Report to the Legislature

Report on Health Impacts of Outdoor Artificial and Natural Turf Fields

California Department of Resources Recycling and Recovery

October 2010

This report can be found on the Internet at www.calrecycle.ca.gov/Tires/2011007.pdf

Publication # DRRR-2011-007

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I. Executive Summary

Recent use of outdoor athletic fields made from artificial turf containing recycled crumb rubber (often derived from waste tires) has generated concerns as to whether these fields adversely impact human health. This report looks into the possible human health risks of these fields with respect to four subjects: skin abrasions, bacteria harbored by the turf, inhalable particulate matter, and volatile organic compounds. Based on its analysis of the data collected for this study, the California Office of Environmental Health Hazard Assessment (OEHHA) concluded these fields do not pose a serious public health concern, with the possible exception of an increased skin abrasion rate on artificial turf relative to natural turf.

OEHHA's field sampling looked into the potential for inhaling harmful materials (particulate matter and volatile organic compounds) and showed the concentrations of these materials above these fields were either below the health screening levels or similar to the concentrations in the surrounding area (in the latter case suggesting the artificial turf fields are not the source of the material). The number of skin abrasions suffered on artificial turf fields was found to be two to three-fold greater than on natural turf fields, but the severity of those abrasions did not differ significantly between the two surfaces. Skin abrasions are of concern since those serious enough to serve as portals of entry for bacteria could lead to infections by methicillin-resistant *Staphylococcus aureus* (MRSA). Artificial turf fields were found to harbor fewer bacterial species and a smaller number of live bacteria than natural turf fields. All of these data taken together, along with data that currently exist from other studies, suggest outdoor artificial turf fields do not represent a serious human health risk with regard to the inhalation of chemicals or particulates above these fields. While the smaller number of bacteria detected on artificial turf tends to lessen the risk of skin infection, the greater number of skin abrasions tends to increase the risk.

II. Introduction

Artificial turf fields currently exist in at least two forms or "generations." The older generation is constructed similarly to outdoor carpeting (e.g., Astroturf), consisting of a backing material to which artificial "blades" of grass are directly attached. The newer generation consists of an "infill" layer of crumb rubber (i.e., finely ground rubber particles, from new rubber or waste tires) and/or sand, on top of which is placed plastic netting that holds the plastic "blades." The new generation of artificial turf field is by far the most common type installed today for sports-playing surfaces and is used in both indoor and outdoor applications, mostly as football and soccer fields.

The infill material used for these new generation artificial turf fields, particularly crumb rubber from old tires, has been the source of concern for city and school officials who have installed the fields, as well as for parents of athletes and the athletes themselves. This is because crumb

rubber from old tires has the potential to present several health hazards including, but not limited to, inhalable particulate matter, heavy metals, and volatile organic compounds. Concerns also have been raised regarding how these fields affect the number and severity of injuries to athletes as well as the potential for causing bacterial infection, particularly from the methicillin-resistant strain of *Staphylococcus aureus* (MRSA), a bacterium responsible for several difficult-to-treat infections in humans.

To address these concerns in a California context, Senate Bill 1277 (Maldonado, Chapter 398, Statutes of 2008) required CalRecycle (the Department of Resources Recycling and Recovery, which replaced the California Integrated Waste Management Board) to prepare, in consultation with the Office of Environmental Health Hazard Assessment (OEHHA) and the Department of Public Health (DPH), a study that assesses the effects of artificial turf on human health and the environment.

To accomplish this, in June 2008 CalRecycle entered into an Interagency Agreement with OEHHA to study the effects of the new generation of artificial turf fields on human health and the environment. The scope of this study included five sections:

1. A literature review to understand more fully the existing body of knowledge on the subject and to determine critical gaps in that knowledge.
2. A survey to determine the number and severity of skin abrasions to athletes on artificial turf fields in comparison to those on natural turf fields.
3. A field study to measure the numbers and types of bacteria harbored by artificial turf relative to natural turf.
4. A field study to determine the amount and composition of inhalable particulate matter (PM 2.5) above the fields as well as the risk to human health (if any) posed by these emissions.
5. A field study to determine the amount and composition of the volatile organic compounds (VOCs) above both artificial and natural turf fields as well as the risk to human health (if any) posed by these emissions.

