SYNTHETIC TURF

INDUSTRY'S CLAIMS VERSUS THE SCIENCE

A CAREFUL ANALYSIS OF STUDIES THAT INDUSTRY USES TO JUSTIFY SAFETY CLAIMS



ENVIRONMENT & HUMAN HEALTH, INC.

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I. Introduction



The synthetic turf industry continually states publicly that numerous studies show that synthetic turf fields with crumb rubber infill are safe.

A CAREFUL ANALYSIS OF STUDIES INDUSTRY USES TO JUSTIFY SAFETY CLAIMS

Studies the Synthetic Turf Council and the Synthetic Turf Industry Say Prove that Fields Are "Safe"

- The synthetic turf industry continually states publicly that numerous studies show that synthetic turf fields with crumb rubber infill are safe. Environment and Human Health, Inc. (EHHI) concluded that those studies needed to be carefully read and analyzed to see if they actually proved the safety of the fields, as they claimed.

- The Synthetic Turf Council (STC) continually changes its list of studies.[1] The list that EHHI has worked with and analyzed was compiled by STC in 2016. It has taken a year to analyze the listed studies, which were current when this project was undertaken.

- The STC lists their studies chronologically, so they appear in this report in the same way. The website showing the full study, along with EHHI's summary and analysis of each original study, is included in this report. The abstract and URL of each study cited are listed in the Appendix.

Comments from the Synthetic Turf Council (STC)

- In STC's Executive summary of March 3, 2016, it states: "In early 2015, in response to increased public interest in the potential health effects of synthetic turf sports fields with recycled rubber infill, the Synthetic Turf Council began compiling a list of available studies and making them more readily accessible to the public."[1]

A sampling of comments from the synthetic turf industry

- More than 50 independent and credible studies from groups such as the U.S. Consumer Product Safety Commission, and statewide governmental agencies such as the New York State Department of Environmental Conservation, New York State Department of Health and the California Environmental Protection Agency, have validated the safety of synthetic turf…"[1] – Synthetic Turf Council

- "Studies exist that indicate that exposure to rubber tires is greater for humans while standing roadside in any urban area than on a synthetic turf field. The rubber particle size utilized in synthetic turf fields is too large to be airborne, while the microscopic particles that come off tires from vehicles as they drive the road are microscopic. If tire rubber were ever going to become a concern, the use of vehicles and exposure roadside would be a tremendous cause for concern."[2] – Mark Nicholls of Turf Industries

- "Based on the more than 90 scientific studies that have already looked into the safety of synthetic turf fields and other surfaces with recycled rubber infill, we believe the answers are already out there."[3] – Safe Field Alliance and the Synthetic Turf Council



EHHI concluded that those studies needed to be carefully read and analyzed… It has taken a year to do so.

[1] http://c.ymcdn.com/sites/www.syntheticturfcouncil.org/resource/resmgr/Docs/STC_CRI_ExecSummary2016-0303.pdf
[2] http://www.niaaa.org/assets/Synthetic-turf-is-safe.pdf
[3] http://www.businesswire.com/news/home/20170103005986/en/Safe-Fields-Alliance-Synthetic-Turf-Council-Issue



EHHI has always maintained, and continues to maintain, that a product that contains as many carcinogens as synthetic turf does is not safe for children, students or athletes to play on.

Comments from Environment & Human Health, Inc. (EHHI)

- Most of the studies that the STC says proves the fields are safe find numerous chemicals, some of which are carcinogenic, in the fields, though some of the studies report that the chemicals are not at levels high enough to be available for intake and to cause health issues.
- What all the studies fail to explain is what it means to be exposed to multiple chemicals at the same time—even if each individual chemical is found to be at a low level.
- EHHI has always maintained, and continues to maintain, that a product that contains as many carcinogens as synthetic turf does is not safe for children, students or athletes to play on.

Comments from the National Institute of Environmental Health Sciences (NIEHS)

- Chemicals can sometimes act together to cause cancer, even when low-level exposures to individual chemicals might not be cancer-causing, or carcinogenic.[1]
- This important finding emerged from an international task force of more than 170 cancer scientists, known as the Halifax Project, who collaboratively assessed the carcinogenic potential of low-dose exposures to chemical mixtures in the environment. This is the concern about synthetic turf with crumb rubber infill, which is why EHHI considers it a danger to human health.
- The following studies are those listed by STC as of 2016 and will be listed in chronological order. Each study has been read thoroughly and summarized with the study's limitations and EHHI's conclusions. The original study's abstract can be found in the Appendix, along with the original study's website.

[1] https://www.niehs.nih.gov/news/newsletter/2015/7/science-exposure/index.htm

II. Overview of the Problem



- What a careful reading of the studies shows is that they by no means prove that synthetic turf fields are safe.

- On the contrary, many studies show that the fields are not safe; analysis reveals how limited some of the actual studies are; and some studies recommend that further research be done.

What a careful reading of the studies shows is that they by no means prove that synthetic turf fields are safe.

Leaching from synthetic turf fields containing crumb rubber

- A number of the studies relate to the leaching capabilities of crumb rubber. In all the studies about leaching, zinc levels were high enough to pose risks to aquatic life, and many showed zinc levels above the EPA safety levels for fresh water.

- A number of the leaching studies showed that the smaller the rubber particle size the greater the amounts of chemicals and metals leached from the material. Crumb rubber is very small in size.



Fourteen of the 22 studies tested for lead—and in all of them, lead was found.

Lead was found in all fields when looked for

- Fourteen of the 22 studies tested for lead—and in all of them, lead was found. Lead was also found in the virgin rubber (EPDM) sample.
- The studies showed that lead levels varied greatly among fields. For instance, one field showed lead concentrations 500 to 1000 times higher than the other fields tested.
- According to the U.S. Centers for Disease Control and Prevention, no safe blood lead level in children has been identified.

Health risks indicated in the indoor field study

- The Connecticut Study showed that the indoor field that was tested had high levels of chemicals and metals. The air in the indoor field was only sampled for 25 minutes, yet the study found high levels of toxins in the air.
- The study found indoor fields to be worrisome, recommended a more strongly worded warning, and called for specific instructions on how to avoid inhalation exposures on indoor fields that contain crumb rubber.
- This important part of the study was not highlighted. Today, few people are aware of the recommendations on potential health risks associated with indoor synthetic turf fields.

Chemicals found in the testing of synthetic turf with crumb rubber

- Studies found that the samples contained chemicals that were carcinogenic.



- The Connecticut Study found 27 chemicals of concern and 13 carcinogens. Although the study claimed that cancer risks were small, they concluded they were slightly higher for children 12 years and older.
- Another study found 11 volatile compounds and nine metals leaching and outgassing from 17 crumb rubber samples.
- One study found polycyclic aromatic hydrocarbons (PAHs) in one soccer player's urine.
- The total concentration of metals and chemicals varied widely among the samples, even within each field tested.
- Although numerous studies found many chemicals—including carcinogens—in the sampling, industry claimed that the levels of each were low, and did not pose a health issue. The researchers did not take into consideration the synergistic effect of exposing players to so many chemicals at the same time.

Studies have shown that exposures to many carcinogens at the same time can cause cancer, even when individual levels of each carcinogen are low.



Many of the chemicals found in crumb rubber have had no toxicity testing by the federal government, and therefore their toxic effects are unknown.

- Studies have shown that exposures to many carcinogens at the same time can cause cancer, even when individual levels of each carcinogen are low.

- Many of the chemicals found in crumb rubber have had no toxicity testing by the federal government, and therefore their toxic effects are unknown.

Exposure studies

- Many of the studies considered inhalation, dermal and ingestion exposures to contaminants emitted into the air by crumb rubber, but then failed to examine the cumulative effect of exposures through all three routes simultaneously for children playing on the fields.

- The effects of the chemicals and metals found in many of the studies were not considered with respect to children with asthma, allergies and other respiratory issues. For instance, there was no investigation of synthetic turf fields or crumb rubber infill for concentrations of latex or for the impact of exposures to the fields on children and adults with latex allergies.

Toddler and small children's playgrounds

- Many government agencies and non-profits have recommended rubber tire mulch as the surfacing material for our smallest children's playgrounds, despite its toxicity.

- Waste tire rubber mulch is shredded up using the same waste tires that crumb rubber is made from and therefore contains the same carcinogens and irritants as crumb rubber.

- The National Recreation and Park Association (NRPA) is the leading non-profit organization dedicated to the advancement of public parks, recreation and conservation—and yet they recommend crumb rubber infill.



- When the Obamas moved into the White House with their two small children in 2008, the National Recreation and Park Association (NRPA) advised them to install rubber mulch in their children's playground, thus placing toxic material at the White House.

- Although the Consumer Product Safety Commission (CPSC) recommends wood chips as surfacing material for toddler playgrounds, they also recommend rubber mulch, which is made from waste rubber tires.[1]

- The studies analyzed in this report show that waste tires, whether shredded into crumb rubber or into mulch for playgrounds, contain many carcinogens, irritants and heavy metals.

- Many of these studies also show that these toxins outgas. Our smallest children should not be playing on such a toxic material.

The studies analyzed in this report show that waste tires, whether shredded into crumb rubber or into mulch for playgrounds, contain many carcinogens, irritants and heavy metals.

[1] https://www.cpsc.gov//PageFiles/122149/325.pdf

III. Analyses of Individual Studies



This study offers no confirmation that synthetic turf fields are safe. Instead the study concludes that leaching of organic compounds increases as shredded rubber particles decrease in size.

Study Number 1

Leaching of DOC [dissolved organic carbon], DN [dissolved nitrogen] and inorganic constituents from scrap tires

http://www.sciencedirect.com/science/article/pii/S004565351500082X

AUTHORS: Meric Selbes, Ozge Yilmaz, Abdul A. Khan, Tanju Karanfil
PUBLISHED: *Chemosphere*, Volume 139
DATE: November 2015

This study is peer reviewed and presents original research.

The purpose of this study was to examine the leaching of selected organic and inorganic compounds from recycled rubber samples made from scrap tires shredded into crumb rubber and different size tire chips.

Results of this study confirmed that as the size of shredded tire particles gets smaller, more dissolved organic carbon (DOC) and dissolved nitrogen (DN) leach from the rubber material. The study found that the time of soaking mattered and that most leaching occurred at the beginning of soaking time and then decreased over time.

A mixture of scrap car and truck tires collected from stockpiles was cut into five particle sizes, the smallest size being crumb rubber. Over 28 days, these samples were soaked in leaching solutions replicating six conditions: (1) 3 different pHs; (2) acidic rainwater; and (3) hard and soft groundwater.

- This study concluded that the leaching of organic compounds increased as the scrap tire sample size decreased. Crumb-sized samples showed a significantly higher amount of leaching than the larger-sized rubber tire chips. As an explanation of this, researchers hypothesized that the extent of organic leaching is related to more freshly revealed surface areas in smaller sized samples when they were cut during processing.

  During their characterization of organic compounds, researchers detected aniline, benzothiazole and benzothiazolone among the organic compounds they found in these samples.

- The study found rapid initial leaching rates, followed by slower but constant rates for both organic and inorganic compounds measured, with the exception of iron and manganese, which leached at constant rates throughout. Researchers hypothesized that iron and manganese were leaching from wires present in samples and so dissolved at a more continuous rate than the compounds found in the rubber portion of the samples.

- Small amounts of lead were detected in all samples, even though researchers note it is not listed among the components of tires.

  According to the U.S. Centers for Disease Control and Prevention (CDC), "Protecting children from exposure to lead is important to lifelong good health. No safe blood lead level in children has been identified. Even low levels of lead in blood have been shown to affect IQ, ability to pay attention, and academic achievement. And effects of lead exposure cannot be corrected."

- The researchers recommended that "it is likely that there are many other compounds that have not been identified so far. Thus, further research is warranted to identify and quantify other organic compounds leaching from scrap tires and to assess their potential environmental and health impacts during various land applications."



Conclusion

This study offers no confirmation that synthetic turf fields are safe. Instead the study concludes that leaching of organic compounds increases as shredded rubber particles decrease in size.

The results of testing suggest that exposure to acidic rainwater or groundwater may increase the rates at which dissolved organic carbon (DOC) and some inorganic compounds leach from crumb rubber infill. The study also found rapid initial leaching rates for compounds they measured.

While these rates may drop to a constant level over time, this observation raises a health concern about an increased risk of exposures, especially to children, from new fields and playgrounds containing recycled rubber infill and mulch, as well as from fields and playgrounds that are routinely refilled to replenish the surface cushion because of infill and mulch migrating due to use and weather. Finally, the identification of lead in all samples observed in this 2015 study is of great concern.

The results of testing suggest that exposure to acidic rainwater or groundwater may increase the rates at which dissolved organic carbon (DOC) and some inorganic compounds leach from crumb rubber infill.

Study Number 2

Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666

AUTHORS: B.T. Pavilonis, C.P. Weisel, B. Buckley, P.J. Lioy
PUBLISHED: *Risk Analysis*, Volume 34
DATE: January 2014



This study is peer reviewed and presents original research.

The purpose of this study was to examine possible exposures and associated health risks from playing on artificial turf fields containing crumb rubber infill due to the contaminants they may contain.

Results of this study confirmed the presence of small concentrations of metals, including lead and chromium, as well as semivolatile organic compounds (SVOCs) in the material tested and led researchers to caution that testing is necessary to ensure safe play.

New crumb rubber infill and artificial turf fiber products as well as samples from New Jersey artificial turf fields using crumb rubber infill were exposed over time to synthetic lung, sweat and digestive fluids. The resulting mixtures were measured for trace metals and potentially toxic organic compounds. This was done to estimate actual exposures and risks players might experience by inhaling, swallowing, or skin contact with these components of artificial fields.

- This study concluded that crumb rubber infill and turf fiber materials vary widely in their composition and therefore large and many samples from each field may be needed to characterize any health risk posed to players by using these fields.
- The two most readily identified organic compounds, extracted using synthetic lung and sweat fluids, were semivolatile organic compounds (SVOCs).[1] These compounds are not regulated or present in toxicological databases at this time, so the hazard they pose cannot be defined.
- Small amounts of lead were detected in almost all field samples of crumb rubber and in some fiber samples. Researchers noted that there was a "large

The findings of PAHs, SVOCs and lead and other metals, along with the fields' high variability, led the researchers to recommend the testing of each artificial field in order to characterize the field's health risk to players, especially children.

[1] The two SVOCs are 4-tert-ocyl phenol and butylated hydroxytoluene (BHT); they were "readily bound" in the lung and sweat extracts.

range in lead measurements within and between fields" they sampled. One field sample contained a high lead level which was on the same order of magnitude as the New Jersey Department of Environmental Protection (NJ DEP) cleanup value.[2] One new fiber sample contained a very large concentration of lead and chromium—this sample far exceeded the NJ DEP cleanup values for both those metals.[3]

According to the U.S. Centers for Disease Control and Prevention (CDC), "Protecting children from exposure to lead is important to lifelong good health. No safe blood lead level in children has been identified. Even low levels of lead in blood have been shown to affect IQ, ability to pay attention, and academic achievement. And effects of lead exposure cannot be corrected."

- The identification of lead in almost all field samples in this 2014 research led the authors to recommend that all infill and fibers should be certified for low or no lead content before they can be purchased or installed as a minimum protection to children.



Protecting children from exposure to lead is important to lifelong good health. No safe blood lead level in children has been identified.

Conclusion

The researchers found that although levels of metals, semivolatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs) were below what would be expected to cause health problems for those who would play on the fields, they also found that concentrations varied greatly from field to field. It was also found that small amounts of lead were identified in the fields.

The findings of PAHs, SVOCs and lead and other metals, along with the fields' high variability, led the researchers to recommend the testing of each artificial field in order to characterize the field's health risk to players, especially children. The researchers called for special attention to be given to the testing of lead in each field.

[2] The field sample containing a high level of lead measured 260 mg/kg of the metal. The New Jersey Department of Environmental Protection (NJDEP) cleanup value is 400 mg/kg.

[3] The fiber sample containing a large concentration of lead and chromium measured 4400 mg/kg for lead and 820 mg/kg for chromium. The NJDEP cleanup for those metals respectively are 400mg/kg and 20 kg/mg.

Study Number 3

Environmental-sanitary risk analysis procedure applied to artificial turf sports fields

http://link.springer.com/article/10.1007/s11356-012-1390-2

AUTHORS: Barbara Ruffino, Silvia Fiore, Maria Chiara Zanetti
PUBLISHED: *Environmental Science and Pollution Research*, Volume 20
DATE: July 2013

This study is peer reviewed and presents original research.

The purpose of this study was to evaluate the content of artificial turf fields and the dust and gases they produce in order to assess their risk to children and adults through inhalation or direct skin contact. The findings were then compared to the risk people face from traffic pollution in Turin, Italy.

The researchers concluded that dust and gases inhaled on artificial turf fields were less of a health risk to children and adults than traffic pollution. However, important details of their methods are missing, so it is not possible to confirm their conclusion.

Researchers failed to discuss the large number of highly variable levels of chemicals, gases and metals detected in the artificial turf fields they sampled—even though some of the contaminants were measured at levels well above safety guidelines. The study also did not address the risk these chemicals and metals may pose to players who swallow the crumb rubber particles or who are exposed by direct contact to them through skin wounds or turf burns.

- The study detected 21 chemicals, gases and metals in highly variable amounts in the leachate from artificial turf fields containing crumb rubber infill.[1]
- From the fields containing crumb rubber, researchers identified 12 chemicals, gases and metals, including carcinogens, in concentrations that exceed Italian soil quality guidelines for residential areas.[2] In this group, levels of benzene, toluene and benzo(a)anthracene exceeded Italian soil quality guidelines for industrial areas.

[1] Concentrations of benzothiazole (BTX) polycyclic aromatic hydrocarbons (PAHs) metals and anions in the eluates were obtained according to the EN 12457/2 compliance test.

[2] Concentrations of BTX, PAHs and metals were identified.



Cobalt, another heavy metal, was found in all of the artificial fields. Since this study was published in 2013, cobalt has been added as a probable human carcinogen.



- Of the metals, lead was found in all of the fields—in one crumb rubber field, the level was three times Italy's soil quality guideline for residential use. All the artificial turf fields contained lead, with one artificial field well above recommended levels. For the artificial fields tested, lead levels (mg/kg) were 308, 37.5, 20.0, and 19.7, respectively. According to the U.S. Centers for Disease Control and Prevention (CDC), no safe blood lead level in children has been identified.

- Cobalt, another metal, was found in all of the artificial fields. Since this study was published in 2013, cobalt has been added as a probable human carcinogen to the U.S. Department of Health and Human Services 14th Report on Carcinogens (November 3, 2016). Barium was also found in two fields containing crumb rubber and the field containing thermoplastic infill at levels far exceeding EPA and WHO water quality standards.[3]

- The research article did not provide details about methods. Pertinent missing information includes weather conditions during sampling (season, air temperature, and humidity), the height of air sampling stations on the

The study also did not address the risk these chemicals and metals may pose to players who swallow the crumb rubber particles or who are exposed by direct contact to them through skin wounds or turf burns.

[3] The Water Quality Association 2014 Barium Fact Sheet Available at: https://www.wqa.org/Portals/0/Technical/Technical%20Fact%20Sheets/2014_Barium.pdf



The study did not consider the health effects of exposing athletes to so many chemicals at the same time and what those exposures mean to those who play on artificial turf fields.

fields and in traffic, whether the fields were sampled while they were being used, and whether samples were taken from highly used areas of the fields or from the same areas of every field.

It also appears that 12 samples were taken from each field using an extractor fan and they were merged into one sample per field for testing. This would not allow for the researchers to assess exposure variations due to team position or in high-traffic areas of the field. These flaws inhibit the accuracy of the risk assessment analysis performed in this study.

Conclusion

It is the researchers' conclusion that artificial turf fields pose less health risk to children and adults than traffic pollution. Because this study was conducted and reported with many limitations, it is simply not possible to confirm their conclusion. The study identified a number of contaminants, including chemicals, gases and metals that are carcinogens or irritants, with some exceeding air and water quality safety standards.

The study did not consider the health effects of exposing athletes to so many chemicals at the same time and what those exposures mean to those who play on artificial turf fields.

Study Number 4

New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds

https://www.ncbi.nlm.nih.gov/pubmed/23337354

AUTHORS: O. Kruger, U. Kalbe, E. Richter, P. Egeler, J. Römbke, W. Berger
PUBLISHED: *Environmental Pollution*, Volume 175
DATE: April 2013

This study is peer reviewed and presents original research.

The purpose of this study was to assess test methods that may provide a reliable risk assessment of environmental and health hazards due to chemicals and metals in crumb rubber infill and entire artificial turf systems.

Results of this study show that the components of artificial turf systems may be significantly toxic to our environment and that the run-off and drainage from artificial turf systems should be further investigated.

Using two methods, the researchers tested samples of several types of infill containing new or recycled rubber and plastic, as well as complete artificial turf systems. Batch testing measured chemicals and metals leaching (called leachates) from individual components and column testing measured leachates from entire artificial turf systems.

Both methods assessed the environmental impact on two species—*Pseudokirchneriella subcapitata* (a fresh-water microscopic alga) and *Daphnia magna* (a fresh-water small planktonic crustacean).

- Materials tested included EPDMs (ethylene propylene diene monomer rubbers, synthetic rubbers made from oil and natural gas), TPEs (thermo-plastic elastomers, sometimes referred to as thermoplastic rubbers, often made of rubber and plastic), and SBRs (styrene-butadiene or styrene-butadiene rubbers, used to make car and truck tires).

  These different rubbers are commonly used as the infills in artificial turf fields. The tests showed that leachate from EPDM had the highest effect upon *Daphnia magna*—the crustaceans. However, most synthetic turf fields are cushioned with SBR crumb rubber made from shredded waste



The results of this study show that artificial turf fields constitute toxic effects on biological organisms.



The researchers concluded that the two approaches showed that the components of artificial turf systems may have a significant "ecotoxicological potential"—the potential to harm our environment.

tires. In most cases, the waste tires have a greater level of heavy metals. In this study, researchers found that samples of SBR had the highest toxic effect on *P. subcapitata*—the algae that live in fresh water ponds. These algae are quite sensitive to the presence of toxic substances, including metals, and so are broadly used in the study of the effects of toxic chemicals on biological organisms.[1]

- The researchers concluded that the two approaches showed that the components of artificial turf systems may have a significant "ecotoxicological potential"—the potential to harm our environment.
- They cautioned, however, that testing single components might overestimate the environmental impact and so might not provide the basis

[1] The researchers observed the maximum effect concentrations of artificial turf system leachates in freshwater algal growth inhibition tests and *Daphnia* acute toxicity tests as well as these accompanying parameters of column and batch test leachates: zinc concentrations, PAH concentrations (15 EPA-PAHs without acenaphthlene), total organic compounds, total nitrogen, pH values, electrical conductivity and turbidity.

for a realistic risk assessment but that more complicated testing of the combined components of these fields was "laborious and time consuming;" so they advised testing new materials as single components and basing their toxicity on a simulation of the complete field assembly.

