The Health Implications of Synthetic Turf Fields with Crumb Rubber Infill

A Human Health Risk Assessment for the
Municipality of North Cowichan

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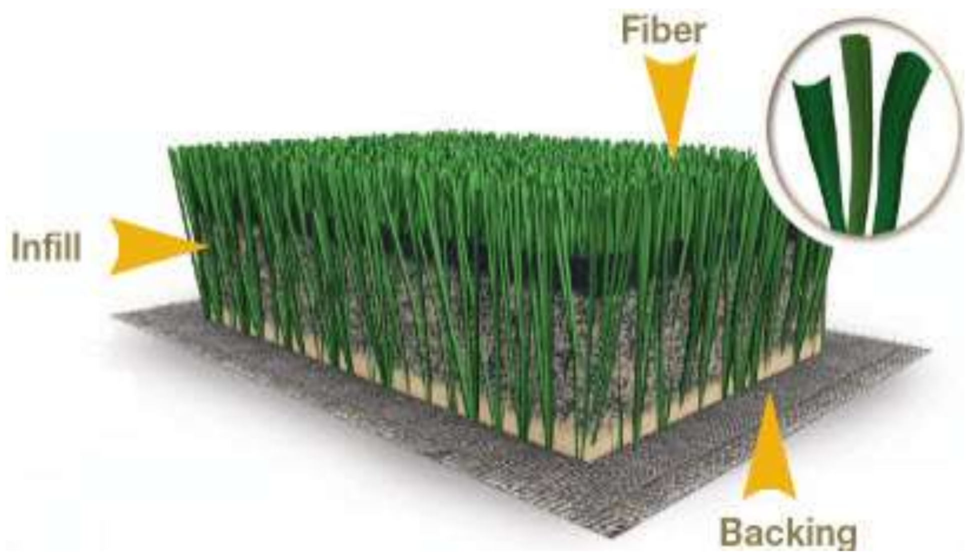
Background

The Director of Parks and Recreation for the Municipality of North Cowichan contacted the Central Island MHO Office requesting information on the health implications of synthetic turf fields, as they are preparing to go to tender on the development of a new field for the Sherman Road Park. This is in response to concerns raised by a Councilor regarding the hazards of crumb rubber.

The Municipality has considered two possible products for installation: Astroturf GT and FieldTurf XM6-60.

Figure 1: FieldTurf system, http://www.fieldturf.co.nz/about-fieldturf.html



The synthetic turf is composed of three layers as shown in Figure 1. The synthetic grass blades are monofilaments made of polyethylene. FieldTurf XM6-60 uses a styrene-butadiene rubber and silica sand infill. Astroturf GT uses recycled truck tire crumb rubber and silica sand infill.

The use of rubber crumb materials for turf fields may provide several benefits. The infill can cushion falls and reduce injuries when compared to harder surfaces. The low maintenance of synthetic turf systems reduces water, fertilizer and pesticide use. The recycling of rubber tires for infill also reduces the overall burden of rubber waste on landfills.

Current Status in BC

Concerns regarding the potential health hazards of synthetic turf fields have been raised on multiple occasions in the media, by local government and in the academic literature.

In 2008, Fraser Health received a request to review the potential health effect from exposure to materials used in the manufacture of several synthetic turf fields in Delta (Kuntz and Brotherson, 2008). Pacific Environmental Consulting and Occupational Hygiene Services was commissioned to test metal levels in crumb rubber and coloured fibers of four synthetic turf fields and concluded that, although the coloured fibers contained lead, chromium and zinc, the public health risk appeared negligible. The crumb rubber contained low to negligible concentrations of lead. After field-testing and consultation with the British Columbia Centre for Disease Control, Fraser Health reported that there were “no significant health concerns related to the presence of lead or other metals in some synthetic fields.” They also noted that, while lead chromate was present in some of the fields, the US Consumer Product Safety Commission demonstrated a low likelihood of significant exposure.