This report to the Legislature in fulfillment of the requirements of SB 1277 first summarizes the primary findings of OEHHA's literature review, and then the primary findings from OEHHA's survey and field sampling. OEHHA's full report to CalRecycle is available at the following link: http://www.calrecycle.ca.gov/Publications/Tires/2010009.pdf

III. Results of the OEHHA Study

Literature Review and Data Gap Analysis

OEHHA's literature review and data gap analysis focused on published studies that pertained to the scope of this project (PM 2.5, VOCs, abrasions and bacteria), including two very recent reports from the state and city of New York. Based on this review, OEHHA concluded that "Totals of 65 and 85 chemicals were identified at relatively low concentrations in the air above

the two fields [in the two New York studies]. Many of these occurred at similar concentrations in the air sampled upwind of the fields. Concentrations of particulates above the fields were similar to the levels upwind of the fields. Both reports concluded that these fields did not constitute a serious public health concern, since cancer or non-cancer health effects were unlikely to result from these low-level exposures."

OEHHA also identified eight data gaps that either were not covered in existing studies or were not covered adequately:

1. *A comprehensive study similar to that of Dye et al. (2006) is needed to identify the chemicals and particulates in the air over **outdoor** artificial turf fields. Using the indoor data from Dye et al. (2006) for estimating the health risks from outdoor fields probably overestimates those risks.*
2. *Dye et al. (2006) did not determine what amount of each chemical was released by the artificial turf field and what amount was present in the ambient air. Therefore, a study of **outdoor** artificial turf fields should include measurements from both above the fields and off of the fields.*
3. *No study has measured the metals content of the particulates within the respirable range (PM 2.5) released by artificial turf fields. In addition, it is not known if field use increases particulate release.*
4. *The variables of field age and field temperature should be monitored to determine whether they influence the release of chemicals and particulates into the air above these fields.*
5. *Data are needed for the amount of time athletes spend on artificial turf playing fields in order to accurately calculate their exposure to any chemicals or particulates they release. Data are needed for a variety of sports, age groups, and for both men and women. Other subgroups with potentially heavy exposure to fields include coaches, referees, and maintenance workers.*
6. *Only a single study was located that compared the rate of skin abrasions on the new generation of artificial turf to natural turf. This was for high school football. Similar studies are needed for other sports, age groups, and for both male and female athletes.*
7. *No data were located on the seriousness of the skin abrasions suffered by athletes on the new generation of artificial turf compared to natural turf.*
8. *The bacterium MRSA has not been detected in artificial turf fields. However, fields in California have not been tested. Therefore, fields from different regions of the state should be tested to verify that the new generation of artificial turf does not harbor MRSA or other bacteria pathogenic to humans.*

In its subsequent work as part of this study, OEHHA addressed a number of these data gaps by: 1) surveying athletic trainers about skin abrasion rates during intercollegiate soccer games; and 2) sampling artificial and natural turf fields during 2009 and 2010 for the presence of bacteria (including MRSA) in components of the fields and for concentrations of VOCs and PM2.5 in the air above the fields. Results of these surveys and sampling events are described below.

Challenges Encountered in OEHHA's Field Study

A number of challenges were encountered during this project. Most notable among these challenges was gaining permission to test on the artificial turf fields and the ability to test for VOCs during appropriately hot days of at least 90 degrees Fahrenheit. Hot days are needed because VOC emissions can increase as the field temperature increases. While these challenges were not sufficient to halt the progress of the study, additional time and resources were required to address them.

Many owners of fields were not comfortable having their fields used for this study and felt that doing so would make the users of the fields uncomfortable. They were also uneasy about the results of the testing and what that might mean for their operations, whether they would have to remove the fields, or whether people would stop using their fields

To determine the worst-case scenario for VOC exposure over these fields, it was necessary to sample at high temperatures because VOCs are released from recycled crumb rubber at higher rates as the temperature increases. During the first summer (2009) of this study period, a stop work order related to the state's budgetary shortfalls made it impossible for OEHHA to contract with the necessary laboratory to complete the tests for VOCs at high temperatures. In order to collect meaningful and useful data, the contract scope and timeline had to be extended to allow for data collection during the hot summer months of 2010.

