May 26, 2015

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Verdant Health Commission
Public Hospital District No. 2, Snohomish County
4710 196th St. S.W.
Lynnwood, WA 98036

Re: Evaluation of Human Health Risks for Synthetic Field Turf

Dear Mr. Kosovich:

We are pleased to provide you with a screening level risk assessment and literature review related to the use of artificial turf fields at the former Woodway High School fields. As discussed in our proposed scope of work provided on May 13, 2015 this is a limited assessment that has focused on publically available data, supplemented in some cases by additional data provided by manufacturers. Our proposed scope of work originally specified that three different turf infills (FieldTurf SBR, GeoTurf, and NikeGrind) would be evaluated (in addition to our general review). Unfortunately, data from only the first two of the specific products were provided in time for inclusion in this report. However, we have evaluated some preliminary data for the NikeGrind product and its risk profile does not appear to be substantially different from the other products.

This evaluation is only intended to address potential risks from chemical exposures related to artificial turf products, and does not address ecological concerns, physical injuries, or heat stress. Our evaluation is intended to illustrate the current "state of the science" related to artificial turf infills. Where information was lacking we used the best information available to address data gaps and uncertainties.

In addition to providing the results of our risk assessment, we have provided an introduction to many of the concepts of toxicology, exposure evaluation, and risk assessment to help provide context for our work. Those sections, the results, and conclusions of our evaluation are provided below.

Based on the data publically available for this analysis, the chemical levels found in FieldTurf SBR and GeoTurf infill do not present a risk to people playing on or using the fields with these products. These conclusions are consistent with those of multiple regulatory agencies that have evaluated the risk from artificial turf products in general (*e.g.*, CalOEHHA, 2007; New York City Department of Health and Mental Hygiene, 2009; US EPA, 2009; Connecticut Dept. of Public Health, 2010; CalOEHHA, 2010), including evaluations that are more complex than this screening level assessment. Although there are limitations with a screening level risk assessment such as this one, the consistent conclusions from other evaluations that the data do not indicate an increased risk of health effects from chemical exposure lends additional support to our conclusion.

Introduction to Toxicology

Paracelsus, a founder of modern toxicology, was one of the first to understand that specific chemicals cause the toxic effects of a poison (EC, 2003). As such, toxicology is defined as "the study of how natural or man-made poisons cause undesirable effects in living organisms" (ATSDR, 2011). The degree to which a substance can cause damage is described as it's "toxicity", and the toxicity of a substance depends on several factors, including the amount (dose) entering the body, the route of entry into the body, and biological characteristics of the exposed individual (ATSDR, 2011; EC, 2003). These factors are critical to the study of toxicology, and are discussed in more detail below.

Dose

- The dose is the actual amount of a chemical that enters the body.
- Paracelsus postulated that the body's response to a poison was directly related to the dose received. He is best known for coining the phrase that is the fundamental assumption in toxicology, "All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy." (Society of Toxicology, 2015).
    - Essentially, this means that all chemicals can be toxic and it is the amount taken into the body that determines whether or not they will cause poisonous effects. Therefore, toxicity is not caused solely by any exposure to a particular chemical, but by exposure to too much of it.
    - This concept is now referred to as the dose-response relationship, which correlates exposure and the spectrum of observable effects (EC, 2003).
- The amount of a substance that is necessary to elicit an effect can be established by measuring the response relative to an increasing dose using experimental animal, human clinical, or cellular studies (EC, 2003).
    - The dose level at which a toxic effect is first encountered is known as the threshold dose (ATSDR, 2011; EC, 2003). At doses below the threshold, the body can negate the substance's effects by detoxifying or repairing any injury. However, once these protective mechanisms are overwhelmed, the injury can no longer be prevented and the severity of the damage increases. Some regulatory agencies assume for substances that cause cancer there is no threshold (ATSDR, 2011); however, research has shown that thresholds may be dependent on how the carcinogen functions.
    - When looking at experimental data, the threshold is referred to as the lowest observable adverse effect level (LOAEL) and the dose below it in which there was no effect is referred to as the no observable adverse effect level (NOAEL) (EC, 2003). The NOAEL and the LOAEL are important doses used in risk assessment to develop health guideline levels.
    - The dose-response relationship can be visualized in Figure 1 below.

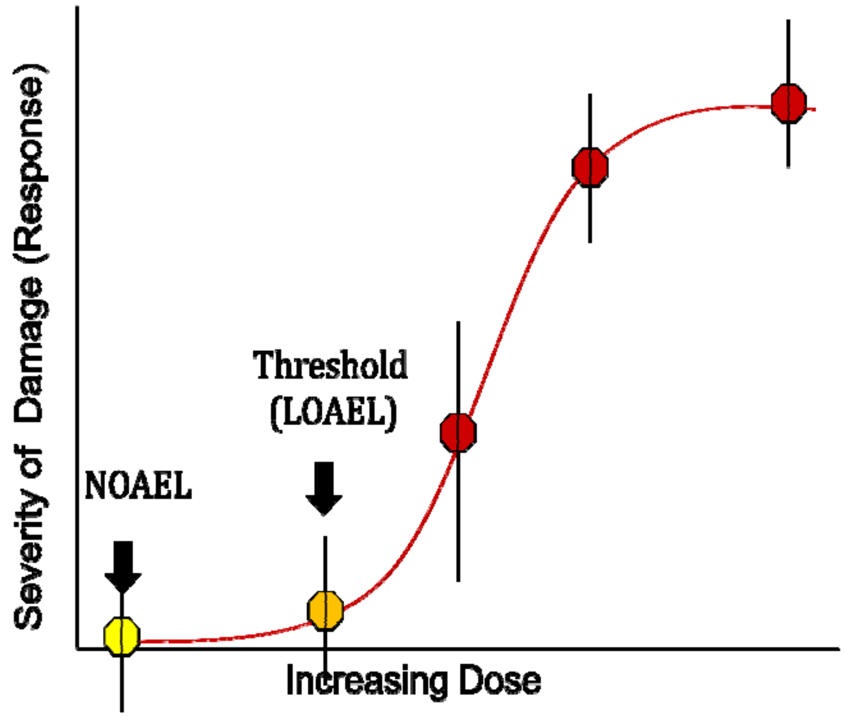

Figure 1 Dose-response Relationship. Circles indicate experimental observations, with the yellow circle indicating the dose at which no adverse effect was observed (NOAEL) and the orange circle indicating the threshold dose, also known as the lowest observable adverse effect level (LOAEL). Adapted from Lewandowski and Norman (2015).

- A real-world example of a substance that has an obvious dose-response relationship is aspirin. As shown in Figure 2, low doses of aspirin (~1-2 tablets) are recommended as a therapeutic dose as a prophylactic against heart disease and to alleviate headaches. However, once this threshold has been met, adverse effects occur, and the severity of effect increases with dose. For instance, ingesting 10 tablets may cause nausea while ingesting 100 tablets will cause death.

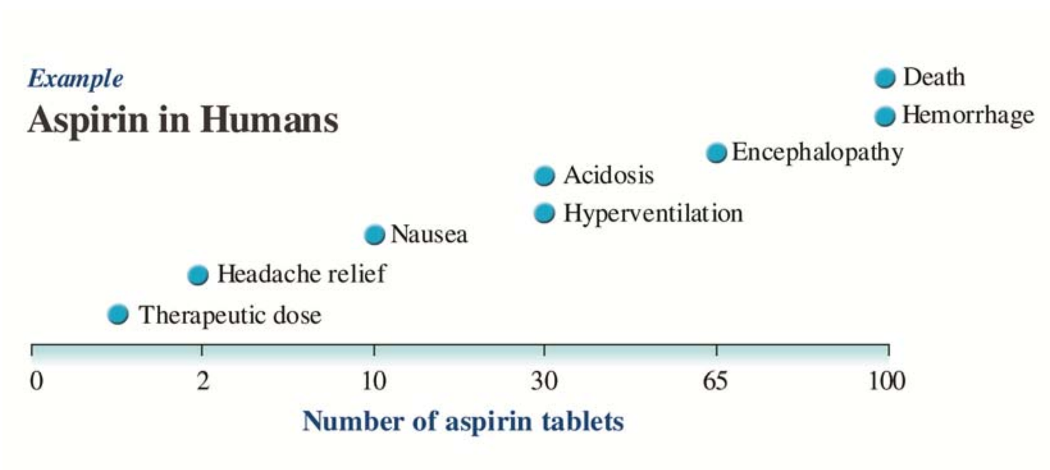

Figure 2. The Dose-Dependent Effects of Aspirin (based on information in Hardman *et al.*, 2001)

Exposure

- Chemicals need to first come into contact with the body before they can cause adverse effects (CCOHS, 2015). They then must reach the target site within the body (EC, 2003).
- There are two main factors that affect an individual's exposure to a substance: (1) the route of exposure; and (2) the frequency and duration of exposure (ATSDR, 2011, EC, 2003).
- Routes of exposure include oral (ingesting the substance), dermal (skin contact with the substance), or inhalation (breathing in the substance) (EC, 2003 215-4854).

Biological Characteristics

- Biological characteristics are factors specific to the individual exposed to the chemical. They include age, sex, diet, co-existence of infectious disease, and other genetic determinants (EC, 2003).
- These factors affect exposure and dose through modifying uptake, absorption, distribution and metabolism of the chemical, and in doing so, alter the response to the insult (EC, 2003). Susceptible populations may include babies, pregnant women, and the chronically ill, and the elderly.

Introduction to Risk Assessment

Risk assessment is the systematic evaluation of the likelihood of an adverse effect arising from exposure in a defined population. In the context of the risk assessment, risk is defined as the "probability of an adverse outcome based upon the exposure and potency of the hazardous agent(s)." (Faustman & Omenn, 2008). What this ultimately means is that without exposure and toxicity, there is no risk.

The risk assessment process contains both qualitative and quantitative components, as qualitative information (*i.e.,* the nature of the endpoints and hazards) is incorporated with a quantitative analysis (*i.e.*, assessment of the exposures, individual susceptibility factors, and the magnitude of the hazard) (Faustman & Omenn, 2008). The results of the risk assessment are used to facilitate risk management and guide the decision making process.

Standard Regulatory Risk Assessment

- The standard risk assessment framework has four key steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization (Faustman & Omenn, 2008).
  - Hazard identification involves assessing the toxicity of chemicals and examines whether a stressor has the potential to cause harm to humans systems, and if so, under what circumstances (US EPA, 2012a).
    - It ultimately answers the question: *Does the agent cause adverse health effects?*
  - Toxicity or dose-response assessment examines the numerical relationship between exposure and effects (US EPA, 2012a).
    - It answers the question: *What is the relationship between dose and response?*

    - This step has two components: (1) an assessment of all of the available data and the selection of the critical adverse effect (*i.e.*, the significant adverse biological effect that occurs at the lowest exposure level, which depending on the data, is usually the LOAEL or the NOAEL) and (2) extrapolation to estimate the risk beyond the lower range of available observed data taking into account uncertainties in the data (such as variability, susceptibility, and quality of the data) (US EPA, 2012b).
        - The critical adverse effect is also known as the point of departure and the extrapolation to human-relevant doses is also known as calculating the reference dose (RfD). Mathematically:
            - RfD = point of departure / uncertainty factors
        - US EPA defines the RfD as, "An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."
- Exposure assessment examines what is known about the frequency, timing, and levels of contact with a hazard (US EPA, 2012a).
    - It answers the question: *What types, levels, and duration of exposure are experienced or anticipated?*
    - This step involves determining the sources of exposure, route, and nature of the exposure followed by an estimation of exposure to the population of interest using standard calculations. For example, to determine if the artificial turf fields pose a health hazard, one would have to know the frequency, timing, and level of contact with the field. In addition, the concentration of potential contaminants in the field would have to be known, either *via* measured data or modeling estimations.
- Risk characterization evaluates how the data support the conclusions and the nature of the risk from the exposure at issue (US EPA, 2012a).
    - It answers the question: *What is the extra risk of health problems in the exposed population?*
    - The primary quantitative steps in the risk characterization are the calculation of the hazard index (HI) and cancer risk. These values are compared to "acceptable" risk levels published by regulatory agencies (in general, for non-carcinogens, an HI < 1 is acceptable, and for carcinogens a cancer risk less than 1 in a million is acceptable).
    - Depending on the results of the quantitative assessment, the risk characterization may provide additional detail on the toxicity of the chemicals involved, including comparison of exposure to health effects levels (as opposed to RfDs or guideline levels).
    - In addition, the risk characterization usually contains a discussion of uncertainty and the overall conclusions of the assessment.

Screening Risk Assessment

In some cases, a screening level risk assessment is conducted prior to a standard risk assessment as a means of determining whether a standard risk assessment is necessary. Screening risk assessments use a variety of conservative (*i.e.*, health protective) assumptions in an attempt to insure that health risks are not underestimated. In other words, risks calculated in screening risk assessment are most likely overestimated. The result of this practice is that if the calculated risks in a screening risk assessment are within acceptable parameters, the risk assessor can be fairly certain that exposure to the chemical in question does not pose a health risk.