Using anecdotal evidence, an investigative journalism article published in 2014 by NBC examined the possibility of a link between the crumb rubbers used in synthetic turf fields and cancer rates among soccer players (Rappleye, 2014). Following the publication of this article, the City of Richmond was asked by Council to review their plans for a synthetic-turf field. Upon review, they decided to proceed with the project as “the crumb rubber-recycled truck tire product is the present industry standard and [they had] not been advised of any verified health hazards from using the product" (van Den Hemel, 2014). The concerns raised by the NBC article were also reported in a Vancouver newspaper, the Georgia Straight (Johnson, 2015). This article surveyed several local experts including the department head of cancer-control research at the B.C. Cancer Research Centre who touched on the need for further research to better characterize risks.

Irrespective of the concerns raised about the health implications, a search of the Health Canada website identified no product advisories on synthetic turf systems.

Health Risk Assessment

A review of the literature resulted in a significant number of studies evaluating the potential health implications of synthetic turf systems. These studies identified potential risks that could be divided into two categories: chemical exposures and physical health effects.

Chemical Exposure

Crumb rubber infill has been known to contain various organic compounds, as well as metals such as lead, zinc and chromium. These compounds may be released into the environment through breakdown of the rubber. Individuals using the field may be exposed to these chemicals through skin absorption, inhalation or ingestion.

In order to determine the potential toxicity of crumb rubber, the hazards and degree of exposure must be assessed. Potentially toxic organic compounds, such as polycyclic aromatic hydrocarbons, have been identified at elevated levels in crumb rubber. Several studies examined the levels of organic compounds in vapour emissions when crumb rubber was exposed to elevated temperatures and estimated minimal risk of health effects. Levels were noted to be higher in indoor environments. Similar conclusions were made for both ingestion and skin absorption routes of exposure.

While lead has been identified in synthetic turf, the levels have consistently been measured lower than international thresholds. Zinc has also been measured at elevated levels, although there is minimal risk of toxicity. Few studies examined the risk of exposure to these metals. One study reported that, although the lead in crumb rubber was likely to be highly absorbed in the intestine, the overall levels in the samples were low.

After reviewing the literature it was concluded that, although crumb rubber may contain potentially toxic metals and mutagenic organic compounds, there is insufficient evidence to indicate that the level of exposure with casual use would exceed the threshold for risk to human health.

Physical Health Effects

Three potential physical effects of synthetic turf on human health were identified: injury risk, heat-related illness and bacterial infection.

The risk of injury appears to be equivocal between natural grass and synthetic turf. Although the evidence is weak, there may be a difference in the types of injuries between the two surfaces. One study also surveyed professional footballers and reported a perception of increased risk of injury on synthetic turf compared to natural surfaces.

Under direct sunlight and moderately high ambient temperatures, synthetic turf may reach temperatures high enough to cause heat-related injuries. Temperature control options, such as field irrigation, appear to be ineffective. In order to mitigate the risk of heat-related illness, use should be limited during days with high ambient temperatures. Those operating and using the fields should be educated on prevention and management of heat-related illness.

Synthetic turf does not appear to increase the risk of bacterial infection. Although turf can be a risk of abrasions that provide a means of access for infectious organisms, transmission typically occurs with other practices, such as poor sanitation, sharing equipment, whirlpool use etc. Users of the field can therefore reduce the risk of infection by maintaining good hygienic practices.

Conclusion

Given the current available evidence it is concluded that the existing information does not suggest that synthetic turf fields have a substantive independent effect on human health.

Appendix A – Evidence Review

A review of the literature resulted in a significant number of studies evaluating the potential health implications of synthetic turf systems. These studies identified potential risks that could be divided into two general categories. Chemical exposures were related to organic compounds and heavy metals. Physical health effects included risk of injury, heat-related illness and bacterial infection.

Chemical Exposure

While crumb rubber has been demonstrated to contain heavy metals and various organic compounds with the potential for toxicity, questions have been raised as to whether the degree of exposure with regular use of synthetic turf fields poses a risk.

There are three modes of potential exposure to contaminants for individuals using synthetic fields with crumb rubber:

- **Inhalation**
- **Ingestion**
- **Dermal absorption**

This exposure may be directly related to the rubber granules, or to contaminants released from granule degradation. The US Environmental Protection Agency (2009) identified various organic compounds and metals that may contaminate the recycled tires used for rubber infill (Table 1).

