COMMITTEE REPORT:

PEER REVIEW OF AN EVALUATION OF THE HEALTH AND ENVIRONMENTAL IMPACTS ASSOCIATED WITH SYNTHETIC TURF PLAYING FIELDS

JUNE 15, 2010

A REPORT BY

THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING
QUI TRANSTULIT SUSTINET
1976

FOR

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

THE CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION

THE CONNECTICUT DEPARTMENT OF PUBLIC HEALTH

UNIVERSITY OF CONNECTICUT HEALTH CENTER

COMMITTEE REPORT:

PEER REVIEW OF AN EVALUATION OF THE HEALTH AND ENVIRONMENTAL IMPACTS ASSOCIATED WITH SYNTHETIC TURF PLAYING FIELDS

A REPORT BY

THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

ORIGIN OF INQUIRY:	THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION THE CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION THE CONNECTICUT DEPARTMENT OF PUBLIC HEALTH UNIVERSITY OF CONNECTICUT HEALTH CENTER
DATE INQUIRY ESTABLISHED:	JANUARY 4, 2010
DATE RESPONSE RELEASED:	JUNE 15, 2010

This limited-scope analysis consists of a peer review by an Academy committee of a study, "An Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields," conducted by The Connecticut Agricultural Experiment Station, the Connecticut Department of Environmental Protection, the Connecticut Department of Public Health, and the University of Connecticut Health Center. The content of this report lies within the province of the Academy's Environment Technical Board. The report is hereby released with the consent of the Peer Review Committee.

Richard H. Strauss
Executive Director

MEMBERS OF THE PEER REVIEW COMMITTEE ON AN EVALUATION OF THE HEALTH AND ENVIRONMENTAL IMPACTS ASSOCIATED WITH SYNTHETIC TURF PLAYING FIELDS

Vicki Hanrahan Ainslie
Senior Research Scientist
Occupational Safety and Health Division
Georgia Tech Research Institute

Dana B. Barr, PhD
Research Professor
Rollins School of Public Health
Emory University

Jonathan Borak, MD
Clinical Professor of Epidemiology & Public Health and Clinical Professor of Medicine
Yale University
President, Jonathan Borak & Company, Inc.

Allan J. Cessna, PhD
Research Scientist
Agriculture and Agri-Food Canada
Environmental Health National Program
Currently on assignment to: Environment Canada
National Water Research Institute
Saskatoon, Saskatchewan, Canada

Albert J. Fry, PhD *(Academy Member)*
E.B. Nye Professor of Chemistry
Wesleyan University

Tammy Jones-Lepp, MSc
Research Chemist
Office of Research & Development
National Exposure Research Laboratory
US Environmental Protection Agency

Paul Lioy, PhD
Professor of Environmental & Occupational Medicine
University of Medicine & Dentistry of New Jersey – Robert Wood Johnson Medical School; and Deputy Director of Government Relations & Director, Exposure Measurement & Assessment Division, Environmental & Occupational Health Sciences Institute
UMDNJ-RWJMS & Rutgers

Woodhall Stopford, MD, MSPH
Assistant Professor of Community and Family Medicine, Division of Occupational & Environmental Medicine
Duke University

Arthur Wickman
Head, Health Sciences Branch & Senior Research Scientist
Georgia Tech Research Institute

Research Team

PEER REVIEW REPORT MANAGER

David Pines, PhD
Associate Professor
Chair of Civil, Environmental, and Biomedical Engineering
University of Hartford

ACADEMY PROJECT STAFF

Richard H. Strauss
Executive Director

Ann G. Bertini
Assistant Director for Programs

STATEMENT OF INQUIRY: PROJECT INTENT AND BACKGROUND

On behalf of the Connecticut Department of Environmental Protection (DEP), the Connecticut Department of Public Health (DPH), the University of Connecticut Health Center (UCHC), and The Connecticut Agricultural Station (CAES), the Connecticut Academy of Science and Engineering (CASE) performed a peer review of their final report on the Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields. The scope of the Technical Review includes an examination of the appropriateness of the methods used to sample contaminants, conduct laboratory analysis, and perform human and ecological risk assessment. The Peer Review Committee (PRC) also evaluated the appropriateness of conclusions reached in the environmental and human health risk assessments. In addition, the PRC provided suggestions for future studies that were not part of the state agencies' scope of work.