- In a screening level risk assessment, hazard identification usually is already completed to some extent, and analytical data is available for the evaluation
- The toxicity assessment is simplified by using screening guideline values that have already been published by various governmental or regulatory agencies. These health effect guideline values are not in units of dose (as is typical for a standard risk assessment), but are in units of the exposure medium (*e.g.*, soil, water, air) to allow for simple comparisons to environmental sampling data.
- Instead of conducting a detailed exposure assessment, simplified assumptions are used in the calculation of the screening guideline values described in the toxicity assessment. For instance, US EPA uses a standard body weight of 70 kg (154 lbs) and a water consumption rate of 2 L (0.53 gallons) to convert a US EPA RfD into a screening level that can be compared to a chemical's concentration in water.
- The risk characterization portion of a screening risk assessment contains many of the similar components as a standard risk assessment. Concentrations that exceed health guideline values are discussed and evaluated, and sources of uncertainty and/or variability in the evaluation are detailed.
- Example: Screening Risk Assessment for Chlorine Gas At a Public Pool
  - Users of a local pool have been concerned about the chlorine odor at the pool, and wonder if their exposure might put them at risk for health effects.
  - A local environmental consulting company has been to the pool, and collected several air samples and sent them to a laboratory for analysis. The maximum air concentration reported by the laboratory was 0.003 $\mu g/m^3$.
  - The US EPA residential screening level (RSL) for chlorine gas is 0.015 $\mu g/m^3$.
  - As the maximum concentration at the pool is significantly less (5-fold) than the screening level, there is no expectation of risk to the pool users.
  - If the maximum concentration had instead been 0.018 $\mu g/m^3$ (above the RSL), that does not necessarily indicate there is a health risk due to the conservative nature of the RSL. In this situation, a risk assessor would evaluate how the RSL was derived, the uncertainty factors involved, the critical effect, the population exposed, and any number of other factors and determine if further investigation (*e.g.*, a standard risk assessment) was warranted.

Artificial Turf Risk Assessment

In order to evaluate the possible risk from exposure to chemicals in the two types of artificial turf products (as well as to artificial turf products in general), a screening risk assessment was conducted in addition to a review of the literature relevant to these products. This review was extensive, but should not be considered exhaustive due to the voluminous database and limited time available.

The exposure scenarios of interest include children, adolescents, or adults playing on the surface or watching from nearby. Thus several different screening guidelines that are protective of ingestion, inhalation, and dermal contact were selected for this evaluation. Chemical concentrations in samples of artificial turf products were compared to US EPA RSL residential soil guidelines (US EPA, 2015), concentrations of chemicals detected in ambient air above artificial turf products were compared to US EPA RSL residential air guidelines, and concentrations detected using product leaching protocols were compared to health based groundwater protection standards (NJDEP, 2013).

These guidelines should be considered to be conservative (*e.g.*, health protective) for assessment of a product such as artificial turf. For example, the soil and air RSL guidelines are intended to be protective of people (including sensitive subpopulations and children) exposed to chemicals 365 days per year for a lifetime. For soil, these guidelines assume dermal contact with the soil, inhalation of soil dust, and ingestion of soil particles.

Considerations

Screening level risk assessments are intended to be simplified exercises to determine if the possible risks related to an exposure are significant enough to warrant further investigation. In many cases, as mentioned above, exceeding a screening guideline does not necessarily indicate that a risk is likely. This is particularly true for a product based risk assessment, such as for artificial turf products. Several important considerations are detailed below.

- A significant volume of literature was evaluated to identify metal and organic chemical concentrations in artificial turf products, in the ambient air above those products, and in leachate from those products. The data collected can be found in Appendix A. However, the limited time frame for compilation of these data indicate that this literature search should be considered extensive, but not exhaustive.
- The data collected range in date from 2008 to 2014. There are many different types of products involved, from multiple manufacturers. As two of the products of considerable interest to the Verdant Health Commission were FieldTurf SBR and GeoTurf, we have limited our summary tables in this report to data from those two products. In addition, due to the reformulation of many products due to issues related to lead in 2008, we have focused on data that have been produced since 2010. The other data evaluated are in the appendices, and will be discussed qualitatively.
- As discussed briefly above, the soil and air RSL guidelines are intended for use at residential sites where exposure occurs from a variety of pathways over a lifetime. In addition, these guidelines assume that exposure is through the media of interest—namely, soil or air. The bioavailability[1] of these chemicals from artificial turf products appears to be substantially different than from soil and possibly air. Studies that have evaluated the bioavailability of chemicals from artificial turf have noted that there is likely to be limited availability from this substance (Pavilonis *et al.*, 2014; van Rooij and Jongeneelen, 2010; CalOEEHA 2007; US EPA, 2009).

[1] The bioavailability of a substance is a measure of how much is absorbed *via* a particular route of exposure. For instance, when arsenic is ingested in soil, only about 60% of the total ingested is absorbed.

Table 1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Residential Screening Level, HQ = 0.1 (mg/kg)	Washington State/ Seattle Area Background Levels (90^{th} Percentile or Range)	Curtis & Tompkins (2011) for Limonta Sport USA[1]		Teter Engineering (2015) for Sprinturf[2]					
			Limonta Infill-Pro Geo (mg/kg)	Limonta Turf-Max-S (mg/kg)	FieldTurf Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2011) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2012) (mg/kg)	FieldTurf SBR (TestAmerica, 2011a) (mg/kg)	FieldTurf SBR (TestAmerica, 2011b) (mg/kg)
Metals										
Antimony	3.1	NI	ND	ND	3.7	3.4	NA	NA		
Cobalt	2.3	NA	ND	ND	130	120	NA	NA		
Thallium	0.078	NA	0.9	ND	< 0.74	< 0.8	NA	NA		
Zinc	2,300	85	11	45	16,000	13,000	NA	NA		
SVOCs and VOCs										
Benzo(a)anthracene	0.15	0.0016-6.0							< 9.7	< 62
Benzo(a)pyrene	0.015	0.0017-6.7							< 9.7	< 62
Benzo(b)fluoranthene	0.15	0.0032-7.3							< 9.7	< 62
Benzo(k)fluoranthene	1.5	0.0013-2.0							< 9.7	< 62
Bis(2-ethylhexyl)phthalate	38								90	160

Notes:
HQ = Hazard Quotient; SBR = Styrene butadiene rubber; SVOC = Semivolatile Organic Compound; VOC = Volatile Organic Compound.
(1) Data from Curtis & Tompkins (2011, pp. 5-6).
(2) Data from Teter Engineering (2015, Appendix Table A-1, A-3). Note that the values from Table A-3 were converted to mg/kg for comparison across studies.
NA = Not Analyzed; ND = Not detected; NI = Not identified.
Highlighted cells are those with values above their respective Residential Screening Levels.
Data was not reported for blank cells.

Table 2 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Guideline Level (µg/L)	Curtis & Tompkins (2011) for Limonta Sport USA[1]		Teter Engineering (2015) for Sprinturf[2]				
		Limonta Infill-Pro Geo (µg/L)	Limonta Turf-Max-S (µg/L)	FieldTurf-SPLP Cryogenic Crumb Rubber (A-1007/T12) (Li *et al.*, 2010a) (µg/L)	FieldTurf-SPLP Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf-SPLP Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf-WET SBR (TestAmerica, 2011a) (µg/L)	FieldTurf-WET SBR (TestAmerica, 2011b) (µg/L)
Metals								
Aluminum	4,000							
Antimony	120	ND	ND	NA	< 1	< 1	< 200	< 200
Arsenic	3	ND	ND	< 3.0	< 1.2	< 1.2	< 200	< 200
Barium	120,000	430	ND	13	2.8	< 1	220	< 200
Beryllium	20	ND	ND	NA	< 4.3	< 4.3	< 80	< 80
Cadmium	80	ND	ND	< 1	< 1.3	< 1.3	< 100	< 100
Cobalt	2,000	ND	ND	NA	1.1	2.4	< 200	< 200
Copper	26,000	ND	ND	0.69	< 1	9.7	880	310
Lead	100	ND	ND	0.19	< 1	< 1	< 100	< 100
Manganese	1,000							
Mercury	40	ND	ND	NA	< 0.2	< 0.2	< 2	< 2
Nickel	2,000 (soluble salts)	ND	ND	0.65	< 3.0	< 3.0	< 200	< 200
Selenium	800	ND	ND	NA	< 1	< 1	< 200	< 200
Silver	800	ND	ND	NA	< 1	< 1	< 200	< 200
Thallium	10	ND	ND	NA	< 1	< 1	< 200	< 200
Vanadium	2	ND	ND	NA	< 1.1	< 1.1	< 200	< 200
Zinc	40,000	ND	ND	2,450	240	870	15,000	5,900

Notes:
NA = Not analyzed; ND = Not detected; SBR = Styrene butadiene rubber; SPLP = Synthetic precipitation leachate procedure.
(1) Data from Curtis & Tompkins (2011, pp. 13-14).
(2) Data from Table A-2 and A-4.
Data was not reported for blank cells.

Chemical Characteristics of SBR Infill

The substances that exceeded a screening guideline in at least one artificial turf product sample (using the selection criteria discussed above) are presented in Tables 1 and 2. In addition, the Washington State soil background concentrations of these substances are also presented. The implications of these exceedances are discussed below.

- Of the 55 chemicals tested in the soil analyses, 51 (93%) were below their respective screening guidelines.
- In every case except one, the exceedances are less than an order of magnitude (10-fold). Given the conservative nature of these RSL guidelines, it is unlikely that these exceedances are significant in terms of excess risk.
- In addition to the less than 10-fold exceedances, as mentioned above these chemicals are all embedded in a matrix that multiple studies (Pavilonis *et al*., 2014; van Rooij and Jongeneelen, 2010; CalOEEHA, 2007; US EPA, 2009) have deemed renders them less bioavailable when ingested or exposed dermally.
- The one exceedance that is greater than an order of magnitude is for cobalt. As noted previously, the use of conservative screening guidelines as well as the lack of bioavailability of this metal from the SBR make any adverse health effects unlikely. In addition, the toxicity value used to derive the cobalt RSL is called a "Provisional Peer-Reviewed Toxicity Value" (PPRTV). These are secondary toxicity values used when US EPA has not derived a value using the standard process. The PPRTV for cobalt is based on a 2 week human study that saw decreased iodine uptake in the thyroid, which was then reduced by a factor of 3,000 to address limited data. The US EPA rates the confidence in this value as "low." Based on this evaluation, the likelihood of cobalt exposure from artificial turf products constituting a health threat is low.
- Data from the recent studies of FieldTurf SBR do not show detectable levels of PAHs (see Table 1); however, the limit of detection in these samples is higher than the RSL guidelines. Samples from older studies of FieldTurf SBR have detected PAHs in the product (see Appendix A). The levels detected are similar to those seen in normal Seattle residential area soils (see Table 1; WDOE, 2011).
- Leaching data (Table 2) from FieldTurf SBR indicate that no applicable screening guidelines were exceeded (60 of 60 passed).

Chemical Characteristics of GeoTurf Infill

As with the FieldTurf SBR results, the levels of compounds found in GeoTurf are presented in Tables 1 and 2. Several important considerations are detailed below.

- Of the 17 chemicals tested in the soil analyses, 16 (94%) were below their respective screening guidelines.
- Only one compound in GeoTurf exceeded a US EPA RSL—thallium. This compound exceeded its RSL by over an order of magnitude. As with cobalt, the toxicity value used to derive thallium's RSL is a PPRTV. The basis for the RSL is hair follicle atrophy observed in a rat study, which was considered to be similar to effects observed in humans. The observed dose was

adjusted by a 3,000 fold to address limited data. Based on this evaluation, the likelihood of thallium exposure from artificial turf products constituting a health threat is low.

- There is a significant uncertainty in the evaluation of GeoTurf infill due to the lack of analytical data comparable to SBR studies. No literature data were found that evaluated any organic compounds or pesticides which might be applied to natural products. Additional data related to this was requested from the manufacturer.
- Leaching data (Table 2) from GeoTurf indicate that no applicable screening guidelines were exceeded (18 of 18 passed).

Overall Evaluation of Two Types of Infills

Based on the data publically available for this analysis, the chemical levels found in FieldTurf SBR and GeoTurf infill do not present a risk to people playing on or using the fields with these products. In addition, for the PAH data available for SBR products, these products do not present a substantially different risk profile than playing in soil in the Seattle area.

Some concern has been expressed regarding the possible carcinogenicity of SBR, either from the PAH and metal content (which do not appear to be substantially elevated or bioavailable), or from other unknown chemicals. Several studies have evaluated the *in vitro* genotoxicity or mutagenicity[2] of actual SBR and have uniformly found that the substance tested negative or the results were comparable with urban sites in general (Birkholz *et al*., 2003; Schiliro *et al*., 2013).

Uncertainty Analysis

As with any scientific endeavor, there are a variety of sources of uncertainty in this analysis. Most of that uncertainty is related to the quality of the data that were identified for our screening risk assessment. Those issues are addressed specifically below.