- They reviewed previous research and stated that "due to the complex chemical composition of the artificial turf system components, especially of scrap tires, and the large number of leachable, possibly hazardous, compounds, a thorough risk assessment is difficult." Their review cited:
  - Previous studies identified these contaminants released from artificial fields: zinc, polycyclic aromatic hydrocarbons (PAH), volatile compounds and additives like benzothiazole, as well as aniline and phenol.
  - Previous leaching tests on tire rubber found an increase in toxicity with longer leaching times to both algae and crustaceans. Other experiments showed significant toxicity from tire wear leachates to crustaceans and that shredded tire leachates were significantly toxic to algae and toxic to fish.
  - Previous research also showed that tire debris extracts increased the cell mortality and damaged the DNA of human lung cells.
- The researchers noted that their tests also indicated that these ecotoxic compounds were possibly being released from artificial turf fields: polymer additives, preservatives and UV-protecting agents, among others.

Conclusion

The results of this study show that artificial turf fields constitute toxic effects on biological organisms. Therefore, this study in no way concludes that synthetic turf fields are safe.

On the contrary, this study demonstrates that chemicals and metals leaching from synthetic turf fields are significantly toxic to our environment. The study also finds that synthetic plastics pose a toxic effect on the environment in which they are found.



This study demonstrates that chemicals and metals leaching from synthetic turf fields are significantly toxic to our environment.

STUDY NUMBER 5

Artificial turf football fields: environmental and mutagenicity assessment

http://link.springer.com/article/10.1007%2Fs00244-012-9792-1

AUTHORS: T. Schilirò, D. Traversi, R. Degan, C. Pignata, L. Alessandria, D. Scozia, R. Bono, G. Gilli

PUBLISHED: *Archives of Environmental Contamination and Toxicology,* Volume 64
DATE: January 2013



This study is peer reviewed and presents original research.

The purpose of this study was to analyze air samples taken directly over artificial turf fields and to compare them with samples taken from air monitoring stations located in urban areas. This was done in order to determine whether artificial fields presented a greater exposure risk than the rest of the city due to the fine particles and chemicals present in synthetic turf containing crumb rubber infill.

The study also looked at the concentrations of three aromatic hydrocarbons: benzene, toluene and xylene; compounds that other crumb rubber analyses have not often found in the product.

Results of the study samples taken from the eight sites tested showed no significant difference between the field monitoring and the urban area monitoring.

Air samples were captured above six soccer fields and from two air quality monitoring stations at urban locations during two courses of sampling. These two sampling periods were meant to account for weather and seasonal differences. During the June sampling, no players were active on the fields. Sampling in November was performed during matches. The air quality monitoring stations were placed above city streets in residential/commercial zones in the urban center of Turin, an industrial city in northwestern Italy.

The samples were analyzed to identify, measure, and compare levels of fine particles (PM_{10} and $PM_{2.5}$) in the air above the fields and and in the air of the off-field air stations.

The samples were analyzed to identify, measure, and compare the levels of fine particles (PM_{10} and $PM_{2.5}$) in the air above the fields and and in the air of the off-field air stations.

- The soccer fields sampled included four artificial fields containing infill rubber from used tires, one field containing thermoplastic infill, and one

clay field. Two of the fields containing recycled rubber infill were one and one half years old. The other fields were three years old.

The field measurements were performed approximately two meters (6.6 feet) above the top of the penalty area. Researchers noted that the measurements they gathered could underestimate the actual concentrations of particle-bound PAHs to which the athletes were exposed because of the location of the air sampler.[1]

- Off-field air sampling stations were located six meters (19.7 feet) and two meters (6.6 feet) above centrally located sites near traffic in the same city. The higher station measured for PM_{10} and the lower station measured for $PM_{2.5}$. Air samples from these and the field sites were collected in late spring and autumn. Air temperatures during the two sampling periods ranged between 0°C and 34°C (32°F and 93.2°F).

- Twelve PAHs were identified from fine particles captured during both sampling sessions at each of the sites. Researchers noted that test results showed more cell changes from compounds in PM_{10} samples and fewer cell changes from compounds in $PM_{2.5}$ samples taken from artificial fields as compared to those from the off-field air stations.

Conclusion

The researchers found that artificial turf fields presented no more risks to health than urban centers. However, it must be noted that the urban centers they sampled were urban traffic areas. There have been many studies that have looked at and monitored urban traffic and these studies have found that urban traffic creates enough pollution and particulates to cause health problems for residents who live nearby. Therefore, to say that artificial turf fields are comparable to urban traffic does not prove the fields provide a safe environment.

This study only sampled a small number of fields, and within this small sample they only looked for three chemical compounds, which had historically not been found in crumb rubber. The fields were not sampled during the hottest weather, which in this region is July. The study concluded that further work will be necessary to assess the actual scenarios of exposure by inhalation and the corresponding risks.



This study only sampled a small number of fields; within this small sample they only looked for three chemical compounds that have not been historically found in crumb rubber infill.

[1] Researchers suggested that the use of personal samplers might better estimate the concentrations of PAHs to which athletes are exposed.

Study Number 6

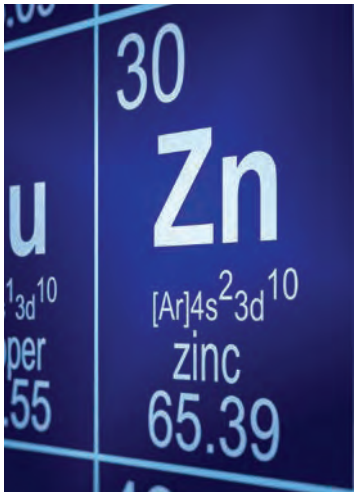
Comparison of Batch and Column Tests for the Elution of Artificial Turf System Components

http://pubs.acs.org/doi/abs/10.1021/es301227y

AUTHORS: O. Krüger, U. Kalbe, W. Berger, K. Nordhauβ, G. Christoph, and H.-P. Walzel

PUBLISHED: *Environmental Science & Technology,* Volume 46

DATE: December 2012



Zinc oxide is used in the manufacture of tires recycled as crumb rubber infill and as part of the bound elastic basic layer of artificial turf fields.

This study is peer reviewed and presents original research.

The purpose of this study was to compare the results of two laboratory leaching methods—batch testing and column testing—of artificial turf field components to determine which type of test is more accurate for environmental and human health risk assessments of the fields.

The study included a review of previous research about artificial turf fields, including information about their construction, materials and the contaminants these materials may contain. Based on the review, the researchers tested for zinc and polycyclic aromatic hydrocarbons (PAHs) as the most significant contaminants possibly present. Zinc oxide is used in the manufacture of tires recycled as crumb rubber infill and as part of the bound elastic basic layer of artificial turf fields, and PAHs are found in the softening agents used in those tires.

Zinc at high levels in water is harmful to aquatic organisms. As a result, EPA has set freshwater quality criteria for zinc (0.12 mg/L) for aquatic species. According to the Agency for Toxic Substances and Disease Registry, some PAHs are reasonably expected to be human carcinogens and may also affect the skin, liver and immune system.

The researchers found significantly higher zinc released in batch tests as compared to column tests they performed. They concluded that column tests more accurately represent field conditions due to test mechanics and because column tests can measure the release of contaminants over time. Significant variations in batch test results, limits to the column tests and how results were reported do not allow us to confirm this conclusion.

- Batch tests were conducted on samples from six German producers and factory suppliers. Samples were ground or cut and put into glass bottles with twice as much doubly distilled water then tumbled for 24 hours.



Each test batch rested for fifteen minutes then it was centrifuged, filtered and tested. Column testing was not fully described other than to specify use of German standards, glass columns and doubly distilled water and certain sample sizes and fractions of collection. All tests were done three times.

- Nine samples of crumb rubber and three samples of bound elastic basic layer, which may contain recycled rubber, were batch tested. Results were listed. There were significant variations in the test results for concentrations of zinc and PAHs, turbidity and electrical conductivity. For zinc, eight of the crumb rubber samples and all of the bound layer samples tested above EPA freshwater criteria for aquatic organisms.

- Only five of the nine samples of crumb rubber were column tested. Results of only four of these tests were presented and they were graphed, not listed. Researchers explained that the zinc results from one sample were "too high for a mutual illustration." Differences between batch and column test results for zinc were described as "relative excess findings" in batch tests ranging from 15% to 687%. This is highly significant variation. Column tests results for zinc and PAHs concentrations were varied, but show concentrations of zinc and electrical conductivity generally declined with time while PAHs declined over time, with some fluctuations among the samples.

This report does not prove the safety of synthetic turf fields, especially in aquatic organisms.



Both batch and column tests found zinc levels well above EPA freshwater quality standards for aquatic organisms.

Conclusion

Researchers concluded that column tests are closer to field conditions and are therefore more accurate than batch tests. Because samples are tumbled during batch testing, the study predicted that this might cause an excess release of contaminants. Column tests percolate samples rather than tumble them and researchers believe this may be closer to what actually happens to a field. They also concluded that column tests were more accurate in analyzing the crumb rubber contaminants as they leach over time.

Differences between batch and column test results for zinc ranged from 15% to 687%, which raises the question of whether these two test methods are at all comparable.

Additionally, both batch and column tests found zinc levels well above EPA freshwater quality standards for aquatic organisms. Batch test results for zinc show large variations between the crumb rubber samples, indicating wide differences in the composition of the test material. Because of the huge variances shown, neither method is adequate to characterize the safety of an artificial turf field, which can contain up to 40,000 recycled rubber tires. This report does not prove the safety of synthetic turf fields, especially if one is an aquatic organism.

Study Number 7

Zinc Leaching from Tire Crumb Rubber

http://pubs.acs.org/doi/pdf/10.1021/es3024379

AUTHORS: Emily P. Rhodes, Zhiyong Ren, David C. Mays
PUBLISHED: *Environmental Science & Technology,* Volume 46
DATE: December 2012

This study is peer reviewed and presents original research.

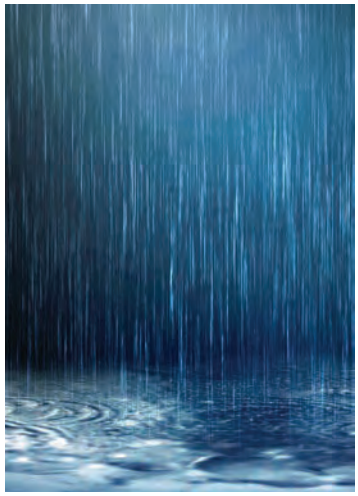
The purpose of this study was to investigate how particle size, exposure time and flow dynamics affect the rate that zinc leaches from the crumb rubber made from recycled waste tires. The study included a review of previous research into the toxic effects of zinc leaching from tire wear particles on the environment and aquatic life.

Tires contain between 1% and 2% zinc. The researchers reported that zinc oxide is added to tires during the manufacturing process, and zinc is therefore present in recycled tire crumbs. Elevated levels of zinc are harmful to a variety of aquatic species.

According to the Agency for Toxic Substances and Disease Registry, zinc attaches to soil, sediments, and dust in the air. Through rain and snow, it migrates from the air into groundwater, lakes, streams and rivers, where it builds up in fish and other organisms. In humans, exposure to large amounts of zinc can be harmful. As a result, EPA has set freshwater quality criteria for zinc (0.12 mg/L) for aquatic species.

The researchers found that the smaller the particle size of crumb rubber and the longer the particles were exposed to water, the greater the leaching of zinc. Tests showed that when crumb rubber is exposed to flowing water, there is an initial surge of zinc leaching followed by a steady rate over time.

The study was conducted using three leaching tests: EPA's synthetic precipitation leaching procedure (SPLP) was performed on unwashed crumb rubber to investigate the effect of size; quiescent (calm) batch leaching tests were performed on washed crumb rubber to measure the effect of time; and column leaching tests on washed and unwashed crumb rubber were used to measure the effects of flowing water on the rate of zinc leaching from the particles.



Zinc attaches to soil, sediments, and dust in the air. Through rain and snow, it migrates from the air into groundwater, lakes, streams and rivers, where it builds up in fish and other organisms.



Their findings showed zinc leached from recycled tire crumbs at concentrations significantly above EPA freshwater limits for the protection of aquatic organisms.

- The study showed that as the particles of crumb rubber got smaller, more zinc leached from them. The highest concentration of zinc leached in the SPLP tests was 1.3 mg/L—well above the EPA freshwater limit for aquatic species.

- Crumb rubber particles were washed then soaked in unstirred water for up to 96 hours to determine that zinc was released from the crumb rubber at a steady rate over that time. The highest concentration of leached zinc in these tests was 2.7mg/L—again, well above the EPA freshwater limit for aquatic species.

- Unwashed and washed crumb rubber particles were place in acrylic columns and exposed to flowing tap water. While the water's acidity (pH) in each of the three test columns was different, researchers decided not to investigate the role of pH in this study.

  Results showed an initial spike of zinc leaching from the unwashed crumb rubber at a higher rate than the washed crumb rubber followed by a steady rate of leaching for all samples for 24 hours. In the two unwashed samples, initial spikes in the rate zinc leached were well above the EPA freshwater limit for aquatic species, at levels of 2.63 mg/L and 2.55 mg/L, respectively. Zinc concentrations reached healthy levels in these samples after two and a half hours in the first case and twenty hours in the second case.

Conclusion

This study was conducted by scientists in the Department of Civil Engineering. The research showed that crumb rubber particle size, time spent soaking, and flow dynamics affect the amount of zinc leaching from recycled crumb rubber. Their findings showed zinc leached from recycled tire crumbs at concentrations significantly above EPA freshwater limits for the protection of aquatic organisms.

The exclusion of consideration of the water pH as a factor in zinc leaching presents a serious limitation to this study. The researchers concluded that washing crumb rubber reduced the initial rate of zinc leaching from samples exposed to flowing water but did not affect the steady rate thereafter. No human health assessment was part of this research.

Study Number 8

Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598

AUTHORS: Sunduk Kim, Ji-Yeon Yang, Ho-Hyun Kim, In-Young Yeo, Dong-Chun Shin, Young-Wook Lim
PUBLISHED: *Environmental Health and Toxicology,* Volume 27
DATE: January 2012

This study is peer reviewed and presents original research.

The purpose of this study was to assess the risk of ingestion exposure of lead by particle sizes of the crumb rubber infill.

Results of this study confirm that the exposure of lead ingestion and risk level increases as the particle size of crumb rubber gets smaller.

The bioavailability and health exposure of lead extracted were assessed and the researchers estimated the health risk. The Hazard Index was calculated by comparing the daily intake and average exposure doses of a survey group of 275 students age 7 to 18 found on artificial turf playing surfaces at schools or parks.

- This study concluded that exposure to lead through ingestion of crumb rubber particles increases as the particle size of crumb rubber gets smaller.
- Small-sized particles in the form of powder, caused by the deterioration of rubber on the field, may be "unconsciously inhaled" during activities on artificial turf.
- Both the digestive extraction and acid extraction methods showed that the daily ingestion dose was twice as high in particles smaller than 250 μm compared to particles larger than 250μm.
- The World Health Organization recommends a daily intake dose of lead for children to be 0.035 mg/kg-day, and EPA of Denmark suggests 0.001 mg/kg-day. According to this study, the Hazard Index (which is calculated



Small-sized particles in the form of powder, caused by the deterioration of rubber on the field, may be "unconsciously inhaled" during activities on artificial turf.

by comparing children's daily intake dose and average exposure dose values) for elementary, middle and high school students in average exposure scenarios to crumb rubber was .01 to 0.1 and they calculated that most elementary school students' Hazard Index exceeds the 0.1.



- This study was conducted analyzing EPDM rubber as the crumb rubber infill material. EPDM is a synthetic rubber product usually referred to as "virgin" rubber. However, most synthetic turf fields are infilled with crumb rubber that uses shredded waste tires, and in most cases, the waste tires have a greater level of heavy metals.

  The study noted "It is known that lead has a strong toxicity even when just a small amount of lead enters inside the human body. In the case that the human body is exposed to lead, the smaller the particle size and the younger the age of the exposure group, the higher the absorption rate inside the body, and it is known that only a portion of lead that is not absorbed is discharged from the human body.

  In addition, lead that enters the body is absorbed instead of calcium. Thus, children who need a lot of calcium, even when exposed to the same amount of lead as adults, an even larger amount of lead that exceeds the level of adults is absorbed inside by the children's body."

  According to the U.S. Centers for Disease Control and Prevention (CDC), "Protecting children from exposure to lead is important to lifelong good health. No safe blood lead level in children has been identified. Even low levels of lead in blood have been shown to affect IQ, ability to pay attention, and academic achievement. And effects of lead exposure cannot be corrected."

This study...suggests that lead is released from the crumb rubber, and increases as the particles get smaller. This fact means that lead can be ingested by those who play on these fields.

Conclusion

This study in no way offers assurance that the fields are safe. In fact, the suggests that lead is released from the crumb rubber, and increases as the particles get smaller. This fact means that lead can be ingested by those who play on these fields.

Study Number 9

Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment

http://www.sciencedirect.com/science/article/pii/S0048969711007601

AUTHORS: Edoardo Menichini, Vittorio Abate, Leonello Attias, Silvia De Luca, Alessandro di Domenico, Igor Fochi, Giovanni Forte, Nicola Iacovella, Anna Laura Iamiceli, Paolo Izzo, Franco Merli, Beatrice Bocca
PUBLISHED: *Science of the Total Environment,* Volume 409
DATE: November 2011

This study is peer reviewed and presents original research.

The purpose of this study was to identify metals and organic compounds found in crumb rubber infill used in artificial turf playing fields and to assess the possible increased cancer risk they might pose to players using the fields.

The study included a review of previous research. Crumb rubber infill was taken from 13 Italian artificial fields and analyzed for 25 metals and nine polycyclic aromatic hydrocarbons (PAHs). To investigate a worst-case scenario, additional samples of crumb rubber were taken from the field showing the highest content of PAHs and tested for more organic compounds.

Air samples were also captured and analyzed from two fields and compared to air captured from other sites in Rome. A health risk assessment measured the lifetime cancer risk to athletes playing on the fields as a result of their exposure to the chemicals and metals present in the infill.

The study showed concentrations of zinc and benzo(a)pyrene (a PAH) greatly exceeded the New York state and Italian soil safety standards, and were up to 100 times the Italian soil safety standards. PAHs were present at highly variable levels, with benzo(a)pyrene at levels exceeding New York state and Italian soil safety standards in nine and six fields, respectively.

In an additional sample taken from one field with high levels of PAHs, researchers also identified polychlorinated biphenyls (PCBS), poly-cholorinated dibenzodioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs). These are persistent compounds commonly referred to as dioxins.



The study showed concentrations of zinc and benzo(a)pyrene (a PAH) greatly exceeded the New York state and Italian soil safety standards, and were up to 100 times the Italian soil safety standards.



The levels of PCBs, in total, were 1000 times the Italian soil safety standards.

The levels of PCBs in total, were 1000 times the Italian soil safety standards. PAHs identified in air samples taken on two of the fields were considered to be at levels equal to or slightly above background samples taken off the fields in urban traffic areas. The researchers determined a one in a million lifetime cancer risk for an athlete playing on crumb rubber infill, but they cautioned that more work is needed to assess actual exposure scenarios and reach comprehensive conclusions.

- Zinc was found in all 13 fields tested at levels above New York state cleanup standards. In 12 fields, zinc levels exceeded Italian soil safety standards, in some fields by up to 100 times the standard.

- Cobalt exceeded Italian soil safety standards in samples from six fields. Cobalt was added as a substance reasonably anticipated to cause human cancer in the 14th Annual Report on Carcinogens (RoC) in 2016.[1]

[1] National Toxicology Program, Department of Health and Human Services. 2016. Report on Carcinogens, Fourteenth Edition. Fact Sheet: Cobalt and Cobalt Compounds That Release Cobalt Ions In Vivo. Available: https://www.niehs.nih.gov/health/materials/cobalt_508.pdf [accessed 8/12/2017].

- A PAH, benzo(a)pyrene, is another substance reasonably anticipated to be a human carcinogen,[2] and was found to exceed Italian soil safety standards in nine fields, again in some cases at up to 100 times the limit, and was above New York soil cleanup standards in six fields.

- On the field containing high levels of PAHs, the researchers took an additional sample of crumb rubber to evaluate its contents more completely. Within and released from this sample were additional PAHs as well as compounds commonly known as dioxins—polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The sum of PCBs in this sample was 1000 times the Italian soil safety standard. According to the World Health Organization (WHO), "dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and also cause cancer.[3]

- Air samples were taken from two fields to provide an assessment of whether total suspended particles and PAHs might be found at higher levels above the artificial fields as compared to samples captured elsewhere in Rome. The analysis showed air above the fields had identical or only slightly elevated levels of PAHs as compared to urban traffic areas. The researchers assessed an elevated lifetime cancer risk of one in a million for very active players on crumb rubber fields, and they predicted an even lower risk for more sporadic athletes, despite previous findings of metals, PAHs, and dioxins at levels exceeding soil safety standards in the fields.

Conclusion

Found in the crumb rubber infill, collected from 13 Roman artificial turf fields, were metals and organic compounds of environmental and human health concern, including those reasonably anticipated to cause cancer. Some fields contained contaminants, especially zinc and benzo(a)pyrene, in concentrations well above Italian and New York state soil safety standards. Zinc was found in all 13 fields sampled, and levels of zinc and benzo(a)pyrene were found at up to 100 times the Italian soil safety standards. In one field, the sum of PCBs was 1000 times the Italian soil safety standard.



Found in the crumb rubber infill, collected from 13 Roman artificial turf fields, were metals and organic compounds of environmental and human health concern, including those reasonably anticipated to cause cancer.

[2] National Toxicology Program, Department of Health and Human Services. 2016. Substances Listed in the Fourteenth Report on Carcinogens. Report on Carcinogens, Fourteenth Edition. Available: https://ntp.niehs.nih.gov/ntp/roc/content/listed_substances_508.pdf [accessed 8/12/17], see page 2.

