to for human health. When an ecosystem is in balance it is more resilient and, in turn, more reliably offers environmental services including flood protection. Healthy aquatic ecosystems also contribute to maintaining good recreational water quality. The governments of Canada and Ontario (2014) have recently prioritized reducing excessive nutrients, and reducing or eliminating releases of harmful pollutants in order to protect human and aquatic ecosystem health and well-being.

Summary of Evidence

Assessing the water quality of the runoff from artificial turf is complex and study results vary depending on the type of artificial turf examined (such as, older or newer generation surface or the type of infill material), the types of assessment methods undertaken, and other factors. In general, natural grass areas and the soil beneath create a good medium to purify water as it leaches through the root zone and the soil into underground aquifers (Turfgrass Producers International, 2010). On the other hand, artificial turf has no natural filtration properties and over time, the synthetic materials found in artificial turf may leach into water runoff and potentially impact aquatic life.

To date, several studies have characterized the contaminants in the drainage of artificial turf with rubber crumb infill (Bristol & McDermott, 2008; Cheng & Reinhard, 2010; Hofstra, 2007; Lim & Walker, 2009; Moretto, 2007). In general, the concentrations of heavy metals and contaminants in the drainage of artificial turf are low, with the exception of zinc. Two studies that assessed the drainage from artificial turf fields produced with rubber crumb, found no toxic effects on tested species (Bristol & McDermott, 2008; Moretto, 2007). One lab study found that rubber crumb derived entirely from truck tires might have an impact on aquatic life, but when more accurate tests were conducted, no adverse impacts were predicted (Lim & Walker, 2009). In a Norwegian assessment (cited in Keml, 2006) concluded, however, there could be a risk of negative effects on aquatic organisms both in the water and in the sediment, with zinc contributing most to this risk, and smaller contributions from phenols and polycyclic aromatic hydrocarbons (PAHs). Overall, studies indicate that the total amount of hazardous substances that leaches from artificial turf is small, and any effect on the environment is expected to be limited, especially when compared with water quality impacts from urban runoff.

A major limitation of these studies is that they are point-in-time field observations which do not account for the evolution of contaminant release rates and interactions with other environmental conditions over time. This makes it difficult to draw conclusions about the potential long-term risks of water contaminants from artificial turf. In light of these limitations, a recent systematic review (Cheng et al., 2014) has called for coordinated laboratory and field investigations to characterize the release of heavy metals and organic contaminants from artificial turf.

Conclusions

Available research indicates that hazardous substances from the crumb rubber can leach into water but at levels which are unlikely to be a risk to human health. More research is needed to fully assess the risk regarding the presence of zinc and some other substances in drainage water from crumb rubber fields and their effects on aquatic and sediment-dwelling organisms.

2.1.6 Biodiversity and Ecosystem Health

It is well-established that human health and wellness depend to a large degree on goods provided by natural and managed ecosystems. These goods and other benefits provided by ecosystems are collectively referred to as “ecosystem services”. A key concern raised regarding the replacement of natural grass with artificial turf, is the loss of ecosystem services and biodiversity.

Summary of Evidence

Some of the major ecosystem benefits provided by natural surfaces include: rainwater entrapment, retention and water recharge; climate regulation; soil building capacity; oxygen generation; carbon sequestration; and absorbing pollutants from the air (Beard & Green, 1994). Natural surfaces also provide a habitat for insects and other organisms. Artificial turf on the other hand, does not have these ecological benefits and provides no organic biodiversity due to its compacted base structure. Artificial turf can also compromise tree development. The practice of using root barriers during artificial turf field installations to prevent root evasion, which can lead to surface cracking, is predicted to inhibit tree root development (State Government of Victoria, 2011). According to the Toronto Green Standards, trees require approximately 30m³ of soil to grow to a mature size, which is important for maximizing shade and other ecological functions (City of Toronto, 2014). There are also concerns about the loss of tree planting opportunities around artificial turf. It is unknown whether facility owners will be consistently able to overcome issues such as soil compaction or be able to afford the costs associated with rehabilitating and returning the space to a naturalized or natural turf area in future.

Mitigating Strategies

Toronto schools have indicated that, in some cases, the use of artificial turf fields can provide opportunities for enhancing existing natural areas. There are two reasons for this: schools have generally been reluctant to plant trees near or around existing natural grass fields because shade comprises grass growth; and in situations where natural grass cannot be maintained due to the high intensity of use and poor site conditions (for example, grading or soil erosion) artificial turf installations can provide the impetus to also improve surrounding conditions, which maximizes the benefits of naturalized surfaces over the long term. Actions that help address the carbon-footprint of an installation may also be part of a strategy to mitigate loss of ecosystem services and biodiversity. Some of these include mass tree-planting initiatives and reusing all of the topsoil that is removed from sites during installations.

Conclusions

Due to its compacted base and synthetic surfaces, artificial turf surfaces do not provide the ecological or biodiversity benefits of natural turf. The use of root barriers during some installations may also inhibit tree root development. However, in some situations, schools have indicated that the use of artificial turf can help reduce pressures on the natural areas of their properties.

Options to Reduce Risk

- 1) Efforts can be taken to improve site conditions surrounding artificial turf to help offset the ecosystem functions that are lost with the artificial turf. These measures can include planting trees near artificial turf fields and creating new green spaces.

2.1.7 Carbon Footprint

Increasing concentrations of greenhouse gases (GHGs) in the atmosphere is changing the climate. Reduction of net releases of GHGs is critical to limit their concentrations in the air to acceptable levels. The carbon footprint of an activity is a way to estimate its impact on climate change.

Summary of Evidence

Few independent studies were found that compared the carbon footprint of a natural grass field to artificial turf. Results of lifecycle assessments can vary greatly due to the many different assumptions made and the different natural and artificial turf systems that are compared. Results from different assessments are usually not comparable.

Natural grass acts a carbon sink by removing carbon dioxide from the atmosphere through photosynthesis and sequestering it as organic carbon in soil. A typical lawn (2,500 sq. ft.) has been estimated to convert enough carbon dioxide from the atmosphere to provide adequate oxygen for a family of four (Turfgrass Producers International, 2010). While the carbon footprint for natural grass typically comes from the initial installation and ongoing maintenance stages,⁹ a U.S. study estimated that managed lawns capture four times more carbon from the air than is produced by the engine of today's typical lawnmower (Sahu, 2008). The same study found that well-managed natural grass helps remove pollutants from the air, creating both a greater carbon benefit and improved air quality.¹⁰

Some studies have concluded that the carbon emissions related to the maintenance of turf, including watering, fertilizer use and mowing, results in higher carbon emissions that are not fully offset by the carbon sequestration of grass (Uhlman et al., 2010). However, a study done for Upper Canada College when it installed its artificial turf field estimated that the total GHG emissions from the manufacturing, transporting, installing, maintaining and disposing of a 9,000 square meter artificial turf field over a 10-year period would emit 55.6 tonnes of carbon dioxide while the construction and maintenance of a natural grass field of the same size would remove 16.9 tonnes of carbon dioxide (Meil & Bushi, 2007). The study estimated that 1861 trees would need to be planted to achieve a 10-year carbon-neutral artificial turf field at this site.

Mitigation Strategies

Several measures have been proposed to offset the carbon footprint of artificial turf. Requiring natural or recyclable materials in the construction and design of artificial turf, such as shock pads made from recycled material, also reduces the overall carbon footprint of the artificial turf. Planting trees and reusing all the topsoil that is removed from sites during artificial turf installations are options that can reduce for the carbon footprint of an artificial turf (Meil & Bushi, 2007). One Toronto school promotes carbon neutral sporting events through the use of carbon offsets such as planting trees.

⁹ Natural grass fields may require fertilizers which are made using very energy-intensive manufacturing processes.

¹⁰ While one published study reported that natural grass sports fields do not store as much carbon as ornamental lawns, due to soil disruption by tilling and re-sodding (Townsend-Small & Czimczik, 2010), various computation errors were later found in these estimated (Neighbourhood Nursery, 2010).

Conclusions

Typical artificial turf fields have functional lifetimes of 10 to 20 years and are constructed mostly from synthetic materials. Artificial turf also requires ongoing maintenance, often involving fuel-powered machinery, which generates GHGs. While construction and maintenance of natural fields also release GHGs, natural grass fields remove carbon from the atmosphere acting as "carbon sinks". Assessments of the carbon footprint of artificial turf have come to different conclusions; these are likely the result of the different types of fields compared, assumptions made, and site-specific factors.

Options to Reduce Risk

- 1) More sustainable design and construction measures for existing and future artificial turf fields can help offset GHG emissions related to the life-cycle of artificial turf. In addition, mass tree planting initiatives, reusing all the topsoil that is removed from sites during installations, ensuring sustainable disposal, and hosting carbon-neutral events can help reduce the carbon footprint of artificial turf.

2.2 Built Environment and Lifestyle Factors

2.2.1 Physical Activity

Physical activity has many health benefits; it has been clearly associated with decreased rates in chronic diseases such as heart disease, some cancer and diabetes. Despite this, most Canadians do not engage in the levels of physical activity required to maintain their health; 69% of Canadian adults and 91% of Canadian children and youth are not getting the recommended levels of daily physical activity (Colley et al., 2011). Numerous studies and research from across Canada have also identified the lack of physical activity as a key contributor to Canada's high (and growing) obesity rates (Bryan & Katzmarzyk, 2011; Janssen & LeBlanc, 2010). One of the most commonly cited benefits of artificial turf is that it could increase access to recreational facilities, thereby increasing opportunities for physical activity among children, youth and adults.