CASE TECHNICAL REVIEW PROCESS

- Appointed a Peer Review Committee comprising Academy members and other experts to conduct a peer review of the final study report.
- Provided study materials to the PRC and organized and facilitated committee meetings to discuss and deliberate on the topic.
- Submitted questions to state agencies for consideration in preparation of report briefing to the PRC.
- Conducted a briefing of the final study report by CAES, DEP, DPH, UCHC, and for the PRC.
- Facilitated communication between the PRC and state agencies on questions that arose from review of the final study report and state agency briefing.
- Briefed state agencies on the PRC's final report.
- Produced a report summarizing the PRC's analysis of the final study report.

Introduction

The CASE Peer Review Committee (PRC) was provided with an overall executive summary and the following study partner reports:

- *Artificial Turf Field Investigation in Connecticut Final Report* prepared by the University of Connecticut Health Center Section of Occupational and Environmental Medicine, March 30, 2010 (referred to as UCHC Report)
- *Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut* by the Connecticut Department of Public Health, Program in Environmental and Occupational Health Assessment, April 5, 2010 (referred to as DPH Report)

- *Artificial Turf Study: Leachate and Stormwater Characteristics* by the Connecticut Department of Environmental Protection, March 2010 (referred to as DEP Report)
- *2009 Study of Crumb Rubber Derived from Recycle Tires Final Report* by The Connecticut Agricultural Experiment Station, Department of Analytical Chemistry (referred to as CAES Report)

On April 28, the state agencies briefed the PRC on the final report studies and responded to the questions submitted by the PRC. The committee asked additional questions following the briefing and discussed with the state agencies their preliminary findings and comments. The state agencies responded to the questions and comments submitted by the PRC by either modifying their final reports or submitting a separate written response justifying why the report should not be changed. The PRC then submitted their findings, comments, remarks to the CASE Project Management Team for finalizing the draft peer review report. The committee provided comments on the draft report, which was then finalized on June 4, 2010.

Overview

The state agencies provided the following summary of their reports on the evaluation of the health and environmental impacts associated with synthetic turf playing fields to the PRC:

> *"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 with some having toxic or carcinogenic properties. Human 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. Rainwater may leach chemicals from the rubber into underlying groundwater or nearby streams. 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. The current investigation involved air sampling at 1 indoor and 4 outdoor artificial turf fields under summer conditions in Connecticut. The main goal was to document air concentrations of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), rubber-related chemicals (e.g. benzothiazole), and particulate matter less than 10 micron (PM10) at these fields under conditions of active use. These data were then used in a human health risk assessment that focused on children or adults using these fields. In companion studies, off-gas studies were performed in two separate laboratories (Connecticut Agricultural Experiment Station; Wisconsin Occupational Health Laboratory) to evaluate the range of chemicals that could volatilize from crumb rubber from these fields at elevated temperature. Chemical migration in runoff from the outdoor fields was evaluated by collecting leachate in association with rain events.*
>
> *The laboratory studies showed off-gassing of numerous compounds including polycyclic aromatic hydrocarbons (particularly naphthalenes), VOCs (e.g., benzene, hexane, methylene chloride, styrene, toluene), and rubber-related SVOCs (benzothiazole, tert-octylphenol, butylated hydroxytoluene). The primary constituent detected by both laboratories was benzothiazole. Pre-weathering the crumb rubber outdoors for ten weeks decreased the volatile emissions 20-80%.*
>
> *The field investigation detected a variety of compounds that were present above the fields at concentrations greater than the range seen in background samples. Based upon the pattern of detection, it is considered likely that benzothiazole, acetone, toluene, methyl ethyl ketone, methyl*

isobutyl ketone, butylated hydroxytoluene, naphthalenes and several other PAHs were field-related, with other detected chemicals less certain to be field related. For example, benzene, methylene chloride, methyl chloride and acrolein were detected only in personal monitoring samples and not in the stationary samplers placed just above the field. This suggests that sampling equipment or host exhaled breath may be a source of some of these VOCs. In general, detections were higher at the one indoor field compared to the outdoor fields, in some cases (e.g., benzothiazole), more than 10 times higher. Testing for volatile nitrosamines and PM10 failed to find detections above background while detections of lead in crumb rubber were below well accepted criteria.