[3] World Health Organization. 2016. Fact Sheet: Dioxins and their effects on human health. Available: http://www.who.int/mediacentre/factsheets/ fs225/en/ [accessed 8/12/17].



The National Toxicology Program has continued to discuss skin contact as an exposure route for PAHs as part of its Report on Carcinogens.

Air samples taken from two fields and compared to samples taken from urban traffic areas found no significant elevated risk from inhaled PAHs for players using crumb rubber fields. However, the researchers concluded that more scientific assessment was needed to evaluate the actual exposures faced by athletes and to reach a more comprehensive conclusion about the safety of crumb rubber infill.

In calculating their health risk assessment, the researchers did not consider the impact of dermal exposure to PAHs, which had been determined in previous research. This study was done in 2011, well after previous research showed that skin contact with PAH-contaminated soil and the use of skin products based on coal tar were sources of exposure to PAHs. In addition, since this study, the National Toxicology Program has continued to discuss skin contact as an exposure route for PAHs as part of its Report on Carcinogens.[4]

Studies that factor in dermal exposures, along with inhalation of PAHs, may be required to accurately assess lifetime cancer risks faced by athletes who play on artificial fields cushioned with crumb rubber.

[4] National Toxicology Program, Department of Health and Human Services. 2016. Polycyclic Aromatic Hydrocarbons: 15 Listings. Report on Carcinogens, Fourteenth Edition. Available: https://ntp.niehs.nih.gov/ntp/roc/content/profiles/polycyclicaromatichydrocarbons.pdf [accessed 8/12/17], see page 6.

Study Number 10

Crumb Infill and Turf Characterization for Trace Elements and Organic Materials

http://www.nj.gov/dep/dsr/publications/turf-crumb-infill-study.pdf

AUTHORS: Paul J. Lioy and Clifford Weisel
DATE: October 2011

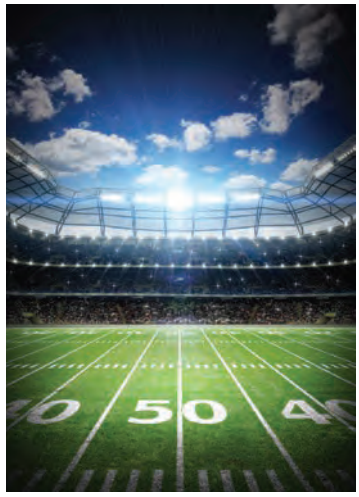
This research is not peer reviewed and includes a literature review and original research. The report was prepared for the New Jersey Department of Environmental Protection.

The purpose of this report was to evaluate crumb products used in synthetic turf fields and in public parks. The study was done to determine what hazardous chemicals they may contain and to measure the health risk these products may pose to players using them. The researchers wanted to provide objective and scientific information on potential health hazards of infill products for communities who want to install these surfaces.

Materials sampled included nine new crumb products, eight new fiber and backing components of artificial turf fields, and infill from seven New Jersey artificial fields aged two to seven years old.

Bioavailability tests were performed on the samples using synthetic lung, digestion and sweat fluids to simulate exposures players may endure. Then researchers reported results for 11 metals, including carcinogens and lead, and identified 550 unique organic compounds, including semi-volatile and volatile organic compounds.

The report concluded that levels of chemicals available by these routes were so low they did not present a risk to players using synthetic turf fields, with the exception of lead found in one new turf fiber sample. It emphasized the need to avoid lead-based paints in the material. Also noted was the large number and variety of organic compounds identified at very low concentrations in the materials for which no hazard data was available in 2011. The report concluded with the recommendation that bioaccessibility studies should be performed on- all new turf and infill products.



The report concluded with the recommendation that bioaccessibility studies should be performed on all new turf and infill products.



This conclusion did not take into consideration that exposures to many chemicals at the same time have health risks that are not fully understood—even when the chemicals are at low levels.

- This report examined infill products used to cushion synthetic turf fields, including crumb rubber, but not rubber mulch, which is used in public parks to cushion playground areas. Materials tested included nine new crumb infill products; of these, one sample was cryogenic crumb rubber and one sample was ethylene propylene diene terpolymer (EPDM), a form of synthetic rubber.

  The report did not specify whether the cryogenic crumb rubber sample was from recycled tires. Seven other new fiber and backing components of turf fields were tested. Crumb infill from seven New Jersey synthetic turf fields between two to seven years old was also tested. The report did not specify whether the field samples were crumb rubber infill, EPDM, TPE, sand, or other mixtures.

- Lead was extracted in varied detectable amounts from all twenty-four samples of new and used infill and new fibers sampled. One new fiber sample was one hundred times New Jersey soil cleanup standards.

Conclusion

The study concluded that even though there were many and varied levels of metals and organic compounds in the new and field samples of artificial turf infill and fibers, they did not pose a risk to players because they were not available through ingestion, inhalation, or dermal contact. This conclusion did not take into consideration that exposures to many chemicals at the same time have health risks that are not fully understood—even when the chemicals are at low levels.

The study looked at heavy metals, but failed to assess zinc levels. Rubber tires have large amount of zinc. Zinc levels in past studies of crumb rubber have been high enough to harm aquatic organisms, plants and possibly humans. Zinc was not tested for in this study.

According to the U.S. Centers for Disease Control and Prevention (CDC), "Protecting children from exposure to lead is important to lifelong good health. No safe blood lead level in children has been identified."

When so many chemicals are found in a product along with so many heavy metals, it is hard to claim that product is safe.

Study Number 11

Design of a new test chamber for evaluation of the toxicity of rubber infill

http://www.tandfonline.com/doi/abs/10.3109/15376516.2011.583293?journalCode=itxm20

AUTHORS: J.F.P. Gomes, H.I. Mota, J.C.M. Bordado, M. Baião, G.M. Sarmento, J. Fernandes, V.M. Pampulim, M.L. Custódio, I. Veloso

PUBLISHED: *Toxicology Mechanisms and Methods*, Volume 21
DATE: September 2011

This study is peer reviewed and presents original research.



The purpose of this study was to create and test a chamber that would simulate real environmental conditions found on synthetic turf fields.

The purpose of this study was to create and test a chamber that would simulate real environmental conditions found on synthetic turf fields in order to measure the potential air and water pollutants released by crumb rubber infill and assess the health impact the pollutants had on humans and aquatic organisms.

The study included a short review of previous research about substances of high concern in the crumb rubber infill made from recycled rubber tires. It also described the test chamber that the researchers built to simulate real artificial turf field conditions. The chamber was designed to test and analyze the contaminants in the air and water runoff from four samples.

The researchers reported non-detectable or very low levels of contaminants in the air and water tested in their chamber. They concluded that the crumb rubber sampled presented no risk to humans or aquatic organisms and that the chamber provided a comprehensive tool to measure the risk posed by contaminants in crumb rubber because it could be used to test airborne pollutants and leachates at the same time.

However, since the sample size was so small and no comparable testing was done using existing equipment on the same samples, it is not possible to confirm their conclusion.

- In an acrylic-walled container, four samples of crumb rubber were exposed to conditions meant to simulate environmental conditions found on real artificial turf fields. The study article did not detail size, other



Surface temperatures of artificial turf fields have been documented anywhere from 117°F to 200°F, well above the test range analyzed in this study.

than to say two of the cryogenic samples were different sizes, or which, if any, of the samples were coated with acrylic, even though they wrote that this coating may reduce release of leachates and airborne contaminants from crumb rubber infill.

- The chamber allowed for the capture of pollutants in the air above the simulated field as well as those leaching from water running off the field due to rain. The samples were exposed to limited air and water temperatures. Surface temperatures of artificial turf fields have been documented anywhere from 117° F to 200° F,[1] well above the test range analyzed in this study.

- Leaching analysis was performed using acidic water (pH4 to pH5) and exposing samples for 24 and 48 hours. These times do not present real conditions in terms of rainwater and snow (normal rainwater has an acidity of 5.6) or the life-span of an artificial turf field, which averages eight to 10 years.

[1] Williams C.F. and Pulley, G.E. 2003. Synthetic Surface Heat Studies. Brigham Young University. Available: http://cahe.nmsu.edu/programs/turf/documents/brigham-young-study.pdf [accessed 8/12/17].



Conclusion

The researchers concluded that their test chamber offered a complete health and environmental assessment of crumb rubber infill used in artificial turf fields. However, it is not clear that this is the case. Does such a chamber represent accurately what 22 soccer players, running up and down a synthetic turf field, are actually exposed to? Players on a field create crumb rubber dust that players breathe in, and those exposures were not accounted for in this study.

The test samples were heated to temperatures that were below where many fields have been tested previously. In addition, the study's conclusions were based on a small number of samples.

Finally, it should be noted that one of the researchers is affiliated with a firm holding patents on cryogenic crumb rubber. (Cryogenic refers to freezing the waste tires to break them up more easily into the crumb rubber pieces used in synthetic turf infill.)

Does a [testing] chamber represent accurately what 22 soccer players, running up and down a synthetic turf field, are actually exposed to? Players on a field create crumb rubber dust that players breathe in, and those exposures were not accounted for in this study.

Study Number 12

An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields

http://c.ymcdn.com/sites/www.syntheticturfcouncil.org/resource/resmgr/Docs/Stern,_Alan,_NJ_DEP,_An_Eval.pdf

AUTHOR: Stuart L. Shalat, ScD.

DATE: July 2011



The study found that lead was present at varying levels in all five fields tested.

This study, although not peer reviewed, includes a literature review and original research. The New Jersey Department of Environmental Protection (NJDEP) funded the project, performed by Dr. Shalat at the Environmental and Occupational Health Sciences Institute (EOHSI). The study was presented as a final report (see above) from Dr. Shalat to Dr. Alan H. Stern, Office of Science, NJDEP, and summarized by Dr. Shalat and Alan H. Stern in August 2011.[1]

The purpose of this study was to measure the levels of heavy metals in New Jersey artificial turf fields and assess whether the metals were present in a form that could be inhaled by the players on the fields. The metals looked for were chromium, cadmium, arsenic and lead.

Air and wipe samples were taken by a robot moving on five fields and compared to air samples taken from stationary air samplers and from one personal air sampler worn by a boy who was playing with a soccer ball alone on one of the synthetic turf fields.

The study found the level of lead in air and wipe samples significantly elevated in one field that was eight years old—the oldest field sampled. The researchers concluded that their study was too limited to allow them to generalize their conclusions in terms of the safety of other artificial fields. However, the study and summary did recommend that artificial turf fields, in particular those fields older than three years, should be wipe-tested for lead. They also recommended that when elevated levels of lead are identified, more extensive air sampling should be conducted.

[1] Shalat, S.L. and Stern, A.H. 2011. Office of Science [New Jersey Department of Environmental Protection] Research Project Summary: An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Field. Available: http://www.state.nj.us/dep/dsr/publications/turf-pm.pdf [accessed 8/12/17]

Five New Jersey artificial turf fields with crumb rubber infill were investigated using a robot capable of taking wipe and air samples as it moved across the central part of each field, agitating the field surface. Stationary air samples were collected at midfield and along the sidelines of each field. On one field, an air sample was collected from a personal air sampler worn by a 12-year-old boy who played for an hour as he would during soccer practice. The air and wipe samples were then analyzed and compared for particulate concentrations of lead, chromium, cadmium and arsenic.

- In air samples, the robot measured two to eight times the particulate concentrations that were measured by stationary samplers on four out of the five fields tested.
- When compared to the air samples taken from the boy's personal sampler, results indicated that the robot provided a reasonable estimate of exposure for one person using the field.
- In the summary introduction, researchers noted that lead may be found in both the plastic grass blades and the crumb rubber infill of the synthetic turf fields. The study found that lead was present at varying levels in all five fields tested and that the oldest field contained the highest level of inhalable lead.

  The wipe sample for this eight-year-old field contained 500 to 1000 times the lead concentration of the other fields. The lead was then made available in the air at significant levels when it was agitated by the motion of the robot across the field's surface. In their summary, researchers noted that individual fields could contain sufficient levels of lead to pose a health concern, especially if they were used repeatedly. According to the U.S. Centers for Disease Control and Prevention (CDC), no safe blood lead level in children has been identified.
- The study was limited in size to five fields out of 47 potential fields. There were seven cases where New Jersey communities had initiated contact with state agencies for an assessment of the potential health hazards of their artificial turf fields. Despite this original concern, in the end only five communities out of nearly 50 that were contacted by researchers agreed to testing.

Conclusion

The study found that lead was present at varying levels in all five fields tested. The oldest field contained the highest level of inhalable lead. The wipe sample of this eight-year-old field contained 500 to 1000 times the lead concentration of the other fields.



Only five communities out of nearly 50 that were contacted by researchers agreed to testing, showing a reluctance to find the fields harmful.



Researchers noted that individual synthetic turf fields could contain sufficient levels of lead to pose health concerns for players, especially if the fields were used repeatedly.

The study was limited by its size. Tests were conducted on five synthetic turf fields using a stationary air sampler and a robot on each field, with additional air samples taken using one person on one of the fields. The test results showed that a robot moving across the surface provided accurate estimates of exposure for one player on a field. This movement mobilized particulate matter from the surface into the air above the fields.

On the oldest field, inhalable lead present at very high levels was mobilized at significant levels into the air above the field. Despite these findings, the study did not go on to analyze what would happen in a realistic exposure scenario when two teams of soccer players were moving together at the same time upon these fields.

In summary, researchers noted that individual synthetic turf fields could contain sufficient levels of lead to pose health concerns for players, especially if the fields were used repeatedly. The study went on to recommend that artificial turf fields, in particular those fields older than three years, should be wipe-tested for lead and, when elevated levels of lead are found, more extensive air sampling should be conducted.

Study Number 13

Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment

http://www.ct.gov/dph/lib/dph/environmental_health/eoha/pdf/artificial_turf_benzothiazole_2011.pdf

AUTHORS: Gary Ginsberg, Brian Toal, Tara Kurland

PUBLISHED: *Journal of Toxicology and Environmental Health, Part A: Current Issues,* Volume 74

DATE: July 2011

This study is peer reviewed and presents original research.

The purpose of this study was to develop calculations that would allow the Connecticut Department of Health (CT DPH) to measure the carcinogenic potential of inhaling benzothiazole (BZT) by using information about ingesting 2-mercaptobenzothiazole (2MBZT). The study was not designed to confirm or deny the safety of crumb rubber infill used in synthetic turf fields.

BZT, found in five synthetic fields in Connecticut, is known to exert acute toxicity as well as being a respiratory irritant. However, because there were serious data gaps in the BZT toxicity data, the study called for more research to fill those gaps.

The study included a literature review of previous laboratory studies of BZT and a related chemical, (2MBZT),[1] and previous investigations of synthetic turf fields. As of 2011, the toxicity of 2MBZT had been more thoroughly tested than BZT.

In this study, researchers used 2MBZT as a surrogate for BZT in order to explore the acute, chronic and carcinogenic potency of BZT, in support of a



BZT, found in five synthetic fields in Connecticut, is known to exert acute toxicity as well as being a respiratory irritant.

[1] As of December 14, 2016, 2-Mercaptobenzothiazole (2MBZT) has been added to the United States Environmental Protection Agency (U.S. EPA) Office of Pesticide Program Supporting document to docket# EPA-HQ-OPP-2014-0558 – Listing of 72 chemical substances removed from the currently approved inert ingredient list.

See: U.S. EPA. 2016. Listing of 72 inert ingredients removed from the approved listing. Regulations.gov. Available: https://www.regulations.gov/document?D=EPA-HQ-OPP-2014-0558-0056 [accessed 8/12/17].

health risk assessment of synthetic turf fields being conducted at that time by the Connecticut Department of Health (CT DPH).

The researchers concluded that there was a large degree of uncertainty about the toxic health effects of BZT and 2MBZT, but that in sufficient exposures the chemicals may be carcinogenic and damage the liver, kidneys and central nervous system. The study formulated a health risk formula using 2MBZT to assess for cancer risk in crumb rubber field investigations, but researchers cautioned that this was a only a screening-level assessment.



The study was not designed to confirm or deny the safety of the crumb rubber infill.

Because BZT and 2MBZT share some chemical properties, and because 2MBZT had been more thoroughly tested for health effects, the researchers used previously published potency information about the cancer risk of ingesting 2MBZT to calculate the cancer risk of inhaling BZT found in crumb rubber infill. This was done in order to assist the CT DPH in its study of Connecticut artificial turf fields.

Conclusion

A literature review of previous research on two related chemicals, BZT and the more scrutinized chemical 2MBZT, indicated that BZT may pose a health risk at high exposures.

While it was noted that BZT may be mutagenic and carcinogenic, the researchers cautioned that their conclusion was based on an imperfect comparison to 2MBZT and that there were metabolic differences between the two chemicals.

Despite these differences, and facing a wide degree of uncertainty about the toxicity of BZT, the researchers developed a health risk formula using information about the ingestion of 2MBZT to measure the carcinogenic health risk of inhaling BZT.

The point of this study was to develop a calculation that allowed for the CT DPH to measure the carcinogenic potential of inhaling BZT by using information about ingesting 2MBZT. The study was not designed to confirm or deny the safety of the crumb rubber infill used in synthetic turf fields.

Study Number 14

Artificial Turf Field Investigation in Connecticut Final Report

http://www.ct.gov/deep/lib/deep/artificialturf/uchc_artificial_turf_report.pdf

AUTHORS: Nancy Simcox, Anne Bracker, John Meyer

DATE: July 2010

This report was peer reviewed and published as a government document. The report contains original research included in articles published in the* Journal of Toxicology and Environmental Health, *Part A: Current Issues, Volume 74, 2011. Funding for this project was provided by the Connecticut Department of Environmental Protection.

This report identified and measured lead, volatile and semi-volatile organic compounds (VOCs and SVOCs), including polycyclic aromatic hydrocarbons (PAHs), nitrosamines and particulate matter (PM_{10}) in bulk samples of recycled tire crumb rubber infill and in the air above synthetic turf fields cushioned with the material, so that the data might be used in a possible health risk assessment planned in Connecticut.

Results showed variable concentrations of VOCs, benzothiazole and other miscellaneous SVOCs, with the highest concentrations found on an indoor artificial turf field. It is noteworthy that the indoor field research included personal air sampling times that were very brief, at less than 25 minutes, and still recorded levels were highest on that field. Researchers concluded that more study was necessary to understand chemical exposures in indoor fields.

- Personal and area air samples were collected and analyzed. Two study team members wore personal air samplers at waist-level to collect air samples during two hours of active play with two other players on six fields. Four of the fields were outdoor artificial turf fields, one was an indoor artificial field, and one was an outdoor grass field. Area air samples were also collected during one to two hours of simulated active play on the same six fields. Off-field air samples were captured to serve as background information and one field was also sampled for a six-hour period when the field was not active.

- Bulk material was collected and analyzed. Composite bulk samples of artificial turf fiber and crumb rubber infill were collected from five locations



This study identified and measured lead, volatile and semi-volatile organic compounds (VOCs and SVOCs), including polycyclic aromatic hydrocarbons (PAHs), nitrosamines and particulate matter (PM_{10}).



The indoor field produced the highest toxic concentrations of volatile organic compounds (VOCs). The study cautioned that more research was needed to understand the exposures from the indoor artificial turf fields.

on each of the five artificial fields investigated. The material was analyzed for lead. In addition, one bulk crumb rubber infill sample was collected at each of 11 fields and analyzed for targeted SVOCs, VOCs and other chemicals.

- Limitations of the research include:
  - Small sample size, short sampling times (particularly on the indoor field, where personal air samples were collected for less than 25 minutes), and technical difficulties in coordinating and implementing the sampling plan and collecting area air samples.
  - Reporting of analytic results was complicated because analysis was subcontracted to three different labs.
  - Lead concentrations in bulk crumb rubber analyzed for this study could not be compared to contemporaneous analysis for lead done on other bulk samples by the Connecticut Agricultural Experiment Station (CAES) due to the use of different analytical methods, even though this study and CAES sampled from two of the same outdoor fields.

- Personal air sampling was restricted to two study team members wearing samplers, simulating active play against two other study team members. Real active play at practice or games is conducted by 22 team members at play for about two hours.

- Researchers decided to limit particulate matter analysis to PM_{10} because limited prior research did not find smaller rubber dust particles sized $PM_{2.5}$. This decision to limit testing to PM_{10} eliminated the possibility that exposure by inhalation of smaller particles would be part of the planned future risk assessment.

Conclusion

Despite many limitations to this research, of 60 VOCs tested in the air, four VOCs were associated with the turf. Out of 22 PAHs identified, there were six found at levels two-fold greater than at background locations on at least two fields. Two rubber-related SVOCs, benzothiazole and butylated hydroxytoluene (BHT), were detected in personal and area air samples.

Lead was detected in all the composite bulk samples of fiber and crumb rubber infill collected, at levels below what the EPA considers a "soil-lead hazard" in play areas (400 ppm). However, the U.S. Centers for Disease Control and Prevention (CDC) states that there is no safe level of lead in the blood of children.

Personal air-sampling was very limited on the only indoor artificial turf field tested. Sampling time was for less than 25 minutes at this site, while outdoor fields were sampled for one to two hours. Real conditions at practice or play involve 22 athletes at play for about two hours. Even though sampling was very limited at the indoor field tested, this field produced the highest toxic concentrations of VOCs, benzothiazole, and miscellaneous SVOCs in personal and area air samples.

The study cautioned that more research was needed to understand the exposures from the indoor artificial turf fields. The air sample results in this study clearly suggest that a more strongly-worded warning is necessary at indoor fields that contain crumb rubber infill. The study found that without additional and proper ventilation, the indoor fields pose a health threat to those who play on them, because they have higher levels of toxins in the air than are protective of human health.



Without additional and proper ventilation, the indoor fields pose a health threat to those who play on them because they have higher levels of toxins in the air than are protective of human health.

STUDY NUMBER 15

Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut

http://www.ct.gov/deep/lib/deep/artificialturf/dph_artificial_turf_report.pdf

AUTHORS: Gary Ginsberg and Brian Toal

DATE: July 2010



This assessment was peer reviewed and published as a government document. The assessment contains original research including a human health risk assessment, a short literature review, and a toxicity profile on a rubber-related chemical, benzothiazole (BZT). The research was included in articles published in the Journal of Toxicology and Environmental Health, Part A: Current Issues, Volume 74, 2011.

The objective of this human health risk assessment (HHRA) was to estimate exposures and risks for children—12 and older—playing on artificial turf. In July 2009, Connecticut field researchers collected air samples from five artificial turf fields. They sampled four outdoor fields and one indoor field.