Playing Time - Structured

Weather is an important factor in use-times for both natural turf and artificial turf. Natural fields may require several days to become playable after heavy rainfall, though this recovery time is affected by how natural playing surfaces have been designed. A design solution that considers the entire surrounding system, and not just the playing surface, can reduce the required recovery time of natural turf after a heavy rainfall.

Weather-related losses in use-time can be large. Some estimates from relatively temperate locations suggest that natural fields are unavailable for an average of 10 days a year because of rain (Simon, 2010). In addition to weather-related time loss, all natural fields must be given time to rest to allow for rejuvenation.

The quality of natural turf surfaces also vary according to weather conditions. Natural turf can have large areas of bare ground which become hard and dusty during dry periods or muddy during wet periods, making it less than ideal for play. For example, the natural turf of the University of Toronto back campus was known to get badly degraded and be deemed unfit for play by Ontario University Athletics (University of Toronto, 2010). Maintenance efforts could ensure a quality playing surface only for a very limited time, causing long wait lists for intramural teams (University of Toronto, 2010).

While artificial fields recover quickly after a heavy rainfall, some have argued that the availability of the field can be compromised by hot weather conditions. The New York City Department of Health and Mental Hygiene (Denly et al., 2008) reported that synthetic turf fields may become too hot to play on when temperatures are high. To date, there has been no study examining losses in use-time on artificial turf because of heat-related conditions. Toronto schools and school boards note that artificial turf can extend the playing season – the heat-retaining properties allow it to remain snow and ice-free for longer periods when temperatures begin to drop in winter. One author has estimated that artificial turf provides, on average, 2000-3000 usable hours of playing time per year, compared with natural turf, which provides between 300-800 hours of playing time (Simon, 2010).

Unstructured Physical Activity

While most research to date indicates that artificial fields provide more hours of play, there has been limited research characterizing the type of play which is promoted by artificial turf. Generally speaking, turf is expected to promote rule-bound physical activity. According to a local school-based research study (Dyment, 2005), where play areas dominated by turf and asphalt, promoted only limited types of play, notably active, repetitive, rule-based games like tag and soccer. In contrast, school grounds which were "greened" with a diversity of environmental features such as trees, gardens, and nature trails offered a wide range of play opportunities and students were often less bored. Without access to conducive play areas, there is a risk of losing opportunities for unstructured, outdoor activities, which have been associated with cognitive, behavioural and physical health benefits in children (McCurdy et al., 2010).

Conclusions

Artificial sports fields provide more total available hours of usage than current natural fields and can extend playing seasons. While the playing surface may be used for structured play for more hours per year, there is insufficient evidence to assess if the presence of artificial turf fields increases the overall levels of physical activity of the population as a whole. With respect to the type of physical activity promoted by artificial turf, there is some evidence to suggest that turf surfaces promote rule-bound competitive play rather than more diverse nature-based play opportunities often preferred by school-age children and important for their development.

Options to Reduce Risk

- 1) Seek community input when planning sports field and playground upgrades and renovations, including the installation of artificial turf. Prioritize field and playground types that suit the needs and interests of users and promote both structured and unstructured physical activity; consult with green infrastructure design experts to enhance opportunities for nature-based, unstructured play alongside artificial turf fields.

2.2.2 Injuries

When compared to natural grass, first and second generation artificial turf have been associated with an increased injury risks across a number of sports (Dragoo & Braun, 2010). Since the 1960s, artificial turf companies have made significant strides to simulate more natural surfaces and to provide added safety features such as shock pads. This section reviews available research looking at injury risks related to third generation artificial turf.

Injury Incidence and Injury Types – Summary of evidence

A systematic review conducted in 2011 compared injuries on third and fourth generation artificial turfs to natural turf and concluded that there is strong evidence that rates of injury between new generation artificial turfs and natural turfs are comparable (Williams et al., 2011). A more recent meta-analysis comparing injuries among soccer players found that under some conditions, injury risk among competitive soccer players may be lower on artificial turf compared to natural grass (Williams et al., 2013). The types and number of injuries also varies by sport played. Few studies look at sports other than football and soccer (Dragoo & Braun, 2010).

While studies to date do not demonstrate any significant difference in overall injury incidence, studies do note differing injury patterns between the two surfaces (Williams et al., 2011). Reviewed studies suggest that artificial turf increases the risk of ankle injuries compared to natural grass (Williams et al., 2011). Evidence concerning the risk of knee injuries is inconsistent (Williams et al., 2011). A recent systematic review of knee injury (i.e. anterior cruciate ligament) risk factors in male athletes concluded that artificial turf may increase the risk of non-contact knee injuries (Alentorn-Geli et al., 2014). However, this review did not compare risk factors related to artificial turf and natural grass. Studies examining all knee injuries on natural grass have been mixed as well (Orchard, 2001; Orchard et al., 1999). There is some evidence to suggest that different grass types are also associated with different injury rates, with thick Bermuda grass being associated with higher rates of knee injuries in comparison to thinner rye grass varieties (Orchard et al., 2005).

There is some evidence that artificial turf reduces the rates of muscle strain injuries for soccer players (Williams et al., 2011). More research is needed to clarify the direction of this effect with respect to other types of sports such as football and rugby. In relation to injury severity, the range of definitions used to describe severity makes it difficult to make objective comparisons between studies (Williams et al., 2011). Generally, injuries are divided into categories of severity according to the length of absence from matches and training sessions, but the length of absence for each category varies from study to study.

Mechanisms and Risk Factors for Injury – Summary of Evidence

Most research suggests that there are two specific surface properties which may impact injury rates on artificial turf; this includes surface traction and shock absorbance. Some research also suggests that player fatigue may increase the risk of injury. These potential risk factors are discussed below.

Surface Traction

Surface traction relates to how sticky or “grabby” the surface is. There are various types of traction, but the most commonly studied types of traction related to artificial turf surfaces are translational and rotational traction. Translational traction (or linear traction) refers to the traction that resists the shoe's sliding across the surface. For an athlete, high translational traction equates to the shoe gripping the surface and allowing faster linear speed and low translational traction means the shoe tends to slip. Rotational traction (or torque) refers to the traction that resists rotation of the shoe during pivoting movements. For athletes, high rotational traction equates to a greater tendency for foot fixation during changes of direction and low rotational traction means the shoe releases from the surface more easily.

Research clearly points to a correlation between increased rotational traction and greater rates of injury. One study found similar or higher rotational traction of the natural turfgrass compared to artificial turf surfaces (McNitt & Petrunak, 2007). Other studies have found higher peak torque (rotational traction) (Livesay et al., 2006; Villwock et al., 2009) and rotational stiffness on artificial turf surfaces compared to natural grass surfaces (Villwock et al., 2009). Another study found differing foot-loading patterns on artificial turf (Ford et al., 2006), which may explain the higher incidence of ankle injuries found in a recent systematic review (Williams et al., 2011).

Shock Absorbance (Surface Hardness)

Surface hardness or the surface's ability to absorb shock is linked to the level of impact on players during a collision with the field. Increased hardness may therefore translate to higher injuries such as concussions, fractures and dislocations. Shock absorbance is measured by using the G-max value where one “G” represents one unit of gravity. Currently, fields with a G-max of greater than 200 are considered unsafe for athletic play, based on standards set by the U.S. Consumer Products Safety Commission (USCPSC) and the American Society for Testing and Materials International (ASTM) (McNitt & Petrunak, 2007).

Several studies have examined the impact attenuation properties of artificial turf. Factors such as infill type, amount of infill, infill compaction, and the presence of a shock pad are thought to determine hardness levels. One study found that artificial fields with shock pads had lower surface hardness values compared to no-pad systems (McNitt et al., 2004). The same study found that infill depth did not affect surface hardness, but that mixtures of sand and crumb rubber infill resulted in lower surface hardness (McNitt et al., 2004).

In another study artificial turf was found to maintain its engineered hardness levels well below the maximum G-max rating of 200 after wear (McNitt & Petrunak, 2007). They also found that natural grass had similar or higher G-max values than infilled artificial turf systems. The authors concluded that unlike natural grass which can vary in hardness according to soil-moisture content, artificial fields exhibit consistent levels of shock absorbance in wet and dry conditions and over time.

With respect to injuries related to surface hardness, one study examined the impact attenuation properties of six third generation artificial fields and a natural grass turf to assess the risk of incurring a mild traumatic brain injury (TBI) (Theobald et al., 2010). They found that artificial turf surfaces had a greater than 10% risk of causing mild brain injuries within achievable fall heights. Natural grass on the other hand, required fall heights exceeding those possible during games to reach the 10% risk for a mild TBI.

Player Fatigue (Physiological Response)

A few studies have assessed the physiological responses of physical activity on artificial turf compared to other ground surfaces. The majority of these single studies suggest that physiological responses do not differ markedly between surface type, including during constant-speed running (Sassi et al., 2011) and more dynamic activities, such as playing soccer (Hughes et al., 2013; Nedelec et al., 2013; Tessitore et al., 2012). However, one study found higher heart rate and blood lactate levels among young soccer players running on artificial turf compared to natural grass (Di Michele et al., 2009). In a survey of Swedish soccer players, players perceived it to be physically harder to play and run without the ball on artificial turf compared to natural grass (Andersson et al., 2008). The shock absorbency on artificial turf may explain differences in findings – with softer artificial turf surfaces requiring more energy expenditure.