The risk assessment considered compounds detected above background as potentially field-related unless they were not detected on turf fields in previous studies or in the current off-gas studies (e.g., acrolein). This led to a list of 27 chemicals of potential concern (COPCs) 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.

Results indicate cancer risks slightly above de minimis levels for all scenarios evaluated with children playing at the indoor facility having the highest exposure and risk. However, these 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 cancer risk driver, benzene, was only above background in personal monitoring samples. 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.

A total of eight stormwater samples were collected from three synthetic turf fields and analyzed for total metals, hardness, pH, volatile organic compounds, semi-volatile organic compounds, pesticides/ polychlorinated biphenyls (PCBs) and acute aquatic toxicity (48 hours for Daphnia pulex and 96 hours for Pimephales promelas). The sampling analysis detected various metals and semi-volatile compounds in the stormwater, with three samples exhibiting acute toxicity for both Daphnia pulex and Pimephales promelas. The only analyte in the stormwater detected in concentrations exceeding acute aquatic toxicity criteria for surface waters was zinc. Zinc exceedences of the acute criteria were detected in the same three stormwater samples that exhibited acute toxicity for both Daphnia pulex and Pimephales promelas. These results showed that there is a potential risk to surface waters and aquatic organisms associated with whole effluent and zinc toxicity of stormwater runoff from artificial turf fields. The DEP recommends that, where feasible, stormwater runoff from artificial turf fields that is discharged to surface waters, be handled in a manner that incorporates best management practices, such as stormwater treatment wetlands, wet ponds, infiltration structures, compost filters, sand filters or biofiltration structures."

Reports' Contribution to the Health and Environmental Impacts Associated with Artificial Turf Playing Fields

The state's study provides the scientific community with valuable data on the off-gassing of indoor and outdoor artificial turf fields during conditions of active use on warm (76 - 86°F), sunny days with little wind. Laboratory studies were also performed to evaluate the importance of preweathering on the emission of volatile and semi-volatile organic compounds from crumb rubber material. In addition, field and laboratory leachate studies provided data on the potential environmental impact of the stormwater runoff from artificial turf fields on the surface waters and aquatic organisms.

Primary Finding

The CASE Peer Review Committee concluded based on a review of the state's reports that there is a limited human health risk, and an environmental risk as shown by the high zinc levels detected. Furthermore, it is believed that some of the results can be easily misinterpreted by the public.

The primary concern is on the "headline" finding of the DPH report: "*Results indicate cancer risks slightly above de minimis levels for all scenarios evaluated …*" The review of the reports and the data collected by the state agencies indicates that such a conclusion is far too conservative (i.e., overstates the risks) and unsupported by the actual data.

The following is the basis for DPH's systematic overstatement of exposure and risk in conducting the risk assessment (Note that the page numbers all refer to the DPH report):

a. All exposures at all fields were assumed to have been the same as the highest level measured at any field at any time:

> *"the highest on-field result (regardless of sample type) was taken to represent what might be coming off the fields."* (p. 6)

DPH describes this "*highest on-field*" approach as representing "*a worst case composite*." (p. 10)

b. Background levels were not subtracted from the measured levels on fields, hence the reported results represent the sum of ATF emissions <u>plus</u> background:

> *"… the entire concentration was considered to be field-related – there was no background correction."* (p. 6)

This leads to important analytical errors. For example:

> The DPH report describes positive results for benzene at Field C (Figure 7, p. 47), but the UCHC report states that all of the benzene levels measured at Field C (0.54-0.61 $\mu g/m^3$) were substantially below the concurrent background level (0.92 $\mu g/m^3$).

The correct interpretation of the Field C data is that benzene was NOT detected above background and therefore there is NO evidence that benzene was off-gassing from the ATF. Thus the Field C data are NOT evidence of benzene from ATF.