The study identified 27 chemicals of potential concern, including 13 carcinogens

In 2010, Connecticut researchers took this data and analyzed the personal air and stationary air samples to determine their acute or chronic, cancerous or non-cancerous health effects in school-aged children and adults. Results were analyzed for multiple volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and targeted rubber-related and miscellaneous semi-volatile organic compounds (SVOCs).

Sample data was limited by the plan size, the number of sampling events and the technical difficulties in implementing the collection strategy. Because air sample collections occurred during warm—not hot—weather, exposures due to extreme heat were not addressed. Additionally, the researchers chose to exclude dermal and ingestion exposure routes from their assessment; only inhalation exposures were considered. The human health risk assessment focused on air sample results for multiple VOCs and SVOCs. Exposures to latex, lead or zinc were not part of this health assessment.

The researchers identified 27 chemicals of potential concern in the air samples they reviewed. Non-cancer risks were assessed for all of these chemicals. Cancer risks were assessed for 13 chemicals. Acute health risks were developed for 15 chemicals. They calculated cancer and non-cancer risks for acute and chronic exposures to these chemicals in four possible scenarios—children playing on



indoor fields, children playing on outdoor fields, adults playing on indoor fields, and adults playing on outdoor fields.

The researchers found the presence of benzothiazole (BZT) to be clearly field-related. They expressed uncertainty as to whether several PAHs and VOCS might be field–related. They concluded that cancer risks in all scenarios were slightly above de minimis (negligible) but were higher for children than for adults. They determined there was little concern for chronic, non-cancer risk despite their uncertainty about significantly (two-fold) elevated exposure risks at the indoor field as compared to the outdoor fields, due to air-borne, off-gassed chemicals.

They advised adequate ventilation for indoor fields, installing outdoor fields during cooler months, and noted that any dermal or respiratory allergic reactions experienced on the fields might be a result of on-field exposure and should be reported to physicians and the local health department.

- The assessment found that two VOCs, benzene and methylene chloride, were the greatest contributors to cancer risk in each scenario with additional small contributions by chloromethane, BZT and PAHs. Some doubt was cast upon the presence of benzene and methylene chloride as contributors because they were found only in the air samples collected in

Play on the indoor field was for less than 25 minutes—a much shorter period of time than was called for in the plan...yet the chemical levels in the air samples were the highest collected in the investigation.



Their conclusion was that cancer risks in all scenarios were slightly above de minimis (negligible) but were higher for children than for adults.... They recommended adequate ventilation for all indoor artificial fields.

personal air monitors. The researchers hypothesized the chemicals were a result of the equipment itself or were exuded by the people wearing the personal air monitors.

- BZT, a rubber-related chemical, was the only targeted SVOC detected above background levels on both the indoor and outdoor fields. The results for the indoor field were 11.7 times greater than the outdoor results.
- Limitations to the research include:
  - The study was narrowed to investigate only inhalation exposures to athletes who play on outdoor and indoor artificial turf fields. Dermal and ingestion exposure routes were not considered. Since BZT may be available for skin contact in the crumb rubber infill and rubber dust, the researchers suggested it could cause skin irritations to players on the fields.
  - Air samples were collected in warm weather, not on hot summer days when VOCs may off-gas in greater amounts from the crumb rubber infill.
  - The study had a small sample size. Samples were only collected from four outdoor fields and one indoor field.
  - The study's sampling plan was not fully implemented due to technical difficulties with equipment and environmental conditions. In the case of one field, pesticide spraying took place adjacent to the field on the day samples were collected. On other fields, field air samples were not collected at all heights, as planned.
  - Play on the indoor field was for less than 25 minutes—a much shorter period of time than was called for in the plan. Despite this, chemical levels in air samples from this field were the highest collected. There was no ventilation on the field when sampling was done. No attempt was made to collect more samples when the field was ventilated, or during longer play time. The assessment included the flawed data.
  - On all fields sampled there were only two people wearing personal air monitors and two other people on the field. Sampling ranged from less than 25 minutes to two hours. This simulation did not reflect real play conditions on a synthetic turf field—it is typical for 22 athletes to play for about two hours.
  - The exposure scenario was formulated to assess risk to children of average age 12 to adult. Children ages birth to three were not



included in this assessment. Therefore, exposure risks remain unknown for infants and toddlers who are present on the sidelines while their siblings practice and play on artificial turf fields.

- The report recommended adequate ventilation for all indoor artificial fields. It also recommended that dermal or respiratory allergic reactions suffered on the fields should be reported to physicians and local health departments.

Conclusion

Despite all the limitations and exclusions, the researchers concluded that all cancer risks were negligible, even though the study noted that cancer risks were found to be slightly higher for children ages 12 and older. The study identified 27 chemicals of potential concern, including 13 carcinogens—yet the risks were declared negligible. The study found elevated levels of the chemical BZT, which is a serious irritant, but they declared the fields pose no acute risk to children.

This study has been touted by industry as showing that synthetic turf fields are safe. This study has many flaws, and in no way proves that the fields are safe. The study raises more questions than it answers.

Exposure risks remain unknown for the infants and toddlers who are present on the sidelines while their siblings practice and play on artificial turf fields.

Study Number 16

2009 Study of Crumb Rubber Derived from Recycled Tires Final Report

http://www.ct.gov/deep/lib/deep/artificialturf/caes_artificial_turf_report.pdf

AUTHOR: X. Li, W. Berger, C. Musante, M.J. Incorvia Mattina

DATE: May 2010

This study was peer reviewed and its findings were included in the synthetic Turf Study of 2010 by the CT Department of Health.



Manganese, nickel and barium were present in all 17 samples; lead was present in 14 samples.

The purpose of this report was to provide laboratory protocols and analytical information about crumb rubber infill derived from recycled tires for a state-funded study conducted by the Connecticut Departments of Environmental Protection (CT DEP) and Public Health (CT DPH), and the University of Connecticut Health Center (UCHC).

The Connecticut Agricultural Experiment Station (CAES) analytical chemists developed and performed laboratory protocols to identify volatile compounds released in the air and organic compounds and heavy metals leaching into water from crumb rubber material (CRM).

Samples of CRM were provided by the CT DEP and, in most cases, were new material that had not been exposed outdoors. CAES researchers created two replicates of each sample and conducted chemical analysis, and compiled and shared data on volatile compounds off-gassing and organic compounds and heavy metals leaching from the samples. Two limited aging and weathering protocols were also designed and implemented and volatile compounds were measured off-gassing from samples exposed to real weather conditions.

Lab emissions tests identified 11 volatile compounds issuing from each of the 17 crumb rubber samples examined in the lab. Seven of these compounds were identified at high enough levels to further analyze their concentrations. Six of the 11 compounds were PAHs. Benzothiazole (BZT), a semivolatile organic compound (SVOC), was present in the largest amount, by an order of magnitude, in the emissions from all of the samples.

Lab tests were also conducted to identify materials that might leach from CRM when exposed to rain. Nine metals were identified leaching from 17 samples of CRM exposed to simulated rainwater (which is slightly acidic). Results showed

a wide variation of elements present in the samples. Zinc was present in the highest concentrations in all the samples, exceeding the other metals by two to six orders. Leaching tests also confirmed that BZT was similarly accessible in both simulated rainwater and non-pH adjusted water.

- The research planned three limited protocols to simulate field conditions that age and weather CRM. Two of the protocols were conducted: New CRM underwent controlled exposure to outdoor environmental conditions outside of the laboratory building.

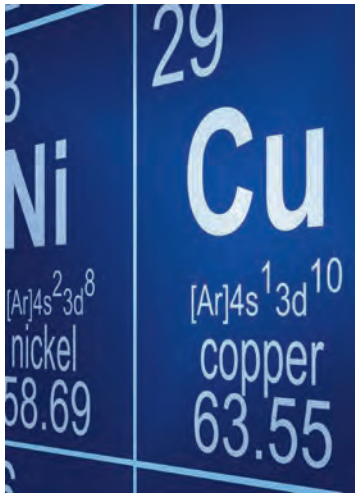
  In another protocol CAES researchers found that two of the unused CRM samples they had conducted research on in the lab were from Connecticut fields that had aged two years since the samples were collected. This allowed the researchers to collect field samples and examine them in the lab to compare emissions of volatile compounds from the samples in new condition, as compared to those that had aged and weathered for two years in real conditions. Results from the controlled exposure tests showed six compounds outgassing at measurable and decreasing rates and finally reaching a consistent rate of outgassing, over 10 weeks' time.

- Lab emissions tests showed a wide range of concentrations of seven volatile compounds in each sample analyzed. BZT was present in the largest amount in every sample.

- Along with high concentrations of zinc in all 17 samples, lab leaching tests identified eight other elements, in widely varied amounts, present in samples of CRM exposed to simulated rain. Manganese, nickel and barium were present in all 17 samples; lead was present in 14 samples; copper was present in 13 samples; chromium was present in 12 samples; and cadmium and arsenic were present in two samples.

- Limitations of the research include:

  - For the most part, aging and weathering research was limited to 10 weeks. Only two samples of CRM were available for weathering comparisons over a longer period of time—after CAES researchers realized that samples provided to them by CT DEP were in new condition and could be tested and compared to the same products that had been in use for two years each on two Connecticut fields. Despite the small sample size and the differences in exposure times, the researchers found remarkable similarity in the results of emissions tests from the two different weathering protocols.



Copper was present in 13 samples; chromium was present in 12 samples; and cadmium and arsenic were present in two samples.



This research identified 11 volatile compounds and nine metals outgassing and leaching.

- Small standard deviations for the emissions research on CRM showed consistency in the concentration values of the two replicates of each sample. We note, however, that the use of only two replicates is a very small sample size and may not accurately portray real differences in the concentrations of chemicals in larger sample sets.

Conclusion

This research identified 11 volatile compounds and nine metals outgassing and leaching from the 17 crumb rubber samples analyzed in the laboratory.

In emission tests, benzothiazole (BZT) was present in all samples and at a higher level than the other metals and chemicals tested.

In the leaching tests, using slightly acidified water to simulate rain-water, zinc was present in all samples and at a higher level yet in the testing. BZT was captured leaching in both simulated rainwater and non-pH adjusted water.

CAES conducted this research in 2009 in order to provide the protocols and chemical analyses for the later Connecticut study that was completed in 2010.

Study Number 17

Safety Study of Artificial Turf Containing Crumb Rubber Infill Made from Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface

http://www.calrecycle.ca.gov/publications/Documents/Tires/2010009.pdf
AUTHORS: Charles Vidair
DATE: October 2010

This study was reviewed by peers at CA OEHHA and was not published. The report includes a health assessment and literature review. The research was funded by California's Department of Resources Recycling and Recovery (CalRecycle) and presented as a Contractor's Report.

Three separate investigations were conducted as part of this study:

- Volatile organic compounds (VOCs) were measured and identified in the air over artificial turf fields and grass fields in Central California.
    - After VOCs were detected in the artificial fields in Central California, researchers conducted a human health risk assessment to determine whether inhaling the VOCs posed a health risk to players using the fields.
- Particulate matter ($PM_{2.5}$) was measured in the air over artificial turf fields and grass fields in cities in the San Francisco Bay Area of California.
- Bacteria were identified and measured in artificial turf fields and grass fields, and the synthetic turf fields at high schools, colleges and universities in the San Francisco Bay Area of California.

The report included a literature review of past research and made comparisons to this study. The study reviewed past research on skin abrasions from synthetic turf fields and ensuing MRSA infections among college athletes. A survey of coaches was conducted to estimate total time spent on the fields by players aged four to 59.

From a target list of 94 compounds, the study detected seven VOCs emitting from air sampled above artificial fields: 2-propanol, cyclohexane, toluene,



The study reviewed past research on skin abrasions from synthetic turf fields and ensuing MRSA infections among college athletes.



Previous research showed the rate of skin abrasions due to contact with artificial turf was two to three times higher for college soccer players as compared to grass fields.

m,p,o-xylenes, isopropylbenzene, 4-ethyltoluene and 1,2,4-trimethylbenzene. The study found no relationship between surface temperatures and airborne VOC concentrations. At the time of the study, none of the seven VOCs investigated were on the California (CA) list of cancer-causing chemicals, so cancer risks were not calculated. The study concluded that athletes playing on artificial turf fields were unlikely to experience either chronic or acute health effects due to inhaling these VOCs.

$PM_{2.5}$ levels were below the level of detection in the air above the fields so no health risk assessment for particulate matter was developed. The samples were tested to determine whether they contained any heavy metals; no detectable levels of any heavy metals were found. The study concluded that the surface does not release respirable dust containing significant amounts of heavy metals.

Fewer bacteria were identified on the artificial turf fields as compared to the grass fields. However, previous research showed the rate of skin abrasions due to contact with artificial turf was two to three times higher for college soccer players as compared to contact with grass fields. Because this higher rate of skin abrasions may increase the risk of skin infections, the study recommended protective clothing and equipment and prompt treatment of wounds, especially for athletes playing on artificial turf, and suggested that there be further research measuring skin infection rates in athletes playing on artificial turf and grass fields.

- To test for VOCs, researchers captured air from stationary samplers placed four feet above fields in Central California. Eight air samples were collected at each of four artificial fields and four adjacent or nearby grass fields. Collection occurred for 45-minute periods during summer days. Air and surface temperatures were monitored.

  The age of the artificial fields ranged from eight months to five years. The report does not specify whether the fields were in use or inactive while air samples were collected. There was little consistency among the four artificial fields regarding the VOCs detected. VOC levels at each artificial field were similar to the levels captured upwind of them on grass fields.

- To test for $PM_{2.5}$, air was captured at three San Francisco Bay Area city-owned artificial fields. At each field, one sample was collected directly above the field and one sample was collected upwind of the field, in



consecutive three-hour periods. The next day this process was repeated. A stationary air sampler was used at a height of four feet. The air samples directly above the field were collected during active play. The sample contents were measured for lead and other heavy metals.

- To test for bacteria, samples were collected from five artificial turf fields and two grass fields owned by high schools, colleges and universities in the San Francisco Bay Area. Each field was sampled in three locations. Crumb rubber/sand infill and plastic blades were collected from the artificial fields. Soil and blades of grass were collected from the grass fields.

  A total of 42 samples was cultured in the laboratory. In each culture, MRSA was quantified along with the three most prominent species of bacteria present. The results show fewer bacteria, in both variety and quantity or organisms, in the artificial turf fields as compared to grass fields. MRSA was identified in only one sample of blades from a grass field.

- To estimate the health risks to soccer players from inhaling these VOCs, the researchers developed acute and chronic exposure scenarios using time

The study noted that research was only done on outdoor fields and that future testing should be done on indoor fields as well.

estimates provided by soccer coaches in the California Youth Soccer Association (CYSA). The coaches were asked to provide the number of hours per year that enthusiastic soccer players, ages four to 59, spend in organized practice or play.

- Limitations of the research include:
  - A small number of fields were tested and a small number of samples were captured at each field.
  - No newly installed artificial turf fields were tested even though researchers noted that VOC emissions decrease over time in laboratory tests, so it is likely that VOC concentrations in the air above fields would be greatest shortly after the fields were installed.
  - In the investigation of VOCs, the report does not say whether air samples were collected during active play or when the fields were empty.
  - The report noted that it is not known whether field age, processing method temperatures (ambient vs. cryogenic), or source of tires (trucks or cars) or tire age at the time of processing influence VOCs or $PM_{2.5}$ released from crumb rubber infill.
  - The report noted that this research was only of outdoor fields and that future testing should be done of indoor fields as well because VOCs and $PM_{2.5}$ may accumulate in the air above indoor fields.
  - The report noted "Recycled tire rubber emits hundreds of VOCs (CIWMB, 2003). Our target list of VOCs contained 94 chemicals (U.S. EPA Method TO-15). Therefore, it was not possible to screen for all of the VOCs emitted by recycled crumb rubber. Since many remain unidentified, their concentrations above artificial turf, as well as their potential health effects, are unknown."



"Recycled tire rubber emits hundreds of VOCs.... Therefore, it was not possible to screen for all of the VOCs emitted by recycled crumb rubber."

Conclusion

There was little consistency among the four artificial fields regarding the VOCs detected. The study found:

- No correlation between concentrations or types of VOCs detected above artificial fields and the surface temperature of the fields.



- VOC levels at each artificial field were similar to the levels captured upwind of them on grass fields.
- Particulate matter measured was below levels of detection and no heavy metals, including lead or zinc, were detected.
- No significant levels of bacteria were identified on artificial fields. However, because previous studies had found significantly higher rate of turf burns among athletes who played on artificial turf as compared to grass fields, they recommended protective clothing and gear during play on artificial turf, and they suggested further research into skin infection rates among college athletes.
- Of the many data gaps and limitations noted in the report, most significant is the comment that "it was not possible to screen for all of the VOCs emitted by recycled crumb rubber."
- Despite this disclosure, the study concluded that adverse health effects were unlikely for people using artificial turf fields.

The study recommended protective clothing and equipment and prompt treatment of wounds.

Study Number 18



Toxicological assessment of coated versus uncoated rubber granulates obtained from used tires for use in sport facilities

https://www.ncbi.nlm.nih.gov/pubmed/20565000

AUTHORS: Gomes, H. Mota, J. Bordado, M. Cadete, G. Sarmento, A. Ribeiro, M. Baiao, J. Fernandes, V. Pampulim, M. Custódio, I. Veloso

PUBLISHED: *Journal of the Air & Waste Management Association*, Volume 60

DATE: June 2010

This study was peer reviewed and published. Two coauthors are engineers with Recipneu, a company that produces and markets crumb rubber made from recycled tires. Samples tested were also provided by this company.

The researchers performed laboratory tests to determine whether coated crumb rubber particles made from recycled rubber tires would leach chemicals and metals at lower levels than uncoated crumb rubber particles.

Two additional laboratory tests were performed: One test measured and compared the percentage of inhalable crumb rubber particles; another test assessed the toxicity of coated and uncoated crumb rubber to luminescent bacteria.

Crumb rubber particles with two different coatings were tested. Test results indicated that coating crumb rubber particles may reduce the amount of chemicals and heavy metals leaching from the coated crumb rubber as compared to the uncoated material.

Samples were provided by Recipneu, a company that uses a process that freezes and pulverizes recycled tire material to make crumb rubber.

The research found differences in the effectiveness of the two coatings. Although the study gave reports on the results of these tests, the composition of the coatings was not completely disclosed. One coating was PVC, which has been prohibited from textile products due to its harmfulness to human health. The other coating leached tin above a safe health limit. Specific, limited disclosures about the crumb rubbber coatings cautioned that both contained flame-retardants.

- Limitations of the research include:
  - Very small sample size.

Specific, limited disclosures about the crumb rubbber coatings cautioned that both containrd flame-retardants.

- No air emissions were tested.
- Leaching tests were performed for short soaking periods.
- The research does not indicate the acidity of the solution or the length of time the materials were soaked before leachates were measured for PAHs; test results are described as "water leachates." For the tests measuring heavy metal leachates, the solution is described as "acidic water." Therefore, it is unknown whether the time periods and solutions for the two leachate tests replicate similar field conditions.
- The samples and coauthors of the research were from the same company. .

Conclusion

The research was performed to assess whether crumb rubber coatings would reduce chemicals and metals leaching from the material. Results indicate that coated crumb rubber may be somewhat less toxic than uncoated material. The researchers cautioned that the coatings might contain harmful substances. They described this toxicity assessment as a "first step" toward a necessary and more comprehensive evaluation of the products.

It should be noted that, as of 2016, most recycled rubber material used in synthetic turf fields is less expensive crumb rubber rather than the frozen and pulverized (cryogenic) infill[1] which was the focus of this study. A single sample of the less expensive crumb rubber was examined in this research. That sample was investigated only for the percentage of inhalable particles it produced. This sole sample of less expensive crumb rubber produced a much higher percentage of $PM_{2.5}$ and PM_{10} than frozen and semi-frozen crumb rubber samples that were similarly tested.



The researchers cautioned that the coatings might contain harmful substances.

[1] U.S. EPA Meeting with the Synthetic Turf Council, Recycled Rubber Council, and Safe Fields Alliance. March 22, 2016. Final Meeting Minutes. FOIA document, transcribed notes. See page 4:

Statements of Rom Reddy, Sprinturf and Safe Fields Alliance and Amy Brackin, Synthetic Turf Council.

Reddy: Ambient processing has by far the biggest market share. It is a mechanical milling process; the tire material is granulated.

Brackin: Cryogenic processing is generally more expensive. It uses liquid nitrogen; pulverizes the tire material into smaller pieces.

STUDY NUMBER 19

A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds

https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=215113&simpleSearch=1&searchAll=EPA%2F600%2FR-09%2F135

AUTHOR: The research was prepared by the National Exposure Research Laboratory (NERL) Office of Research and Development, U.S. Environmental Protection Agency (U.S. EPA) with contributions from the Agency's Tire Crumb Science Workgroup.

DATE: November 2009

This study was reviewed by peers and administrators and was approved for publication as a U.S. EPA document. The research was funded by the U.S. EPA.



The study generated limited data from air and material samples taken above and on the surface of six artificial turf fields and two playgrounds.

The objective of this project was to produce a very limited scoping study that evaluated sampling and analysis methods for future research of selected contaminants found in rubber tire material used as playing field infill and for playground surfaces.

The study generated limited data from air and material samples taken above and on the surface of six artificial turf fields and two playgrounds.

- Methods evaluated in this research were as follows:
  - Air samples were analyzed for volatile organic compounds (VOCs).
  - Stationary air samples were analyzed for particulate matter (PM_{10}).
  - Surface materials were collected and analyzed. From the artificial fields, the crumb rubber infill and plastic grass blades were collected. From the playgrounds, shredded rubber tires and rubber formed and colored to look like wood mulch were collected.
  - Wet surface wipe samples from fields and playgrounds were analyzed for extractable metals, including lead.
  - Using EPA methods validated for lead in soil, the researchers analyzed the bioaccessibility (the amount available for absorption in the human body) of the lead extracted from materials and wipe samples.



- Researchers determined that the study protocol and many of the collection and analysis methods were reliable and could be used in future field studies. One exception was that laboratory methods to analyze the bioaccessibility of lead were determined to be inappropriate for wet surface wipe samples taken from fields and playgrounds.

- The limited results showed low concentrations of 12 VOCs similar to those in ambient air, with one exception—methyl isobutyl ketone (MIBK), a rubber-related solvent, was found at slightly elevated levels in the air above one field.

- Concentrations of PM_{10} and metals, iincluding lead, measured in the air above the turf fields were similar to background concentrations. Concentrations of PM_{10} and the metals carried by airborne particles, including lead, at the playground tested, during high play activity, were higher than background levels.