Table 1: Potential contaminants in rubber tires (USEPA, 2009)

Organic Compounds	Metals
• Acetone	• Arsenic
• Aniline	• Barium
• Benzene	• Cadmium
• Benzothiazole	• Chromium
• Chloroethane	• Cobalt
• Halogenated flame retardants	• Copper
• Isoprene	• Lead
• Latex	• Manganese
• Methyl ethyl ketone	• Mercury
• Methyl isobutyl ketone	• Nickel
• Naphthalene	• Zinc
• Nylon	
• Phenol	
• Pigments	
• Polycyclic aromatic hydrocarbons	
• Polyester	
• Rayon	
• Styrene-butadiene	
• Sulfur compounds	
• Toluene	
• Trichloroethylene	

Of the organic compounds found in crumb rubber, polyaromatic hydrocarbons (PAHs) are often considered to pose the greatest risk to human health. The Centre for Disease Control's Agency for Toxic Substances and Disease Registry (1995) reports that exposure to PAHs have resulted in tumor formation and birth defects in animal models. Aside from a risk of mutagenicity in humans with chronic exposure to some PAHs, other effects on humans have not been reported. The USEPA has identified benz[a]anthracene (B[a]A) and benzo[a]pyrene (B[a]P), as well as several other PAHs, as probable human mutagens. These are likely to pose a health risk only at levels beyond a certain threshold.

Lead is often cited as the most concerning heavy metal found in crumb rubber. Exposure to elevated levels of lead can lead to neurological damage, anemia and reproductive problems (USEPA, 2013). Ingestion and inhalation of environmental zinc may cause adverse effects on health; however, this only occurs at significantly elevated levels of exposure (Agency for Toxic Substances and Disease Registry, 2005). Other metals listed in Table 1 were consistently found to be at negligible levels in crumb rubber samples, as reported in the literature.

Cheng et al. (2013) described the various mechanisms by which the contaminants present in crumb rubber may be released into the environment through breakdown of the rubber granules (Table 2).

Table 2: Environmental mechanisms of crumb rubber degradation (Cheng et al., 2013)

Mechanism	Effect on Crumb Rubber
Ozone	Reacts with surface of rubber introducing cracks
Oxygen	Causes oxidation damage to rubber
Water	Causes leaching of soluble chemicals
Heat	Accelerates oxidation of crumb rubber
Sunlight	Accelerates oxidation of crumb rubber and degrades anti-degradents on the surface
Climate Conditions	Wet climates promote leaching and loss of protective coatings while hot and dry climates facilitate oxidation
Weather Conditions	Freezing can facilitate cracking of rubber. Weather also contributes to previously mentioned mechanisms.
Abrasion	Mechanical breakdown of rubber

TRC performed a comprehensive risk assessment of synthetic turf fields in 2008 for the New York City Department of Health and Mental Hygiene. They reported that crumb rubber infill has been known to contain polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), benzothiazole, certain metals, phthalates, alkylphenols and benzene, particularly given the use of recycled tires. A review of 11 different risk assessments resulted in the conclusion that, although exposure to these chemicals is likely to occur during use of the fields, the overall dose is likely to be too small for any significant health effect. They also noted that the measure of potential exposure was very conservative in these assessments. Although they noted that children might be more susceptible to potential toxicity from contaminants, the reviewed studies appeared to address this issue. The authors expressed the need for further research to better assess health risk from crumb rubber exposure.

The California Environmental Protection Agency (2007) evaluated the potential health risks from chemical exposure (both heavy metals and organic compounds) to recycled waste tires in playground and track products for two ingestion pathway scenarios. These included chronic hand-to-mouth activity by children aged 1 to 12 years old and a one-time ingestion of 10 g of crumb rubber by a 3 year old child. They found that, aside from zinc and aniline, all the detected compounds with screening levels were below a level of concern. Although the estimated ingestion exposure was deemed not to pose a significant mutagenic risk, they did estimate the cancer risk to be 2.9 in 1,000,000. However, this was limited by the lack of field study and the assumption that bioavailability was 100%.