Similar concerns impact all of the data as used by DPH in the risk assessment.

c. The personal samplers probably included contributions from other sources or sampler issues. Hence the reported personal sampler results represent the sum of ATF emissions plus background plus other sources, making the reported sampler results suspect. This issue was not taken into consideration in the risk assessment:

> *"… personal monitors yielded considerably higher concentrations of analytes than detected on the field suggesting a contribution from the host in some manner. Since this percentage is unknown, the personal monitor detects were used to represent what may have been coming off the field for the purpose of the risk assessment."* (p. 7)

d. Field samples were obtained on warm (temperature range at 3 feet above artificial turf: 76-86°F), sunny days with little wind. DPH recognized that cool, cloudy or windy days would result in lower exposures, but that was not included in their exposure data:

> *"… we assume that these results apply to the 4 warmest months with no allowance for days with clouds or high wind which would mitigate exposure."* (p. 10)

e. It is possible that the DPH risk assessment assumed eight months of summer-type exposure per year, but the report is unclear:

> *"Given that field sampling occurred in July under sunny, low wind conditions, VOC off-gassing from the outdoor fields would be overestimated if the entire 8 month/year exposure period was simulated based upon the results. Instead, we assume that these results apply to the 4 warmest months…"*

A description of how exposures were estimated for the other four months of annual exposure was not found in the report. It would be important to understand the methods used by DPH to extrapolate VOC off-gassing from warm, sunny, low wind conditions in July to cool, cloudy, windy conditions in March and October and how the results were adjusted to deal with hot summer days, not present during the study.

f. The risk assessment used a non-standard adjustment for ventilation rates, which seemingly leads to higher estimates of ventilation and dose. Documentation with an explanation as to why it was considered appropriate in this situation should be provided in the report.

g. A non-standard Unit Risk factor for benzene was adopted without scientific justification, other than that it was "conservative" and would therefore yield higher estimated risk:

> *"The unit risk factor for benzene used in this risk assessment is the average of the upper bound from the IRIS unit risk range and the value from Cal OEHHA. The Cal OEHHA value is well above the IRIS range for reasons not immediately apparent and is not*

> *necessarily any more reliable. The value chosen for the current purposes is considered to be conservative and may overestimate benzene potency."* (p. 21)

In summary, the DPH risk assessment systematically overstates the risks of ATF by overstating exposures, by including improbable contaminants, and by using non-standard estimates of cancer potency and ventilation.

Moreover, it appears that it is the intention of DPH to be overly conservative in estimating ATF-related risks. For example, the DPH report acknowledges that its exposure assessments were at the upper bound of plausibility:

> *"Exposure assessments for use of these fields are generally conservative … and meant to assess the risk as an upper bound of plausible use of this resource. However, the average use rate is likely to be considerably lower …"* (p. 21)

Their "headline" conclusion, however, reflects none of that concern: "*Results indicate cancer risks slightly above de minimis levels for all scenarios evaluated …*" The conclusion fails to indicate that such risks are highly improbable, reflecting a series of systematic overestimates of exposure and risk, and including a contaminant that is almost certainly not actually off-gassing from the crumb rubber.

The CASE Peer Review Committee strongly urges DPH to revise its risk assessment and then present its findings with appropriate cautions. At the least, the various assumptions underlying the risk assessment should be compiled and presented in a manner so that they can be understood by non-scientists (e.g., parents and journalists) reading the report.

In addition, the range of uncertainty should be explicitly stated. For that purpose, the committee provides the following paraphrase of a statement found in numerous California Office of Environmental Health Hazard Assessment (OEHHA) risk assessments:

> *While it is theoretically possible that the true risk could exceed this value, that is considered unlikely. On the other hand, it is plausible that the lower bound on the human risk includes zero. In other words, it possible that use of ATF poses no human risk whatever.*

Finally, the PRC is very aware of the shrinking resources available to support our children's education and recreation activities. It is almost certain that the "headline" conclusion of the DPH report will become the focus of media reports and will unnecessarily frighten parents as well as school and municipal supervisors. Parents may be motivated to withdraw their children from beneficial athletic activities, and schools and towns will consider the financially wasteful removal of existing fields. This would be an unfortunate result, one that would likely pose greater risks to the welfare of Connecticut than the continued use of outdoor ATF fields.

However, the committee would like to see the risk assessment address the issue of very young children, i.e., toddlers, crawling infants, and their exposure to some of the compounds presented, given their propensity for putting things in their mouths and their proximity to the ground.