- Total extractable metal concentrations in infill, artificial grass blades, and playground material samples were low, and lead concentrations were, on average, below the EPA safety standard for lead in soil. Researchers noted,

Concentrations of PM_{10} and the metals carried by airborne particles (including lead) at the playground tested, during high play activity, were higher than background levels.

however, that lead concentrations in materials were highly variable *among* the sites and *within* each site. This was also true of other metals extracted from materials samples, especially at the playgrounds sampled. Extractable lead concentrations in wipe samples were present but averaged below the EPA standard for lead in residential floor dust.



Metals, including lead, were found in widely varying concentrations. With regard to lead, there was up to a 36-fold difference found in the seven samples of tire crumb material taken from one playground.

- Researchers determined that EPA methods used to analyze the bioaccessibility of lead were not appropriate for wet surface wipe samples, so wet wipe samples were not evaluated to determine whether the lead they contained was available to harm players on fields or playgrounds.
- The bioaccessibility of lead in materials sampled from the fields and playgrounds was low, on average, but varied widely, even among samples taken from one site. With regard to lead, there was up to a 36-fold difference found in the seven samples of tire crumb material taken from one playground.

  In samples of plastic grass blades, lead bioaccessibility varied in blades of different colors. Researchers found that samples with the highest levels of lead showed the lowest levels of bioaccessibility, which spurred them to call for additional research to understand the mechanism underlying this fact.
- Limitations (researchers noted many limitations):
  - The sampling size was very small—there were only six fields and two playgrounds that participated in the study. A very small number of samples were collected at each site.
  - The sampling plan was only completely executed on two fields and one playground.
  - Air sampling and some material sampling was repeated at only one field, two days in a row, and those results were compared for consistency.
  - The protocol was only duplicated on a second day at one field.
  - Limited data was generated and researchers noted it was not applicable to any other fields or playgrounds.

- Rubber-related semivolatile organic compounds (SVOCs), which are a subgroup of VOCS, were not captured or analyzed and no protocols to do so were explored.
- No new fields were analyzed—the age of the fields ranged from two to five years at the time. One playground was four years old and the other one was of undetermined age.
- Activities on the fields and playgrounds were not controlled or well-described.
- Recycled tire material collected showed wide variations in metals, including lead, within each of the sites and from site to site.
- Samples collected by stationary air sampling equipment to measure particulate matter were costly in terms of time and equipment.
- Smaller and more respirable particles of $PM_{2.5}$ were not collected or analyzed for their chemical and metal content.

Conclusion

Researchers determined that study protocols and many collection and analysis methods used were reliable and could be implemented in future field studies, with one exception. The exception was EPA's method of analyzing bioaccessibility of lead that was determined to be inappropriate for wet surface wipe samples.

Limited results showed that on average there were low levels of 12 VOCs and metals, including lead. These were found in the samples of air, materials, and the surface wipes of fields and playgrounds containing recycled rubber infill and mulch. Methyl isobutyl ketone (MIBK), a rubber-related solvent, was found at slightly elevated levels in the air above one field.

Metals, including lead, were found in widely varying concentrations in materials sampled from each site and from site to site. The bioaccessibility of these concentrations of lead also varied widely among the samples. This study called for additional investigations to better understand the study's findings.

The study called for additional investigations to understand this finding. In addition, according to the U.S. Centers for Disease Control and Prevention



This study called for additional investigations to better understand the study's findings.



This study was designed to evaluate methods that could be used and verified when analyzing synthetic turf fields and rubber mulch playground material, and that is what the study should be used for.

(CDC), no safe blood lead level in children has been identified and the effects of lead exposure cannot be corrected.

The study concluded that more research was necessary to determine the location and number of material samples that should be collected at each site because of the substantial variability of the materials that can be found at any single site.

As noted, the objective of this study was to produce evaluated sampling and analysis methods for future research of selected contaminants found in rubber tire material used as playing field infill and for rubber mulch playground surfaces.

Therefore, the researchers cautioned it was not possible to reach comprehensive conclusions about the materials and air they sampled because that was not the objective of the study.

This study was designed to evaluate methods that could be used and verified when analyzing synthetic turf fields and rubber mulch playground material, and that is what the study should be used for.

Study Number 20

Hydroxypyrene in urine of football [soccer] players after playing on artificial sports field with tire crumb infill

https://link.springer.com/article/10.1007%2Fs00420-009-0465-y

AUTHORS: Joost G.M. van Rooij and Frans J. Jongeneelen
PUBLISHED: *International Archives of Occupational and Environmental Health*, Volume 83
DATE: September 2009

This study was peer reviewed and published. The research was conducted in The Netherlands by IndusTox Consult, a consulting company in the areas of occupational toxicology and exposure science. The project was funded by a consulting network and soccer, tire and recycled rubber industry stakeholders.



Rubber tire material is widely known to contain a number of highly toxic compounds that...are harmful to health.

The study measured the uptake of polycyclic aromatic hydrocarbons (PAHs) by adult soccer players who played on an artificial turf field cushioned with crumb rubber infill made from recycled tires.

Rubber tire material is widely known to contain a number of highly toxic compounds, including PAHs, which are volatile organic compounds that are bioavailable to human beings through skin contact or inhalation and are harmful to health.

First, a sample of crumb rubber infill from one artificial turf field was analyzed for a total concentration of PAHs, which were found in the amounts of 20-40 mg/kg for this particular field.

Seven volunteer players played for two and a half hours on the field. Researchers observed that the players were covered in black rubber dust on their knees, elbows and the palms of their hands. The players' urine was collected for a three-day period, starting the day before and ending the day after their time on the field. The urine specimens were tested for 1-hyroxypyrene, which is a chemical indicator of human exposure to PAHs.

Results showed elevated levels of 1-hyroxypyrene in the urine of only one player. The researchers concluded that the exposure of soccer players to PAHs on artificial fields is minimal and within the range of PAH exposure due to

other environmental sources and from diet. However, these findings came with significant limitations.

- Limitations of the research include:
  - The sample size was very small—only seven players on one field for only a two-and-a-half-hour period.
  - The study was careful to note that data is scarce about 1-hydroxypyrene excretion in persons exposed in venues other than the workplace.
  - Three of the players were found to have elevated levels of 1-hydroxypyrene before they played on the field due to possible exposures at work. Two players ate a burger directly after they played, which may have contributed to enhanced levels of 1-hydroxypyrene post-play.
  - The test results showed that the background levels of 1-hydroxypyrene can vary significantly among different individuals and even within the same person despite the researchers' efforts to control these variations and these variations may indicate that there are unknown sources of PAH exposure.
  - Samples containing high concentrations of 1-hydroxypyrene were treated as out of range and were excluded from the data—25 of 138 samples were rejected for this reason. Conversely, eight urine samples that contained concentrations below detection were included in calculations with a value of two-thirds of the detection limit. This weighted the calculations more heavily towards the lower detectable levels.



One of the seven players tested showed an elevated level of 1-hydroxypyrene—a marker for PAH exposure—in his urine.

Conclusion

Because only one of seven soccer players who were tested showed an elevated level of 1-hydroxypyrene in their urine after playing on recycled rubber tire infill for two and one half hours, the researchers concluded players are minimally exposed to these volatile organic compounds when they play on artificial fields.

This very small sample in no way can verify that players will not be heavily exposed to PAHs and thus show levels in their urine.



The research was extremely limited, shown by a number of factors:

- Only seven players were sampled.
- The seven persons only played on one synthetic turf field for only two and a half hours.
- There were problems with controlling the background sources of PAHs both before and after the exposure period.
- The calculations were weighted at the lower end because the study excluded the urine samples that showed high concentrations, although the study included the non-detectable concentrations.
- Finally, there was a lack of data about what the levels of 1-hydroxypyrene excretions are normally in the general population.

The researchers tested the soccer players for the chemical compound 1-hydroxypyrene because, when it is excreted from the body, it serves as a marker for PAH exposures.

There were problems with controlling the background sources of PAHs both before and after the exposure period.

Study Number 21

An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb Rubber-Infilled Synthetic Turf Fields

http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

AUTHORS: Ly Lima and Randi Walker

DATE: May 2009



Significant concentrations of zinc, aniline, phenol and benzothiazole (BZT) were leaching from the crumb rubber.

This report was not peer reviewed and was not intended to broadly address potential public health concerns rising from the use of synthetic turf fields. The investigation was conducted by the New York State Department of Environmental Conservation (NYSDEC) and New York State Department of Health (NYSDPH). The report was published as a government document by the NYSDEC. RTP Environmental Associates, Inc., a consulting company, collected field samples for the air quality survey that was part of this investigation.

- The study was conducted in two parts, which consisted of:
  - A laboratory investigation of unused crumb rubber infill
  - An investigation of crumb rubber samples from two artificial turf fields, a grass field, and a baseball field
- Unused crumb rubber infill was investigated using:
  - Leaching tests
  - Off-gassing tests
  - An acid digestion test for total lead content

Field samples were investigated using samples of air and airborne particulate matter (PM_{10} and $PM_{2.5}$), material from wipes and material microvacuumed off the field surfaces, plastic grass blades, groundwater and surface water runoff. Researchers also gathered meteorological measurements, including surface temperatures from two artificial turf fields, one grass field, and one baseball field.

Test results were assessed to estimate human health risks due to inhalation of airborne contaminants as well as the risk to aquatic life from contaminants leaching from the crumb rubber infill.



- First, the results from the laboratory investigation of unused crumb rubber infill:
  - Tests were conducted on unused crumb rubber infill obtained from four New York State tire-processing facilities.
- Leaching tests:
  - Leaching was taking place from the crumb rubber. Results indicated that significant concentrations of zinc, aniline, phenol and benzo-thiazole (BZT) were leaching from the material. Zinc, aniline and phenol were identified in concentrations above groundwater safety standards. There are no safety standards for BZT.
- Off-gassing tests:
  - Although researchers were able to compile a list of 18 chemicals in the unused material which they used in the field investigation portion of this research, concentrations of volatile and semivolatile organic compounds (VOCs and SVOCs) off-gassing from unused crumb rubber infill were difficult to evaluate because the material has been found to absorb VOCs.

The study cautioned that sufficient distance and soil barriers must be placed between the contaminating synthetic turf fields and groundwater in order to protect public health.



Tests were conducted on two New York City artificial turf fields, one grass field, and one baseball field.

- Acid digestion test:
  - Lead was identified in various low concentrations in unused crumb rubber but below federal safety standards for lead in soil.
- Environmental Assessment:
  - This study concluded that while there may be a potential impact on aquatic life due to zinc leaching from crumb rubber solely derived from truck tires, a negative impact is unlikely for crumb rubber made from a mixture of truck and car tires.
- Second, the results from the laboratory investigation of crumb rubber from two artificial turf fields:
  - Tests were conducted on two New York City artificial turf fields, one grass field, and one baseball field.
- Groundwater tests:
  - Groundwater test results at the two artificial turf fields targeted for this survey identified no chemicals or metals in groundwater. However, the groundwater was collected from deep wells and researchers noted that they would perform additional testing at more shallow depths in the future to better characterize the potential risk.

- Air Tests:
  - At one field, air sample results identified that concentrations of airborne benzene posed a health risk greater than one in one million. Concentrations of three tentatively identified compounds (1,3-pentadiene, (E)-1,3-pentadiene and 1,4-pentadiene) were estimated to pose cancer risks ranging from two-to-four per 100,000. These concentrations were also found in air samples upwind from the field, so researchers suggested that the artificial field was not the source of contamination.
- Material Tests:
  - Surface materials were collected from three locations at each of the two artificial fields. Samples included rubber, grass, cord material, crustal minerals and plant material (pollen and mold). These were collected by wiping and microvacuuming the field surface. Several blades of plastic grass were also collected at each field. Very large and very small particles were observed but no respirable rubber dust at all was found in the samples. Only collection details and a brief summary of findings were reported—test results are available upon request.
- Health Assessments:
  - Air sample and particulate matter results were assessed for their cancer and non-cancer risks to human health due to inhalation of chemicals or particles. Although the researchers concluded that the two fields posed no risk to public health, they did warn that samples collected at artificial fields of different ages, different designs, or from indoor fields, may yield very different results.
- Heat Assessment:
  - Surface temperatures on the two artificial turf fields were significantly higher than those measured on a nearby grass field or baseball field. The average temperatures on the two synthetic surfaces were 42° and 35° higher than on the other fields. These findings suggest that direct contact with artificial field surfaces and their elevated temperatures may cause discomfort, even thermal injury (burns), and pose greater potential for heat stress from prolonged contact with the surface.
- Limitations of the study:
  - According to the researchers, laboratory conditions did not reflect real field conditions.
  - Only two synthetic turf fields were used for analysis in this study. One of the fields was four years old, and the other was less than a year old.



The researchers...warn that samples collected at artificial fields of different ages, different designs, or from indoor fields, may yield very different results.



Zinc, aniline and phenol were identified in concentrations above groundwater safety standards. There are no safety standards for BZT.

- Unknown compounds and mixed isomers (compounds with the same chemical formula but different structures) emitted from unused crumb rubber samples were excluded from the field study evaluation list.
- Results for the field surface water survey are based on only one sample. The sample was collected at a third artificial turf field—not one of the fields that were otherwise analyzed. This sample was not tested for rubber-related chemicals.
- Two different laboratories were used for testing, and the laboratory conducting the surface water analysis used higher detection thresholds than the one used to conduct the groundwater analysis.

Conclusion

Leaching was taking place from the crumb rubber. Results indicated that significant concentrations of zinc, aniline, phenol and benzothiazole (BZT) were leaching from the material. Zinc, aniline and phenol were identified in concentrations above groundwater safety standards. There are no safety standards for BZT.

The study cautioned that sufficient distance and soil barriers must be placed between the contaminating synthetic turf fields and groundwater in order to protect public health.

Lead was identified in various low concentrations in unused crumb rubber, but levels were below federal safety standards for lead in soil.

At one field, air sample results identified that concentrations of airborne benzene posed a health risk greater than one in one million. Concentrations of three tentatively identified compounds (1,3-pentadiene, (E)-1,3-pentadiene and 1,4-pentadiene) were estimated to pose cancer risks that ranged from two-to-four per 100,000. These concentrations were also found in upwind air samples from the field, so researchers suggested that the artificial field was not the source of contamination.

In this study, only two synthetic turf fields were used for analysis. One field was four years old and the other was less than one year old. Although the researchers concluded that the two fields posed no risk to public health, they did warn that samples collected at artificial fields of different ages, different designs, or from indoor fields, may yield very different results. This report was not intended to broadly address all synthetic turf health concerns.

Study Number 22

Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill

https://www1.nyc.gov/assets/doh/downloads/pdf/eode/turf_aqs_report0409.pdf

AUTHOR: Karen M. Vetrano, Ph.D.

DATE: March 2009

This project was conducted by TRC, an engineering, environmental consulting and construction management firm, on behalf of the New York City Department of Health and Mental Hygiene. The research was not peer reviewed or published and was funded by a grant from the New York Community Trust, in partnership with the Fund for Public Health in New York.

TRC was contracted to conduct an air quality survey of the New York City outdoor synthetic turf fields. TRC was asked to investigate the release of contaminants from crumb rubber infill in the fields and to assess their potential for inhalation exposures to young children.

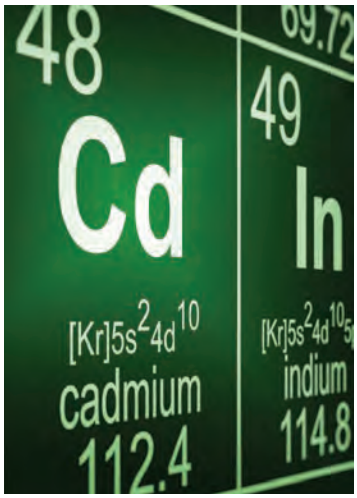
Stationary air samples were collected at two synthetic turf fields. Additional air samples, collected upwind of these fields and at one grass field, were sampled to provide background samples for comparison. Crumb rubber infill samples were also collected and analyzed to compare their contents and concentrations with the air sampling results.

All samples were measured for concentrations of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), including PAHs and benzothiazole, metals and particulate matter ($PM_{2.5}$). The compounds were selected based upon previous studies that showed their presence in recycled rubber tire material.

Air samples collected from above the synthetic turf fields showed eight VOCs present at low concentrations. These concentrations are similar to background samples collected upwind of the fields and over the grass field. In addition, seven VOCs were tentatively identified at low concentrations, but they could not be verified by the standard analytical methods used by the researchers and so these concentrations were listed as estimates only. No SVOCs were detected in any of the air samples. Two metals were detected at low concentrations similar to the background samples. Likewise, concentrations of $PM_{2.5}$ were low, and similar to the background samples.



Additional air samples, collected upwind of these fields and at one grass field, were sampled to provide background samples for comparison.



Of the metals tested, six were detected: arsenic, barium, cadmium, chromium, lead and zinc.

Bulk material samples of crumb rubber infill were measured for concentrations of VOCs, SVOCs and metals. Naphthalene, which may be considered either volatile or semivolatile, was detected at low concentrations. Six metals were detected in a range of various concentrations. At one field, concentrations of lead and zinc exceeded the New York State Department of Environmental Conservation (NYS DEC) soil cleanup standards for restricted residential land uses.

Researchers concluded that compound concentrations in air and bulk samples were so low that they posed no threat to children and therefore a risk assessment was unwarranted. New York City replaced one synthetic turf field in Manhattan due to the elevated concentration of lead in one bulk material sample from that field.

- The samples were collected at only three fields, and only two were synthetic turf fields. The sampling took place over only four separate days in late August 2008. Four samples were collected at each of the two synthetic turf fields, and two samples were collected upwind of those synthetic turf fields.

  The collection of air samples analyzed for VOCs was only done for only one hour. Collection of air samples analyzed for SVOCs, metals and particulate matter occurred for only two hours. All air samples were collected during the middle part of the day from a height of three feet above the playing surface, which was determined to be the breathing zone of children. Various play activities were simulated at each site.

- Air samples were tested for concentrations of 69 VOCs. Eight VOCs were identified at low concentrations with five of these occurring in low concentrations at both the synthetic turf fields and grass field: acetone, chloromethane, ethanol, toluene and methylene chloride. Three VOCs found at low concentrations were unique to the synthetic turf fields: 2-butanone (MEK), chloroform and n-hexane.

  In addition, seven VOCs were detected and tentatively identified. Results could not be verified so their concentrations were estimated. Of these, four were at low concentrations and unique to the synthetic turf fields: isobutane, pentane, 2-methyl-1,3-butadiene (isoprene) and 2-methylbutane. Acetaldehyde was present in similar, low concentrations above one synthetic turf field and the grass field. Hexanal and nonanal were identified only above the grass field.

- Air samples were also tested for concentrations of 18 SVOCs (17 PAHs and benzothiazole) and particulate matter ($PM_{2.5}$). None of the SVOCs were



detected. The concentrations of $PM_{2.5}$ above the synthetic turf fields were very similar to those upwind of the fields and above the grass field. Air samples were measured for concentrations of ten metals. Of these, two were detected: chromium and zinc. Zinc was detected only in air samples collected above the grass field and upwind of the synthetic turf fields.

Concentrations of chromium were found in various ranges at all three sites and in both background air sample locations where the air was collected upwind of the synthetic turf fields. Samples taken from the three fields and the upwind sites all exceeded the New York State air guideline levels for chromium.

However, researchers cast doubt on these findings because the concentrations of chromium were consistent among the five sites tested and were less than five times the concentration in the blank sample. Researchers therefore disregarded these detections.

- One sample of the crumb rubber infill was collected from each of the two synthetic turf fields and was analyzed. This was done to confirm the compounds of concern that might be found in the air samples analyzed.

Concentrations of chromium were found in various ranges at all three sites and in both background air sample locations where the air was collected upwind of the synthetic turf fields.



The detection of chromium in air samples taken from the fields was disregarded as a technical error. There was no retesting, even though levels of the samples exceeded New York State air guideline levels.

The bulk material was analyzed for 77 organic compounds, including VOCs and SVOCs, and eight metals. Only one organic compound, naphthalene, was detected. Of the metals tested for, six were detected: arsenic, barium, cadmium, chromium, lead and zinc. The metals were detected at various low levels with two exception: concentrations of lead and zinc in the bulk material sampled from the Manhattan synthetic turf field exceeded the respective soil cleanup guidelines for restricted residential land uses.

The elevated lead level triggered the replacement of the Manhattan synthetic turf field as well as further investigation of New York City synthetic turf fields for the presence of lead.

- Limitations of the study:
  - The sample size was very small. Only two synthetic turf fields were tested. At each site, only four air samples were collected—each at only one height—three feet above the field. At the two synthetic turf fields, only one bulk material sample of crumb rubber infill was collected and analyzed. Only two upwind air samples were collected near each of the synthetic turf fields.
  - The grass field sampled and used as the control field was a baseball field, while the synthetic turf fields were soccer fields.
  - The simulated activity at the grass field was different than the activity described at one synthetic turf field. The activity at the other synthetic turf field was not characterized at all.
  - Weather conditions were not consistent among the three sites during the sampling periods. At one synthetic turf field, conditions shifted, and included rain while samples were collected. At the other synthetic turf field and the grass field, conditions were sunny and clear.
  - Only two stationary air samplers were used on the field at each site. Players moved around the devices.
  - Air samples were collected at only the one height of three feet.
  - Air sample collection for VOCs was only for a one-hour period.
  - Rubber-related SVOCs, including PAHs and benzothiazole, were not detected in any of the air or bulk material samples. This failure to detect did not trigger a repeat or duplication of sample collection and analysis or any cautionary statement by researchers. This finding

is divergent from previous research, which identifies these chemicals in rubber tire material.

- The detection of chromium in air samples taken from the fields was disregarded as a technical error. There was no retesting, even though levels of the samples exceeded New York State air guideline levels.

Conclusion

The objectives of this limited air quality study were to characterize the concentrations of contaminants in the air above two synthetic turf fields and one grass field in New York City, and to assess the health risks these compounds and metals pose when they are inhaled by children.

Despite the detection of multiple VOCs and metals in air and bulk material samples, the study found that the concentrations were so low that they did not pose a health risk to children and therefore an inhalation exposure risk assessment was not warranted.