Challenges and Data Gaps Remaining

- A small number of fields were sampled in the OEHHA study. Sampling additional fields might allow detection of effects that were missed due to the relatively small sample size.
- Fields comprising the OEHHA study were located in either the San Francisco Bay Area or the Central Valley. While California contains a variety of different climates and geographies, time and budgetary constraints only allowed testing at a relatively small number of these different areas.
- Field age and its relationship to VOC release, PM2.5 release, skin abrasion rate and bacterial population were not investigated in a systematic manner. The changes occurring in artificial turf over time have not been carefully characterized. Such a study, while time consuming and expensive, could prove to be important if artificial turf's properties change significantly as it ages. The routine cleaning performed on artificial turf fields might also affect these properties.
- Since there are limited data, it is unclear how the bacterial populations of artificial and natural turf vary according to the weather or season.
- Incidental ingestion of crumb rubber was not included as a route of exposure for this study since the inhalation route was considered a higher priority. Therefore, exposure via the oral route represents a data gap.

Skin Abrasion Analysis

Overall OEHHA Finding: "The rate of skin abrasions due to contact with the turf was 2- to 3-fold higher for college soccer players competing on artificial turf compared to natural turf….. The higher skin abrasion rate would tend to increase the risk of skin infection in athletes using artificial turf relative to athletes using natural turf (but see next section on 'Bacteria Identification and Quantification')."

Discussion: In order to determine the effect that artificial turf fields have on abrasion rates and seriousness, OEHHA gathered data from athletic trainers for varsity soccer teams from 33 universities and colleges throughout California and Nevada. Information for 524 games was collected. Data were gathered on the number of abrasions, the severity of the abrasions, and the location of the abrasions. OEHHA determined athletes playing on artificial turf fields were between two and three times as likely to suffer an abrasion as on natural turf. Table 1 shows the number of abrasions reported per 1,000 player hours for each type of surface, as well as for each gender separately as well as combined.

Table 1 – Skin Abrasion Rates

Gender Group/surface type	Abrasions per 1,000 player hours	Abrasion rate ratio: rate on artificial/rate on natural (95 percent Confidence Interval)
Women/artificial turf	39	3.0 (2.0-4.4)
Women/natural turf	13	
Men/artificial turf	27	2.3 (1.4-3.7)
Men/natural turf	12	
Men and Women/artificial turf	35	2.7 (2.0-3.7)
Men and Women/natural turf	13	

OEHHA also determined the severity of those abrasions was similar for athletes playing on either artificial or natural turf fields. Table 2 shows the number of abrasions reported in each of three abrasion categories for both types of playing surface. OEHHA determined the distributions of abrasions among seriousness categories were not significantly different for the two surfaces. However, due to the small number of category 3 abrasions reported, it is difficult to determine whether surface type influences the number of this type of abrasion; OEHHA recommended additional data be collected in order to make this determination.

Table 2 – Seriousness of Skin Abrasions

Surface Type	Abrasion category 1 (red only)	Abrasion category 2 (pinpoints of bleeding)	Abrasion category 3 (extensive bleeding)
Artificial Turf	28	52	9
Natural Turf	28	46	3

The great majority of abrasions occurred on the leg or thigh, regardless of surface type. However, there were some differences in the locations of the abrasions based on surface type. Leg/thigh abrasions occurred at a higher frequency on artificial turf fields compared to natural turf, while hip/buttocks abrasions occurred at a higher frequency on natural turf. The difference in location of abrasions was statistically significant; however, due to the low number of abrasions reported at sites other than the leg/thigh, OEHHA recommended additional data be collected in order to determine whether these differences were reproducible.