Data Quality

- The air data available for this evaluation were inadequate to conduct an appropriate analysis of the risk from inhaling possible VOCs off-gassing from turf material or particulates associated with the FieldTurf SBR or GeoTurf infills. The studies of other SBR products that did conduct appropriate analyses found similar concentrations of chemicals upwind and downwind, however, which is supportive of minimal emissions from the turf surfaces. Thus, although a product specific analysis was not possible, a number of studies of other SBR surfaces indicate that chemical and particulate concentration above the fields are unlikely to pose a health risk.
- The available data support that over time and across brands there is variability in the chemical composition of SBR. Data were not available related to multiple batches of GeoTurf. As noted in previous reviews, this variability adds a source of uncertainty into the analysis. However, in general, even with this uncertainty the levels of chemicals found in SBR over the years have not been found to present an unacceptable risk by multiple regulatory agencies.
- There was a lack of data from GeoTurf for many of the chemicals evaluated for SBR. These include standard VOCs and SVOCs, as well as pesticides, which could be significant depending

[2] In toxicology, *in vitro* (test tube) tests are often used to screen chemicals to determine if they might have cancer-causing potential.

on where the coconut and cork components of the GeoTurf products are sourced. The impact of this uncertainty on the analysis cannot be determined without additional analytical data.

- For each of the products, much of the composition data available has been determined by standard analytical methods. In some cases, there may be chemicals inherent in the base materials that have not been disclosed, or of which manufacturers are unaware. The impact of this uncertainty on the analysis cannot be determined without additional data on the source and composition of the base materials. However, in general it appears that the analytical methods chosen in each study are reasonable considering the origin of the product (*i.e.*, it is reasonable to assume that recycled tires would contain metals, VOCs, SVOCs, *etc.*).

Carbon Nanotubes

- Carbon nanotubes are nanoparticles that may be used in tires, as well as many other products. There are many different types of nanotubes, with different physical and chemical characteristics. The toxicity of carbon nanotubes has been the subject of intense research over the last decade, with hundreds of studies being published on many different types of these materials (*e.g.*, Manke *et al*., 2013; Kuempel *et al*., 2012).
- Toxicity studies of carbon nanotubes have reported a wide range of toxicity depending on the structure of the nanotube, the nature of the test system (*e.g.*, *in vitro*, animal), and type of effect (for example, see Grosse *et al*., 2014; Manke *et al*., 2013; Kuempel *et al*., 2012). The International Agency for Research on Cancer (IARC) has reviewed the toxicity of three different types of nanotubes; they found possible evidence of carcinogenicity for one specific type, but the data were not sufficient to classify the other two types they evaluated (Grosse *et al*., 2014).
- Evaluating the risk from exposure to carbon nanotubes that may be present in artificial turf products is complicated by a number of factors. These include the lack of any information about concentration or type of nanotube in the source material, the lack of information on any transformation that may occur during manufacture of the tires, and the lack of information about the rate of release of the native nanotube *versus* an aggregated or agglomerated nanotube from the artificial turf product.
- Even if the nature of the native nanotubes used to manufacture the tires used for SBR was known, it is likely that these nanotubes would undergo agglomeration or aggregation during the manufacturing process. In addition, they are embedded or encapsulated within the tire rubber. Thus, it is uncertain if the material that would be released from an artificial turf product such as SBR would resemble the original material or not. Studies of nanoparticle release from composites (Nowack *et al*., 2013; Froggett *et al*., 2014) and other products generally have found that most of the material released from the product is larger particles, with any nanomaterials imbedded within a matrix which would presumably limit their bioreactivity.
- For the reasons discussed above, the impact of the uncertainties surrounding the possible addition of carbon nanotubes to tires on our analysis cannot be determined. However, based on the research conducted to date, it appears that nanotubes would not be released in their "original" chemical state, and would be weathered/eroded into chemically and/or physically different structures.

Carbon Black

- Carbon black is a powdered form of elemental carbon, which has a number of uses in consumer products. One of its most common uses is as reinforcing agent in rubber, including tires, but it is also used in pigments for inks, paints, plastics, and coatings. Depending on the manufacturing process, carbon black may have particle sizes ranging from nanometers to micrometers.
- As with carbon nanotubes, the chemical characteristics of carbon black particles that are used to manufacture tires may not be the same characteristics as particles that may be produced as tire particles wear. Carbon black particles are expected to agglomerate and aggregate, and are embedded in the rubber matrix of tire crumb until there are released by wear and abrasion.
- The toxicity of carbon black has primarily been informed by studies of carbon black workers, with high exposure levels unlikely to be relevant to artificial turf users. In relation to non-cancer effects, carbon black workers exposed to these high levels generally were subject to relatively minor respiratory tract symptoms such as cough, and bronchitis. These effects were similar to effects seen in workers exposed to other relatively inert dusts.
- Given that the levels of particulate matter (which would include levels of carbon black) detected above artificial turf fields has been found to be low and consistently below general particulate matter guideline levels, it is relatively certain that carbon black exposures at artificial turf fields would be substantially lower than in worker populations.
- The International Agency for Research on Cancer has labeled carbon black as a possible human carcinogen (Group 2B), based primarily on epidemiology data from the worker populations discussed above. While this is a source of some uncertainty in our analysis, it is unlikely that the type of carbon black released from artificial turf products is similar to that which workers were exposed to, and the exposure levels would be expected to be much lower.

Potential Allergic Reactions

- Most reviews of possible health effects from exposure to artificial turf projects focus on systemic or organ-specific effects of exposure to chemicals. However, there is also the possibility for allergic responses to the chemicals in these substances. These include possible sensitization to metals, as well possible reactions to organic chemicals or biological proteins. Two organizations (Norwegian Institute of Public Health, 2006, CalOEHHA, 2010) did evaluate exposure to components of SBR and found no evidence that exposure to SBR (either metals or latex) resulted in allergic reactions. In the case of GeoTurf, some portion of the population may have an allergic response to coconut and/or cork; cases of occupational sensitization to coconut fibers and occupational asthma from cork dust have also been documented (Deschamps *et al*., 2003; Stutius *et al*., 2010; Winck *et al*., 2002 ; Winck *et al*., 2004; Wittczak *et al*., 2005). As noted with carbon black, it is unlikely that the levels of coconut fibers and/or cork dust about GeoTurf fields would approach those found in occupational settings. However, there are no sampling data available to determine if this is actually the case (as opposed to data with FieldTurf infills). This is not likely a source of significant uncertainty in our evaluation, but as no rigorous allergy testing or environmental sampling of GeoTurf has been conducted it should be considered.

Review of Regulatory Agency (and Other) Evaluations of Artificial Turf

Over the last eight years, numerous US regulatory and other governmental agencies have evaluated the potential health risks involved with exposure to chemicals associated with artificial turf fields. The focus of almost all of these evaluations has been the potential toxicity of chemicals associated with SBR. Each of these reports have limitations based on the methodology used and data available for their analysis. However, in cases where these reports conducted quantitative risk assessments, they without exception concluded that the data support that use of these fields is safe. A summary of these analyses can be found in Appendix B.

Conclusions

Based on the data publically available for this analysis, the chemical levels found in FieldTurf SBR and GeoTurf infill do not present a risk to people playing on or using the fields with these products. These conclusions are consistent with those of multiple regulatory agencies that have evaluated the risk from artificial turf products in general (*e.g.*, CalOEHHA, 2007; New York City Department of Health and Mental Hygiene, 2009; US EPA, 2009; Connecticut Dept. of Public Health, 2010; CalOEHHA, 2010), including evaluations that are more complex than this screening level assessment. Although there are limitations with a screening level risk assessment such as this one, the consistent conclusion that the data do not indicate an increased risk of health effects from chemical exposure lends additional support to our conclusion.

We appreciate the opportunity to work with Verdant Health Commission on this project. If you have any questions or comments on our evaluation, please do not hesitate to contact us.

Sincerely,

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Appendix A

Data Tables

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Residential Screening Level (mg/kg)	Washington State/Seattle Area Background Levels (90th Percentile)	Curtis & Tompkins (2011 215-4632) for Limonta Sport USA[1]		Teter Engineering (2015 215-4633) for Sprinturf[2]		US EPA (2009 210-1256)[3]					
			Limonta Infill-Pro Geo (mg/kg)	Limonta Turf - Max-S (mg/kg)	Green Crumb Rubber (mg/kg)	Black Crumb Rubber (mg/kg)	Turf Field Infill Crumb Rubber - F1D1 (Range, mg/kg)	Turf Field Infill Crumb Rubber - F2, F3 (Range, mg/kg)	Turf Field Infill Crumb Rubber - F4, F5, F6 (Range, mg/kg)	Turf Field Blades- F1D1 (Range, mg/kg)	Turf Field Blades - F2, F3 (Range, mg/kg)	Turf Field Blades - F4, F5, F6 (Range, mg/kg)
Metals												
Antimony	3.1	NI	ND	ND	4.6	4.1						
Arsenic	0.67	7	0.48	ND	<0.24	<0.23						
Barium	1500	NI	10	0.48	4.5	5.8						
Beryllium	16	0.6	ND	ND	<0.097	<0.093						
Cadmium	7	1	ND	ND	0.54	0.53						
Chromium	12000	48	ND	ND	<0.41/2.7[1]	<0.41/1.7[1]	0.3-1.0	0.4-0.9	0.3-1.0	1.0-73.1	1.2-1.9	3.7-177
Cobalt	2.3	NI	ND	ND	120	120						
Copper	310	36	4.3	4.2	30	27						
Lead	400	24	ND	ND	21	26	13.1-34.7	20.6-61.2	10.7-47.7	2.8-389	2.4-2.8	2.1-701
Magnesium	NI	NI										
Mercury	2.3	0.07	ND	ND	<0.017	<0.015						
Molybdenum	39	NI	0.29	0.25	0.63	0.72						
Nickel	150	48	0.38	0.95	2.2	1.9						
Selenium	39	NI	ND	ND	<0.49	<0.46						
Silver	39	NI	ND	ND	<0.24	<0.23						
Thallium	0.078	NI	0.9	ND	<0.49	<0.46						
Titanium	14000	NI										
Vandium	NI	NI	0.77	ND	1.3	0.84						
Zinc	2300	85	11	45	14000	14000	5050-19200	3120-12300	2660-11400	316-730	199-255	131-206
SVOCs and VOCs												
1,2-Dichlorobenzene	180											
1,2,4-Trichlorobenzene	5.8											
1,3-Dichlorobenzene	NI											
1,4-Dichlorobenzene	2.6											
2-Chlorophenol	39											
2,4-Dichlorophenol	18											
2,4-Dimethylphenol	120											
2,4-Dinitrophenol	12											
2,4-Dinitrotoluene	1.7											
2,4,5-Trichlorophenol	620											
2,4,6-Trichlorophenol	6.2											
3,3'-Dichlorobenzidine	1.2											
Acenaphthene	350				<0.25	<0.49						
Acenapthylene	NI				<0.25	<0.49						
Aniline	43											
Anthracene	1700				<0.25	<0.49						
Azobenzene	5.6											
Benzo(a)anthracene	0.15				0.85	1.7						
Benzo(a)pyrene	0.015				0.95	2.1						
Benzo(b)fluoranthene	0.15				0.99	2						
Benzo(g, h, i)perylene	NI				3.6	10						
Benzo(k)fluoranthene	1.5				<0.25	0.54						
Benzoic acid	25000											
Bis(2-chloroethyl)ether	0.23											

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Residential Screening Level (mg/kg)	Washington State/Seattle Area Background Levels (90th Percentile)	Curtis & Tompkins (2011 215-4632) for Limonta Sport USA[1]		Teter Engineering (2015 215-4633) for Sprinturf[2]		US EPA (2009 210-1256)[3]					
			Limonta Infill-Pro Geo (mg/kg)	Limonta Turf - Max-S (mg/kg)	Green Crumb Rubber (mg/kg)	Black Crumb Rubber (mg/kg)	Turf Field Infill Crumb Rubber - F1D1 (Range, mg/kg)	Turf Field Infill Crumb Rubber - F2, F3 (Range, mg/kg)	Turf Field Infill Crumb Rubber - F4, F5, F6 (Range, mg/kg)	Turf Field Blades- F1D1 (Range, mg/kg)	Turf Field Blades - F2, F3 (Range, mg/kg)	Turf Field Blades - F4, F5, F6 (Range, mg/kg)
Bis(2-chloroisopropyl)ether	NI											
Bis(2-ethylhexyl)phthalate	38											
Butylbenzyl phthalate	280											
Carbazole	NI											
Chrysene	15				2.3	4.9						
Di-n-butylphthalate	620											
Di-n-octylphthalate	62											
Dibenz(a,h)anthracene	0.015				<0.25	0.52						
Diethyl phthalate	4900											
Dimethylphthalate	NI											
Diphenylamine	150											
Fluoranthene	230				3	60						
Fluorene	230				<0.25	<0.49						
Hexachlorobenzene	0.33											
Hexachlorobutadiene	6.2											
Indeno(1,2,3-cd)pyrene	0.15				0.47	1.3						
Isophorone	560											
N-Nitrosodiphenylamine	110											
Naphthalene	3.8				0.77	1.6						
Nitrobenzene	5.1											
Pentachlorophenol	0.99											
Phenanthrene	NI				1.2	2.5						
Phenol	1800											
Pyrene	170				9.3	19						

Notes:

NA = Not Analyzed; ND = Not Detected; NI = Not Identified; SVOC = Semivolatile Organic Compound; VOC = Volatile Organic Compound.