Mitigation Strategies

Strategies to prevent sports-related injuries on artificial turf generally relate to footwear and surface hardness levels. Footwear plays a major role in the amount of traction a player experiences. Turf-style cleats (shorter cleats) have been noted to reduce torque in comparison to soccer or rounded cleat patterns intended for play on natural grass (Livesay et al., 2006; McGhie & Ettema, 2013; Villwock et al., 2009). With respect to surface hardness, several reports recommend that routine surface impact testing be performed to ensure that accepted G-max standards (lower than 200) for playing surface hardness are met (Drakos et al., 2013; McNitt & Petrunak, 2007). Performing regular grooming and brushing of artificial fields has also been noted to minimize the potential of infill compaction which can increase hardness levels (State Government of Victoria, 2011).

Conclusions

Artificial turf and natural grass have comparable rates of injury, with differences in injury pattern. Research suggests that artificial turf increases the risk of ankle injuries, with mixed evidence regarding knee injuries and muscle strains. There is little evidence available regarding player-surface contact injuries such as concussions and fractures. Injuries on artificial turf may partially be explained by higher rotational traction (torque) compared to natural grass surfaces, differing foot-loading patterns, footwear characteristics, and player fatigue. In terms of surface hardness, artificial turf fields can provide a safer

playing surface than paved surfaces and are either as soft as or softer than natural grass fields in the colder months.

Options to Reduce Risk

- 1) Manufacturer specifications should be followed; perform regular grooming and brushing of the field to minimize the potential of infill compaction.
- 2) Perform routine surface impact testing to ensure that accepted G-max standards for playing surface hardness are met. The currently accepted standard for G-max safe levels is 200G, as set by the U.S. Consumer Product Safety Commission and ASTM International. To ensure consistent compliance and safety, impact testing should be performed regularly. Over time, synthetic surfaces become harder and G-max values increase at a rate determined by the materials used, construction, level of play and frequency of use. Annual testing provides a historical trend for any given field and alerts managers to problems before they become critical.
- 3) Implement proper injury prevention education and erect signage, advising users of potential injury risks and measure they could take to reduce those risks. Field users, coaches and parents can be advised of the potential for lower extremity injuries, such as ankle injuries and users can be encouraged to wear appropriate footwear to reduce the chance of injury. Users can also be advised of the potential for fatigue while using softer artificial turf surfaces, which require more energy expenditure.

2.2.3 Skin Abrasions & Infections

A concern often raised when exploring the impact of artificial turf on health is bacterial infections. It is important to take into account two key factors: the ability of the artificial surface to create abrasions that can be the vehicle for contracting and spreading infections; and the hospitability of the surface itself to pathogens which can be the source of infections. This section reviews these issues by discussing research related specifically to risk of abrasions, risk of infections and the presence of bacteria on artificial turf.

Abrasion – Summary of Evidence

With respect to the risk of skin abrasions, evidence suggests that newer types of artificial turf are more abrasive than natural turf. The choice of infill may play a critical role in abrasion, as sand-based infill will be more abrasive than rubber (Government of Western Australia, 2011a). One clinical study compared the effects of sliding on natural and artificial turf and found that artificial turf caused less inflammation but more abrasion compared to natural grass, in both wet and dry conditions (Peppelman et al., 2013). An observational study found that the incidence of skin injuries on artificial turf in American football players was higher than on natural grass (Meyers & Barnhill, 2004). Similarly, Vidair (2010) found that the rate of skin abrasions was two- to three-fold higher for college soccer players competing on artificial turf compared to natural turf.

Athlete perceptions of risk of abrasions on artificial turf also appear to be higher (Burillo et al., 2014; Kazakova et al., 2005; Zanetti, 2009). Many of the negative perceptions of artificial turf among athletes

stem from first generation of artificial turf (Astroturf). A study from Penn State University assessed surface abrasiveness by pulling foam blocks over different artificial turf surfaces (McNitt & Petrunak, 2007). The results indicate that infill systems (second and third generation artificial turf) are less abrasive than older carpet-like turf (first generation). The same study found that regular grooming lessens the abrasiveness of the field.

Infections- Summary of Evidence

With respect to skin abrasions facilitating infections, two retrospective cohort studies were conducted to evaluate outbreaks of methicillin-resistant *staphylococcus aureus* (MRSA) among professional and college level American football players. These studies found that skin breaks caused by turf burns facilitated MRSA infection and likely contributed to the spread of infection through skin-to-skin contact during play (Begier et al., 2004; Kazakova et al., 2005). While these studies establish a link between the occurrence of turf burns and MRSA infection, good hygiene and first aid practices might have prevented spread.

Presence of Bacteria – Summary of Evidence

There has been some research examining the presence of harmful bacteria on artificial turf compared to natural grass. One study examined the presence of *Staphylococcus aureus* (*S. aureus*) on artificial turf through sample tests and did not find *S. aureus* on artificial turf (Serensits et al., 2011). Another study examining the survival of *S. aureus* isolates found that it survived for as long on natural grass as it did on artificial turf, in both indoor and outdoor settings (A. S. McNitt & Petrunak, 2011). The authors reported that *s. aureus* has a very low rate of survival outdoors, particularly when exposed to UV light and higher temperatures and that the survival on artificial turf seems to be greatest on the fibres compared to the crumb rubber (McNitt & Petrunak, 2011). Another study examined community associated MRSA (CA-MRSA) isolates on indoor artificial turf surfaces and found that survival is dependent on the availability of nutrients (Waninger et al., 2011). A study commissioned by the State of California (Vidair, 2010) reported fewer bacteria (i.e. MRSA and other *Staphylococci* capable of infecting humans) on artificial turf compared to natural grass.

Conclusions

Available research suggests that artificial turf may increase the risk of skin abrasions which can in turn facilitate infections. If good hygienic practices are used when skin abrasions occur, artificial turf surfaces do not appear to pose an increased risk due to the presence of harmful bacteria, such as MRSA, as compared to natural turf.

Options to Reduce Risk

- 1) Prevent and treat skin abrasions promptly. Some strategies may include: using protective clothing and equipment when playing on artificial turf; obtaining proper treatment of skin abrasions by cleaning and disinfecting affected areas and covering abrasions as soon as possible.
- 2) Perform regular field grooming to lessen the abrasiveness of artificial fields. Manufacturer specifications should be followed to determine frequency and methods for field grooming.

2.2.4 Surface Upkeep

In addition to the other human health impacts associated with artificial turf, several concerns have been raised regarding turf maintenance and sanitation. Unlike natural surfaces which have high biological activity which helps degrade pathogens and organic materials, artificial turf cannot break down such materials as easily.

Summary of Evidence

Several reports have highlighted potential sanitation issues where bodily fluids (blood, sweat, spit, etc), and animal waste are not cleaned up properly on artificial turf (Government of Western Australia, 2011b; State Government of Victoria, 2011). Similarly, if organic material is not adequately removed from artificial turf surfaces, there is potential for moss and algae growth which can be harmful to human health and may inhibit water infiltration. If artificial turf is installed on top of a paved surface, it is also possible for mold to grow underneath the artificial turf surface. In such cases, manufactures recommend cleaning the surface with common bleach (Synthetic Turf Products, 2014). Surface softeners, mild household detergents, algaecides and moss killer products may also be used for regular maintenance (State Government of Victoria, 2011). While concerns have been raised about exposure to such cleaning agents, there has been no studies have specifically examined the risk of products used in maintenance of artificial turf. Discussions with facilities that maintain artificial turf indicate that the products used in the maintenance of artificial turf are of similar nature to other cleaning products used in general building maintenance. Other maintenance concerns relate to surface hardness and quality. Some issues include infill compaction and dispersion, ripped seams, and keeping fibres upright to maintain optimal cushioning and playability. If the surface is not maintained properly, fibres can eventually split and then fold over and 'cap' the surface. If this occurs, the surface can become hard, traction can be diminished, and drainage reduced. The 'exposed' artificial grass fibres across the surface will also be vulnerable to faster ultra-violet degradation (State Government of Victoria, 2011).

Mitigation Strategies

In conversations with schools, it was identified that several formal and informal measures are being taken to address maintenance and sanitation concerns. Regular maintenance practices by schools may include brushing, raking in areas that have become compacted, and periodic replacement of infill. With respect to sanitation, while deep cleaning with sanitizing agents is not a regular practice in Toronto schools, other measures have been taken to keep surfaces clean. This includes a "no food or (non-water) drink" policy, and additional garbage bins near artificial turf fields to manage increased waste generated through after-school activity. To address student health-related incidents on artificial turf fields such as vomiting or accidents involving blood, caretaking staff treat such situations in the same way they would treat indoor incidents (i.e. mopping and disinfecting the area).

On the whole, discussions with facility managers in Toronto indicate that they are well aware of the maintenance requirements of artificial turf sports fields, and are taking measures to ensure compliance

with manufacturer specifications. These could be strengthened with additional measures to mitigate concerns regarding the sanitation practices related to use by community residents (i.e. dog walking) or private rentals, which can be subject to less supervision. Similarly, appropriate maintenance protocols can ensure that artificial turf fields in schools are maintained throughout the year.

Conclusions

In general, artificial turf lacks the natural biodegrading properties of natural surfaces, making it more susceptible to unsanitary conditions for users. Although artificial turf is generally hardwearing, maintenance is also essential to meet the specified performance and safety requirements throughout its life cycle.