OEHHA further concluded that "Preventing skin abrasions should be given the highest priority for preventing skin infection. Protective clothing and equipment should be considered, especially when games take place on artificial turf. Treating skin abrasions should be given the next highest priority. Considering the bacterial data discussed in the following section, disinfecting artificial turf fields should be the lowest priority. Creating artificial turf with decreased abrasiveness towards athletes, while still retaining its strength and durability relative to natural turf, represents a challenge in materials engineering."

Bacteria Identification and Quantification

Overall OEHHA Finding: "Fewer bacteria were detected on artificial turf compared to natural turf. This was true for MRSA and other *Staphylococci* capable of infecting humans. This would tend to decrease the risk of skin infection in athletes using artificial turf relative to athletes using natural turf."

Discussion: OEHHA tested both artificial and natural turf fields for amounts and species of bacteria present. Samples were taken of the grass blades (both artificial and natural) as well as substrate (crumb rubber/sand infill or natural soil). These samples were cultured at a laboratory and the three most common bacteria were identified and quantified. The samples also were tested for MRSA.

Table 3 shows artificial turf contained fewer species of bacteria per field than did the natural turf. It was also determined that greater concentrations of bacteria were found on natural turf than on artificial turf. Individual bacteria are measured in colony forming units (CFUs). The samples from the artificial turf fields contained between 0 and 53,000 CFUs per gram of material, while the samples from the natural turf fields contained between 637,000 and 305,000,000 CFUs per gram of material.

Table 3 – Bacterial Species and Concentration

Field Type	Bacterial Species per Field	Bacteria per Gram of Material
Artificial	4-10	0-53,000
Natural	11-14	637,000-305,000,000

With regard to the bacterial genus *Staphylococcus*, 7 percent of samples from artificial turf fields contained bacteria from this genus compared to 50 percent of samples from natural turf fields. MRSA tests revealed that no artificial turf fields contained this strain, while a single sample from natural turf fields did contain the MRSA bacteria.

OEHHA concluded artificial turf fields containing recycled crumb rubber harbor fewer bacteria than natural turf fields, suggesting that bacteria survive and proliferate better on natural turf than on artificial turf.

Airborne Particulate Matter Analysis

Overall OEHHA Finding: "$PM_{2.5}$ and associated elements (including lead and other heavy metals) were either below the level of detection or at similar concentrations above artificial turf athletic fields as upwind of these fields. No public health concern was identified."

Discussion: Particulate matter in the 2.5 micron size or smaller ($PM_{2.5}$) can have adverse health effects particularly when it is comprised of toxic materials, including heavy metals. PM2.5 is small enough to be inhaled and travel into the deepest part of the lungs. Because the infill of the new generation of artificial turf fields is made from used tires, and because tire rubber contains heavy metals (such as lead and nickel), PM2.5 derived from recycled tires has the potential to be inhaled followed by deposition of heavy metals in the lung tissue.

In 2009, OEHHA took samples over three artificial turf fields as well as upwind from the turf fields. The samples from the areas upwind were used as controls to determine if the $PM_{2.5}$ (if any) was attributable to the fields or was present in the ambient air. Air sampling was conducted during periods of active field usage for soccer games and practices. The results of these tests

showed that for two of the three fields, the amount of $PM_{2.5}$ above and upwind of the fields was below the detection limit (i.e., not enough to register on the equipment used to measure it) and for the third field the amount of $PM_{2.5}$ over the field was similar to the amount in the upwind samples. This suggests there is very little to no $PM_{2.5}$ being released from these fields. X-ray fluorescence testing measured the amounts of five elements in the PM2.5: sodium, calcium, potassium, chlorine, and sulfur. The concentrations of these elements were similar in the samples taken above the fields compared to the upwind samples. This suggests the source of these elements is not the fields, but rather some source in the environment around the fields. All heavy metals tested were below the detection limits (arsenic, cadmium, chromium, lead, manganese, mercury, nickel, zinc). This study suggests artificial turf fields are not a significant source of $PM_{2.5}$ or of heavy metals associated with $PM_{2.5}$.