Air and crumb rubber infill samples and analyses were not repeated despite three red flags:

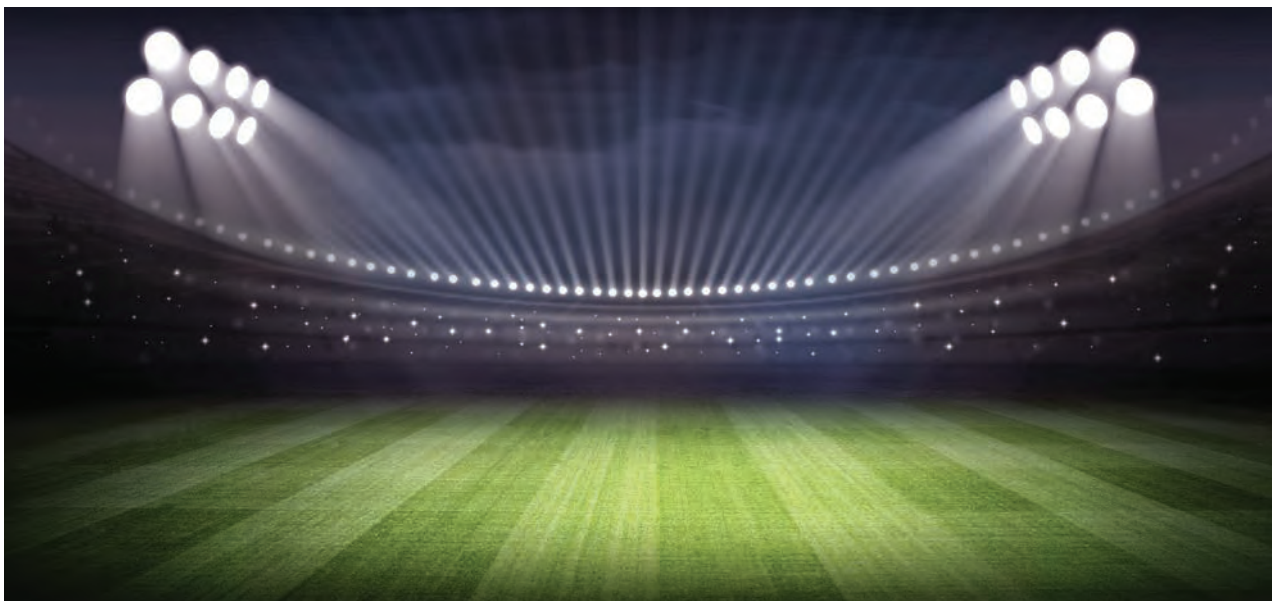
- No PAHs or benzothiazole were detected in the air above the synthetic fields or in the bulk material samples.
- In addition, chromium was found in the air samples from all three fields, and in both background air sample locations where air was collected upwind of the synthetic turf fields. Neither the absence of rubber-related SVOCs nor the consistent detection of chromium at levels exceeding the New York State air guideline triggered duplication of air samples or further investigation.
- The crumb rubber infill itself was tested for 77 organic compounds, including VOCs and SVOCs, and only one organic compound, naphthalene, was found. This finding should have sent up yet a third red flag.

  Crumb rubber infill had been previously studied many times with the results showing many VOCs and SVOCs in the material. The failure of this study to identify rubber-related compounds of concern in samples of crumb rubber infill should have created questions for the researchers about the validity of the study's findings.



The failure to identify compounds of concern in crumb rubber infill should have created questions of the validity of the study.

IV. Summary of the Report



Careful reading of the 22 studies on industry's list shows that many of them had serious testing flaws and limitations.

This report was written to inform the public about studies that industry says prove fields are "safe."

- This report was written so that the public can understand what is actually in the studies that industry continually claims prove the safety of synthetic turf fields.
- Careful reading of the 22 studies on industry's list shows that many of them had serious testing flaws and limitations. These studies do not serve as proof that synthetic turf fields are safe.
- When a research study found that synthetic turf fields contained numerous toxic chemicals, including carcinogens, industry often answered these findings with statements that admitted there were many chemicals in synthetic turf, but claimed that their presence did not mean that those who played on the fields were exposed or harmed by those chemicals.
- This reasoning by industry does not stand up to scientific scrutiny.

- The studies, so far, do not take into account the synergistic health effects of exposures to many toxic chemicals at the same time. In addition, studies often have not taken into account all routes of exposures when coming to their conclusions.
- None of the studies investigated how the higher surface temperatures found on synthetic turf fields may increase chemical exposures that can affect athletes and children who use these fields during warmer months.
- These investigatory gaps, and many more, along with industry's claims that the studies proved the synthetic turf fields were safe, made it clear that careful reading and analysis of industry's list was crucial.

A number of findings from the studies:

- Highly varied concentrations of chemicals and metals were found in samples from within each artificial turf field tested. These findings are important for future studies.
- The air above an indoor field had very high levels of toxic chemicals—even though the indoor field was only tested for 25 minutes. This study recommended adequate ventilation for all indoor artificial turf fields in order to protect the public's health.
- Lead that was found in one field was 500 to 1,000 times the lead concentration of other fields sampled within the same study.
- Many chemicals and metals were found in a number of studies. Some of these were at low concentrations, but some of them exceed air and water safety standards.
- Lead was found in numerous samples of synthetic turf fields—even after industry promised to stop using lead to dye the plastic grass for artificial fields.
- Zinc was found at levels above the EPA Fresh Water Standards.
- Synthetic turf fields were found to pose a toxic threat to biological organisms.
- As shredded rubber particles decreased in size, the leaching of organic compounds increased.



Lead that was found in one field was 500 to 1,000 times the lead concentration of other fields sampled within the same study.



Because of the variability of the fields, one study called for the testing of every artificial field to measure its risk to players, especially children.

- Because of the variability of the fields, one study called for the testing of every artificial field to measure its risk to players, especially children.
- In order to protect the public's health, it was recommended that sufficient distance and soil barriers be placed between artificial turf fields and groundwater.
- Benzothiazole (BZT), an irritant, was emitted in air samples and was found leaching from crumb rubber samples.

Many studies mentioned limitations to the testing methods and many had limitations not mentioned:

- Many did not adequately list the study's testing methods.
- Many did not assess harm to human health as part of their research.
- Many did not consider all routes of exposure: inhalation, dermal (skin), and ingestion.
- Many did not have an adequate number of testing samples or testing fields.
- Some concluded that more research was needed to investigate the potential health effects of using crumb rubber on fields and playgrounds. Because of the variability of the fields, one study called for the testing of every artificial field to measure its risk to players, especially children.
- Some did not look for chemicals that have previously been found in crumb rubber.
- Some cautioned that more research was needed before any conclusions could be made about the safety or harmful effects of crumb rubber or artificial turf.

None of the studies considered the following:

- None examined the synergy of being exposed to many chemicals at the same time and what this may mean for the health of those who play on artificial fields.



- None considered the cancer risk to players from dermal exposures to polycyclic aromatic hydrocarbons (PAHs) found in crumb rubber.
- None examined whether players are exposed to latex when they play on artificial turf fields or rubber mulch playgrounds.
- None measured the health impact for children with asthma or allergies when they play on artificial turf fields or playgrounds with rubber tire mulch surfacing.
- None examined additional exposures when people sit next to the synthetic turf fields as they watch athletic matches. Often those on the sidelines are small children who can pick up rubber crumbs and put them in their mouths.
- None considered the additional exposures to crumb rubber as the tiny pellets migrate from the fields into cars, schoolrooms, and homes.
- None performed an epidemiological survey of players or others who have been exposed to artificial turf fields or rubber mulch playgrounds for the

Often those on the sidelines are small children who can pick up rubber crumbs and put them in their mouths.

last decade or longer. Maintenance workers would be very vulnerable to health effects.

- Despite industry's claims that synthetic turf fields with crumb rubber are safe, many towns and schools have become skeptical of these claims. Because of this skepticism, many are opting for alternative infills, even though most of the alternative infills are more expensive.



Despite industry's claims that synthetic turf fields with crumb rubber are safe, many towns and schools have become skeptical of these claims.

- Many of the alternative infills have a number of the same issues as the crumb rubber, but the largest problem is that none of the alternatives have undergone independent testing.
- Some alternative infills are either sand (silica) or crumb rubber coated with a plastic polymer. Industry claims the coating makes the products safer and cooler in the summer months. To make them "safer," industry has imbedded the plastic coating with an antibacterial called Microban, which is a trade name for triclosan. EPA has banned triclosan from soaps because it has been associated with hormone disruption and antibiotic resistance.
- With constant play and weather exposures, the plastic coating can break down and the encapsulated material can then be exposed as the plastic coating wears away.
- Another alternative infill touted by industry as safer than crumb rubber is EPDM, which stands for ethylene propylene diene monomer rubber.
- EPDM is often called by industry "virgin rubber." EPDM is a type of synthetic rubber that—like waste tires in crumb rubber—also contains many toxic chemicals and heavy metals, as well as carbon black.
- The Safety Data Sheet for EPDM reveals that the product is a possible cancer hazard—and that it can be an irritant to lungs, eyes and skin. In addition, the International Agency for Research on Cancer (IARC) classified carbon black as possibly carcinogenic to humans.
- Studies have shown that short-term exposure to high concentration of carbon black dust is a respiratory irritant.



- This report reveals that industry cited a group of studies of varying scientific quality, as it tried to prove that synthetic turf fields were safe. The studies, at the very least, establish a certainty of exposures to organic chemicals and metals that have been known to be toxic for many decades, if not for centuries.

- Cancer data collected by the University of Washington women's soccer coach Amy Griffin should be the focus of additional research. The data show that although soccer goalkeepers constitute only 10% of soccer players, goalkeepers represent 60% of those soccer players who have gotten cancer and played on synthetic turf. Since soccer goalkeepers are the most heavily exposed to the crumb rubber, these numbers are important and should be studied further.

- Environment and Human Health, Inc. maintains that there is no safer surface for athletic play than natural grass. If towns and schools would invest half the money they put into synthetic turf fields and put it into state-of-the-art natural grass fields, the health of our children, athletes and our planet would be far better protected.

Environment and Human Health, Inc. maintains that there is no safer surface for athletic play than natural grass.

V. Recommendations



Recommendations for the Federal Government

- The federal government should remove all references to the safety of synthetic turf fields with crumb rubber from its websites.
- The federal government should require that indoor synthetic turf fields be properly ventilated because of the accumulation of toxins that outgas from the indoor fields.
- The federal government should recommend that outdoor synthetic fields with crumb rubber not be used in the heat, due to the fact that fields become excessively hot. For instance, when the air is 89°F, the temperature of the fields ranges from 145°F to 160°F, and when the air is 91°F the field might reach 161°F. That temperature is too hot for the fields to be safe to use.
- The federal government should do more to support and recommend that schools and towns install state-of-the-art natural grass fields instead of plastic synthetic turf fields.
- The federal government should track the cancers that have arisen in those people who have played on synthetic turf fields. In addition, because there are so many chemical irritants in these fields, the federal government should track the asthma cases that have developed from using the fields, as well as other allergic reactions that people who play on these fields develop.



Recommendations for States

- States should stop financially supporting the installation of synthetic turf fields with crumb rubber.
- States should remove all references to the safety of synthetic turf fields with crumb rubber from state government websites.

  States should recommend that outdoor synthetic fields with crumb rubber should not be used in the heat due to the fact that fields become excessively hot. For instance, when the air is 89°F, the temperature of the fields ranges from 145°F to 160°F, and when the air is 91°F the field might reach 161F°. That temperature is too hot for the fields to be safe to use.
- States should do more to support and recommend that schools and towns install state-of-the art natural grass fields instead of plastic synthetic turf fields.
- States should track the cancers that have arisen in those who have played on synthetic turf fields. In addition, because there are so many chemical irritants in these fields, the states should track the asthma cases that have developed from using the fields, as well as other allergic reactions that people who play on these fields develop.



Recommendations for Towns

- Town Planning and Zoning Commissions should no longer approve synthetic turf fields with crumb rubber.
- Towns should not allow toddler and children's playgrounds to have ground-up rubber tire mulch as surfacing material in their playgrounds. Rubber mulch made from waste tires contains the same carcinogens and heavy metals as crumb rubber.
- Towns should do more to support and recommend that schools and towns install state-of-the-art natural grass fields instead of plastic synthetic turf fields.

Recommendations for Schools

- Schools should recommend installing state-of-the-art natural grass fields instead of plastic synthetic turf fields.
- Schools should not allow their toddler and children's playgrounds to use ground-up rubber tire mulch as surfacing material. Rubber mulch made from waste tires contains the same carcinogens and heavy metals as crumb rubber.
- Schools should be aware of all students with asthma and other allergies, especially those who use synthetic turf fields.



- Synthetic turf fields with crumb rubber should not be used when the temperature is hot. For instance, when the air is 89°F, the temperature of the fields ranges from 145°F to 160°F, and when the air is 91°F the field might reach 161°F. That temperature is too hot for the fields to be safe to use.

- If a school already has a synthetic turf field with crumb rubber installed, the school will need to place recommendations for using the fields where they can be easily seen by those who play on the fields. The following recommendations should be posted:

  - Shower after using the field. If you cannot shower, wash your hands, face, and any open skin areas.
  - Wash your clothes, making sure there are no crumb rubber particles in your socks, pants, or other articles of clothing.
  - Be careful not to bring crumb rubber particles into the school building.
  - Always wear shoes on artificial turf.
  - Clean any cuts or abrasions immediately.
  - Brush your hair thoroughly after play.

Recommendations for Individuals

- Students and athletes with a history of asthma and other allergic reactions should be especially careful when playing on synthetic turf fields.



- Individuals should work with their school PTAs and school boards to educate schools about the dangers of synthetic turf fields with crumb rubber. Parents should do more to support and recommend the installation of natural grass fields.
- If a school, nursery school, or town has a playground with rubber tire mulch as its surfacing material, keep your young child off that playground. Encourage the school to remove the rubber mulch and replace it with sand or wood chips.
- Do not use a synthetic turf field in the heat because it gets too hot to be safe to use. In addition, the heat causes the toxins in the fields to outgas at a greater rate, which increases chemical exposures.
- If your school already has a synthetic turf field with crumb rubber installed, you should insist that the school place recommendations for using the field where they can be easily seen by those who play on the fields. The following recommendations should be posted:
  - Shower after using the field. If you cannot shower, wash your hands, face, and any open skin areas.
  - Wash your clothes, making sure there are no crumb rubber particles in your socks, pants, or other articles of clothing.
  - Be careful not to bring crumb rubber particles into the school building.
  - Always wear shoes on artificial turf.
  - Clean any cuts or abrasions immediately.
  - Brush your hair thoroughly after play.

VI. Appendix

Appendix Study Number 1

http://www.sciencedirect.com/science/article/pii/S004565351500082X

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Leaching of DOC [dissolved organic carbon], DN [dissolved nitrogen] and inorganic constituents from scrap tires

AUTHORS: Meric Selbes, Ozge Yilmaz, Abdul A. Khan, Tanju Karanfil
PUBLISHED: *Chemosphere*, Volume 139
DATE: November 2015

Abstract

One concern for the recycle and reuse of scrap tires is the leaching of tire constituents (organic and inorganic) with time, and their subsequent potential harmful impacts in environment. The main objective of this study was to examine the leaching of dissolved organic carbon (DOC), dissolved nitrogen (DN), and selected inorganic constituents from scrap tires. Different sizes of tire chips and crumb rubber were exposed to leaching solutions with pH's ranging from 3.0 to 10.0 for 28 days. The leaching of DOC and DN were found to be higher for smaller size tire chips; however, the leaching of inorganic constituents was independent of the size. In general, basic pH conditions increased the leaching of DOC and DN, whereas acidic pH conditions led to elevated concentrations of metals. Leaching was minimal around the neutral pH values for all the monitored parameters. Analysis of the leaching rates showed that components associated with the rubbery portion of the tires (DOC, DN, zinc, calcium, magnesium, etc.) exhibited an initial rapid followed by a slow release. On the other hand, a constant rate of leaching was observed for iron and manganese, which are attributed to the metal wires present inside the tires. Although the total amounts that leached varied, the observed leaching rates were similar for all tire chip sizes and leaching solutions. Operation under neutral pH conditions, use of larger size tire chips, prewashing of tires, and removal of metal wires prior to application will reduce the impact of tire recycle and reuse.

Appendix Study Number 2

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666/

Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers

AUTHORS: MB.T. Pavilonis, C.P. Weisel, B. Buckley, P.J. Lioy
PUBLISHED: *Risk Analysis*, Volume 34
DATE: January 2014

Abstract

To reduce maintenance costs, municipalities and schools are starting to replace natural grass fields with a new generation synthetic turf. Unlike Astro-Turf, which was first introduced in the 1960's, synthetic field turf provides more cushioning to athletes. Part of this cushioning comes from materials like crumb rubber infill, which is manufactured from recycled tires and may contain a variety of chemicals. The goal of this study was to evaluate potential exposures from playing on artificial turf fields and associated risks to trace metals, semivolatile organic compounds

(SVOCs), and polycyclic aromatic hydrocarbons (PAHs) by examining typical artificial turf fibers (n=8), different types of infill (n=8), and samples from actual fields (n=7). Three artificial biofluids were prepared which included: lung, sweat, and digestive fluids. Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials.

Appendix Study Number 3

http://link.springer.com/article/10.1007/s11356-012-1390-2

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Environmental-sanitary risk analysis procedure applied to artificial turf sports fields

AUTHORS: Barbara Ruffino, Silvia Fiore, Maria Chiara Zanetti
PUBLISHED: *Environmental Science and Pollution Research*, Volume 20
DATE: July 2013

Abstract

Owing to the extensive use of artificial turfs worldwide, over the past 10 years there has been much discussion about the possible health and environmental problems originating from styrene-butadiene recycled rubber. In this paper, the authors performed a Tier 2 environmental-sanitary risk analysis on five artificial turf sports fields located in the city of Turin (Italy) with the aid of RISC4 software. Two receptors (adult player and child player) and three routes of exposure (direct contact with crumb rubber, contact with rainwater soaking the rubber mat, inhalation of dusts and gases from the artificial turf fields) were considered in the conceptual model. For all the fields and for all the routes, the cumulative carcinogenic risk proved to be lower than 10^{-6} and the cumulative non-carcinogenic risk lower than 1. The outdoor inhalation of dusts and gases was the main route of exposure for both carcinogenic and non-carcinogenic substances. The results given by the inhalation pathway were compared with those of a risk assessment carried out on citizens breathing gases and dusts from traffic emissions every day in Turin. For both classes of substances and for both receptors, the inhalation of atmospheric dusts and gases from vehicular traffic gave risk values of one order of magnitude higher than those due to playing soccer on an artificial field.

Appendix Study Number 4

http://www.sciencedirect.com/science/article/pii/S0269749112005490?via%3Dihub

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds

AUTHORS: O. Kruger, U. Kalbe, E. Richter, P. Egeler, J. Römbke, W. Berger
PUBLISHED: *Environmental Pollution*, Volume 175
DATE: April 2013

Abstract
Artificial surfaces for outdoor sporting grounds may pose environmental and health hazards that are difficult to assess due to their complex chemical composition. Ecotoxicity tests can indicate general hazardous impacts. We conducted growth inhibition (Pseudokirchneriella subcapitata) and acute toxicity tests *(Daphnia magna)* with leachates obtained from batch tests of granular infill material and column tests of complete sporting ground assemblies. Ethylene propylene diene monomer rubber (EPDM) leachate showed the highest effect on *Daphnia magna* (EC(50) < 0.4% leachate) and the leachate of scrap tires made of styrene butadiene rubber (SBR) had the highest effect on P. subcapitata (EC(10) = 4.2% leachate; EC(50) = 15.6% leachate). We found no correlations between ecotoxicity potential of leachates and zinc and PAH concentrations. Leachates obtained from column tests revealed lower ecotoxicological potential. Leachates of column tests of complete assemblies may be used for a reliable risk assessment of artificial sporting grounds.

Appendix Study Number 5

http://link.springer.com/article/10.1007%2Fs00244-012-9792-1

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Artificial Turf Football Fields: Environmental and Mutagenicity Assessment

AUTHORS: T. Schilirò, D. Traversi, R. Degan, C. Pignata, L. Alessandria, D. Scozia, R. Bono, G. Gilli
PUBLISHED: *Archives of Environmental Contamination and Toxicology,* Volume 64
DATE: January 2013

Abstract
The public has recently raised concerns regarding potential human health and environmental risks associated with tire crumb constituents in the artificial turf of football fields. The aim of the present study was to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM_{10} and $PM_{2.5}$) and related polycyclic aromatic hydrocarbons (PAHs), aromatic hydrocarbons (BTXs), and mutagenicity of organic extracts from PM_{10} and $PM_{2.5}$. No significant differences were found between PM_{10} concentrations at an urban site and on a turf football field, both during warm and in cold seasons, either with or without on-field activity. $PM_{2.5}$ concentrations were significantly greater at the urban site in the cold season as was the ratio of $PM_{2.5}$ to PM_{10}. BTXs were significantly greater at urban sites than on turf football fields on both on warm and cold days. The ratio of toluene to benzene (T/B ratio) was always comparable with that of normal urban conditions. The concentration of PAHs on the monitored football fields was comparable with urban levels during the two different sampling periods, and the contribution of PAHs released from the granular material was negligible. PM_{10} organic extract mutagenicity for artificial turf football fields was greater, whereas $PM_{2.5}$ organic extract mutagenicity was lower, compared with the urban site studied. However, both organic extract mutagenicity values were comparable with the organic extract mutagenicity reported in the literature for urban sites. On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city.

Appendix Study Number 6

http://pubs.acs.org/doi/abs/10.1021/es301227y

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Comparison of Batch and Column Tests for the Elution of Artificial Turf System Components

AUTHORS: O. Krüger, U. Kalbe, W. Berger, K. Nordhauβ, G. Christoph, H.-P. Walzel
PUBLISHED: *Environmental Science & Technology*, , Volume 46
DATE: December 2012

Abstract

Synthetic athletic tracks and turf areas for outdoor sporting grounds may release contaminants due to the chemical composition of some components. A primary example is that of zinc from reused scrap tires (main constituent, styrene butadiene rubber, SBR), which might be harmful to the environment. Thus, methods for the risk assessment of those materials are required. Laboratory leaching methods like batch and column tests are widely used to examine the soil-groundwater pathway. We tested several components for artificial sporting grounds with batch tests at a liquid to solid (LS) ratio of 2 L/kg and column tests with an LS up to 26.5 L/kg. We found a higher zinc release in the batch test eluates for all granules, ranging from 15% higher to 687% higher versus data from column tests for SBR granules. Accompanying parameters, especially the very high turbidity of one ethylene propylene diene monomer rubber (EPDM) or thermo plastic elastomer (TPE) eluates, reflect the stronger mechanical stress of batch testing. This indicates that batch test procedures might not be suitable for the risk assessment of synthetic sporting ground components. Column tests, on the other hand, represent field conditions more closely and allow for determination of time-dependent contaminants release.