Options to Reduce Risk

- 1) Owners and/or operators of artificial turf fields should at minimum follow manufacturer specifications for maintenance to address performance-related concerns.
- 2) Health and hygiene measures can be adopted to address sanitation-related concerns. These may include:
 - a. Remind users to avoid common causes of sanitation concern, such as spitting, bringing food and letting pets urinate or defecate on artificial turf; signage around artificial turf fields can help to remind users to maintain the cleanliness and safety of the artificial turf;
 - b. Treat incidents involving bodily fluids in the same way as indoor incidents;
 - c. Perform regular sweeping of leaves and other debris from the surface to prevent rapid decomposition of organic material which can encourage algae and moss growth;
 - d. Treat areas affected by algae, moss, or mold as soon as possible using special cleaning agents, as specified by manufacturers; and
 - e. Perform periodic deep cleaning with sanitizers.

2.2.5 Access to the Natural Environment

A key concern raised about the use artificial turf in an urban setting like Toronto, is the loss of green space and the related health and social benefits that come with it. Green spaces are loosely defined as open, undeveloped land with natural vegetation and can include parks, playgrounds, sports fields, forests, wooded areas, meadows, trails, community gardens and ravines. Research suggests that there are three main types of engagement with green space which support human health and wellbeing: physical activity, rest and restoration, and social engagement. These are described in the next section and followed by a brief discussion of existing research gaps and possible strategies to address concerns regarding loss of green space.

Benefits of Green Space – Summary of Evidence

Evidence suggests that contact with green spaces independently promotes physical activity (Humpel et al., 2002; Kaczynski & Henderson, 2007) and a higher frequency of play among children (Taylor et al., 1998).

Studies also show that contact with green spaces can be psychologically and physiologically restorative, reducing blood pressure and stress levels (Mitchell & Popham, 2008). These restorative qualities also appear to be important to children's health, as it is linked to reduced levels of attention deficit, improved cognitive ability and development, and reduced aggressive behavior (Bell & Dymont, 2006; Harnik & Welle, 2011). Numerous studies also show that nearby green space mediates health by promoting community ties and social support (Maas et al., 2006; Masuda et al., 2012; Plane & Klodawsky, 2013). These social benefits have also been observed in children. A report from Evergreen (Dymont, 2005) indicates that students attending schools with "green grounds" experience many socio-ecological benefits such as: more diverse play opportunities; enhanced social relations; increased learning opportunities; and enhanced relationships with the natural world.

While the studies noted above demonstrate the positive health impacts of green spaces, there has been little research examining differences in green space types. In other words, few studies contrast or compare elements of green space and their relative benefits. It is very difficult to compare the health benefits of a natural grass sports field relative to a community garden, for instance. No research has explicitly examined if artificial turf has the same health and social benefits as natural green space. However, there is some research which suggests that improving the quality of play spaces (i.e. upgrades, new equipment and renovations) can result in increased physical activity (Active Living Research, 2011). No studies looking at the health impacts of spaces that combine green and non-green design elements have been found.

Mitigating Strategies

The challenges of balancing the demand for field time with the need to maintain natural turf are well-documented. Consultations with schools and boards also indicate that artificial turf in secondary schools can help leverage existing high school athletics programs since such fields help draw regional tournaments and other events. While artificial turf may be appropriate under these circumstances, some have argued that installation of artificial turf should only be considered when other alternatives have been fully considered. A recent report on landscape guidelines for New York City parks highlights various alternatives that could be considered before using artificial turf. Some of these include constructing multiple high quality natural fields which can be rotated and constructing sand-based natural sports fields (New York City Department of Parks & Recreation, 2010).

Where artificial turf is slated for installation, examples from other cities suggest that public involvement would help mitigate concerns about access to green space. In New York, field renovation projects have often been presented to community boards, which has helped the community make more informed decisions about artificial turf (Huber, 2006). In Vancouver, public consultations have resulted in site selection criteria which reflect green space concerns (cited in (Huber, 2006). The City of Seattle has established a Joint Athletic Facilities Development Program with the local school district to examine the city's athletic field system as a whole in order to make improvements for both field users and

neighbourhoods (Seattle Parks and Recreation, 2007).¹¹ These are consistent to best practices in park development which includes public engagement in the planning and design of play spaces. Such participation maximize benefits to the community being served and is more likely to foster positive use of park space (Active Living Research, 2011; Harnik & Welle, 2011).

Combining green and non-green design elements may also be one way of maximizing green space benefits alongside artificial turf. For instance, the Trust for Public Land in the U.S. has supported exemplary participatory park and school ground design processes, which have included artificial turf features alongside green features (Harnik & Welle, 2011). More locally, plans to install artificial turf in the University of Toronto's back campus include natural landscaping and street furniture which are expected to revitalize the area and provide new possibilities for the public to enjoy the back campus (University of Toronto, 2010).

Conclusions

Urban green spaces are essential to the mental, social and community well-being of city residents. Green space also makes cities more energy efficient and less vulnerable to the effects of climate change. Parks and playgrounds with a diversity of well-maintained "green" features are also important for children's health. Good design practices community participation in park design can increase benefits of the newly designed space and help mitigate the negative impacts of artificial turf on green space.

Options to Reduce Risk

- 1) Take a community-wide approach for assessing the need for and planning sports field and playground upgrades and renovations, including the installation of artificial turf.
- 2) Explore the feasibility of natural alternatives, such as rotating natural turf fields or using high quality, wear and drought tolerant grass varieties.
- 3) If artificial turf is to be used, enhance green infrastructure components around the field, including those that promote nature-based play.
- 4) Give preference to locating artificial turf in areas which would otherwise not be available as an active space for a community.

2.2.6 Neighbourhood Design Impacts

Pressures on Community Services and Facilities

Declining enrolments and the provincial education funding formula based on the number of students is putting the TDSB in particular under financial pressure. To address this, the Board has been obliged to sell surplus property holdings or develop partnerships with private developers who will pay the cost of facility upgrades in return for exclusive rights to fields. These sales and partnerships are resulting in the loss of green spaces now used by communities for leisure and physical activities. While these properties are managed and maintained by the school boards, they are part of the overall community assets of a city.

¹¹ A similar initiative is being led in Mississauga which involves the two school Boards and the City. The aim is to develop a regional approach to planning and installing artificial turf fields to maximize opportunities for students and neighbouring communities.

Urbanization and Land-Use Pressures

Increased population density increases demands for quality recreational spaces that can withstand intensified use. In Toronto, there is a deficit in the number of playing fields available and the deficit continues to grow as the population increases. Field availability impacts schools, childcare centres, and sport leagues, and community users.

Background

Several concerns have been raised about the impact of artificial turf facilities on community quality of life. While these neighbourhood design impacts are of real concern to local residents, many are beyond the impact of artificial turf surfaces themselves. Additional facility amenities such as stadium lights, weather domes, or spectator seating, and greater field use through rentals that often accompany proposals for artificial turf can have impacts on the surrounding community. Overall, these impacts can be expected from the installation of professional sized sports fields, whether natural or artificial. This section briefly reviews some of these concerns in more detail by drawing on examples of artificial turf projects in Toronto.

In a recent TDSB report, several neighbourhood impacts are highlighted. Most of these relate to increases in "non-permitted activity" during after school hours, prompting increased noise and garbage which puts a strain on school caretaking staff (TDSB, 2013). Other community groups have raised concerns about increased traffic and parking pressures and compromised community character. For instance, the proposal to install a domed artificial field at Central Tech High School in Toronto was expected to attract 120 players at full capacity and potentially an additional 500 spectators for larger non-school events (Harbord Village Resident Association, 2014). The local resident association expressed concern that this could create additional pressures on traffic and displace neighbourhood permit parking holders as visitors would seek on-street parking close to the facility.

Above and beyond potential pressures caused by increased field use, are community concerns about the design of artificial turf facilities. Drawing again from the Central Tech example, the site plan included proposals to install high-intensity lighting which may negatively affect nearby residents (Harbord Village Resident Association, 2014). The height and intensity of the lights were such that light may spill onto adjacent properties. The originally planned dome proposed for Central Tech was to be higher than the main school building in order to meet regional sports tournament requirements (Harbord Village Resident Association, 2014). Community residents raised concerns that for five to six months of the year, views of the historic school would be lost. Ultimately, a compromise between stakeholders was struck regarding facility design, allowing the project to move forward with a planned dome height reduced to address these neighbourhood concerns (Harbord Village Resident Association, 2015). Similar concerns about cultural heritage were raised regarding the installation of artificial turf on the University of Toronto's back campus (University of Toronto, 2010).

Other neighbourhood concerns have been raised which relate to the direct properties of artificial turf fields. As a synthetic surface, artificial turf is subject to increased glare when exposed to direct sunlight. This can be problematic for artificial turf users playing sports on such fields and visitors. With respect to noise, artificial turf fibres can be expected to absorb some noise, but not as much as grassed areas.

Concerns have also been raised about strong odours, particularly for indoor artificial fields infilled with rubber crumb. Concerns have also been raised about unpleasant odours caused by animal waste left on artificial turf fields.

Conclusions

Although the impacts of artificial turf are expected to vary from community to community, where artificial turf fields increase field permit availability, negative impacts on quality of community life are possible. These factors include neighbourhood design issues such as: increased noise, litter, traffic and parking pressures; light spill and glare onto adjacent properties; and potential loss of community character.

Options to Reduce Risk

- 1) Integrate community input into the design and management of artificial turf facilities well in advance of its installation to ensure that community concerns are addressed.

2.2.7 Contaminated Sites

One advantage of synthetic turf systems is that they can be used on historically contaminated soil to eliminate the need for deeper imported soil fills and reduce construction costs without compromising public health. In Toronto, there have been a few examples of artificial turf being used as a barrier between the surface and underlying contaminated soil. For example, in 2008, Waterfront Toronto officially opened the Cherry Beach Sports Fields which included two regulation-sized elite soccer and lacrosse artificial turf fields which served as a cap over the contaminated area. The project also included the construction of a children's playground and enhancements to the existing natural grove areas (Waterfront Toronto, 2014).