Johns (2008) did a risk assessment of cancer risk among children and teenage athletes playing on a sport team who used synthetic turf fields five times a week for either three or seven years. They found that cancer risks resulting from dermal contact and through incidental ingestion of crumb rubber were below the EPA risk threshold level of 1 in 1,000,000 and non-cancer risks were less than the EPA threshold of 1.0. The potential toxins included arsenic, zinc, acetaldehyde, benzene, bis(2-ethylhexyl)phthalate, benzo(a)pyrene (BaP), MIBK, toluene, total carcinogenic PAHs, total PCBs and xylenes.

NIPH (2006) studied the risks of chronic ingestion of 1 g rubber infill for a 30 kg child per tournament, training session or match on synthetic turf. Assuming 100% bioavailability they compared the dosing to NOAEL levels for two-day exposure and 6 month chronic exposure. They concluded that this chronic exposure would result in no elevated risk of health effects. Volatile organic compound levels were also measured from indoor synthetic turf fields and were elevated, although not at a level that would be associated with elevated health risk. The estimated cancer risk was 2×10^{-6}.

Pavilonis et al. (2014) evaluated potential exposures from playing on synthetic turf fields and associated risks to trace metals, semi-volatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs). Using samples, including typical synthetic turf fibers, different types of infill (crumb rubber) and samples from actual fields, they developed synthetic biofluids based on lung, sweat and digestive fluids to determine exposure via ingestion, inhalation and dermal routes of exposure. Most PAHs, aside from naphthalene and acenaphthylene in total extracts, were below detection levels. No SVOC's were identified in the extracts. Heavy metals were measurable, although most below levels where they would be considered a risk to health. Lead was detected in all bio-fluid field samples, with the highest concentration being 260 mg/kg (ie 260 ppm). One of the new turf fibers had the highest lead content of 4400 mg/kg, although this was an isolated finding.

Menchini et al. (2011) found zinc levels in crumb rubber to be 2 magnitudes of order higher than Italian limits. This mirrors the findings of the CalEPA study, which calculated the maximum detected zinc concentration among crumb rubber in playgrounds and track products was 5-fold higher than the sub-chronic minimum risk level for children. They found B[a]P levels in crumb rubber to be 2 magnitudes of order higher than Italian limits. They estimated that, based on the levels of inhaled B[a]P measured, the excess lifetime cancer risk was approximately 1×10^{-6} for an athlete with an intense 30-year activity. This was assumed to be much lower for intermittent or casual athletes.

Simcox et al. (2011) studied the organics compound and particulate matter levels in the air over three types of fields in Connecticut: indoor and outdoor synthetic turf, as well as natural grass. They did this through personal monitoring devices worn at belt level. They identified volatile organic compounds, although noted that in most samples the levels were equivalent to natural turf. They reported that levels of organics, such as naphthalene, benzothiazole and butylated hydroxytoluene, were higher on indoor fields. They also measured lead concentrations and found levels in synthetic turf crumb rubber fields to be below the public health targets.

Laboratory testing by the New York City Department of Parks and Recreation in 2009, demonstrated lead levels in crumb rubber infill from 112 local synthetic fields between non-detectible levels and 240 ppm, with 96% of samples falling below 100 ppm. All fields tested below the EPA threshold of 400 ppm for soil samples from children's recreation areas. They found that volatile organic compound concentrations were generally higher on synthetic turf from fields in Connecticut, although some levels were equivocal to natural fields. PAH concentrations were found to be higher on indoor fields than outdoor.

Zhang et al. (2008) examined the composition of seven samples of rubber granules and one sample of synthetic grass fiber from synthetic turf fields of various ages, as well as the bioaccessibility of heavy metals and PAHs. They found that rubber granules often contained PAHs at levels above health-based soil standards set by the New York State Department of Environmental Conservation (DEC). The PAH levels were lower in samples from older fields. Although these levels were found to be elevated, they also analyzed the bioavailability of the PAHs via ingestion and found that absorption through this route of exposure was unlikely. There were elevated levels of zinc in the samples, the highest of which was 9988 ppm. The samples had low levels of lead, the highest of which was 53 ppm; however, this had a high bioaccessibility in the synthetic gastric fluid.

van Rooij and Jongeneelen (2010) performed a limited study of the excretion of hydroxypyrene, a PAH, in the urine of seven football players following 2.5 hours of play on a synthetic turf field. After controlling for diet and other potential exposures to PAHs, they found no significant change in urine hydroxypyrene concentrations before and after exposure. They noted that this is comparable to uptake from the environment and diet.