(1) Data from Curtis & Tompkins (2011, pp. 5-6).

(2) Data from Teter Engineering (2015, Tables 1 and 3).

(3) Data from US EPA (2009, Table 7, p .32). Note, more chemicals were analyzed but they were not reported in summary tables.

(4) Data from Zhang *et al.* (2008, Tables 4 and 5). Note that the values were converted to mg/kg for comparison across studies.

(5) Data from Pavilonis *et al.* (2013, Tables 2 and 3, pp. 5, 6).

(6) Data from Teter Engineering (2015, Appendix Tables A-1 and A-3). Note that the values from Table A-3 were converted to mg/kg for comparison across studies.

Highlighted cells are those with values above their respective Residential Screening Level.

Data was not reported for blank cells.

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Zhang *et al*. (2008 208-5919)[4]								
	Sample 1 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 2 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 3 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 4 A-Turf Fibers from Riverside Park (mg/kg)	Sample 5 FieldTurf Rubber Crumb from Parade Grounds (mg/kg)	Sample 6 FieldTurf Rubber Crumb from Parade Grounds (mg/kg)	Sample7 FieldTurf Rubber Crumb from Sara Roosevelt Park (mg/kg)	Sample 8 Astroplay Rubber Crumb from E. Rochester HS (mg/kg)	New Crumb Infill - Sweat (Range, mg/kg)
Metals									
Antimony									
Arsenic	3.55	1.57	ND	0.28				0.28	<0.50
Barium									
Beryllium									<0.20
Cadmium	0.21	0.41	0.37	ND				0.22	<0.090–0.11
Chromium	0.87	1.68	0.69	3.93				0.93	0.70–1.2
Cobalt									
Copper									<0.080–0.54
Lead	5.76	53.5	4.63	2.8				3.12	0.090–1.6
Magnesium									<7.0–980
Mercury									
Molybdenum									
Nickel									
Selenium									<1.9
Silver									<0.10
Thallium									
Titanium									0.60–1.3
Vandium									6.0–21
Zinc	5710	9988	NA	NA				NA	
SVOCs and VOCs									
1,2-Dichlorobenzene									
1,2,4-Trichlorobenzene									
1,3-Dichlorobenzene									
1,4-Dichlorobenzene									
2-Chlorophenol									
2,4-Dichlorophenol									
2,4-Dimethylphenol									
2,4-Dinitrophenol									
2,4-Dinitrotoluene									
2,4,5-Trichlorophenol									
2,4,6-Trichlorophenol									
3,3'-Dichlorobenzidine									
Acenaphthene	ND	0.03	ND	ND	0.16	0.09	ND	ND	
Acenapthylene									
Aniline									
Anthracene	0.03	0.17	ND	0.01	0.03	0.03	ND	ND	
Azobenzene									
Benzo(a)anthracene	1.23	1.26	0.31	ND	0.29	0.98	0.06	ND	
Benzo(a)pyrene	8.58	3.56	0.78	0.08	0.61	0.25	0.06	0.41	
Benzo(b)fluoranthene	3.39	2.19	ND	ND	1.08	0.58	0.2	0.43	
Benzo(g, h, i)perylene	7.75	2.61	2.73	0.11	0.85	0.46	2.03	ND	
Benzo(k)fluoranthene	7.29	1.78	0.17	ND	0.14	0.18	0.1	0.99	
Benzoic acid									
Bis(2-chloroethyl)ether									

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Zhang *et al*. (2008 208-5919)[4]								
	Sample 1 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 2 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 3 A-Turf Rubber Crumb from Riverside Park (mg/kg)	Sample 4 A-Turf Fibers from Riverside Park (mg/kg)	Sample 5 FieldTurf Rubber Crumb from Parade Grounds (mg/kg)	Sample 6 FieldTurf Rubber Crumb from Parade Grounds (mg/kg)	Sample7 FieldTurf Rubber Crumb from Sara Roosevelt Park (mg/kg)	Sample 8 Astroplay Rubber Crumb from E. Rochester HS (mg/kg)	New Crumb Infill - Sweat (Range, mg/kg)
Bis(2-chloroisopropyl)ether									
Bis(2-ethylhexyl)phthalate									
Butylbenzyl phthalate									
Carbazole									
Chrysene	1.32	7.55	ND	ND	1.96	1.34	0.06	4.9	
Di-n-butylphthalate									
Di-n-octylphthalate									
Dibenz(a,h)anthracene	3.52	1.55	ND	ND	0.71	0.52	1.43	ND	
Diethyl phthalate									
Dimethylphthalate									
Diphenylamine									
Fluoranthene	0.11	0.37	ND	ND	5.08	3.54	25.4	ND	
Fluorene	0.76	0.77	ND	ND	0.5	0.45	ND	ND	
Hexachlorobenzene									
Hexachlorobutadiene									
Indeno(1,2,3-cd)pyrene	0.4	0.37	ND	ND	ND	ND	ND	ND	
Isophorone									
N-Nitrosodiphenylamine									
Naphthalene	ND	0.1	0.4	0.2	0.03	0.03	ND	0.86	
Nitrobenzene									
Pentachlorophenol									
Phenanthrene	0.06	4.35	ND	ND	2.19	1.46	ND	ND	
Phenol									
Pyrene	3.73	8.76	ND	ND	6.24	9.61	2.45	13.5	

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Pavilonis *et al*. (2013 214-1253)[5]												
	New Turf Fiber - Sweat (Range, mg/kg)	Field Samples - Sweat (Range, mg/kg)	New Crumb Infill - Digestive (Range, mg/kg)	New Turf Fiber - Digestive (Range, mg/kg)	Field Samples - Digestive (Range, mg/kg)	New Crumb Infill - Lung (Range, mg/kg)	New Turf Fiber - Lung (Range, mg/kg)	Field Samples - Lung (Range, mg/kg)	New Crumb Infill - Nitric Acid (Range, mg/kg)	New Turf Fiber - Nitric Acid (Range, mg/kg)	Field Samples - Nitric Acid (Range, mg/kg)	All Samples - Sweat (Maximum, mg/kg)	All Samples - Lung (Maximum, mg/kg)
Metals													
Antimony													
Arsenic	<0.10	1.4–1.7	<0.10–0.48	<0.040	<3.0	<0.50	<0.20	<0.050	<0.70–0.80	<0.040–4.0	<0.70		
Barium													
Beryllium	<0.20	<0.20	<0.40	<0.40	<0.40	<0.50	<0.20	<0.030	<0.70	<0.040–0.51	<0.70		
Cadmium	<0.030	<0.20	<4.0	<0.30	2.5–11	<0.20	<0.090	<0.090	<0.70–1.1	<0.50	<0.70		
Chromium	0.10–1.3	2.1–2.7	<7.0	<0.60–0.74	<6.0	<0.20–0.66	<0.090–0.12	<0.050	<0.70–16	0.34–820	<0.70–0.92		
Cobalt													
Copper	0.030–1.6	1.8–2.2	<20–32	<1.0–1.6	<20	<0.40–0.58	<0.2–2.0	<0.20	<0.70–36	0.69–110	8.8–59		
Lead	0.030–12	<0.20–1.5	5.3–66	<0.30–4.7	2.5–260	<0.20–0.26	<0.02–0.61	<0.020–0.023	<0.010–17	0.53–4400	4.1–140		
Magnesium	3.3–18	<10	<1000–4600	<90	<900	650–970	77–300	<100	<7.0–7800	<30–12000	<70–160		
Mercury													
Molybdenum													
Nickel													
Selenium	<0.60	<0.70	<0.90–1.5	<0.10	<2.0	<2.0	<0.90	<0.10	<1.0	<0.10–2.9	<0.60–1.3		
Silver	<0.060	<0.70	<0.20–0.23	<0.20	<0.40–0.90	<0.50	<0.20	<0.10	<10	<8.0	<10		
Thallium													
Titanium	0.10–1.1	3.2–4.0	<10	<0.10	<10	1.5–6.7	0.20–0.96	<0.40	<0.70–18	0.81–820	1.9–9.6		
Vandium	0.50–1.6	15–18	<1.0	<0.10–0.12	<1.0	0.65-3.0	0.39–1.5	<0.70	<0.10–2.1	<40	<0.80–0.74		
Zinc													
SVOCs and VOCs													
1,2-Dichlorobenzene													
1,2,4-Trichlorobenzene													
1,3-Dichlorobenzene													
1,4-Dichlorobenzene													
2-Chlorophenol													
2,4-Dichlorophenol													
2,4-Dimethylphenol													
2,4-Dinitrophenol													
2,4-Dinitrotoluene													
2,4,5-Trichlorophenol													
2,4,6-Trichlorophenol													
3,3'-Dichlorobenzidine													
Acenaphthene												<0.11	<0.05
Acenapthylene												<0.17	<0.09
Aniline													
Anthracene												<0.08	<0.04
Azobenzene												<0.49	<0.24
Benzo(a)anthracene												<0.31	<0.16
Benzo(a)pyrene												<1.4	<0.74
Benzo(b)fluoranthene												<1.2	<0.56
Benzo(g, h, i)perylene													
Benzo(k)fluoranthene												<1.9	<0.69
Benzoic acid													
Bis(2-chloroethyl)ether													

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical	Pavilonis *et al*. (2013 214-1253)[5]												
	New Turf Fiber - Sweat (Range, mg/kg)	**Field Samples - Sweat (Range, mg/kg)**	**New Crumb Infill - Digestive (Range, mg/kg)**	**New Turf Fiber - Digestive (Range, mg/kg)**	**Field Samples - Digestive (Range, mg/kg)**	**New Crumb Infill - Lung (Range, mg/kg)**	**New Turf Fiber - Lung (Range, mg/kg)**	**Field Samples - Lung (Range, mg/kg)**	**New Crumb Infill - Nitric Acid (Range, mg/kg)**	**New Turf Fiber - Nitric Acid (Range, mg/kg)**	**Field Samples - Nitric Acid (Range, mg/kg)**	**All Samples - Sweat (Maximum, mg/kg)**	**All Samples - Lung (Maximum, mg/kg)**
Bis(2-chloroisopropyl)ether													
Bis(2-ethylhexyl)phthalate													
Butylbenzyl phthalate													
Carbazole												<0.35	<0.18
Chrysene												<1.1	<0.54
Di-n-butylphthalate													
Di-n-octylphthalate													
Dibenz(a,h)anthracene												<2.0	<0.98
Diethyl phthalate													
Dimethylphthalate													
Diphenylamine													
Fluoranthene												<0.11	<0.06
Fluorene												<.07	<0.03
Hexachlorobenzene													
Hexachlorobutadiene													
Indeno(1,2,3-cd)pyrene													
Isophorone													
N-Nitrosodiphenylamine													
Naphthalene												<0.03	<0.02
Nitrobenzene													
Pentachlorophenol													
Phenanthrene												<0.10	<0.05
Phenol													
Pyrene												<0.10	<0.05

Chemical			Teter Engineering (2015 215-4633) for Sprinturf[6]					
	All Samples - Digestive (Maximum, mg/kg)	All Samples - Total Extract (Maximum, mg/kg)	FieldTurf 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2011) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2012) (mg/kg)
Metals								
Antimony			0.18	0.24	3.7	3.4	NA	NA
Arsenic			0.39	<1	<0.37	<0.4	<0.7	<0.7
Barium			2.2	0.41	2.7	6.4	NA	NA
Beryllium			<0.4	<0.4	<0.15	<0.16	<0.7	<0.7
Cadmium			1.5	<0.5	<0.37	<0.4	<0.7	<0.7
Chromium			0.72	1.9	1.2	1.9	<0.7	<0.7
Cobalt			<5	<5	130	120	NA	NA
Copper			11	0.4	54	26	15	59
Lead			<0.3	<0.3	15	8.4	40	8
Magnesium								
Mercury			0.011	<0.033	<0.15	<0.16	NA	NA
Molybdenum			NA	NA	0.57	0.64	NA	NA
Nickel			1.6	0.52	2	2.9	NA	NA
Selenium			0.37	<0.5	<0.74	<0.8	<1.2	1.3
Silver			0.14	<0.5	<0.37	<0.4	NA	NA
Thallium			1	<1	<0.74	<0.8	NA	NA
Titanium								
Vandium			0.52	0.55	1.2	2.2	0.71	0.74
Zinc			9,990	2.8	16,000	13,000	NA	NA
SVOCs and VOCs								
1,2-Dichlorobenzene								
1,2,4-Trichlorobenzene								
1,3-Dichlorobenzene								
1,4-Dichlorobenzene								
2-Chlorophenol								
2,4-Dichlorophenol								
2,4-Dimethylphenol								
2,4-Dinitrophenol								
2,4-Dinitrotoluene								
2,4,5-Trichlorophenol								
2,4,6-Trichlorophenol								
3,3'-Dichlorobenzidine								
Acenaphthene	<0.56	<0.03						
Acenapthylene	<0.68	2.48						
Aniline								
Anthracene	<0.42	<0.02						
Azobenzene	<2.5	<0.12						
Benzo(a)anthracene	<1.7	<0.08						
Benzo(a)pyrene	<7.6	<0.37						
Benzo(b)fluoranthene	<6.4	<0.31						
Benzo(g, h, i)perylene								
Benzo(k)fluoranthene	<7.2	<0.34						
Benzoic acid								
Bis(2-chloroethyl)ether								