2.3 Equity and Access Factors

Including equity considerations is an important aspect of an HIA. This section looks at factors that could impact more disadvantaged groups disproportionately. Access to green space is crucial to ensure opportunities for active lifestyles and improved quality of life for all members of society. Two equity concerns discussed here include: access and proximity to recreational and leisure space; and accessibility for people with disabilities. It is recognized that funding arrangements or operation of these facilities can influence the overall equity impacts.

Accessibility for People with Disabilities

One of the potentially positive impacts of artificial turf is its potential to provide accessible infrastructure design which may in turn promote greater opportunities for physical activity and outdoor leisure for diverse community members such as the elderly, people with injuries, and people with disabilities.

Generally, artificial playing surfaces are more uniform which may make it easier for people using mobility aids to use. More comprehensive artificial turf projects may be subject to Accessibility Building Standards that require features such as access ramps and improved lighting to ensure access to people with disabilities.

2.3.1 Public Access to Recreational and Leisure space

Research shows that children from communities of lower socio-economic status rely more on, and have more familiarity with, their local neighbourhoods than children of higher socio-economic status (cited in (Bell & Dymont, 2006). For many of these children, a school ground may be one of the only easily accessible outdoor spaces to be active, play freely and experience nature (Thomson & Philo, 2004). In a Toronto-based study (Dymont, 2005), for many students, their only outside playtime happened at school for a variety of family, personal and safety reasons – for example, parents working after school, concerns about children’s safety outdoors, lack of outdoor play spaces nearby, or because children were enrolled in after-school programs. In park-poor neighborhoods, children generally play in streets, alleyways, vacant lots, or they simply stay inside (Active Living Research, 2011). This creates an unsafe environment for children and may encourage physical inactivity.

The Toronto schools indicated that installations of artificial turf fields have been driven historically by local fundraising efforts. This means that initial installations were typically in economically privileged areas of the city. To assess if existing artificial turf fields in Toronto are located in more advantaged neighbourhoods, a spatial analysis was done in for the 57 locations that use artificial turf. No correlation was found, meaning that artificial turf facilities are not predominantly located in either low or high income neighbourhoods.

The implications of this body of research on the use of artificial turf can be interpreted in two ways. First, artificial turf installations may potentially create or reinforce disparities in access to quality recreational space if rental (permit) costs are prohibitive or if publicly accessible facilities are not in close proximity to disadvantaged communities. On the other hand, if artificial turf is publicly accessible and used to revitalize a barren school ground or a park in a disadvantaged community, this may be a benefit to children and the community.

Mitigation Strategies

The TDSB and the TCDSB are creating decision-making frameworks for future uses of artificial turf that prioritize elementary schools with a high intensity of use. While these frameworks still allow for some fundraising, the upfront capital costs are to be paid by each respective school board. This gives school boards some discretion over placing fields in areas of the city where opportunities for public access can be maximized.

Artificial turf projects in high schools are typically supported by agreements with private developers who pay the full installation, maintenance, and replacement cost of a domed artificial field in return for

exclusive access outside of school-use hours. While this type of partnership provides schools with year round climate controlled access to fields at no cost, such plans may negatively impact community use of the space unless this is considered in the design and operation of the facility. While the spatial analysis done by Toronto Public Health did not find a concentration of artificial turf facilities in more advantaged communities, it is possible that private developers would want to partner with schools where they would get the best returns on investment; this could increase disparities in access if fields are situated in more socio-economically advantaged areas of the city.

Conclusions

Social, equity and access considerations seem to be best addressed by ensuring appropriate design and programming a facility. Artificial turf fields have the potential to enhance health equity in the City by providing opportunities for outdoor recreation within low-income, high-density neighbourhoods where there is often little or no quality recreational space and by providing playing surfaces that can be used by persons needing mobility aids. However, artificial turf fields that replace a natural surface and are constructed for the sole purpose of generating greater field permit availability, may negatively impact local community members by privatizing a space that was previously accessible by the community for unstructured recreation and leisure purposes.

Options to Reduce Risk

- 1) Use community input to address concerns during planning sports field and playground upgrades and renovations, including the installation of artificial turf.
- 2) Include public access provisions into agreements with private sector partners to reduce potential equity concerns around public access.
- 3) A city-wide approach to recreational planning can help ensure that fields are placed in areas of the city where need for access to recreation facilities is greatest.

3 LIMITATIONS OF THE ASSESSMENT

Developments in Natural Turf Surfaces

Since the time many of Toronto's playing fields were initially designed there have been many advances in field building techniques, which could offer better resilience in the face of increasing field use. These advances include: more sophisticated drainage systems; the identification of location-appropriate grass species; high-performance natural grass varieties that can withstand higher intensities of use and more drought tolerant.

Developments in Artificial Turf Surfaces

Since the 1960s, design improvements have created artificial turf systems that are less abrasive and less toxic. Few papers explicitly state the generation of turf studied, which makes it difficult to make comparisons between studies and make generalizable conclusions. For this HIA, special attention was paid to the manufacturing brand, date of study publication and explanation of physical characteristics of the turf to help deduce the surfaces considered. Conclusions found within this document are based upon an analysis of the health impact of third generation artificial turf.

Complex Comparisons

The large variation in design of installations and the characteristics of natural fields and of artificial turf systems make it difficult to accurately compare between impacts of natural and artificial systems.

Cost-benefit analyses between the two surfaces are usually made on an "area of pitch" basis, which does not consider the potential benefit of artificial turf in maximizing physical activity through more available "hours of play".

Research Limitations

Available literature on injuries and toxic exposures is largely limited to the impacts on professional athletes and short-term observations. Confounding variables such as climate, footwear, age and health status of the exposed population, and varying definitions of injury, also make it difficult to draw definitive conclusions about the impact of artificial turf surfaces on human health. At the same time, there are many environmental standards, differences between regulatory agency opinions, and various approaches to sampling/assessment of artificial turf which must be considered when exploring issues related to toxic exposures.

While the original scope of the HIA included the comparison of artificial turf to various surface types that might be used to replace natural grass as well as the use of artificial turf in childcare settings, it was not possible to do this due to lack of available studies. Available literature on rubberized surfacing, as used in children's playground surfaces, is limited and makes it difficult to draw definitive conclusions about an impact on human health. However, given the nature of rubberized surfaces used in play spaces and running tracks, it is anticipated that exposures to contaminants found in these surfaces would be lower than exposures from crumb rubber used in third generation artificial turf systems.

4 CONCLUSIONS

Artificial turf surfaces were first developed for use in sports fields. They are being used in other recreation spaces in schools, childcare facilities, and parks. They are increasingly being used for landscaping along streets, on residential properties and in commercial areas.

The design of artificial turf surfaces and the materials used in them have changed over time to address earlier concerns related to environmental impacts, heat, injuries, and exposure to toxic substances. As the technology continues to evolve it is possible that this will reduce their negative environmental and health impacts even further.

Artificial turf surfaces become much hotter than natural grass which can be a risk for blisters, burns or heat stress during hot weather. Unlike natural grass which has evaporative cooling properties, artificial turf is made of several heat-retaining materials which can significantly increase field surface temperatures, substantially increase air temperatures near fields, and thus contribute to the urban heat island effect in surrounding neighbourhoods. This increases the risk of heat-related health impacts during hot weather events. Widespread use of artificial turf would also make Toronto less resilient to extreme weather events and increase adverse health impacts associated with these events.

While injury patterns differ among natural grass fields and different designs of artificial fields, the available evidence suggests that overall, playing on third generation artificial turf fields does not result in a higher overall risk of injury than playing on natural grass fields.

The use of third generation artificial turf is not expected to result in exposure to contaminants at levels that pose a significant risk to human health provided it is properly installed and maintained, and users follow good hygienic practices (for example, washing hands, avoiding eating on the artificial field, and removing dust from the infill from shoes and clothing before going indoors). While there are still some uncertainties regarding impacts from exposure to some substances found in artificial turf (carbon nanotubes, lead and other metals, latex, some metals, and polyaromatic hydrocarbons, for example), standard hygienic measures will minimize any of these risks. Under such conditions, and in the cases where use of natural turf is not possible or practical, the benefits from increased physical activity on fields are expected to outweigh the risks from exposure to toxic substances.

Natural surfaces are important features of an urban landscape and, as such, should be preserved rather than replaced with surfaces that offer less resilience to extreme weather events and increase the risk of heat-related health impacts. In certain cases artificial turf can offer the prospect of increased activity levels and could be appropriate in areas which would otherwise not be available as an active space for a community. There is an unmet demand for sports facilities in Toronto. Installations of artificial turf sports fields have the potential to help meet this demand by for example: providing playing fields in areas where natural turf cannot be maintained due to intensity of use or characteristic of the site; extending the time of year when the field can be used through extending the playing season; reducing the need of closure after heavy rains; and allowing the use of contaminated lands for sporting facilities.

Overall the main concerns relating to the use of artificial turf are linked to climate change mitigation and adaptation. Widespread use of artificial turf would make Toronto less resilient to extreme weather events and increase adverse health impacts associated with these events. The 2014 Provincial Policy Statement directs municipalities to address climate change mitigation and adaptation, including maximizing the use of vegetation and pervious surfaces. Toronto addresses this through the Toronto Green Standard and zoning bylaw, which limit the use of hard surfaces, including artificial turf, on properties in the city and encourage natural landscaping to reduce the urban heat island impacts of development. City Planning, Parks, Forestry and Recreation, and other relevant City Divisions could review their practices and guidelines to ensure that when artificial turf is used, it provides an overall benefit to Toronto.