Ruffino et al. (2013) performed a risk assessment of five synthetic turf fields in Turin Italy, by examining chemical exposure to adults and children via three routes: direct contact with crumb rubber, contact with rainwater soaking the rubber mat, inhalation of dusts and gases from the synthetic turf fields. The levels of organic compounds and heavy metals in the crumb rubber, associated dust and air were analyzed and for all routes, the cumulative mutagenic risk was lower than 1×10^{-6}.

Marsili et al. (2014) examined crumb rubber for heavy metals and PAHs from different synthetic turf fields in Italy, varying from new to 8 years of age. In contrast to prior studies, they found high levels of zinc and PAHs in all of their samples. All samples had high levels of zinc, the highest of which was 13,202 mg/kg. This compared to the Italian National Amateur League (LND) threshold of 150 mg/kg. Three samples recorded levels of cadmium that exceeded LND threshold of 2.0 mg/kg. The authors evaluated the levels of benzo(a)anthracene (B[a]A), Chrysene, B[a]P and B[ghi]Per in evaporates from crumb rubber heated to a temperature of 60 degrees Celsius. This temperature was chosen as it corresponded to the temperature of the crumb rubber when exposed to an ambient air temperature of 25 degrees Celsius. From this they estimated the lifetime average daily dose of PAHs for athletes and estimated a Cumulative Excess Cancer Risk between 4.91×10^{-9} to a maximum of 1.10×10^{-8}. This would be considered generally below the acceptable risk of 1×10^{-6} set by the USEPA. The authors also attempted to calculate a toxicity equivalent of PAHs from exposure and concluded that exposure would represent a significant contribution to the total daily intake of PAHs; however, this was a theoretical model that the authors described as extreme worst case screening.

Li et al. (2010) used solid-phase microextraction and identified ten organic compounds in the vapour phase of crumb rubber samples, including benzothiazole, antioxidants and several PAHs. This was done at 60^{o} C as per Marsili et al. In an outdoor environment, the authors also found that there was a significant out-gassing of organic compounds from the crumb rubber in the first 14 days, which then stabilized. They also identified significant levels of zinc in the leachate (220 – 13,000 mcg/g).

Llompart et al. (2012) analyzed the composition of recycled tire used in playground surfaces. They reported relatively high levels of PAHs including pyrene, naphthalene, phenanthrene, fluoranthene, and chrysene. Benzo[a]pyrene (B[a]P) was also identified in five samples. Similar to Li et al., they used solid-phase microextraction to identify the presence of these compounds in vapour at two temperatures (25^{o} C and 60^{o} C). Aside those that were less volatile, all the contaminants found in the samples were identified in the vapour phase at room temperature; however, the concentrations of these compounds within the vapour-phase were not reported.

Crumb rubber may contain mutagenic organic compounds and heavy metals that may result in exposure via dermal absorption, inhalation or ingestion; however, insufficient evidence was found in the literature to indicate that the level of exposure with casual use would exceed the threshold for risk to human health.

Physical Health Effects

Injury

Seven studies were identified that compared the risk of injury on synthetic and natural turf.

Ekstrand et al. (2006) compared injury risk among elite European football players on synthetic and natural turf. They found no elevated risk of injury, aside from a slight elevation of ankle injuries; however, this was interpreted with caution given the low numbers.

Fuller et al. (2007) also compared injury risk among male and female NCAA football teams in the US for synthetic and natural turf. This study concluded that there were no significant differences in injury rates between the two surfaces.

Meyers and Barnhill (2004) did a 5 year prospective study of injury risk among high school athletes playing on FieldTurf versus natural grass. Although their conclusions were limited due to numbers, they did note that there were significant differences in the types of injuries between the two surfaces. For example, they found that 0 day time loss injuries were more frequent on synthetic turf while 1 to 2 day time loss injuries were more common on natural turf.