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical			Teter Engineering (2015 215-4633) for Sprinturf[6]					
	All Samples - Digestive (Maximum, mg/kg)	All Samples - Total Extract (Maximum, mg/kg)	FieldTurf 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2011) (mg/kg)	FieldTurf Crumb Rubber (2 Years of Age) (Lioy and Weisel, 2012) (mg/kg)
Bis(2-chloroisopropyl)ether								
Bis(2-ethylhexyl)phthalate								
Butylbenzyl phthalate								
Carbazole	<1.9	<0.09						
Chrysene	<5.5	<0.27						
Di-n-butylphthalate								
Di-n-octylphthalate								
Dibenz(a,h)anthracene	<10	<0.49						
Diethyl phthalate								
Dimethylphthalate								
Diphenylamine								
Fluoranthene	<0.62	<0.03						
Fluorene	<0.35	<0.02						
Hexachlorobenzene								
Hexachlorobutadiene								
Indeno(1,2,3-cd)pyrene								
Isophorone								
N-Nitrosodiphenylamine								
Naphthalene	<0.12	0.27						
Nitrobenzene								
Pentachlorophenol								
Phenanthrene	<0.52	<0.02						
Phenol								
Pyrene	<0.52	<0.02						

Chemical				Teter Engineering (2015 215-4633) for Sprinturf[6]			
	FieldTurf Crumb Rubber (6 Years of Age) (Lioy and Weisel, 2013) (mg/kg)	FieldTurf Rubber (SBR?) (Maxxam, 2009) (mg/kg)	FieldTurf Crumb Rubber (TestAmerica, 2009) (mg/kg)	FieldTurf 10-14 CRYO SBR (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf SBR (TestAmerica, 2011a) (mg/kg)	FieldTurf SBR (TestAmerica, 2011b) (mg/kg)	FieldTurf SBR - Wellesley (Conestoga-Rovers, 2008) (mg/kg)
Metals							
Antimony	NA	NA	<1				
Arsenic	<0.7	<6	<1				
Barium	NA	<5	3.9				
Beryllium	<0.7	NA	<0.4				
Cadmium	<0.7	<0.5	0.36				
Chromium	<0.7	<2.0	1.3				
Cobalt	NA	10	81				
Copper	20	20	19				
Lead	37	<5	36				
Magnesium							
Mercury	NA	NA	0.018				
Molybdenum	NA	4	5.6				
Nickel	NA	<1	3.1				
Selenium	<1.2	NA	1.4				
Silver	NA	<2	<0.5				
Thallium	NA	NA	0.34				
Titanium							
Vandium	0.73	NA	1.3				
Zinc	NA	940	12,000				
SVOCs and VOCs							
1,2-Dichlorobenzene				NA	<9.7	<62	NA
1,2,4-Trichlorobenzene				NA	<9.7	<62	NA
1,3-Dichlorobenzene				NA	<9.7	<62	NA
1,4-Dichlorobenzene				0.025	<9.7	<62	0.021
2-Chlorophenol				NA	<9.7	<62	NA
2,4-Dichlorophenol				NA	<9.7	<62	NA
2,4-Dimethylphenol				<0.990	<9.7	<62	<0.990
2,4-Dinitrophenol				NA	<19	<120	NA
2,4-Dinitrotoluene				NA	<9.7	<62	NA
2,4,5-Trichlorophenol				NA	<9.7	<62	NA
2,4,6-Trichlorophenol				NA	<9.7	<62	NA
3,3'-Dichlorobenzidine				NA	<24	<160	NA
Acenaphthene				0.13	<9.7	<62	<0.2
Acenapthylene							
Aniline				NA	NA	NA	NA
Anthracene				<0.2	<9.7	<62	<0.2
Azobenzene							
Benzo(a)anthracene				<0.2	<9.7	<62	<0.2
Benzo(a)pyrene				<0.2	<9.7	<62	<0.2
Benzo(b)fluoranthene				1.9	<9.7	<62	<0.2
Benzo(g, h, i)perylene							
Benzo(k)fluoranthene				<0.2	<9.7	<62	<0.2
Benzoic acid				NA	NA	NA	NA
Bis(2-chloroethyl)ether				4	<48	<31	<0.2

Table A-1 Comparison of Turf Chemical Content to Residential Soil Screening Levels

Chemical				Teter Engineering (2015 215-4633) for Sprinturf[6]			
	FieldTurf Crumb Rubber (6 Years of Age) (Lioy and Weisel, 2013) (mg/kg)	FieldTurf Rubber (SBR?) (Maxxam, 2009) (mg/kg)	FieldTurf Crumb Rubber (TestAmerica, 2009) (mg/kg)	FieldTurf 10-14 CRYO SBR (Conestoga-Rovers, 2008) (mg/kg)	FieldTurf SBR (TestAmerica, 2011a) (mg/kg)	FieldTurf SBR (TestAmerica, 2011b) (mg/kg)	FieldTurf SBR - Wellesley (Conestoga-Rovers, 2008) (mg/kg)
Bis(2-chloroisopropyl)ether				NA	<9.7	<62	NA
Bis(2-ethylhexyl)phthalate				170	90	160	<0.990
Butylbenzyl phthalate				NA	NA	NA	NA
Carbazole							
Chrysene				<0.2	<9.7	<62	<0.2
Di-n-butylphthalate				4.8	<9.7	<62	<0.990
Di-n-octylphthalate				<0.990	<9.7	<62	<0.990
Dibenz(a,h)anthracene				<0.2	<12	<78	<0.2
Diethyl phthalate				0.25	<9.7	<62	<0.990
Dimethylphthalate				<0.990	<9.7	<62	<0.990
Diphenylamine				NA	NA	NA	NA
Fluoranthene				7.4	<9.7	<62	<0.2
Fluorene				0.2	<9.7	<62	<0.2
Hexachlorobenzene				NA	<9.7	<62	NA
Hexachlorobutadiene				NA	<9.7	<62	NA
Indeno(1,2,3-cd)pyrene				<0.2	<9.7	<62	<0.2
Isophorone				NA	NA	NA	NA
N-Nitrosodiphenylamine				NA	NA	NA	NA
Naphthalene				1.5	<9.7	<62	<0.2
Nitrobenzene				NA	<9.7	<62	NA
Pentachlorophenol				NA	<24	<160	NA
Phenanthrene				3.6	<9.7	<62	<0.2
Phenol				1.9	<9.7	<62	<0.2
Pyrene				16	<9.7	<62	<0.2

Table A-2 Comparison of Airborne Concentrations of Turf Constituents to Residential Air Screening Levels

Chemical	Residential Screening Level (µg/m3)	Milone & MacBroom (2008 215-3891) (FieldTurf - Crumb Rubber)[1] Field F SF-1 ($\mu g/m^3$)	Field F SF-2 ($\mu g/m^3$)	Field F SF-3 ($\mu g/m^3$)	Field F SF-4 ($\mu g/m^3$)	Field F SF-5 ($\mu g/m^3$)	Field G SF-1 ($\mu g/m^3$)	Field G SF-2 ($\mu g/m^3$)	Field G SF-3 ($\mu g/m^3$)	Field G SF-4 ($\mu g/m^3$)	Field G SF-5 ($\mu g/m^3$)	NYC DHMH (2009 212-7391)[2] Synthetic Turf Fields (Range, $\mu g/m^3$)	Background - Grass/Upwind (Range, $\mu g/m^3$)	DPH (2010 212-739 Max. Detect at 4 Crumb Rubber Fields ($\mu g/m^3$)	A DRRR (2010 212-7602 Max. Detect in 4 Towns with Crumb Rubber Fields ($\mu g/m^3$)	ES (2007 215-460 Crumb Rubber (ng/mL air)	Thomas Jefferson Field Max. On-field ($\mu g/m^3$)
Metals																	
Cadmium	0.001											ND	ND				
Chromium	NI											0.87-1.4	ND-1.8				
Copper	NI											ND	ND				
Iron	NI											ND	ND				
Lead	0.15											ND	ND				
Manganese	0.0052											ND	ND				
Nickel	0.0094											ND	ND				
Silver	NI											ND	ND				
Tin	NI											ND	ND				
Zinc	NI											ND	ND-83				
Particulate Matter																	
PM 2.5	1.2											0.003-0.048	0.003-0.05				
PM 10	150																
PM 10 (Cr)	NI																
PM 10 (Pb)	0.15																
PM 10 (Zn)	NI																
SVOCs and VOCs																	
1,2,4-Trimethylbenzene	0.73														10.7		
1,3-Butadiene, 2-methyl	NI																
1,3-Pentadiene	NI																0.46
1,3-Pentadiene, (E-)	NI																NR
1,4-Dichlorobenzene	0.26																0.12
1,4-Pentadiene	NI																NR
1-Methylnapthalene	NI													9.3x10-3			
2-Butanone (MEK)	520											ND-3	ND	2.94			
2-Propanol	21														1.9		
4-(tert-octyl)phenol	NI	<0.19	<0.20	<0.19	<0.19	<0.20	<0.21	<0.21	<0.21	<0.21	<0.21					5.64	
4-Ethyltoluene	NI														6.3		
4-Methyl-2-pentanone	310													3.39			ND
Acenaphthene	NI											ND	ND				
Acenapthylene	NI											ND	ND	6.6x10-3			
Acetone	3200											9.3-51	ND-11	52.2			
Anthracene	NI											ND	ND				
Benzaldehyde, ethyl-	NI																
Benzene	0.36													1.56			0.4
Benzene, 1-ethyl-4-methyl	NI																0.41
Benzo(a)anthracene	0.0092											ND	ND	1.1x10-4			
Benzo(a)pyrene	0.00092											ND	ND	1.9x10-4			
Benzo(b)fluoranthene	0.0092											ND	ND	2.1x10-4			
Benzo(e)pyrene	NI													2.6x10-4			
Benzo(g, h, i)perylene	NI											ND	ND	1.4x10-4			
Benzo(k)fluoranthene	0.0092											ND	ND	8x10-5			
Benzothiazole	NI	<0.19	<0.20	<0.19	<0.19	<0.20	0.39	<0.21	<0.21	<0.21	<0.21	ND	ND	1.2		225.87	
Butane	NI																NR
Butylated hydroxyanisole (BHT alteration product)	49															13.89	

Table A-2 Comparison of Airborne Concentrations of Turf Constituents to Residential Air Screening Levels

Chemical	Residential Screening Level (µg/m3)	Milone & MacBroom (2008 215-3891) (FieldTurf - Crumb Rubber)[1]										NYC DHMH (2009 212-7391)[2]		DPH (2010 212-739	A DRRR (2010 212-7602	ES (2007 215-460	
		Field F SF-1 ($\mu g/m^3$)	Field F SF-2 ($\mu g/m^3$)	Field F SF-3 ($\mu g/m^3$)	Field F SF-4 ($\mu g/m^3$)	Field F SF-5 ($\mu g/m^3$)	Field G SF-1 ($\mu g/m^3$)	Field G SF-2 ($\mu g/m^3$)	Field G SF-3 ($\mu g/m^3$)	Field G SF-4 ($\mu g/m^3$)	Field G SF-5 ($\mu g/m^3$)	Synthetic Turf Fields (Range, $\mu g/m^3$)	Background - Grass/Upwind (Range, $\mu g/m^3$)	Max. Detect at 4 Crumb Rubber Fields ($\mu g/m^3$)	Max. Detect in 4 Towns with Crumb Rubber Fields ($\mu g/m^3$)	Crumb Rubber (ng/mL air)	Thomas Jefferson Field Max. On-field ($\mu g/m^3$)
Carbon Disulfide	73													0.47			
Carbon tetrachloride	0.47																
Chloroform	0.12											ND-2.9	ND				ND
Chromethane	9.4											ND-1.1	ND-1.1	1.7			
Chrysene	0.092											ND	ND	3.4x10-4			
Cyclohexane	630													17.5	1.2		
Cyclohexane, 1,1,3-trimethyl	NI																
Cyclohexane, 1,4-dimethyl	NI																
Decanal	NI																NR
Dibenz(a,h)anthracene	0.00084											ND	ND				
Dichlorodifluoromethane	10																
Ethanol	NI											6.2-22	5.1-8.9				
Ethyl benzene	1.1													4.29			
Fluoranthene	NI											ND	ND	6.8x10-3			
Fluorene	NI											ND	ND				
Freon 11	NI																0.34
Freon 113	NI																0.085
Freon 12	NI																
Heptane	NI													5.72			0.31
Hexadecane	NI															1.58	
Indeno(1,2,3-cd)pyrene	0.0092											ND	ND				
Isopropylbenzene	42 (cumene)														11.6		
Methylchloride	9.4 (chloromethane)																
Methylene Chloride	63											ND-9	ND-6.9	14.1			0.11
Naphthalene	0.083											ND	ND				
n-Hexane	73											ND-2.1	ND	31.3			
Nitrosodibutylamine (n-)	0.0018	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosodiethylamine (n-)	0.000024	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosodimethylamine (n-)	0.000072	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosodipropylamine (n-)	0.0014	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosomorpholine (n-)	0.0015	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosopiperidine (n-)	0.001	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nitrosopyrrolidine (n-)	0.0046	<1.1	<1.1	<1.4	<1.1	<1	<1.3	<1.4	<1.4	<1.4	<1.4						
Nonane	2.1																1.1
Pentane	100																
Pentane, 2-methyl	NI																
Phenanthrene	NI											ND	ND				
Pyrene	NI											ND	ND	6.9x10-3			
Styrene	100													1.96			
Toluene	520											ND-2.7	ND-2	52.7	6.4		
Trichloro-fluoromethane	73																
Trichloro-trifluoromethane	NI																
Xylenes	10													14.7	44.3		

Notes:

ND = Not Detected; NI = Not Identified; NR = Not Reported; SVOC = Semivolatile Organic Compound; VOC = Volatile Organic Compound.