The main findings of the HIA are summarized below.

4.1 Natural Environmental Factors

- Artificial turf is made of several heat-retaining materials which can significantly increase field surface temperatures, substantially increase air temperatures near fields, and potentially contribute to the urban heat island effect in surrounding neighbourhoods. This contributes to increased health risk during hot weather events.
- Increased surface and air temperatures created by artificial turf fields can increase the risk of heat-related illnesses and injuries among users during heat waves, particularly among young children who are more sensitive to extreme heat. Young children and athletes are especially susceptible to heat-related illness such as dehydration, heat exhaustion and heat stroke while exercising in hot conditions.
- Traditional artificial turf systems, designed with subsurface drain pipe systems, can increase storm water run-off, contributing to water quality concerns and increase flooding risks after heavy rainfall or snow melts; situations which are expected to increase in Toronto with climate change.
- Hazardous substances from the crumb rubber can leach into surface or ground water; these releases are below levels of concern to human health. More research is needed to assess the potential impact on the health of aquatic ecosystems from the release of zinc and a few other substances that may be found in artificial turf. Pesticides and fertilizers used in the maintenance of natural turf may also contaminate surface and ground water.
- Artificial turf surfaces do not provide the ecological or biodiversity benefits of natural turf. This is expected to negatively affect nearby trees, other vegetation and reducing the capacity of the ground to absorb rainfall or snow melt, increase flooding risks.
- Natural grass fields serve as important "carbon sinks" in Toronto; while the carbon foot print of artificial turf varies depending on the materials used and design, artificial turf fields release carbon into the atmosphere during their manufacturing, transportation, installation, maintenance and end-of-life disposal stages.
- Evidence suggests that artificial turf fields need less water, which is an advantage in areas with potential water shortages.

- There is insufficient evidence as to the allergenic potential of latex in crumb rubber; more study is required to address uncertainty in exposure estimates for lead, other metals, polyaromatic hydrocarbons and other substances; and further research is needed to more fully understand the potential impact of low-level exposure to carbon nanotubes. These risks can be minimized through the use of standard hygienic practices.
- Based upon a review of the available evidence, third generation artificial turf is not expected to result in exposure to toxic substances at levels that pose a significant risk to health provided it is installed and maintained properly, and that standard hygienic practice such as washing hands, avoiding eating on artificial turf and supervising small children are followed.

4.2 Built Environment and Lifestyle Factors

- Artificial sports fields provide more total available hours of usage than current natural fields and can extend playing seasons.
- While sports fields with artificial turf are often used for structured sports for more hours per year, the impact of such installations on overall levels of physical activity of the population are not known.
- Artificial turf has the potential to allow re-development of contaminated sites for recreational purposes, which could increase opportunities for physical activity.
- Research suggests that artificial turf and natural grass have comparable rates of injury, but with differences in injury patterns.
- In general, artificial turf lacks the natural biodegrading properties of natural surfaces, making it more susceptible to unsanitary conditions for users. There is evidence that artificial turf may increase the risk of skin abrasions which can in turn facilitate infections.
- While artificial turf may offer opportunities to improve athletic programming or revitalize barren spaces, they may also remove opportunities to create new, or retain existing, green space.
- Parks and playgrounds with a diversity of well-maintained "green" features that facilitate more diverse nature-based play opportunities often preferred by school-age are also important for children's development and health.
- Although the impacts of artificial turf are expected to vary from community to community, where artificial turf fields intensify the use of the field for organized sports, negative impacts on quality of community life may occur.

4.3 Equity and Access Factors

- Artificial turf fields may enhance health equity in Toronto when they provide additional opportunities for outdoor recreation within low-income, high-density neighbourhoods where there is inadequate access to quality recreational space.
- Artificial turf can provide playing surfaces more easily used by persons using mobility aids.
- Artificial turf fields that are primarily rented out for specific sporting activities may negatively impact the local community by removing access to a space that was previously available to the community for unstructured recreation and leisure purposes.

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APPENDIX 1: STAKEHOLDER GROUPS CONSULTED

Name	Title	Organization
Municipalities – Policy and Planning		
Karina Richters	Environmental Coordinator	City of Windsor
Playground Design Experts		
Debby Martin	Manager, Evergreen Associates	Evergreen Canada
Heidi Campbell	Senior Design Consultant	Evergreen Canada
Schools and Boards		
Richard Christie	Senior Manager, Sustainability Office, Facility Services	Toronto District School Board
Jeff Latto	Senior Manager, Major Capital Projects and Building Partnerships	Toronto District School Board
Chris Broadbent	Health and Safety Representative	Toronto District School Board
Maia Puccetti	Superintendent of Facilities Services	Toronto Catholic District School Board
Stephanie Foster	Former Executive Director of the Centre for Environment and Sustainability	Upper Canada College

APPENDIX 2: RESULTS OF THE CITY STAKEHOLDER WORKSHOP

Wednesday, January 29, 2014

1:00 p.m. to 4:00 p.m.

277 Victoria Street. Room 506

Participants:

Ronald Macfarlane	Toronto Public Health, Healthy Public Policy
Christine Carrasco	Toronto Public Health, Healthy Public Policy
Josephine Archbold	Toronto Public Health, Healthy Public Policy
Reg Ayre	Toronto Public Health, Healthy Environments
Barbara Lachapelle	Toronto Public Health, Healthy Environments
Sheila Boudreau	City Planning, Urban Design
Linda Douglas	City Planning, Strategic Initiatives Policy & Analysis
Doug Smith	Parks, Forestry & Recreation, Integrated Plant Health Care Program
William (Bill) Snodgrass	Toronto Water, Water Infrastructure Management
Gail O'Donnell	Children's Services, North District Asset Management
Annemarie Baynton	Environment and Energy Division

Regrets:

Jane Welsh	City Planning, Strategic Initiatives Policy & Analysis
Edward Fearon	Parks, Forestry & Recreation, Parks Standards & Innovation

Group Screening Summary

This is a summary of the findings from a screening/scoping session held on January 29th, 2014 with diverse City of Toronto representatives, to identify potential impacts of artificial turf, including differential impacts on different population groups. Findings are based on the knowledge and experience of those present at the session. Tables 1 and 2 below were taken from the TPH Screening-HIA template and the list of determinants and population groups were consolidated based on the group screening exercise.

The next step is to use Table 3 (summary table) to guide the scope of this HIA. The table lists the key areas of impact identified by the group based on priority, some possible questions to address in order to understand these, and suggested evidence sources to answer these research questions.

Please note that this is not a definitive or necessarily complete list of impacts and some may turn out on further assessment not to be relevant. The list is put forward to inform the next stage of the HIA, and is likely to be amended by the working group.

Once this list is reviewed by the group, a review of evidence to provide an estimate of the strength of the evidence and to strengthen the inference of health impacts will be undertaken. We anticipate that published data will not be available for all the impacts listed, and information gaps will have to be supplemented by key informant interviews or other data sources, as necessary.

Table 1. Potential health and environmental concerns of artificial turf

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Environmental Factors			
Air quality	-	3	<ul style="list-style-type: none"> - The main concern here is the volatilization of toxics, such as organic contaminants contained in the crumb rubber infill material. - Air quality concerns are more relevant for indoor/enclosed environments and for localized areas (i.e. the air directly above a field) - It was suggested that other dimensions of air quality be considered (i.e. solar reflectance contributing to UHI which would increase air temperature and negatively impact air quality) - Some concern also expressed about children being differentially exposed given closer proximity to turf surface.
Odour [to be considered under Maintenance and Sanitation]	-	1	
Water quality and filtration	-/0	3	<ul style="list-style-type: none"> - The main water quality concern is the potential leaching of heavy metals and other organic contaminants in the drainage of artificial turf. - The concerns particularly relate to ecotoxicity (i.e. the impact on the growth and survival of nearby plants and biodiversity) - Drinking water is not a concern in a Toronto context - Regarding water filtration, without proper drainage system, rainwater may be diverted to catch basins, depriving nearby trees of water; if proper drainage system in place, effects may be neutral

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Soil quality [to be considered under Vegetation]	+/-	1	<ul style="list-style-type: none"> - Artificial turf functions as a barrier/replacement to soil and therefore soil quality concerns cannot be considered in light of artificial turf. Vegetation concerns to be considered under vegetation below.
Vegetation	-	3	<ul style="list-style-type: none"> - One of the main concerns is tree health (as nearby trees may be deprived of water depending on drainage designs and may also be exposed to toxic runoff). - Installation of turf may also limit the degree to which natural vegetation can be established around artificial turf given modifications to root zones. This may have a potential negative effect on shade in Toronto.
Noise	-	1	<ul style="list-style-type: none"> - Grass absorbs noise (rougher surface)
Other			
Thermal Functions Ecology	-	3	<ul style="list-style-type: none"> - Unlike natural grass, which has evaporative cooling (i.e. evapotranspiration) properties, artificial turf absorbs radiant heat (sunlight) and may contribute to urban heat-island effect. - UV/ 'reflective surfaces' are also a concern, particularly in relation to human heat-effects (e.g. hyperthermia, heat stroke) – see player/user safety below. - Watering artificial turf is said to have a cooling effect, but specifications may not be followed and there is uncertainty about how long the surface stays cool, etc.
Water filtration/detention [to be considered under Water Quality]	-/0	3	

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Water conservation [to be considered under Environmental Burden]	+	2	-
Environmental Burden Carbon footprint	+/-	2	<ul style="list-style-type: none"> - Life-cycle environmental impacts are a key concern, particularly as it relates to the environmental burden from consumption of raw materials, energy and emissions. - Some positive environmental considerations include: decreased need for pesticides and fertilizers; water conservation, use of recycled material in the case of recycled tire rubber. - Potential negative environmental considerations include: larger carbon footprint as artificial turf is constructed from synthetic v.s. natural materials; 12-14 lifecycle means turf must be replaced and burden may be high if components are not recycled at the end of the lifecycle.
Built Environment Factors			
Land use ¹²	+/-	3	<ul style="list-style-type: none"> - Land use is a key concern as the installation of artificial turf inherently involves the modification of an environment (natural or otherwise) into built environment. - Artificial turf may allow playing fields in areas where natural turf can neither be established (e.g. contamination) nor maintained

¹²Land use is the main policy issue at hand and should not be examined as a determinant in and of itself, but rather, in consideration of the range of other determinants listed.