Steffen et al. (2007) investigated the risk of injury between natural grass and synthetic turf among young female football players. They concluded that there was no significant difference in risk between the two types of surfaces.

Soligard et al. (2012) studied the risk of injury among 60,000 teenage football players and also found no significant differences between synthetic and natural turf.

Kristenson et al. (2013) studied the risk of injury among professional football clubs (n = 32) on synthetic and natural turf. Similar to previous studies, they found no significant differences in injury rates for individuals during training and match play between both surfaces; however, when they compared football clubs rather than individuals, they found a significantly higher acute training injury rate (RR 1.31) and overuse injury rate (RR 1.38) for synthetic turf compared with natural grass clubs.

Burillo et al. (2014) surveyed amateur/semi-professional footballers, coaches and referees regarding their experiences with the use of synthetic turf. Of particular interest, the amateur/semi-professional footballers appeared somewhat dissatisfied with the safety of the synthetic turf as opposed to natural grass and dirt fields. On a 10-point Likert scale, the authors reported player satisfaction as 4.73 for muscle strain, 2.71 for skin abrasions and 3.82 for potential of sustaining an injury.

Irrespective of the perception of increased risk of injury, the true risk appears to be equivocal between natural grass and synthetic turf. Although the evidence is weak, there may be a difference in the types of injuries between the two surfaces.

Heat Stress

Three studies examined the temperature differential between natural and synthetic turf, particularly under direct sunlight and high ambient temperatures.

The New York City risk assessment (TRC, 2008) examined the risk of heat related illness among those using synthetic fields. They found that turf with crumb rubber infill could retain significantly elevated temperatures in direct sunlight.

Adamson (2007) also evaluated the temperature of a synthetic turf field at the University of Missouri-Columbia. They found that the FieldTurf field had a surface temperature of 78.3 degrees Celsius on a 36.7 degree day. The head level temperature was 58.9 degrees.

Serensits et al. (2011) examined the impact of various cooling methods on surface temperature of synthetic turf. They reported that on average, the surface temperature of the synthetic turf tended to be 20 degrees Celsius higher than the adjacent natural grass. They found that, while irrigation did decrease the temperature of the synthetic surface, the cooling effect only lasted for approximately 20 minutes.

Given the significant elevation in temperature identified in these three studies, synthetic turf surfaces may pose a risk of heat-related illness, including burns, heat stress and dehydration. The New York City risk assessment also noted that children might be at elevated risk, as they do not adapt to extreme temperatures as well as adults.

Bacterial Infection

Four studies were reviewed that examined the potential risk of bacterial infection through abrasions and dermal contact.

Begier et al. (2004) examined a small cohort of 100 college football players for risks of MRSA infection. They identified 10 cases associated with player position, cosmetic body shaving and synthetic turf burns; however, the turf burns were not always adjacent to the infected area. They also identified other predisposing factors such as exposure to whirlpools and frequent direct person-to-person contact.

The New York City risk assessment (TRC, 2008) examined the risk of bacterial infection among those using synthetic fields, noting that an increased risk of abrasion can predispose individuals to various infections. Reviewing the literature showed that, although abrasions provide a means of access for infections, transmission typically occurred due to other practices, such as poor sanitation, sharing equipment etc. They dismissed previous research by Begier and others on the correlation with "turf burn" as they did not compare to abrasions from other sources. They also reported that synthetic turf is not an ideal environment for microbial growth.

The microbial growth environment of synthetic turf this has been investigated further by Waninger et al. (2011). They studied the ability of community-acquired MRSA (CA-MRSA) to grow on PureGrass, a synthetic turf system with silica and rubber infill. The authors demonstrated that CA-MRSA could grow on synthetic turf in the presence of nutrients (or mucin as a correlate with bodily secretions). They showed that, when the samples were washed or not supplied with nutrients, the CA-MRSA lasted approximately 1 day, compared to 20-50 days in ideal conditions.

Serensits et al. (2011) also analyzed the levels of *s. aureus* bacteria on synthetic turf fields compared to natural fields. They reported the number of *s. aureus* colonies grown from synthetic turf samples to be significantly lower than natural grass. The authors noted that the levels on indoor fields were lower than those outside.

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