(1) Data from Milone & MacBroom (2008, Section 2, Tables 2, 3, 5, and 6, pp. 10-11, 15).

(2) Data from NYC DHMH (2009, Table B-1, p.). Note, more chemicals were analyzed but they were ND.

(3) Data from CT DPH (2010, Table 2, p. 35). Note, more chemicals were analyzed but they were ND.

(4) Data from CA DRRR (2010, Table 11, p. 25). Note, more chemicals were analyzed but were left out because they were ND or considered contamination and not further evaluated.

(5) Data from CAES (2007, Table 2, p. 5). Out-gassing experiment. Note that the values were converted to $\mu g/m^3$ for comparison across studies.

(6) Data from NY DH (2009, Tables 8.4 and 8.5). Note, more chemicals were analyzed but they were not selected for health risk evaluation.

(7) Data from US EPA (2009, Table 6, p .31). Note, more chemicals were analyzed but they were not reported in summary tables. Note that the values were converted to $\mu g/m^3$ when necessary for comparison across studies.

Highlighted cells are those with values above their respective Residential Screening Level.

Data was not reported for blank cells.

Table A-2 Comparison of Airborne Concentrations of Turf Constituents to Residential Air Screening Levels

Chemical	NY DH (2009 215-4606)[6]					US EPA (2009 210-1256)[7]							
	Thomas Jefferson Field Upwind (μg/m³)	Thomas Jefferson Field Max. Downwind (μg/m³)	John Mullaly Field Max On-field (μg/m³)	John Mullaly Field Upwind (μg/m³)	John Mullaly Field Max. Downwind (μg/m³)	Synthetic Turf Field F1D1 - On-field (μg/m³)	Synthetic Turf Field F1D1 - Background (μg/m³)	Synthetic Turf Field F1D2 - On-field (μg/m³)	Synthetic Turf Field F1D2 - Background (μg/m³)	Synthetic Turf Field F2 - On-field (μg/m³)	Synthetic Turf Field F2 - Background (μg/m³)	Synthetic Turf Field F4 - On Field (μg/m³)	Synthetic Turf Field F4 - Background (μg/m³)
Metals													
Cadmium													
Chromium													
Copper													
Iron													
Lead													
Manganese													
Nickel													
Silver													
Tin													
Zinc													
Particulate Matter													
PM 2.5													
PM 10						27.8	29.5	29.8	29.5	NR	NR	31.8	28.6
PM 10 (Cr)						0.0029	0.002	0.0036	0.0033	NR	NR	ND	ND
PM 10 (Pb)						ND	ND	0.0077	0.0063	NR	NR	ND	ND
PM 10 (Zn)						0.0108	0.0238	0.0118	0.0116	NR	NR	0.0314	0.0217
SVOCs and VOCs													
1,2,4-Trimethylbenzene													
1,3-Butadiene, 2-methyl			NR	0.23	NR								
1,3-Pentadiene	1.1	0.58	NR	0.52	0.53								
1,3-Pentadiene, (E-)	NR	0.62											
1,4-Dichlorobenzene	0.18	0.13											
1,4-Pentadiene	NR	0.52											
1-Methylnapthalene													
2-Butanone (MEK)						1.39	1.30	1.12	1.06	1.21	1.09	1.27	1.30
2-Propanol													
4-(tert-octyl)phenol													
4-Ethyltoluene													
4-Methyl-2-pentanone	1.2	ND	ND	0.78	ND	0.53	ND	0.49	ND	ND	ND	ND	ND
Acenaphthene													
Acenapthylene													
Acetone			ND	0.56	ND								
Anthracene													
Benzaldehyde, ethyl-			NR	9.6	NR								
Benzene	0.54	0.41				0.29	0.22	0.26	0.29	0.35	0.38	0.64	0.38
Benzene, 1-ethyl-4-methyl	0.67	0.55											
Benzo(a)anthracene													
Benzo(a)pyrene													
Benzo(b)fluoranthene													
Benzo(e)pyrene													
Benzo(g, h, i)perylene													
Benzo(k)fluoranthene													
Benzothiazole			ND	6.5	ND								
Butane	0.48	0.34											
Butylated hydroxyanisole (BHT alteration product)													

Table A-2 Comparison of Airborne Concentrations of Turf Constituents to Residential Air Screening Levels

Chemical	NY DH (2009 215-4606)[6]					US EPA (2009 210-1256)[7]							
	Thomas Jefferson Field Upwind ($\mu g/m^3$)	Thomas Jefferson Field Max. Downwind ($\mu g/m^3$)	John Mullaly Field Max On-field ($\mu g/m^3$)	John Mullaly Field Upwind ($\mu g/m^3$)	John Mullaly Field Max. Downwind ($\mu g/m^3$)	Synthetic Turf Field F1D1 - On-field ($\mu g/m^3$)	Synthetic Turf Field F1D1 - Background ($\mu g/m^3$)	Synthetic Turf Field F1D2 - On-field ($\mu g/m^3$)	Synthetic Turf Field F1D2 - Background ($\mu g/m^3$)	Synthetic Turf Field F2 - On-field ($\mu g/m^3$)	Synthetic Turf Field F2 - Background ($\mu g/m^3$)	Synthetic Turf Field F4 - On Field ($\mu g/m^3$)	Synthetic Turf Field F4 - Background ($\mu g/m^3$)
Carbon Disulfide													
Carbon tetrachloride						0.57	0.63	0.63	0.63	0.57	0.50	0.57	0.63
Chloroform	0.15	0.084	ND	0.96	0.15								
Chromethane			ND	0.1	0.1								
Chrysene													
Cyclohexane													
Cyclohexane, 1,1,3-trimethyl			NR	0.6	NR								
Cyclohexane, 1,4-dimethyl			NR	1.1	NR								
Decanal	0.46	NR											
Dibenz(a,h)anthracene													
Dichlorodifluoromethane						2.57	2.72	2.47	2.77	2.77	2.52	2.37	2.67
Ethanol													
Ethyl benzene													
Fluoranthene													
Fluorene													
Freon 11	0.69	0.4	0.4	0.69	0.7								
Freon 113	0.13	0.1	0.092	0.22	0.16								
Freon 12			0.74	1	1.1								
Heptane	0.43	0.3											
Hexadecane													
Indeno(1,2,3-cd)pyrene													
Isopropylbenzene													
Methylchloride						0.97	0.99	0.97	0.95	0.93	0.93	0.99	1.07
Methylene Chloride	0.17	0.29	0.19	2.3	3	0.24	0.21	ND	ND	0.21	0.21	0.21	0.21
Naphthalene													
n-Hexane						0.74	0.21	0.28	0.28	0.28	0.18	0.49	0.18
Nitrosodibutylamine (n-)													
Nitrosodiethylamine (n-)													
Nitrosodimethylamine (n-)													
Nitrosodipropylamine (n-)													
Nitrosomorpholine (n-)													
Nitrosopiperidine (n-)													
Nitrosopyrrolidine (n-)													
Nonane	2.5	2.3											
Pentane			NR	0.46	NR								
Pentane, 2-methyl			NR	NR	0.35								
Phenanthrene													
Pyrene													
Styrene													
Toluene						1.58	0.57	0.41	0.45	0.68	0.72	1.05	0.72
Trichloro-fluoromethane						1.46	1.57	1.46	1.52	1.52	1.40	1.35	1.68
Trichloro-trifluoromethane						0.08 (ppbV)	0.08 (ppbV)	0.08 (ppbV)	0.08 (ppbV)	0.08 (ppbV)	0.07 (ppbV)	0.07(ppbV)	0.15 (ppbV)
Xylenes						0.74	0.35	0.43	ND	0.30	0.35	0.61	ND

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Guideline Level (µg/L)	Curtis & Tompkins (2011 215-4632)		Milone & MacBroom (2008 215-3891) (FieldTurf - Crumb Rubber)[2]						Teter Engineering (2015 215-4633) for Sprinturf[3]			
		Limonta Infill-Pro Geo (µg/L)	Limonta Turf-Max-S (µg/L)	Raw Crumb Rubber (µg/L)	Field F (4 months) (µg/L)	Field F (6 months) (µg/L)	Field G (6 months) (µg/L)	Field F (1 year) (µg/L)	Field E (4 months) (µg/L)	Green Crumb Rubber - SPLP 1 (µg/L)	Green Crumb Rubber - SPLP 2 (µg/L)	Black Crumb Rubber - SPLP 1 (µg/L)	Black Crumb Rubber - SPLP 2 (µg/L)
Metals													
Aluminum	4,000												
Antimony	120	ND	ND										
Arsenic	3	ND	ND	<4	<4	<4	<4	<4	<4				
Barium	120,000	430	ND	<50	<50	<50	<50	<50	<50				
Beryllium	20	ND	ND										
Bromide	NI	ND	ND										
Cadmium	80	ND	ND	<5	<5	<1	<1	<5	<5				
Calcium	NI												
Chromium	NI	ND	ND	<50	<50	<50	<50	<50	<50				
Cobalt	2,000	ND	ND										
Copper	26,000	ND	ND	<40	<40	<40	<40	NA	NA				
Iron	NI												
Lead	100	ND	ND	<13	<13	6	4	<13	<13				
Magnesium	NI												
Manganese	1,000												
Mercury	40	ND	ND	<2	<2	<2	<2	<2	<2				
Molybdenum	NI	ND	ND										
Nickel	2000 (soluble salts)	ND	ND	<50	<50	<50	<50	NA	NA				
Potassium	NI												
Selenium	800	ND	ND	<10	<10	<2	<2	<10	<10				
Silver	800	ND	ND	<20	<20	<20	<20	<20	<20				
Sodium	NI												
Thallium	10	ND	ND										
Vanadium	2	ND	ND										
Zinc	40,000	ND	ND	1600	910	1900	1100	2400	4700	8.4	110	38	69
SVOCs and VOCs													
1H-isoindole-1,3(2H)-dione	NI												
1,2-Dichlorobenzene	12,000												
1,2,4-Trichlorobenzene	180												
1,3-Dichlorobenzene	12,000												
1,4-Dichlorobenzene	1,500												
2-Chlorophenol	800												
2(3H)-benzothiazolone	NI												
2,4-Dichlorophenol	400												
2,4-Dimethylphenol	2,000												
2,4-Dinitrophenol	200												
2,4-Dinitrotoluene	NI												
2-Mercaptobenzothiazole	NI												
2-Methylphenol	NI												
2,4,5-Trichlorophenol	14,000												
2,4,6-Trichlorophenol	20												
4-Methylphenol	NI												
3,3'-Dichlorobenzidine	30												

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Guideline Level (µg/L)	Curtis & Tompkins (2011 215-4632)		Milone & MacBroom (2008 215-3891) (FieldTurf - Crumb Rubber)[2]						Teter Engineering (2015 215-4633) for Sprinturf[3]			
		Limonta Infill-Pro Geo (µg/L)	Limonta Turf-Max-S (µg/L)	Raw Crumb Rubber (µg/L)	Field F (4 months) (µg/L)	Field F (6 months) (µg/L)	Field G (6 months) (µg/L)	Field F (1 year) (µg/L)	Field E (4 months) (µg/L)	Green Crumb Rubber - SPLP 1 (µg/L)	Green Crumb Rubber - SPLP 2 (µg/L)	Black Crumb Rubber - SPLP 1 (µg/L)	Black Crumb Rubber - SPLP 2 (µg/L)
Acenaphthene	4,200												
Acetophenone	14,000												
Aniline	NI									<9.6	<9.4	<9.6	<9.4
Anthracene	43												
Benzaldehyde, 3-hydroxyl-4-methoxy	NI												
Benzo(a)anthracene	1												
Benzo(a)pyrene	0.1												
Benzo(b)fluoranthene	1												
Benzo(k)fluoranthene	0.8												
Benzoic Acid	NI												
Benzothiazole	NI												
Benzyl alcohol	NI												
Bis(2-chloroethyl)ether	7												
Bis(2-chloroisopropyl)ether	6,000												
Bis(2-ethylhexyl) phthalate	40												
Butylbenzyl phthalate	2,000												
Carbazole	NI												
Chrysene	2												
Cyclohexane, isothiocyanato-	NI												
Cyclohexaneamine, N-cyclohexyl	NI												
Cyclohexanone	NI												
Dibenz(a,h)anthracene	0.3												
Diethyl phthalate	120,000												
Dimethylphthalate	NI												
Di-n-butyl phthalate	11,000												
Di-n-octylphthalate	20												
Diphenylamine	NI												
Fluoranthene	210												
Fluorene	2000												
Formamide, N-cyclohexyl-	NI												
Hexachlorobenzene	0.4												
Hexachlorobutadiene	8 (Hexachloro-1,3-butadiene)												
Hexanedioic acid, bis(2-ethylhexyl)	NI												
Indeno(1,2,3-cd)pyrene	0.2												
Isophorone	800												
Methane, diethoxy-cyclohexane	NI												
Methyl isobutyl ketone	NI												
Napthalene	6,000												
Nitrobenzene	80												
n-Nitrosodiphenylamine	140												
o-cyanobenzoic acid	NI												
Pentachlorophenol	6												