Volatile Organic Compounds Analysis

Overall OEHHA Finding: "The large majority of air samples collected from above artificial turf had VOC concentrations below the limit of detection….. Nevertheless, [for] seven VOCs detected above artificial turf… all exposures were below health-based screening levels, suggesting adverse health effects were unlikely to occur in persons using artificial turf."

Discussion: Volatile organic compounds (VOCs) are carbon-based chemicals that often occur in a gaseous state or transition to a gaseous state at ambient conditions. Chemical volatility is influenced by temperature so as temperature increases, so does chemical volatility. In order to determine the greatest potential exposure to VOCs from artificial turf fields, air samples were collected when VOC off-gassing from recycled crumb rubber infill was expected to be maximal; i.e., during summer afternoons. It is also important to compare the VOC levels above artificial turf fields to the levels above nearby natural turf fields, to determine whether any chemicals are unique to or elevated over artificial fields.

OEHHA took air samples in the summer of 2010 over four artificial turf fields and four nearby natural turf fields located in the Central Valley. Samples were taken every two hours, eight times during the day, in order to allow comparison of temperature to VOC type and concentration. This time course also ensured that air samples would be collected during the hottest time of each day.

In order to determine whether VOCs found in air sampled from above artificial turf fields were due to the fields themselves, the results were compared to the VOCs found above nearby natural fields. Seven chemicals were detected in at least two samples taken from above an artificial turf field at levels exceeding those detected over the nearby natural turf field. This is consistent with the hypothesis that these VOCs are released by artificial turf. To estimate human exposure to each of these VOCs, OEHHA chose the highest detected concentration for acute exposure and the average concentration adjusted for yearly artificial field usage for chronic exposure. The VOC exposure concentrations were compared to health-based screening levels for both chronic and acute exposure in a screening-level risk assessment (Table 4).

Table 4 – Chronic and Acute VOC exposure: screening-level risk assessment

Chemical	Highest concentration over artificial turf field (µg/m^3)	Acute Screening Value (µg/m^3)	Average concentration over artificial turf adjusted for yearly field usage (µg/m^3)	Chronic Screening Value (µg/m^3)
2-Propanol (aka isopropanol)	1.9	3,200	0.9	7,000
Cyclohexane	1.2	10,300	0.02	80,000
Toluene	6.4	3,700	0.05	300
M,p,o-xylenes	44.3	22,000	0.38	700
Isopropylbenzene (aka cumene)	11.6	4,000	0.10	400
4-Ethyltoluene	6.3	850	0.06	85
1,2,4-Trimethylbenzene (aka pseudocumene)	10.7	70	0.11	7

These data show the concentrations of these chemicals over artificial turf fall below the health risk screening levels. For chronic exposure, the chemical concentrations over artificial turf were between 64 and 4,000,000 times below the health risk screening levels. For acute exposure, the chemical concentrations were between 6.5 and 8,600 times below the health risk screening levels.

OEHHA further concluded that “There was no relationship between surface temperature and the concentrations of VOCs detected above artificial turf fields. Therefore, there is no reason for recommending that field usage in the summer be restricted to cooler mornings as a strategy for avoiding exposure to VOCs.”

IV. Discussion and Recommendations

The results of this research suggest artificial turf fields pose a generally low risk to human health. The VOC analysis determined the chemicals attributable to the artificial turf fields are below the health risk screening levels. The inhalable particulate matter analysis shows a small amount of this material above the artificial turf field and upwind of the field. Furthermore, the elemental composition of the PM2.5 material collected from both above and upwind of artificial turf is similar; suggesting the source of this inhalable particulate matter is something other than the artificial turf fields. For the skin abrasion analysis, while a higher number of skin abrasions occurred on artificial turf fields than on natural turf fields, the severity of those abrasions was similar. For the bacterial analysis, there were fewer bacteria detected on artificial turf compared to natural turf.

When taken together, the data from this study do not indicate any significant public health concerns associated with artificial turf fields containing crumb rubber infill from recycled tires, with the possible exception of an elevated risk of skin abrasions. Based on these findings from the OEHHA final report, CalRecycle recommends that no additional study or action is warranted regarding potential human health impacts associated with the new generation of artificial turf fields.