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Toxics exposure	-	3	<ul style="list-style-type: none"> - A major human health concern is that artificial turf users may be exposed to the rubber particles and other hazardous components through several routes of exposure e.g. ingestion, inhalation, contact/dermal uptake - Some acute and chronic health concerns include: skin sensitivity to plastics, asthma, cancer, etc. - Of particular concern are young children who may be at higher risk of directly ingesting or experiencing hand-to-mouth exposure. - Some concern was also raised about the cleaning materials used on artificial turf (i.e. sanitizers may be toxic).
Maintenance and Sanitation	-	3	<ul style="list-style-type: none"> - Some evidence that regular disinfection/sanitation is required, as pathogens/algae are not broken down (e.g. blood, sweat, animal droppings/urine, etc); - Concern about the development of algae on consistently wet surfaces (as a result of poor drainage and/or overwatering as is the case for some sports such as field hockey) - Some concern regarding the survival of bacteria on artificial turf (i.e. Staphylococcus aureus and Methicillin resistant S. aureus (MRSA)). - Sports research suggests that artificial turf also requires regular maintenance to avoid becoming overly soft and increasing the risks to the athletes. - Some concerns about strong foul odour and headaches when artificial turf is used as a pet space. - In some cases, maintenance specs may not be followed

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Social and Economic Factors			
Income / Economic Considerations	+	2	<ul style="list-style-type: none"> - Artificial turf may generate revenue through user fees - Some suggestion that artificial turf may also increase property values
Education	-	1	<ul style="list-style-type: none"> - Concerns related to the loss of valuable educational opportunities, i.e. grass provides an opportunity to learn about natural systems/cycles (Evergreen study) - Some students may be differentially impacted e.g. when there is limited opportunity to go elsewhere to learn about natural systems or if students have special learning needs and would benefit from learning in natural environments.
Family Cohesion [to be considered under Community & Social Cohesion]	n/a		
Community & Social Cohesion/Inclusion	+/-	2	<ul style="list-style-type: none"> - Artificial turf may promote better use of space for community gathering - Concerns regarding lost opportunities for unplanned recreation/family time given that artificial turf spaces are usually fenced off and require permits for use. - May promote social inclusion through recreation/community space - May exclude groups who are not in close proximity or cannot pay fees.
Social Inclusion [to be considered under Community & Social Cohesion]	Not known	2	
Employment	n/a		
Crime	n/a		

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Housing	n/a		
Other			
Non-permitted activity [to be considered under Leisure]	+/-	2	
Subjective Well-Being and Mental Health aesthetics	+/-	2	<ul style="list-style-type: none"> - Artificial turf is said to create more pleasant streetscape/lawns - Evidence suggests that natural green space has psychological benefits - Many people against artificial turf and do not want to see it being used
Lifestyle Factors			
Physical Activity	+/-	3	<ul style="list-style-type: none"> - Artificial turf is said to extend active play time (from early spring to late fall and potentially in the winter if enclosed); increases overall active play time given that it does not have to be taken out of service for regeneration/maintenance; - increases amount of durable play areas during regular playing times. - some suggestion that kids may also avoid playing on artificial turf when it is really hot (Evergreen study)
Player/User Safety-Injuries/Safety	-/0	3	<ul style="list-style-type: none"> - Perception of increased injury risk on artificial turf, yet research shows little difference in rates but some difference in pattern of injury e.g. shoe-surface interface injuries (i.e. ACL/ankle injuries/turf toe) - Surface characteristics of artificial turf may be safer than other surfaces (i.e. hard surfaces, slippery surfaces, non-uniform/levelled surfaces). - Temperatures on turf get high, may contribute to dehydration (heat stroke and hyperthermia). Of particular concern for the very young and

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
			<p>very old. High temperatures may also increase surface friction leading to blisters and to surface burns among users/players. Watering artificial turf is said to have a cooling effect, but specifications may not be followed.</p> <ul style="list-style-type: none"> - Infections - concerns regarding turf burns as a source of contracting and vehicle for spreading infections
Surface temperature concerns [to be considered by player/user safety]	-	3	
Bacterial infection [to be considered by player/user safety]	-	3	-
Diet—	n/a		
Smoking	n/a		
Alcohol	n/a		
Drug use	n/a		
Sexual behaviour	n/a		
Access to services			
Leisure	+/-	3	<ul style="list-style-type: none"> - If enclosed, may provide year-round recreational space - May not be accessible to persons who do not live within close proximity or cannot pay user fees (implications regarding privatizing leisure space) - Artificial turf on school grounds may attract increases in non-permitted activity/nuisance

Determinant of Health	Predicted Impact on Health positive (+); neutral (0); mixed (+/-); negative (-); not applicable (n/a)	Priority 1-low; 2 – medium; 3-high	Comment Please describe in what way you think an impact might happen. What existing evidence (either presumed or otherwise) do you have for this?
Education system	n/a		***See notes under education under social and economic factors
Social services	n/a		
Transportation	n/a		
Health services	n/a		
Equity Dimensions			
Age [to be considered under populations]	+/-	3	- See notes under populations
Minorities or disadvantaged group	-	3	- Perception that artificial turf is installed only in high-income neighbourhoods/schools
Ability	+	3	<ul style="list-style-type: none"> - Perception that landscaping applications are beneficial to persons with mobility issues/elderly since it requires less maintenance - Playing surfaces may be more uniform, and installation of artificial turf may improve surrounding infrastructure (e.g. ramps, lighting, etc) - thereby promoting accessibility.
Sex/Gender	n/a		
Religion/beliefs	n/a		

Table 2. Population groups considered

Population Category	Description of specific groups and potential differential impacts of artificial turf
<p>Age –related groups (e.g., children, youth, seniors, women of child-bearing age, etc)</p>	<p>Young children (0-5) – young children in child-care centres where there is artificial turf may be differentially exposed, as they require two hours of outdoor activity per day which means they may be exposed to the synthetic materials longer than other users. There is also a potential risk of direct ingestion of rubber crumb among young children. Children are also more susceptible to heat-related concerns (e.g. dehydration/heat stress). Artificial turf in child-care centres may be the only viable option given limited maintenance resources available to maintain natural grass surfaces.</p> <p>School-age children/youth (6-18) – Children/youth in schools where artificial turf is currently installed may benefit from extended playing seasons, but may also be exposed to risks that other school age children are not exposed to in schools with natural playing fields. Children are also more susceptible to heat-related concerns (e.g. dehydration/heat stress). There is also a potential risk of direct ingestion of rubber crumb among younger children.</p> <p>Seniors/older adults –seniors or older adults may be disproportionately affected by heat related issues. For instance, artificial turf lawn bowling greens are traditionally used by older adults.</p>
<p>Disability or pre-existing health conditions (e.g., physical, D/deaf, deafened or hard of hearing, visual, intellectual/developmental, learning, mental illness, addictions/substance use, etc.)</p>	<p>Persons with pre-existing medical/health conditions - Artificial turf may disproportionately affect persons with respiratory conditions such as asthma and/or skin sensitivities.</p> <p>Persons/students with intellectual/developmental disorders/conditions– natural environments are considered to have a positive restorative effect among students with special learning needs/behavioral conditions. These benefits may be lost if natural surfaces are replaced by artificial ones.</p> <p>Persons/students with disabilities or mobility concerns –artificial turf applications for landscaping purposes may be beneficial to persons with mobility issues/elderly who can no longer maintain their lawns/green space. Artificial turf surfaces may also be more uniform, and installation of artificial turf may improve surrounding infrastructure (e.g. ramps, lighting, etc) - thereby promoting physical accessibility.</p>
<p>Low income or economically disadvantaged (e.g., un/underemployed, in receipt of social assistance, etc.)</p>	<p>Perception that artificial turf is installed only in high-income neighbourhoods/schools, thereby disadvantaging school-age children and local residents who cannot access these facilities.</p>

Population Category	Description of specific groups and potential differential impacts of artificial turf
Employed persons or worker groups (e.g., specific occupations/sectors, unionized/non-unionized, etc)	Some concern about care giving staff (i.e. early childhood educators) being differentially impacted given the amount of time they are exposed to artificial turf. Also some concern about maintenance/installation staff being negatively impacted as a result of being in close contact with artificial turf products and sanitizers over several years.
Sport teams or other artificial turf users in general population	Professional athletes should not be considered because risks to this population can be classified as occupational exposures. However, sport teams/other users in the general population should be included.