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Guideline Level (µg/L)	Curtis & Tompkins (2011 215-4632)		Milone & MacBroom (2008 215-3891) (FieldTurf - Crumb Rubber)[2]						Teter Engineering (2015 215-4633) for Sprinturf[3]			
		Limonta Infill-Pro Geo (µg/L)	Limonta Turf-Max-S (µg/L)	Raw Crumb Rubber (µg/L)	Field F (4 months) (µg/L)	Field F (6 months) (µg/L)	Field G (6 months) (µg/L)	Field F (1 year) (µg/L)	Field E (4 months) (µg/L)	Green Crumb Rubber - SPLP 1 (µg/L)	Green Crumb Rubber - SPLP 2 (µg/L)	Black Crumb Rubber - SPLP 1 (µg/L)	Black Crumb Rubber - SPLP 2 (µg/L)
Phenanthrene	NI												
Phenol	40,000									37	15	37	15
Phthalimide	NI												

Notes:

NA = Not Analyzed; ND = Not Detected; NI = Not Identified; SBR = Styrene Butadiene Rubber; SPLP = Synthetic Precipitation Leachate Procedure; SVOC = Semivolatile Organic Compound; TCLP = Toxicity Characteristic Leaching Procedure;

(1) Data from Curtis & Tompkins (2011, pp. 13-14).

(2) Data from Milone & MacBroom (2008, Section 3, Table 4, p. 7). Note that the values were converted to µg/L for comparison across studies.

(3) Data from Teter Engineering (2015, Table 2).

(4) Data from Baumann (2014, Table 1, p. 5).

(5) Data from CAES (2007, Table 3, p. 6).

(6) Data from NY DH (2009, Tables 2.2, 2.3, and 2.4). Note, more chemicals were analyzed but they were ND.

(7) Data from OEEHA (2007, Table 14, p. 54). Note, more chemicals were analyzed but they were not reported in summary table.

(8) Data from Teter Engineering (2015, Tables A-2 and A-4).

Highlighted cells are those with values above their respective Residential Screening Level.

Data was not reported for blank cells.

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Baumann (2014 215-4638)[4]	CAES (2007 215-4603)[5]		NY DH (2009 215-4606)[6]	OEEHA (2007 215-4614)[7]					
	Synthetic Turf (μg/L)	Crumb Rubber - Amount in Water (μg/kg tire)	Crumb Rubber - Amount in Acidified Water (μg/kg tire)	Crumb Rubber (31 samples, average μg/L)	Tire Sample "G" (μg/L)	Tire Sample "S" (μg/L)	Tire Sample "C" (μg/L)	FieldTurf - SPLP 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (μg/L)	FieldTurf - SPLP Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (μg/L)	FieldTurf- SPLP Cryogenic Crumb Rubber (A-1007/T12) (Li *et al*., 2010a) (μg/L)
Metals										
Aluminum				ND						
Antimony				ND	110	42	1.7	<10	<10	NA
Arsenic	<50			ND	6.1	5.4	4.7	<10	<10	<3.0
Barium				30.4	130	110	870	6.3	0.74	13
Beryllium				ND				<4	<4	NA
Bromide										
Cadmium	<4	0.07	0.26	ND	2.2	2.8	1.1	<5	<5	<1
Calcium				2443.5						
Chromium	<5			ND	41	57	35	<5	1.7	<1
Cobalt				ND	45	50	33	1.4	<50	NA
Copper				9.8	1500	960	1600	0.93	5	0.69
Iron				1704.8						
Lead	<40	1.85	3.26	12.8	140	120	48	<100	<100	0.19
Magnesium				ND						
Manganese				20.7						
Mercury	<0.5			ND				<0.2	<0.2	NA
Molybdenum				ND	11	18	8.5	NA	NA	NA
Nickel				ND	27	27	22	<40	<40	0.65
Potassium				ND						
Selenium		246	260	ND	18	10	7.1	NA	NA	NA
Silver				ND				<5	<5	NA
Sodium				ND						
Thallium				ND				<10	<10	NA
Vanadium				ND	9	9.5	5.8	<50	1.1	NA
Zinc	95	20957	55010	1947.4	17000	26000	13000	342	4.3	2,450
SVOCs and VOCs										
1H-isoindole-1,3(2H)-dione					ND	490	ND			
1,2-Dichlorobenzene								NA	NA	NA
1,2,4-Trichlorobenzene								NA	NA	NA
1,3-Dichlorobenzene								NA	NA	NA
1,4-Dichlorobenzene								<5.0	<5.0	NA
2-Chlorophenol								NA	NA	NA
2(3H)-benzothiazolone				261.9	640	450	480			
2,4-Dichlorophenol								NA	NA	NA
2,4-Dimethylphenol				2.6				2.7	<10	NA
2,4-Dinitrophenol								NA	NA	NA
2,4-Dinitrotoluene								NA	NA	NA
2-Mercaptobenzothiazole				52.4						
2-Methylphenol				1.4						
2,4,5-Trichlorophenol								NA	NA	NA
2,4,6-Trichlorophenol								NA	NA	NA
4-Methylphenol				3.2						
3,3'-Dichlorobenzidine								NA	NA	NA

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Baumann (2014 215-4638)[4]	CAES (2007 215-4603)[5]		NY DH (2009 215-4606)[6]	OEEHA (2007 215-4614)[7]					
	Synthetic Turf (µg/L)	Crumb Rubber - Amount in Water (µg/kg tire)	Crumb Rubber - Amount in Acidified Water (µg/kg tire)	Crumb Rubber (31 samples, average µg/L)	Tire Sample "G" (µg/L)	Tire Sample "S" (µg/L)	Tire Sample "C" (µg/L)	FieldTurf - SPLP 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - SPLP Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (µg/L)	FieldTurf- SPLP Cryogenic Crumb Rubber (A-1007/T12) (Li *et al* ., 2010a) (µg/L)
Acenaphthene								<2.0	<2.1	NA
Acetophenone				2.3						
Aniline				103.4	2800	3000	6700	<2.0	<2.1	NA
Anthracene								<2.0	<2.1	NA
Benzaldehyde, 3-hydroxyl-4-methoxy					ND	ND	ND			
Benzo(a)anthracene								<2.0	<2.1	NA
Benzo(a)pyrene								<2.0	<2.1	NA
Benzo(b)fluoranthene								<2.0	3.9	NA
Benzo(k)fluoranthene								<2.0	<2.1	NA
Benzoic Acid				19.8				NA	NA	NA
Benzothiazole				526.3	320	450	390			
Benzyl alcohol				2.8						
Bis(2-chloroethyl)ether								<2.0	<2.1	NA
Bis(2-chloroisopropyl)ether								NA	NA	NA
Bis(2-ethylhexyl) phthalate				1.6				<10	<10	NA
Butylbenzyl phthalate								<10	<10	NA
Carbazole				1.4						
Chrysene								<2.0	<2.1	NA
Cyclohexane, isothiocyanato-				129.6						
Cyclohexaneamine, N-cyclohexyl				208.1	190	410	ND			
Cyclohexanone					ND	ND	48			
Dibenz(a,h)anthracene								<2.0	<2.1	NA
Diethyl phthalate				1.7				3	<10	NA
Dimethylphthalate								<10	<10	NA
Di-n-butyl phthalate				1.2				<10	<10	NA
Di-n-octylphthalate								4.1	<10	NA
Diphenylamine										
Fluoranthene								<2.0	<2.1	NA
Fluorene								<2.0	<2.1	NA
Formamide, N-cyclohexyl-					ND	ND	110			
Hexachlorobenzene								NA	NA	NA
Hexachlorobutadiene								NA	NA	NA
Hexanedioic acid, bis(2-ethylhexyl)					ND	ND	ND			
Indeno(1,2,3-cd)pyrene								<2.0	<2.1	NA
Isophorone				3.6				NA	NA	NA
Methane, diethoxy-cyclohexane				330						
Methyl isobutyl ketone				173.5						
Napthalene				1.4				0.93	<2.1	NA
Nitrobenzene								NA	NA	NA
n-Nitrosodiphenylamine				3.6				NA	NA	NA
o-cyanobenzoic acid					990	ND	910			
Pentachlorophenol								NA	NA	NA

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Baumann (2014 215-4638)[4]	CAES (2007 215-4603)[5]		NY DH (2009 215-4606)[6]	OEEHA (2007 215-4614)[7]					
	Synthetic Turf (µg/L)	Crumb Rubber - Amount in Water (µg/kg tire)	Crumb Rubber - Amount in Acidified Water (µg/kg tire)	Crumb Rubber (31 samples, average µg/L)	Tire Sample "G" (µg/L)	Tire Sample "S" (µg/L)	Tire Sample "C" (µg/L)	FieldTurf - SPLP 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - SPLP Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (µg/L)	FieldTurf- SPLP Cryogenic Crumb Rubber (A-1007/T12) (Li *et al*., 2010a) (µg/L)
Phenanthrene								<2.0	0.76	NA
Phenol				12.8	190	ND	ND	35	0.86	NA
Phthalimide				108.6						

: VOC = Volatile Organic Compound.

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Teter Engineering (2015 215-4633) for Sprinturf[8] FieldTurf- SPLP Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf- SPLP Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf - TCLP 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - TCLP Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - WET SBR (TestAmerica, 2011a) (µg/L)	FieldTurf - WET SBR (TestAmerica, 2011b) (µg/L)
Metals						
Aluminum						
Antimony	<1	<1	NA	NA	<200	<200
Arsenic	<1.2	<1.2	130	140	<200	<200
Barium	2.8	<1	29	2.5	220	<200
Beryllium	<4.3	<4.3	NA	NA	<80	<80
Bromide						
Cadmium	<1.3	<1.3	<100	<100	<100	<100
Calcium						
Chromium	<1	<1	3	3.5	100	<100
Cobalt	1.1	2.4	NA	NA	<200	<200
Copper	<1	9.7	NA	NA	880	310
Iron						
Lead	<1	<1	3.3	<500	<100	<100
Magnesium						
Manganese						
Mercury	<0.2	<0.2	<2	<2	<2	<2
Molybdenum	<3.2	<3.2	NA	NA	<400	<400
Nickel	<3.0	<3.0	NA	NA	<200	<200
Potassium						
Selenium	<1	<1	<250	<250	<200	<200
Silver	<1	<1	<500	<500	<200	<200
Sodium						
Thallium	<1	<1	NA	NA	<200	<200
Vanadium	<1.1	<1.1	NA	NA	<200	<200
Zinc	240	870	NA	NA	15,000	5,900
SVOCs and VOCs						
1H-isoindole-1,3(2H)-dione						
1,2-Dichlorobenzene	<10	<10	NA	NA		
1,2,4-Trichlorobenzene	<10	<10	NA	NA		
1,3-Dichlorobenzene	<10	<10	NA	NA		
1,4-Dichlorobenzene	<10	<10	<50	<50		
2-Chlorophenol	<10	<10	NA	NA		
2(3H)-benzothiazolone						
2,4-Dichlorophenol	<10	<10	NA	NA		
2,4-Dimethylphenol	<10	<10	NA	NA		
2,4-Dinitrophenol	<50	<51	NA	NA		
2,4-Dinitrotoluene	<10	<10	<50	<50		
2-Mercaptobenzothiazole						
2-Methylphenol						
2,4,5-Trichlorophenol	<10	<10	<50	<50		
2,4,6-Trichlorophenol	<10	<10	<50	<50		
4-Methylphenol						
3,3'-Dichlorobenzidine	<20	<20	NA	NA		