Appendix Study Number 7

http://pubs.acs.org/doi/pdf/10.1021/es3024379

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Zinc Leaching from Tire Crumb Rubber

AUTHORS: Emily P. Rhodes, Zhiyong Ren, David C. Mays
PUBLISHED: *Environmental Science & Technology*, Volume 46
DATE: December 2012

Abstract

Because tires contain approximately 1-2% zinc by weight, zinc leaching is an environmental concern associated with civil engineering applications of tire crumb rubber. An assessment of zinc leaching data from 14 studies in the published literature indicates that increasing zinc leaching is associated with lower pH and longer leaching times, but the data display a wide range of zinc concentrations, and do not address the effect of crumb rubber size or the dynamics of zinc leaching during flow through porous crumb rubber. The present study was undertaken to investigate the effect of crumb rubber size using the synthetic precipitation leaching procedure (SPLP), the effect of exposure time using quiescent batch leaching tests, and the dynamics of zinc leaching using column tests. Results indicate that zinc leaching from tire crumb rubber increases with smaller crumb rubber and longer exposure time. Results from SPLP and quiescent batch leaching tests are interpreted with a single-parameter leaching model that predicts a constant rate of zinc leaching up to 96 h. Breakthrough curves from column tests displayed an initial pulse of elevated zinc concentration (~3 mg/L) before settling down to a steady-state value (~0.2 mg/L), and were modeled with the software package HYDRUS-1D. Washing crumb rubber reduces this initial pulse but does not change the steady-state value. No leaching experiment significantly reduced the reservoir of zinc in the crumb rubber.

Appendix Study Number 8

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598/

Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability

AUTHORS: Sunduk Kim, Ji-Yeon Yang, Ho-Hyun Kim, In-Young Yeo, Dong-Chun, Shin, Young-Wook Lim
PUBLISHED: *Environmental Health and Toxicology,* Volume 27
DATE: January 2012

Abstract

Objectives
The purpose of this study was to assess the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability.
Methods
This study estimated the ingestion exposure by particle sizes (more than 250 um or less than 250 um) focusing on recyclable ethylene propylene diene monomer crumb rubber being used as artificial turf filling. Analysis on crumb rubber was conducted using body ingestion exposure estimate method in which total content test method, acid extraction method and digestion extraction method are reflected. Bioavailability which is a calibrating factor was reflected in ingestion exposure estimate method and applied in exposure assessment and risk assessment. Two methods using acid extraction and digestion extraction concentration were compared and evaluated.
Results
As a result of the ingestion exposure of crumb rubber material, the average lead exposure amount to the digestion extraction result among crumb rubber was calculated to be 1.56×10^{-4} mg/kg-day for low grade elementary school students and 4.87×10^{-5} mg/kg-day for middle and high school students in 250 um or less particle size, and that to the acid extraction result was higher than the digestion extraction result. Results of digestion extraction and acid extraction showed that the hazard quotient was estimated by about over 2 times more in particle size of lower than 250 um than in higher than 250 um. There was a case of an elementary school student in which the hazard quotient exceeded 0.1.
Conclusions
Results of this study confirm that the exposure of lead ingestion and risk level increases as the particle size of crumb rubber gets smaller.

Appendix Study Number 9

http://www.sciencedirect.com/science/article/pii/S0048969711007601

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment

AUTHORS: Edoardo Menichini, Vittorio Abate, Leonello Attias, Silvia De Luca, Alessandro di Domenico, Igor Fochi, Giovanni Forte, Nicola Iacovella, Anna Laura Iamiceli, Paolo Izzo, Franco Merli, Beatrice Bocca
PUBLISHED: *Science of the Total Environment,* Volume 409
DATE: November 2011

Abstract

The artificial-turf granulates made from recycled rubber waste are of health concern due the possible exposure of users to dangerous substances present in the rubber, and especially to PAHs. In this work, we determined the contents of PAHs, metals, non-dioxin-like PCBs (NDL-PCBs), PCDDs and PCDFs in granulates, and PAH concentrations in air during the use of the field. The purposes were to identify some potential chemical risks and to roughly assess the risk associated with inhalation exposure to PAHs. Rubber granulates were collected from 13 Italian fields and analysed for 25 metals and nine PAHs. One further granulate was analysed for NDL-PCBs, PCDDs, PCDFs and 13 PAHs. Air samples were collected on filter at two fields, using respectively a high volume static sampler close to the athletes and personal samplers worn by the athletes, and at background locations outside the fields. In the absence of specific quality standards, we evaluated the measured contents with respect to the Italian standards for soils to be reclaimed as green areas. Zn concentrations (1 to 19 g/kg) and BaP concentrations (0.02 to 11 mg/kg) in granulates largely exceeded the pertinent standards, up to two orders of magnitude. No association between the origin of the recycled rubber and the contents of PAHs and metals was observed. The sums of NDL-PCBs and WHO-TE PCDDs + PCDFs were, respectively, 0.18 and 0.67×10^{-5} mg/kg. The increased BaP concentrations in air, due to the use of the field, varied approximately from < 0.01 to 0.4 ng/m^3, the latter referring to worst-case conditions as to the release of particle-bound PAHs. Based on the 0.4 ng/m^3 concentration, an excess lifetime cancer risk of 1×10^{-6} was calculated for an intense 30-year activity.

Appendix Study Number 10

http://www.nj.gov/dep/dsr/publications/turf-crumb-infill-study.pdf

Crumb Infill and Turf Characterization for Trace Elements and Organic Materials

AUTHORS: Paul J. Lioy and Clifford Weisel

DATE: October 2011

Executive Summary

Project Rationale

A study was undertaken to conduct a thorough evaluation for hazardous chemicals within major product lines of crumb infill and associated turf that are available for use on athletic fields and public parks. This included a quantification of the bioaccessibility of hazardous chemicals found in the crumb infill and associated turf product from both newly purchased materials and in-use fields of different ages. The objective was to provide an independent scientific basis to assist communities in their ability to make decisions on the selection of the materials to be used as artificial infill turf fields based on potential exposure to users of the fields to hazardous agent that might be present in the materials.

Methodology

Synthetic lung, sweat and digestive biofluids were analyzed for trace metals, polyaromatic hydrocarbons (PAHs) and scanned for semi-volatile organic compounds. In addition acid extraction for metals and high temperature volatilization for semi-volatile and volatile organic compounds were done to assess total extractable levels of these compounds. The protocols were followed in order to fill a major data gap identified by the 2008 turf/infill workshop, NYC, NY, that bioaccessibilty studies were needed for the inhalation, dermal and ingestion routes of entry into the body for both organic and inorganic materials.

Results

Overall the metals, PAHs and semi-volatile compounds found all classes of materials to be at very low concentrations. Thus, for the metals and compounds identified there would be de minimus exposures and risk among anyone using fields with the exception of lead in a single new turf material. It is therefore prudent to reemphasize the need to avoid lead-based pigments in these materials as coloring agents. For the compounds that have known hazard the levels in the biofluids were below standards for soil cleanup so no formal risk assessment is currently recommended. In addition, the

many organic compounds identified in the biofluids for which there are no hazard data currently available were also at very low concentrations so no further risk assessment is currently recommended unless new hazard information becomes available. In the future, the types of bioaccessibily studies conducted as part of these experiments should be completed for all new turf/infill products.

Appendix Study Number 11

http://www.tandfonline.com/doi/abs/10.3109/15376516.2011.583293?journalCode=itxm20

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Design of a new test chamber for evaluation of the toxicity of rubber infill

AUTHORS: J.F.P. Gomes, H.I. Mota, J.C.M. Bordado, M. Baião, G.M. Sarmento, J. Fernandes, V.M. Pampulim, M.L. Custódio, I. Veloso

PUBLISHED: *Toxicology Mechanisms and Methods,* Volume 21

DATE: September 2011

Abstract

A test chamber was projected and built (according to ISO 16000-9 Standard) to simulate atmospheric conditions experienced by rubber infill (when applied in synthetic turf pitches) and measure accurately the airborne emissions of pollutants such as dusts and volatile organic compounds (VOC), as well as pollutants present in leachates. It should be pointed out that standard ISO 16000-9 is only concerned with the determination of the emission of VOC from building products and furnishing (not specific of synthetic turf materials), whereas other standards are concerned with the emission of leachates only. This procedure is to be considered as a technical option to the lysimeter "global turf system evaluation" when the rubber infill alone is to be evaluated. The advantage of the proposed option considering this "test chamber" is its simplicity and economy. This test chamber is actually installed and being used for tests in LAIST.

Appendix Study Number 12

http://www.nj.gov/dep/dsr/publications/artificial-turf-report.pdf

An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields

AUTHOR: Stuart L. Shalat, ScD

DATE: July 2011

Introduction

In the middle 1960's Monsanto created the first artificial grass, playing surface (Chemgrass) for play areas and athletic fields. Over the years, what later came to be known as AstroTurf and other similar products have become widely accepted and used by communities, schools and stadiums. Recently, controversy has arisen as to the safety of artificial turf playing fields (Claudio, 2008). One particular question of major interest arises with regard to the presence of lead and other metals including chromium, arsenic, and cadmium, which may be present either in the synthetic blades or grass or in the rubber particles used as infill. Since all of these metals are toxic if significant amounts enter the body, the question that needs to be addressed is that while it is known that these metals are present in many of these artificial turf materials, is there a risk of the material entering a person playing on the fields body in such a quantity as to pose a health hazard The primary routes through which materials such as metals can enter the body are through inhalation, ingestion, and direct

trans-dermal absorption. Because of the physical structure of these artificial turf materials and the metals involved, inhalation appears as the most likely candidate as the route of exposure. There is however, a real question as to whether lead or the other metals are present in a form that can result in the formation of respirable or inhalable particulate matter and the more important question is if it is present, is it present at such a level as represent a real health hazard. In order to answer these questions we have conducted a pilot study to assess the potential for exposure to lead, chromium, arsenic and cadmium as a respirable/ inhalable aerosol from playing on artificial turf. The nature of the use of these playing fields is such that the usefulness and representativeness of a static sample is questionable. The reason for this can be appreciated by anyone who has watched athletes run on artificial turf and observed their feet. What can be seen are small black puffs of the material used to provide stabilization to the blades of turf grass, known as infill. While larger particles are visible, smaller potentially respirable particles are also being kicked up from the turf that is not readily apparent. There can be little doubt that with the constant activity inherently present on an artificial turf field during a game, it is likely to result in the suspension and/or resuspension of particulate matter present in the artificial turf. Research has shown that even limited activity on carpeted surfaces can result in multiple orders of magnitude of increases in respirable/inhalable particulate matter (Shalat, et al. 2007, 2011). It is therefore desirable to sample in a non-static fashion for any potential particulate matter that is released from the surface. Unfortunately, it is not really practical to put sampling pumps on athletes during strenuous exercise; however, an alternative is available by using a robotic sampler recently developed at EOHSI.

Appendix Study Number 13

http://www.ct.gov/dph/lib/dph/environmental_health/eoha/pdf/artificial_turf_benzothiazole_2011.pdf

Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment

AUTHORS: Gary Ginsberg, Brian Toal, Tara Kurland

PUBLISHED: *Journal of Toxicology and Environmental Health, Part A: Current Issues*, Volume 74

DATE: July 2011

Abstract

Synthetic turf fields cushioned with crumb rubber may be a source of chemical exposure to those playing on the fields. Benzothiazole (BZT) may volatilize from crumb rubber and result in inhalation exposure. Benzothiazole has been the primary rubber-related chemical found in synthetic turf studies. However, risks associated with BZT have not been thoroughly assessed, primarily because of gaps in the database. This assessment provides toxicity information for a human health risk assessment involving BZT detected at five fields in Connecticut. BZT exerts acute toxicity and is a respiratory irritant and dermal sensitizer. In a genetic toxicity assay BZT was positive in *Salmonella* in the presence of metabolic activation. BZT metabolism involves ring-opening and formation of aromatic hydroxylamines, metabolites with mutagenic and carcinogenic potential. A structural analogue 2-mercaptobenzothiazole (2-MBZT) was more widely tested and so is used as a surrogate for some endpoints. 2-MBZT is a rodent carcinogen with rubber industry data supporting an association with human bladder cancer. The following BZT toxicity values were derived: (1) acute air target of 110 ug/m^3 based upon a BZT RD_{50} study in mice relative to results for formaldehyde; (2) a chronic noncancer target of 18 ug/m^3 based upon the no-observed-adverse-effect level (NOAEL) in a subchronic dietary study in rats, dose route extrapolation, and uncertainty factors that combine to 1000; (3) a cancer unit risk of 1.8E-07/ug-m^3 based upon a published oral slope factor for 2-MBZT and dose-route extrapolation. While there are numerous uncertainties in the BZT toxicology database, this assessment enables BZT to be quantitatively assessed in risk assessments involving synthetic turf fields. However, this is only a screening-level assessment, and research that better defines BZT potency is needed.

Appendix Study Number 14

http://www.ct.gov/deep/lib/deep/artificialturf/uchc_artificial_turf_report.pdf

Artificial Turf Field Investigation in Connecticut Final Report

AUTHORS: Nancy Simcox, Anne Bracker, John Meyer

DATE: July 2010

Executive Summary

The primary purpose of this project was to characterize the concentrations of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), rubber-related chemicals (e.g. benzothiazole), and particulate matter less than 10 micron (PM_{10}) and its constituents in ambient air at selected crumb rubber fields in Connecticut under conditions of active field use.

This project employed a cross-sectional environmental sampling strategy of synthetic crumb rubber turf fields to capture a range of chemical exposures during the summer season when ambient air temperatures are above 75-80 F. Three general types of fields were targeted: outdoor crumb rubber fields, indoor with crumb rubber turf, and an outdoor grass field in a suburban area. Sampling goals were to collect air samples on old and new turf fields during active field use and to collect air samples at background sites upwind and off of each field. A special focus of the design study included personal air sampling of many of the chemicals reported in previous studies (e.g. VOCs and benzothiazole), and other chemicals of potential concern, such as a volatile nitrosamine reported to be part of rubber manufacture. The sampling strategy also included the collection of area air samples for chemicals at different heights on the turf to assess a vertical profile of release. These air samples were collected in areas on the turf field near active play and areas on the turf away from active play. Because crumb rubber includes some amount of dusts and small particles, particulate matter air monitoring was incorporated into the stationary sampling plan (using sampling at a single height only). Bulk samples of turf grass and crumb rubber were also collected, and meteorological data (e.g. air direction, wind speed and ambient air temperature) were recorded.

Industrial hygienists from the Section of Occupational and Environmental Medicine at the University of Connecticut Health Center (OEMUCHC) conducted the field sampling and managed the analytical components of this exposure investigation. This report summarizes the data collected by OEM UCHC. This report identifies and measures chemicals across several synthetic crumb rubber turf fields and background locations. The measurements collected from background locations are necessary to better understand the data because many of these chemicals are present in ambient air as a result of general air pollution.

CT DEP recruited six fields: 4 outdoor turf fields (Fields A-D), 1 indoor turf field (Field K) and 1 outdoor suburban grass area (Field L). Six additional fields were recruited to collect crumb rubber bulk samples only (Fields E-J). Air sampling occurred during July 2009 on crumb rubber fields with polyethylene fibers that were both new (<2 years) and old (>3 years). Algorithms were developed to identify chemicals possibly related to turf. Of the 60 VOCs tested in air, 4 VOCs appear to be associated with turf. Of 22 PAHs, 6 were found in the air on the turf at 2 fold greater concentrations than in background locations on at least two fields. Of the five targeted SVOCs, benzothiazole and butylated hydroxytoluene were the only chemicals detected in the personal and area air samples from outdoor turf fields ranging from <80-1200 ng/m^3 and 80-130 ng/m^3, respectively. Nitrosamine air levels were below reporting levels. PM_{10} air concentrations were greater in background locations than on the turf at all fields with the exception of Field B. However, the PM_{10} air concentration on turf at Field B, 5.89 ug/m^3 was within the range of other PM_{10} background concentrations. All of the composite samples of turf fibers and crumb rubber were below the level EPA considers as presenting a "soil-lead hazard" in play areas (400 ppm).

The airborne concentrations of VOCs, targeted SVOCs (e.g. benzothiazole) and miscellaneous SVOCs were highest at the indoor field. These data were collected from only one indoor facility. Higher concentrations of these chemicals at the indoor field likely reflects the lack of air movement relative to outdoor fields. In addition, the air in the indoor field was not influenced by outdoor factors that may degrade and off-gas chemicals, such as sunlight, rain, and other weather conditions. Furthermore, potential point sources were identified in the facility, (electric carts, portable chargers, and maintenance supplies) and the indoor facility did not have its exhaust system operating on the day samples were collected. More research is needed to better understand chemical exposures in indoor facilities.

Appendix Study Number 15

http://www.ct.gov/deep/lib/deep/artificialturf/dph_artificial_turf_report.pdf

Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut

AUTHORS: Gary Ginsberg and Brian Toal

DATE: July 2010

Executive Summary

Questions have been raised about possible exposures when playing sports on artificial turf fields cushioned with crumb rubber infill. Rubber is a complex mixture of various chemicals including volatile organic chemicals (VOCs), semi-volatile organic chemicals (SVOCs) and metals. Some components have toxic and carcinogenic properties. Exposure is possible, primarily via inhalation, given that chemicals emitted from rubber can end up in the breathing zone of players and these players have high ventilation rates. Previous studies from Europe and the United States provide useful data but are limited particularly with respect to the variety of fields and scenarios evaluated. To enhance this database, the State of Connecticut undertook a multi-disciplinary study of artificial turf fields involving field investigation, laboratory offgas studies and human health risk assessment. These reports were reviewed by the Connecticut Academy of Science and Engineering (CASE) and their comments have been incorporated into the final report.

The current investigation involved air sampling at 1 indoor and 4 outdoor artificial turf fields under summer conditions in Connecticut. On-field and background locations were sampled using a variety of stationary and personal samplers. A total of 27 chemicals of potential concern (COPCs) were found to be above background and possibly field-related on both indoor and outdoor fields. These COPCs were entered into separate risk assessments for outdoor and indoor fields and for children and adults. Exposure concentrations were pro-rated for time spent away from the fields and inhalation rates were adjusted for play activity and for children's greater ventilation than adults. Toxicity values (cancer unit risks, RfCs, acute targets) were taken from national databases or derived by CT DPH. In general, conservative public health protective assumptions were made in calculating risks, especially with regard to the inclusion of detects from personal samplers that may not have been field related. As such, this represents a screening level assessment that is likely to overestimate risk.

In spite of the conservative nature of the assessment, cancer risks were only slightly above de minimis levels for all scenarios evaluated including children playing at the indoor facility, the scenario with the highest exposure. The calculated risks are well within typical risk levels in the community from ambient pollution sources and are below target risks associated with many air toxics regulatory programs. Further, the main risk driver, benzene, was only above background in personal monitoring samples and so may be more related to the sampling equipment or host than being field-related. Chronic non-cancer risks were not elevated above a Hazard Index of 1. The Hazard Index for acute risk was also not elevated above 1 but was close to 1 for children playing at the indoor field. The main contributor to

this Hazard Index was benzothiazole, a rubber-related SVOC. This presents an uncertainty regarding the potential for benzothiazole and other volatile irritants to create a slight irritation response in sensitive individuals playing indoors.

Based upon these findings, the use of outdoor and indoor artificial turf fields is not associated with elevated health risks. However, it would be prudent for building operators to provide adequate ventilation to prevent a buildup of rubber-related VOCs and SVOCs at indoor fields. The current study did not evaluate new fields under hot weather conditions and so the potential for acute risks under this circumstance is another uncertainty. The current results are generally consistent with the findings from studies conducted by New York City, New York State, the USEPA and Norway which tested different kinds of fields and under a variety of weather conditions. Thus, it appears that the current results are reasonably representative of conditions that can be encountered at indoor and outdoor crumb rubber fields, although this tentative conclusion could benefit from the testing of additional fields.

Appendix Study Number 16

http://www.ct.gov/deep/lib/deep/artificialturf/caes_artificial_turf_report.pdf

2009 Study of Crumb Rubber Derived from Recycled Tires Final Report

AUTHORS: X. Li, W. Berger, C. Musante, M.J. Incorvia Mattina

DATE: May 2010

Executive Summary

As part of a broad, State of Connecticut-funded study of several issues associated with artificial turf fields, including components such as crumb rubber infill derived from recycled tires (CRM, crumb rubber material), the Department of Analytical Chemistry at the Connecticut Agricultural Experiment Station (CAES) was charged with conducting a number of laboratory-based studies which are enumerated below:

1. Develop laboratory leaching protocols and simulated crumb rubber aging protocols
2. Develop protocols to identify comprehensively substances which volatilize and leach from crumb rubber and alternative infill materials under laboratory conditions
3. Conduct the laboratory analysis in accordance with submitted procedures
4. Compile data and provide written data report to DEP, DPH and UCHC by November 30, 2009.

We are submitting this report, as required, by 30 November 2009 to the Connecticut Department of Environmental Protection. The report contains the data from the experiments outlined above and conducted in our laboratory. This final report supersedes all previous reports. The timeline associated with the CAES portion of the project is provided here:

- March 2009: purchase of (using study funds), installation of, and familiarization with CombiPal automatic injector for the Varian 3800 gas chromatograph/4000 mass spectrometer in our laboratory.
- March-May 2009: development of solid phase microextraction procedure to identify compounds volatilizing from crumb rubber.
- June 2009: arrival of post-doctoral affiliate, Dr. Xiaolin Li.
- June-July 2009: continued identification of volatile compounds derived from crumb rubber and alternate infill products. Development of rigorous analytical method for quantitation of volatile compounds using direct injection of headspace gas.
- July 2009: initial weathering experiments
- July 2009: preliminary work on leaching study
- August-September 2009: weathering experiments in progress
- August-September 2009: leaching experiments in progress
- August-September 2009: additional samples from Connecticut DEP analyzed

- October-November 2009: leaching and weathering experiments conducted

In sections 2 and 3 of the report we provide the data related to the volatilization of compounds from the all the crumb rubber and alternative infill samples submitted to our laboratory by Connecticut Department of Environmental Protection. In addition, data are included in Sections 4 and 5 which relate to the aqueous leaching experiments and the weathering study of the CRM.