Table 3. Summary of key impacts, research questions and possible evidence sources

Area of impact	Priority	Research questions	Possible evidence sources
Human Health, Social and Economic Factors			
Toxics Exposure	3	<ul style="list-style-type: none"> Does artificial turf, including the rubber particles and other hazardous constituents, pose either a short- or long-term health risk for field users? Do particular routes of exposure to tire rubber crumb pose higher human health risks? Do the products used for the regular maintenance and sanitation of artificial turf pose a health risk for field users and/or staff coming into regular contact with artificial turf? 	<ul style="list-style-type: none"> Published research (e.g. risk assessment studies)
Physical activity	3	<ul style="list-style-type: none"> Compared to natural turf, does artificial turf promote physical activity? (consider: playable time and durability of artificial turf compared to grass; hot temperatures that might cause artificial turf to be closed or be uncomfortable to play on; persons not in organized sports, etc) 	<ul style="list-style-type: none"> Indirect research Grey literature Key informant interviews
Player/user safety	3	<ul style="list-style-type: none"> What is the difference in incidence, nature/severity and mechanisms of injuries sustained on newer generation artificial turfs compared to natural turfs? What length of time can field users of different ages (particularly the very young and very old) be safely exposed to high surface temperatures? 	<ul style="list-style-type: none"> Published research (i.e. injury/sports research)

Area of impact	Priority	Research questions	Possible evidence sources
		<ul style="list-style-type: none"> Is the risk of contracting a bacterial infection through 'turf burns' higher through artificial turf compared to natural grass? 	
Access to leisure	3	<ul style="list-style-type: none"> Do installations of artificial turf improve the availability and use of multi-purpose space? Compared to natural grass, does artificial turf attract after-hour (or unplanned) activity? 	<ul style="list-style-type: none"> Key informant interviews
Equity-Ability/Accessibility	3	<ul style="list-style-type: none"> Do artificial turf surface and surrounding space designs improve accessibility for people disabilities? 	<ul style="list-style-type: none"> Grey literature Key informant interviews
Equity-SES disadvantage	3	<ul style="list-style-type: none"> Is the distribution of artificial turf installations equal across all areas of Toronto? Do proposals to replace natural fields with artificial turf contribute to disparities in access? (i.e. developers may want to only invest in locations of the city where they are guaranteed return on investment; private schools or schools with more fundraising capacity may be able to afford state-of-the art facilities versus low-income schools; only children in organized sports can access). Can the user fees associated with artificial exclude some segments of the population from accessing artificial turf space (i.e. affordability)? 	<ul style="list-style-type: none"> Mapping based on neighbourhood profiles Key informant interviews
Community and Social Cohesion/Inclusion	2	<ul style="list-style-type: none"> Compared to natural green spaces, what is the social and/or community impact of artificial turf? (e.g. opportunities for unplanned community/family recreation, community development, shared community space) 	<ul style="list-style-type: none"> Indirect research Key informant interviews
Income/Economic Considerations	2	<ul style="list-style-type: none"> What is the overall economic impact of artificial turf installations for field owners and/or developers? 	<ul style="list-style-type: none"> Grey literature Key informant interviews
Subjective well-being/Mental Health	2	<ul style="list-style-type: none"> Compared to natural green spaces, what is the impact of artificial turf on mental/psychological well-being? 	<ul style="list-style-type: none"> Indirect research Key informant interviews
Education	1	<ul style="list-style-type: none"> Compared to natural green spaces, what is the impact of artificial turf on early childhood development and education? (e.g. opportunities for learning about natural systems, special learning needs) 	<ul style="list-style-type: none"> Indirect research Key informant interviews

Area of impact	Priority	Research questions	Possible evidence sources
Environmental Concerns			
Thermal Functions	3	<ul style="list-style-type: none"> Does artificial turf adversely contribute to urban heat island? If watering artificial turf reduces field temperatures, what is the length of time the temperature is reduced and by how many degrees? 	<ul style="list-style-type: none"> Published research Grey literature
Water quality and filtration	3	<ul style="list-style-type: none"> Does the drainage from artificial turf with tire rubber crumb infill contribute to toxic runoff and surface/groundwater pollution? 	<ul style="list-style-type: none"> Published research (i.e. field investigations)
Vegetation	3	<ul style="list-style-type: none"> If there is elevated toxicity from the drainage of artificial turf, does this adversely affect the growth, survival and reproduction of surrounding vegetation? Do some artificial turf designs (with/without drainage or quality of drainage) deprive nearby vegetation of water? Do artificial turf designs adversely impact (compromise) existing root zones where trees and other vegetation thrive? 	<ul style="list-style-type: none"> Published research Grey literature
Air quality	3	<ul style="list-style-type: none"> Compared to local background, does the air quality above artificial turf fields pose a health risk for field users? Is there a difference in air quality between indoor/outdoor artificial turf? Does closer proximity to artificial turf surfaces (i.e. height) pose an elevated risk for field users? 	<ul style="list-style-type: none"> Published research
Maintenance and sanitation	3	<ul style="list-style-type: none"> What field maintenance practices are recommended or required to address the development of harmful bacteria (e.g. staphylococcus) or other substances (e.g. algae) on an artificial turf surface? 	<ul style="list-style-type: none"> Grey literature Key informant interviews
Environmental Burden	2	<ul style="list-style-type: none"> Considering manufacturing, transportation, installation, maintenance and disposal, does artificial turf have a larger carbon footprint compared to grass fields? 	<ul style="list-style-type: none"> Published research (i.e. life cycle assessment studies)
Noise	1	<ul style="list-style-type: none"> Compared to grass, does artificial turf negatively impact noise levels? 	<ul style="list-style-type: none"> Indirect research Key informant interviews

APPENDIX 3: DEVELOPMENTS IN ARTIFICIAL TURF TECHNOLOGY

Source: State Government of Victoria. (2011). *Artificial Grass for Sport*. February. Department of Planning and Community Development. Melbourne, Victoria.

Cooler Artificial Grass Carpets

In the case of summer sports, surface heat reduction is a key design criterion. Over the past decade the incursion of artificial surfaces into lawn bowling has been impacted by the increased playing surface heat reflection. For cricketers, with their extended playing time taking place during the hottest months of the year, this is an issue. European yarn manufacturers are marketing yarns which they claim incorporate technology that reduces surface temperatures by up to 35% when compared with regular synthetic turf fields (the first installation of such an artificial grass soccer surface in Australia of this type occurred in Melbourne early in 2010).

In the marketing material for one of these products, the claim is made that the product 'dissipates heat into the atmosphere instead of absorbing heat into the yarn, resulting in a lower surface temperature when exposed to sunlight.' Such advances in technology, if successful, will enable more sports to use artificial grass in warmer climates, hopefully reducing player impacts such as heat stress and rapid dehydration of users.

Rounder Sand

Rounder sand particles (same size) are now being used in Australia on artificial clay tennis courts, with the intention of providing greater longevity from the porous infill layer. Traditionally specified sand granules can compact significantly over time adversely affecting vertical drainage.

Teflon Coated Sand

Some of the rounder sand types referred to above are also coated with a type of teflon to further enhance vertical drainage through the sand infill layer. Several Australian companies are currently experimenting with the development of similar materials.

Different Colour Rubber Granules

Due to the heat-retention properties of black rubber granule infill, and the sometimes darkened nature of the surface, alternate colour rubber granules are now being developed and used. Note though that the longevity/durability of coatings applied to SBR (Styrene Butadiene Rubber - a major component in artificial grass infill systems) is generally unproven at this point in time.

Unwetted Carpet for High Grade Hockey

Due to climate change and the vulnerability of water resources in substantial parts of the world, the International Hockey Federation has called for the development of a playing surface that can be played on dry, which will still produce the playing characteristics required for elite level competition.

Earlier generation watered fields (nylon or polypropylene) cannot be safely played on 'dry' because shoes stick to the surface and there is an absence of the surface conditions that allow for controlled 'slip', rotation and slide. Also, the ball bounce can be affected, with drier fields likely to lead to higher bounce with potentially more risk. Prototype carpets (high-density, low pile, unfilled) are now being played on in several locations around Australia, and the hope is that they will meet the required specifications.

Artificial Grass for Athletics Infields

Several companies are now manufacturing extra long-pile carpets (typically 80mm or so with, say, 60mm of sand or rubber granule infill material) that are being marketed as ideal for athletics field games, i.e. discus, hammer, shot put and javelin throws.

Sophisticated water Harvesting/Storage Systems

Sophisticated water storage systems, are being developed and trialled that allow the capture, and often re-use, of significant water volumes. Refer to <http://www.google.com/patents/US20100294705> for information regarding a unique under field water storage system.

Horizontal Drainage Via a Void Space under the Shock Pad

In mid 2010, several fields were built with a void space beneath the shock pad and the base. Each were created by laying an interconnected layer of typically 30mm high open-cell plastic panels all over the field. The hollow space within the panels (strong enough to take carpet rolls and required machinery) allows water to flow horizontally to collection channels and pits. This is an alternative to vertical drainage and the potential differential settlement that sometimes occurs on fields that have buried drainage pipes.

Organic Infill (Cork, etc)

A developing alternative to rubber granule infill is the option of organic infill, such materials being of plant origin. Able to be re-cycled, these infill types are said to keep the median temperature of artificial grass pitches lower than that of pitches with rubber infill. At the time of publication, the first soccer pitch in Melbourne featuring organic infill had been completed.

Alternative "Eco" Infill

In response to concerns associated with the use of crumb rubber from recycled waste tires, Mondo, a manufacturer of high performance athletic surfaces, research and developed Ecofill Star, a polyolefin-based granule. The product is marketed as being manufactured in a factory-controlled environment with a combination of select raw components that are guaranteed to be free of potentially harmful substances.