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Teter Engineering (2015 215-4633) for Sprinturf[8]					
	FieldTurf- SPLP Ambient Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf- SPLP Cryogenic Crumb Rubber (Curtis & Tompkins, 2013b) (µg/L)	FieldTurf - TCLP 10-14 Cryogenic Crumb Rubber (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - TCLP Crumb Rubber (Wellesley Field) (Conestoga-Rovers, 2008) (µg/L)	FieldTurf - WET SBR (TestAmerica, 2011a) (µg/L)	FieldTurf - WET SBR (TestAmerica, 2011b) (µg/L)
Acenaphthene	<10	<10	NA	NA		
Acetophenone						
Aniline	<10	<10	NA	NA		
Anthracene	<10	<10	NA	NA		
Benzaldehyde, 3-hydroxyl-4-methoxy						
Benzo(a)anthracene	<10	<10	NA	NA		
Benzo(a)pyrene	<10	<10	NA	NA		
Benzo(b)fluoranthene	<10	<10	NA	NA		
Benzo(k)fluoranthene	<10	<10	NA	NA		
Benzoic Acid	<50	<51	NA	NA		
Benzothiazole						
Benzyl alcohol						
Bis(2-chloroethyl)ether	<10	<10	NA	NA		
Bis(2-chloroisopropyl)ether	<10	<10	NA	NA		
Bis(2-ethylhexyl) phthalate	<10	11	NA	NA		
Butylbenzyl phthalate	<10	<10	NA	NA		
Carbazole						
Chrysene	<10	<10	NA	NA		
Cyclohexane, isothiocyanato-						
Cyclohexaneamine, N-cyclohexyl						
Cyclohexanone						
Dibenz(a,h)anthracene	<10	<10	NA	NA		
Diethyl phthalate	<10	<10	NA	NA		
Dimethylphthalate	<10	<10	NA	NA		
Di-n-butyl phthalate	<10	<10	NA	NA		
Di-n-octylphthalate	<10	<10	NA	NA		
Diphenylamine						
Fluoranthene	<10	<10	NA	NA		
Fluorene	<10	<10	NA	NA		
Formamide, N-cyclohexyl-						
Hexachlorobenzene	<10	<10	<50	<50		
Hexachlorobutadiene	<10	<10	<50	<50		
Hexanedioic acid, bis(2-ethylhexyl)						
Indeno(1,2,3-cd)pyrene	<10	<10	NA	NA		
Isophorone	<10	<10	NA	NA		
Methane, diethoxy-cyclohexane						
Methyl isobutyl ketone						
Napthalene	<10	<10	NA	NA		
Nitrobenzene	<10	<10	<50	<50		
n-Nitrosodiphenylamine	<10	<10	NA	NA		
o-cyanobenzoic acid						
Pentachlorophenol	<20	<20	<250	<250		

Table A-3 Comparison of Turf Leaching Results to Regulatory Guideline Levels

Chemical	Teter Engineering (2015 215-4633) for Sprinturf[8]					
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Phenanthrene	<10	<10	NA	NA		
Phenol	<10	<10	NA	NA		
Phthalimide						

Appendix B

Conclusions From Regulatory and Other Agencies

Appendix B: Conclusions From Regulatory and Other Agencies

California Office of Environmental Health Hazard Assessment (2007)

- In 2007, CalOEHHA performed an extensive evaluation of possible exposure to and effects from chemicals in SBR. They evaluated ingestion, gastric bioavailability, and chronic hand-to-mouth activity. The performed a detailed risk assessment that involved calculating hazard indices and cancer risks for these scenarios. They found that none of the scenarios evaluated were associated with unacceptable risks.
- CalOEHHA acknowledges limitations of its study, including uncertainties that might increase or decrease risk estimates, as well as uncertainty in the data evaluated. They also did not perform an evaluation of possible risks related to inhalation exposure.

Connecticut Agricultural Experiment Station (2007)

- This is a "very modest study" of artificial turf infill conducted to determine if compounds volatilized from infill and whether chemicals could leach from the infill. The authors concluded that chemicals did volatilize (including benzothiazole) and leach (zinc, selenium, lead, and cadmium) from the materials under laboratory conditions. They further state that additional data should be collected, in particular from field studies. No statements related to the health implications of the volatilization or leaching are provided.

Connecticut Department of Public Health (2007)

- This "Technical Fact Sheet" was produced in response to concerns related to exposures from artificial turf. It is a general review of the literature available at the time. The authors note that people are exposed to the chemical of concern (metals, PAHs, particulate matter) during everyday activity, and also note that in some urban areas approximately 1-2% of the ambient particulate matter is composed of tire material.
- The evaluation concludes, "Based upon the current evidence, a public health risk appears unlikely. DPH does not believe there is a unique or significant exposure from chemicals that can be inhaled or ingested at these fields. However, there is still uncertainty and additional investigation is warranted."

New Jersey Dept. of Environmental Protection (2007)

- This document is a literature review and evaluation of possible toxicity from ingestion, dermal, and inhalation of component of artificial turf. In general, the authors states that there is not enough information to complete a standard risk assessment. However, the evaluation concludes, "…with the possible exception of allergic reactions among individuals sensitized to latex, rubber and related products, there was no obvious toxicological concern raised that crumb rubber in its intended outdoor use on playgrounds and playing fields would cause adverse health effects in the normal population."

CDC (2008)

- This document is a CDC health advisory that is related to lead samples taken on artificial turf fields. The advisory notes that nylon/polyethylene blend turf fibers may have levels of lead that are a public health concern. Fields with polyethylene fibers only had low levels of lead.
- As noted previously, after 2008 the lead content of artificial turf fields has decreased substantially.

Consumer Product Safety Commission (2008a)

- This is a limited study that evaluated potential risks from exposure to lead at artificial turf fields. The evaluation concluded that young children are not at risk from exposure to lead in these fields. The limitations of the study are explicitly addressed, including sample uniformity, sample method quality, and the uncertain bioavailability of lead from fields.

TRC/New York City Department of Health and Mental Hygiene (2008)

- This document is a literature review and compilation of the other risk assessments conducted up until 2008. They note that, "Eleven different risk assessments applied various available concentrations of COPCs [Chemicals of Potential Concern] and none identified an increased risk for human health effects as a result of ingestion, dermal or inhalation exposure to crumb rubber."

New York City Department of Health and Mental Hygiene (2009)

- Based upon possible data gaps from an earlier review of the literature, an air monitoring study was conducted to determine concentrations of SVOCs, VOCs, metals, and particulate matter above artificial turf fields.
- The only chemicals detected were considered to be either a) at similar levels to background samples, or b) at levels below those associated with possible health effects. None of the PAHs were detected, and a marker for synthetic rubber (benzothiazole) was also not detected.
- Based on the lack of detected and/or elevated concentrations, a risk assessment was not deemed to be necessary. The report did note that one bulk sample contained elevated levels of lead. However, since this time period the levels of lead used in artificial turf products has decreased significantly.

New York State Department of Environmental Conservation (2009)

- This study evaluated the potential toxicity associated with SBR using a number of different experiments.
- The leaching investigation (using the SPLP protocol) found that "Zinc (solely from truck tires), aniline, and phenol have the potential to be released above groundwater standards or guidance

values." However, when the New York dilution-attenuation factor was applied to the results, it indicated that there was unlikely to be an impact on groundwater.

- An evaluation of SBR digested in acid revealed that the levels of lead did not exceed federal standards.
- Ambient air sampling at artificial turf fields did not reveal concentrations that were above normal urban levels or above health guideline levels. Particulate matter samples were not elevated, which the authors indicate is likely because most of the particulate in SBR is not the respirable size range. They conclude, "A public health evaluation was conducted on the results from the ambient air sampling and concluded that the measured levels of chemicals in air at the Thomas Jefferson and John Mullaly Fields do not raise a concern for non-cancer or cancer health effects for people who use or visit the fields."
- Limitations of this study are discussed by the authors, "This report is not intended to broadly address all synthetic turf issues, including the potential public health implications associated with the presence of lead-based pigments in synthetic turf fibers."

US EPA (2009)

- The US EPA conducted a limited scale air monitoring study for VOCs and particulate matter at several artificial turf fields in 2008. In addition, they analyzed multiple artificial turf and wipe samples.
- The air monitoring results did not find that particulate matter or VOCs were elevated above background at the fields, with the exception of one detection of methyl isobutyl ketone. Concentrations of lead in the extraction tests were below levels of concern. The authors note that the aggressive nature of the extraction tests likely overestimates the availability of metals from SBR.
- The report concludes, "On average, concentrations of components monitored in this study were below levels of concern; however, given the very limited nature of this study (i.e., limited number of components monitored, samples sites [sic], and samples taken at each site) and the wide diversity of tire crumb material, it is not possible to reach any more comprehensive conclusions without the consideration of additional data."

Connecticut Dept. of Public Health (2010)

- This evaluation involved air sampling at four outdoor fields and one indoor field in Connecticut, as well as laboratory off-gas studies. A human health risk assessment was prepared using the analytical results.
- The study reported that 27 chemicals were evaluated in the risk assessment due to their detection above the indoor or outdoor fields, and the fact that they were potentially associated with the artificial surface. The authors indicate that conservative, health protection assumptions were used in their assessment.
- The authors report that despite the conservative nature of the assessment, only the indoor scenario showed a risk (slightly) above *de minimis* levels. Non-cancer hazards were not elevated in any scenario. The evaluation concludes, "Based upon these findings, the use of outdoor and indoor artificial turf fields is not associated with elevated health risks."

- The results of this Connecticut study have been published in three peer-reviewed articles (Ginsberg *et al*., 2011a,b; Simcox *et al*., 2011).

Mount Sinai Children's Environmental Health Center (Undated)

- This document is a fact sheet that presents a brief review of the literature. Potential exposure routes, chemical of concern, and exposure levels are discussed. The fact sheet notes that exposure where health effects have been observed from chemicals associated with artificial turf infills are much higher than exposures at artificial turf fields. Several recommendations for minimizing exposure (washing, wearing shoes, *etc.*) are presented.

New Jersey Dept. of Environmental Protection (2011)

- This document presents the results of a limited study of airborne lead concentrations associated with several artificial turf fields in New Jersey. The study observed higher levels of lead were detected during sampling with either a robotic sampler or a soccer player. They also found that where significant amounts of lead were found *via* wipe samples at a field that there was the potential for inhalation exposure. The author concluded, "While it is not possible to draw broad conclusions from this limited sample of fields the results suggest that there is a potential for inhalable lead to be present on turf fields that have significant amounts of lead present as detectable by surface wipes. It also would appear likely from this sample that if the lead is present to any appreciable extent in the wipes it will likely be present in the breathing zone of players who are active on these fields, and that furthermore, these levels potentially exceed ambient EPA standards."
- The levels found in ambient air at fields where high lead levels were observed were approximately half of the US EPA guideline level for lead.

CalOEHHA (2010)

- CalOEHHA undertook a second evaluation of artificial turf in 2010 under contract to the California Department of Resources Recycling and Recovery. The primary focus of their evaluation was VOC and PM2.5 (including metals) concentrations above playing fields using SBR.
- The PM2.5 (and associated metals) samples did not show elevations above the detection limit or normal background. Most VOCs were also below the limit of detection. For those VOCs that were detected, they were generally not consistent across the fields evaluated. Regardless, seven VOCs were evaluated in a screening risk assessment and all were found to be below health based screening levels.
- Interestingly, the report notes that increasing temperatures were not correlated with increasing VOC levels from the fields.

Consumer Product Safety Commission (2013)

- This document is a letter response to an appeal from Public Employees for Environmental Responsibility (PEER). PEER appealed for the removal of CPSC's conclusions regarding artificial turf from 2008, specifically the conclusion in the 2008 press release, "OK to install, OK to play on." PEER believed that headline was misleading given the limited scope of the study. They specifically requested the removal of all materials related to artificial turf from the CPSC's website, the dissemination of a warning regarding exposure to contaminants in artificial turf, and the commissioning of an ambient air study of artificial turf fields.
- The letter denies the appeal request, except for adding an explanatory note about the limitations of the study to the previously posted press release.
- There have been subsequent news stories (*e.g.*, Stockman, 2015) indicating that CPSC has withdrawn its determination that artificial turf is safe. However, we were unable to find any documentation of that on their website, and the 2008 press release (with the added note) is still posted. It is uncertain what these news reports are referring to, but it is possible that the addition of the note on limitations was misinterpreted as a retraction.

Connecticut Dept. of Public Health (2015)

- This document is a letter in response to concerns expressed by a university soccer coach regarding possible cancer clusters related to artificial turf fields. The Connecticut Department of Public Health reiterated its opinion that "…outdoor artificial turf fields do not represent an elevated health risk…"
- The document also states that the cancer cluster reports are anecdotal in nature, and the current news reports of cancer "…does not constitute a correlation or causality and thus raises a concern that currently lacks scientific support."
- Subsequent investigations of this proposed cancer cluster have raised doubts about its validity (Green, 2015), however, as Dr. Green notes in her review there has been no systematic collection of data for these cases so a cluster investigation is not possible currently.

Massachusetts Dept. of Public Health (2015)

- This document is a letter reviewing more recent literature and risk assessment related to artificial turf components. In addition, the author discussed the possible cancer cluster discussed above.
- The review indicates that the recent literature continues to "…suggest that exposure opportunities to artificial turf fields are not generally expected to result in health effects." In addition, the author discusses several issues related to the proposed cluster, including the wide variety of cancers reported.