Appendix Study Number 17

http://www.calrecycle.ca.gov/publications/Documents/Tires/2010009.pdf

Safety Study of Artificial Turf Containing Crumb Rubber Infill Made from Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface

AUTHOR: Charles Vidair

DATE: October 2010

Executive Summary

Introduction

The new generation of artificial turf athletic fields often contains crumb rubber infill made from recycled tires. Crumb rubber infill serves as an artificial soil, supporting the artificial blades of grass, softening the surface, improving drainage, and helping to provide a high-quality playing surface for a variety of sports. However, tire rubber is a complex material, containing many naturally-occurring and man-made chemicals. Crumb rubber made from recycled tires has the potential to release a variety of chemicals and particles into the air. It also represents a potential site of bacterial growth and transmission to athletes using the fields (including methicillin resistant *Staphylococcus aureus,* MRSA). Therefore, OEHHA has evaluated the following aspects of artificial turf safety for fields constructed with recycled crumb rubber infill.

Study Goals

Determine whether the new generation of artificial turf athletic field containing recycled crumb rubber infill is a public health hazard with regard to:

- Inhalation: Do these fields release significant amounts of volatile organic compounds (VOCs) or fine particulates of aerodynamic diameter less than 2.5 microns ($PM_{2.5}$ and associated metals) into the air? If so, are the levels harmful to the health of persons using these fields?
- Skin infection: Do these fields increase the risk of serious skin infections in athletes, either by harboring more bacteria or by causing more skin abrasions (also known as turf burns) than natural turf?

Methods

1. Inhalation hazard
   a. Measure $PM_{2.5}$ and bound metals in air sampled from above artificial turf fields during periods of active field use. Compare to concentrations in the air sampled upwind of each field.
   b. Measure VOCs in the air sampled from above artificial turf fields during hot summer days. Compare to concentrations in the air sampled from above nearby natural turf fields.
2. Skin infection hazard
   a. Measure bacteria on components (infill/soil and blades) of existing artificial and natural turf fields.
   b. With the cooperation of athletic trainers from colleges and universities in California and Nevada, measure skin abrasion rates for varsity soccer players competing on artificial and natural turf fields.

Results and Conclusions

1. Inhalation hazard
   a. $PM_{2.5}$ 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 and upwind of the fields. No public health concern was identified.

b. The large majority of air samples collected from above artificial turf had VOC concentrations that were below the limit of detection. Those VOCs that were detected were usually present in only one or two samples out of the eight samples collected per field. There was also little consistency among the four artificial turf fields with regards to the VOCs detected. Nevertheless, seven VOCs detected above artificial turf were evaluated in a screening-level estimate of health risks for both chronic and acute inhalation exposure scenarios. All exposures were below health-based screening levels, suggesting that adverse health effects were unlikely to occur in persons using artificial turf.

c. There was no correlation between the concentrations or types of VOCs detected above artificial turf and the surface temperature.

2. Skin infection hazard

a. 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.

b. The rate of skin abrasions due to contact with the turf was two- to three-fold higher for college soccer players competing on artificial turf compared to natural turf. This was observed for both female and male teams. Skin abrasion seriousness was similar on the two surfaces. 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.

c. The sum of these effects on the skin infection rate for artificial turf relative to natural turf cannot be predicted from these data alone. Measuring the skin infection rates in athletes competing on artificial and natural turf might determine if there is a significant difference.

Recommendations

1. Inhalation hazard

a. 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.

2. Skin infection hazard

a. 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.

b. Treating skin abrasions should be given the next highest priority. Clean, disinfect and cover abrasions as soon as possible. Keep wounds clean and protected as they heal.

c. Disinfecting artificial turf fields should be the lowest priority. Such efforts may have little effect given the lower numbers of bacteria detected on artificial turf relative to natural turf (based on the results of this study) and the extensive literature suggesting that body-to-body contact is the primary mode of MRSA transmission.

d. It is not known if the abrasiveness of the new generation of artificial turf is primarily determined by the infill or by the blades of grass. Such information would be valuable for engineering new types of turf with decreased abrasiveness. Creating artificial turf with decreased abrasiveness for athletes, while still retaining its strength and durability relative to natural turf, represents a challenge in materials engineering.

Uncertainties and Data Gaps Remaining

1. Inhalation hazard

a. It is not known if the following variables influence $PM_{2.5}$ and VOC release from artificial turf fields containing crumb rubber infill: field age, processing of tire rubber at cryogenic versus ambient temperatures, source of tire stocks (automobile versus truck tires, tire age at the time of processing).

b. This study only measured $PM_{2.5}$ and VOCs above outdoor fields. Indoor fields have received much less attention.

Since $PM_{2.5}$ and VOCs have the potential to accumulate in indoor venues, future testing indoors should be considered.

2. Skin infection hazard
   a. The skin abrasion rate for artificial turf may vary according to age group and type of sport.
   b. The skin abrasion rate may be different for fields containing crumb rubber processed at cryogenic temperatures compared to ambient temperatures.
   c. The skin abrasion rate may vary with field age.
   d. It is not known if skin abrasions caused by artificial and natural turf heal at similar rates.
   e. Few data exist to evaluate whether the bacterial populations of artificial and natural turf vary according to the weather or season.

Appendix Study Number 18

https://www.ncbi.nlm.nih.gov/pubmed/20565000

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Toxicological assessment of coated versus uncoated rubber granulates obtained from used tires for use in sport facilities

AUTHORS: J. Gomes J, H. Mota, J. Bordado, M. Cadete, G. Sarmento, A. Ribeiro A, M. Baiao, J. Fernandes, V. Pampulim, M. Custódio, I. Veloso

PUBLISHED: *Journal of the Air & Waste Management Association*, Volume 60

DATE: June 2010

Abstract

Reuse of tire crumb in sport facilities is currently a very cost-effective waste management measure. Considering that incorporation of the waste materials in artificial turf would be facilitated if the rubber materials were already colored green, coatings were specifically developed for this purpose. This paper presents an experimental toxicological and environmental assessment aimed at comparing the obtained emissions to the environment in terms of polycyclic aromatic hydrocarbons (PAHs), heavy metals, and ecotoxicity for coated and noncoated rubber granulates. This study is a comprehensive evaluation of the major potential critical factors related with the release of all of these classes of pollutants because previous studies were not systematically performed. It was concluded that between the two types of coatings tested, one is particularly effective in reducing emissions to the environment, simultaneously meeting the requirements of adherence and color stability.

Appendix Study Number 19

https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=215113&simpleSearch=1&searchAll=EPA%2F600%2FR-09%2F135

A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds

AUTHOR: The research was prepared by the National Exposure Research Laboratory (NERL) Office of Research and Development, U.S. Environmental Protection Agency (U.S. EPA) with contributions from the Agency's Tire Crumb Science Workgroup

DATE: November 2009

Abstract

Recycled tire material, or "tire crumb," is used as a component in many recreational fields, including synthetic turf fields and playgrounds. The use of tire crumbs in these applications provides several benefits, including reduced sports injury. The public recently has raised concerns regarding potential human health and environmental risks associated with the presence of and potential exposures to tire crumb constituents in recreational fields, especially with regard to children's exposures.

In early 2008, U.S. Environment Protection Agency (EPA) Region 8 requested that the Agency consider this issue. A cross-EPA workgroup inventoried and considered the limited available scientific information: some laboratory studies of tire material content, off-gassing, and leaching characteristics and a few European studies describing the extent and availability of tire crumb constituents for potential human exposure. The workgroup recommended that research be conducted to generate additional field monitoring data for potential U.S. environmental conditions and potential exposures.

A limited-scale study was conducted during the 2008 summer and fall seasons to: (1) gain experience conducting multiroute field monitoring of recreational surfaces that contain tire crumb by evaluating readily available methods for measuring environmental concentrations of tire crumb constituents; and (2) generate limited field monitoring data that will be used by EPA to help the Agency determine possible next steps to address questions from the public regarding the safety of tire crumb infill in recreational fields.

The field sites were selected based on availability and proximity to facilities of EPA's National Exposure Research Laboratory; thus, the results reported here may not be representative of environmental concentrations found at other sites. Because validated methods for sampling synthetic turf fields or playgrounds did not exist, methods used for other microenvironmental sampling were used. The full study protocol was implemented at two synthetic turf fields and one playground. At each field and the playground, air sampling was conducted to collect integrated particulate matter (PM_{10}) and grab volatile at two to three locations on each turf field and playground and also at an upwind background location. The air samples were collected at a height of 1 m in close proximity to, but without interfering with, planned recreational activities. The VOC samples were collected around 2:00 p.m. Wipe samples were collected at the three turf field sampling locations, along with readily available tire crumb infill and turf blade samples. Tire crumb material was collected from the playground. The full protocol was implemented at one of the synthetic turf fields on a second consecutive day providing repeat sampling data. Selected samples were collected at a few additional synthetic turf fields and one playground.

Standard laboratory analysis methods were employed to analyze the environmental samples for the targeted analytes. The PM_{10} samples were analyzed for PM mass, metals, and particle morphology. The VOC samples were analyzed for 56 volatile organic analytes. The wipe and material samples were analyzed for total extractable concentrations of several metals and bioaccessible lead.

Key findings are summarized below.

(1) The study protocol and many of the methods were found to be reliable and could be implemented in the field. Several limitations are noted below.

a. Collecting integrated air samples provided a high burden in terms of time and equipment.
b. Semivolatile organic compounds were not measured.
c. At any single site, there can be substantial variability in the materials used and the concentrations of contaminants measured. More work is needed to determine where to collect samples and how many samples to collect to fully characterize a given site.

d. It was difficult to obtain access and permission to sample at playgrounds and synthetic turf fields. More work is needed to increase public and private owner participation if additional monitoring studies are conducted.

(2) Methods used to measure air concentrations of PM_{10} and metals were found to be reliable.

a. Concentrations of PM_{10} and metals (including lead) measured in air above the turf fields were similar to background concentrations.
b. Concentrations of PM_{10} and metals at the playground site with high play activity were higher than background levels.
c. All PM_{10} air concentrations were well below the National Ambient Air Quality Standards (NAAQS) for PM_{10} (150 ug/m^3). All air concentrations for lead were well below the NAAQS for lead (150 ng/m^3).

(3) Methods used to measure VOCs in air were found to be reliable.

a. All VOCs were measured at extremely low concentrations that are typical of ambient air concentrations.
b. One VOC associated with tire crumb materials (methyl isobutyl ketone) was detected in the samples collected on one synthetic turf field but was not detected in the corresponding background sample.

(4) Methods used to measure extractable metals from turf field blades, tire crumb materials, and turf field wipe samples were found to be reliable. However, the aggressive acid extraction procedure likely will overestimate the concentration of metals that are readily available for human uptake. Since understanding uptake is a key component in understanding risk, methods to determine bioavailable metal concentrations still are needed.

a. Total extractable metal concentrations from the infill, turf blade samples and tire crumb material were variable in the samples collected at a given site and between sites.
b. The average extractable lead concentrations for turf blade, tire crumb infill, and tire crumb rubber were low. Although there are no standards for lead in recycled tire material or synthetic turf, average concentrations were well below the EPA standard for lead in soil (400 ppm).
c. Likewise the average extractable lead concentrations for turf field wipe samples were low. Although there are no directly comparable standards, average concentrations were well below the EPA standard for lead in residential floor dust (40 ug/ft^2).

(5) 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, 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.

APPENDIX STUDY NUMBER 20

https://link.springer.com/article/10.1007%2Fs00420-009-0465-y

This website gives access to the abstract only. You can access the full study through your institution or by paying the required fee.

Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill

AUTHOR: Joost G.M. van Rooij and Frans J. Jongeneelen

PUBLISHED: *International Archives of Occupational and Environmental Health*, Volume 83

DATE: September 2009

Abstract

Background

Artificial sports fields are increasingly being used for sports. Recycled rubber from automotive and truck scrap rubber

tires are used as an infill material for football grounds. There are concerns that football players may be at risk due to exposure from released compounds from rubber infill. Compounds from crumb infill may be inhaled and dermal exposure may occur. A study was performed to assess the exposure of football players to polycyclic aromatic hydrocarbons due to sporting on synthetic ground with rubber crumb infill.

Methods

In this study, football players were trained and had a match on the artificial turf pitch during 2.5 h. They had an intensive skin contact with rubber infill. All urine of seven nonsmoking football players was collected over a 3-day period, the day before sporting, the day of sporting and the day after sporting. Urine samples were analyzed for 1-hydroxypyrene. Confounding exposure from environmental sources and diet was controlled for.

Results

The individual increase of the amount of excretion over time was used as a measure to assess the uptake of PAH. It appeared that the baseline of excreted 1-hydroxypyrene in 4 of 7 volunteers was sufficient stable and that 1 volunteer out of 4 showed after the 2.5-h period of training and match on the playground an increase in hydroxypyrene in urine. However, concomitant dietary uptake of PAH by this volunteer was observed.

Conclusions

This study provides evidence that uptake of PAH by football players active on artificial grounds with rubber crumb infill is minimal. If there is any exposure, than the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet.

Appendix Study Number 21

http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb-River Infilled Synthetic Turf Field

AUTHOR: Ly Lim and Randi Walker

DATE: May 2009

Executive Summary

This report presents the findings from a New York State Department of Environmental Conservation (NYSDEC) study, designed to assess potential environmental and public health impacts from the use of crumb rubber as infill material in synthetic turf fields.

The New York State Department of Health (NYSDOH) evaluated the potential public health risks associated with the air sampling results. The study focused on three areas of concern: the release and potential environmental impacts of chemicals into surface water and groundwater; the release and potential public health impacts of chemicals from the surface of the fields to the air; and elevated surface temperatures and indicators of the potential for heat-related illness ("heat stress") at synthetic turf fields.

The study included a laboratory evaluation, applied to four types of tire-derived crumb rubber (car, truck, a mixture of car and truck, and a mixture cryogenically produced), to assess the release of chemicals using the simulated precipitation leaching procedure (SPLP). The results of this evaluation indicate a potential for release of zinc, aniline, phenol, and benzothiazole. Zinc (solely from truck tires), aniline, and phenol have the potential to be released above groundwater standards or guidance values. No standard or guidance value exists for benzothiazole. However, as leachate moves through soil to the groundwater table, contaminant concentrations are attenuated by adsorption and degradation, and further reduced by dilution when contaminants are mixed with groundwater. An analysis of attenuation and dilution mechanisms and the

associated reduction factors indicates that crumb rubber may be used as an infill without significant impact on groundwater quality, assuming the limitations of mechanisms, such as separation distance to groundwater table, are addressed.

Analysis of crumb rubber samples digested in acid revealed that the lead concentration in the crumb rubber samples were well below the federal hazard standard for lead in soil and indicate that the crumb rubber from which the samples were obtained would not be a significant source of lead exposure if used as infill material in synthetic turf fields.

The evaluation of volatile and semi-volatile organic compounds by off- gassing proved difficult to conduct quantitatively due to the strong absorptive nature of the crumb rubber samples but the results did provide useful information for additional analytes in the ambient air field investigation.

A risk assessment for aquatic life protection performed using the laboratory SPLP results, found that crumb rubber derived entirely from truck tires may have an impact on aquatic life due to the release of zinc. For the three other types of crumb rubber, aquatic toxicity was found to be unlikely. When the results of the column tests are used in this risk assessment model, no adverse impacts are predicted for any of the crumb rubber types evaluated. Although the SPLP results predict a greater release of chemicals, the column test is considered more representative of the field conditions.

The study also included a field sampling component for potential surface and groundwater impacts. This work has not been fully completed at the time of this report. The groundwater sampling that was conducted shows no impact on groundwater quality due to crumb rubber related compounds, but this finding should not be considered as conclusive due to the limited amount of data available. Additional sampling of surface and groundwater at crumb-rubber infill synthetic turf fields will be conducted by NYSDEC. The results will be summarized in a separate report.

A field evaluation of chemical releases from synthetic turf surfaces was conducted at two locations using an air sampling method that allowed for identification of low concentration analytes and involved the evaluation of the potential releases of analytes not previously reported. Few detected analytes were found. Many of the analytes detected (e.g., benzene, 1,2,4-trimethylbenzene, ethyl benzene, carbon tetrachloride) are commonly found in an urban environment. A number of analytes found in previous studies evaluating crumb rubber were detected at low concentrations (e.g., 4- methyl-2-pentanone, benzothiazole, alkane chains (C4-C11)).

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.

The ambient air particulate matter sampling did not reveal meaningful differences in concentrations measured on the field and those measured upwind of the field. This may be explained by the lack of rubber dust found in the smaller size fraction (respirable range) through the application of aggressive sampling methods on the surface of the fields. Overall, the findings do not indicate that these fields are a significant source of exposure to respirable particulate matter.

The results of the temperature survey show significantly higher surface temperatures for synthetic turf fields as compared to the measurements obtained on nearby grass and sand surfaces. While the temperature survey found little difference for the indicators of heat stress between the synthetic turf, grass, and sand surfaces, on any given day a small difference in the heat stress indicators could result in a different guidance for the different surface types.

Although little difference between indicators of heat stress measurements was found, the synthetic turf surface temperatures were much higher and prolonged contact with the hotter surfaces may have the potential to create discomfort, cause thermal injury and contribute to heat-related illnesses. Awareness of the potential for heat illness and how to recognize and prevent heat illness needs to be raised among users and managers of athletic fields, athletic staff, coaches and parents.

This assessment of certain aspects of crumb-rubber infilled synthetic turf fields was designed to collect data under conditions representative of "worst case" conditions (e.g., summer-time temperatures that should maximize off-gassing of chemicals). However, samples collected under different conditions, using different methods or at different fields could yield different results. For example, the results of measurements may be different for fields of other ages or designs (e.g., different volumes of crumb rubber infill, non-crumb rubber infill) or for indoor fields. 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. Information about lead in synthetic turf fibers is available in a Centers for Disease Control and Prevention Health Advisory available at *http://www2a.cdc.gov/han/archivesys/ViewMsgV.asp?AlertNum=00275* [Link not accessible 10/14/2017]

Appendix Study Number 22

https://www1.nyc.gov/assets/doh/downloads/pdf/eode/turf_aqs_report0409.pdf

Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill

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Executive Summary

Synthetic turf fields have been installed in many athletic and playing fields throughout New York City (NYC), the United States and the world. Many of the synthetic turf fields contain crumb rubber infill. Crumb rubber consists of recycled, chipped/pulverized, used automobile tires primarily made from styrene butadiene rubber (SBR). Crumb rubber granules contain a variety of chemicals typical in rubber, including semi-volatile organic chemicals (SVOC) such as polycyclic aromatic hydrocarbons (PAH) and volatile organic chemicals (VOC). In addition, crumb rubber may contain some amounts of particulate matter and metals. Recent concern about the potential for exposure to chemicals found in crumb rubber prompted NYC Department of Parks (DPR) to request assistance from the NYC Department of Health and Mental Hygiene (DOHMH). In response to this request, and with a grant awarded by the New York Community Trust, the DOHMH contracted TRC to lead an intensive literature review focusing on the potential exposures and health effects related to synthetic turf fields and to identify gaps in what is known. The findings from the review were released in a report prepared by TRC titled "A Review of the Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill" (DOHMH 2008). While potential health effects due to heat exposures were identified, an increased risk for human health effects as a result of ingestion, dermal or inhalation exposure to crumb rubber contaminants of potential concern (COPC) was not identified by the review. The review, however, did identify certain knowledge gaps associated with exposure to synthetic turf fields and specifically recommended that air quality related to crumb rubber fields be assessed in the breathing zones of children.

To address the recommendation in the report, with the grant awarded by the New York Community Trust, DOHMH contracted TRC to conduct an air quality survey (AQS). The purpose of the AQS was to investigate the

potential release of contaminants from crumb rubber synthetic turf fields and the subsequent potential exposures in the breathing zones of young children to those airborne contaminants. Although there is potential for ingestion and dermal contact of the crumb rubber infill itself, inhalation exposure would be expected to be a primary route of exposure to any emissions from the synthetic turf.

The AQS consisted of air sampling for a suite of SVOCs (PAHs and benzothiazole), VOCs, metals and particulate matter ($PM_{2.5}$) at two outdoor crumb rubber athletic fields in NYC; Thomas Jefferson Park (East Harlem, Manhattan) and Mullaly Park (Bronx). These COPCs were selected based upon studies showing that SBR crumb rubber contains these classes of COPCs (DOHMH 2008). These studies were either direct analyses of the crumb rubber or air quality studies conducted in indoor soccer halls. In the AQS, stationary samplers placed on turf fields were used to take measurements in the breathing zone of young children (three feet above ground surface). Air samples were collected under simulated playing conditions such as a practice soccer game and walking/running around the samplers. Stationary background samples were collected upwind of the field at the same time as the corresponding active field samples. A grass field also located at Mullaly Park was sampled in a manner similar to the synthetic turf fields for comparison purposes. Air sampling was conducted under summer conditions (August 2009) in the late morning to afternoon hours to represent potentially the highest concentrations of VOCs released due to the heating of the fields by the sun. The AQS results represent the conditions of the day and time when sampling was performed.

The results of the AQS air measurements indicate the following:

- Of 69 VOCs tested, eight VOCs were detected in the air measurements. Although VOCs were detected in the air, there was little evidence of harmful levels at the two sampled synthetic turf fields. Also, there was no consistent pattern to indicate that detected VOCs were associated with the synthetic turf. Similar concentrations were found in the background samples from the comparison grass field and upwind locations.
- For the SVOCs:
  - None of the 17 PAHs tested were detected in any of the ambient air samples.
  - Benzothiazole, which is considered a chemical "marker" for synthetic rubber (DOHMH 2008) was not detected in any of the air samples, including background samples.
  - Of 10 metals tested, two were detected in the ambient air samples. Only one of these metals, however, was detected in the ambient air samples collected from the synthetic turf fields. Similar concentrations were found in both the grass field and upwind samples.
  - Ranges of particulate matter ($PM_{2.5}$) air concentrations from both turf fields were within the background levels found at the comparison grass field and upwind locations.

An analysis of the air in the breathing zones of children above synthetic turf fields did not show appreciable levels from COPCs contained in the crumb rubber. Therefore, a risk assessment related to actual exposure to children was not warranted from the inhalation route of exposure. Results from one of the bulk crumb rubber samples collected as part of this project identified an elevated lead level in the synthetic turf field at Thomas Jefferson Park.*

* DPR is currently replacing the field and continuing to investigate the source of the lead contamination. Using protocols developed by DOHMH, DPR has since tested the remaining synthetic turf installations throughout NYC for lead and has not found a lead hazard. Results will be posted on the DPR website at *www.nyc.gov/parks* when available.