FINDINGS OF THE COMMITTEE

A summary of the CASE Peer Review Committee's findings and suggestions for each aspect of the study is as follows:

ARTIFICIAL TURF FIELD INVESTIGATION IN CONNECTICUT FINAL REPORT BY UCHC

Design of Experiment

The study included the measurement of PM10 particulates with the default presumption that the values could be used as a conservative estimate of PM2.5 exposures. The particulates, however, were not analyzed for either rubber content or the presence of natural rubber latex antigen. If the filter samples are still available from the Connecticut study, consideration should be given to having them analyzed for release of natural rubber latex antigen. If a follow-up study of the indoor field with ventilation in place is considered in the future, a similar analysis of particulates collected should be considered.

Crumb rubber contains about 50% rubber and about 25% natural rubber latex. In turf fields that use crumb rubber, PM2.5 samples contain 50% rubber. One concern with play on these fields is contact allergies to either natural rubber latex or other allergenic components (such as benzothiazole) of crumb rubber.

While this study did not include contact exposure, previous studies have investigated the potential antigen exposures from vulcanized natural rubber latex, such as would be found in crumb rubber (see http://www.health.state.ny.us/environmental/outdoors/synthetic_turf/crumb-rubber_infilled/docs/fact_sheet.pdf). Based on these findings, it is suggested that synthetic turf fields made with crumb rubber have a content warning as follows:

> THIS SPORTS FIELD CONTAINS CRUMB RUBBER WHICH CONTAINS NATURAL RUBBER LATEX.

This warning alerts those individuals with natural rubber latex allergies (about 15% of health workers and about 6% of the general population) to avoid exposure to or use of products containing vulcanized natural rubber latex.

An additional concern from crumb rubber exposures, that would not be seen with block vulcanized rubber, is that inhalation of particulate natural rubber latex antigen is associated with a risk of developing asthma (Miguel et al, 1996; Vanderplas et al, 2009).

Based on data of Miguel et al (1996), there is 27.7 mcg of FDA latex antigen/g of rubber tire particulates. Using the data from Dye et al (2006), there are 7-19 mcg/m^3 of PM2.5 particles above indoor turf playing fields, which are essentially all rubber particulates. At this level of respirable dust generation, there would be 0.2-0.5 ng/m^3 of NRL antigen in the air. This compares with hospital exposures of 96-1664 ng/m^3 of NRL antigen where NRL-related asthma occurs. Therefore, exposures to respirable NRL antigen from playing on outdoor synthetic turf fields would be expected to be appreciably less than this. If there were still a health concern for indoor fields, exposures could be brought to essentially zero by wetting the turf. This is a common practice with carpet-style turf fields (Stopford, unpublished data).

The report should explain why PM10 was measured and not PM2.5. It is the PRC's understanding that PM2.5 is of more concern because particles that size or smaller can better penetrate into the alveoli of the lungs and are not readily cleared from the lungs. This issue is raised because if the amount of PM10 was considered low, perhaps the abrasion of crumb rubber in turf under playing (e.g., soccer) conditions may produce a majority of smaller particles. Therefore, the committee suggests that in future studies, based on Dye et al (2006), that PM2.5 should be measured.

Analytical Methodology

The committee was comfortable with the analytical methodology used and believes that the resulting residue data are reliable. For example, the SVOCs that were found seem more congruous with what one would expect coming off of petroleum products (e.g., rubberized asphalt, phenolic resins, petroleum waxes, polyester, nylon). However, there still remain several issues to be considered with respect to VOCs.

- Some identified VOCs are solvents (e.g., acetone, methylene chloride) commonly used in most analytical laboratories. For example, methylene chloride is a very common laboratory background contaminant, and the committee is suspicious of any detection of it on an outdoor field due to its extreme volatility. The report should indicate whether any precautions were taken in the analytical laboratories to prevent introduction of these solvents into the sample extracts.

  Also, the committee is suspicious of most of the VOCs found, especially the very low molecular weight/high volatility compounds, in the outdoor fields. It is possible that very volatile compounds such as carbon tetrachloride and acetone are being introduced in the lab from some nearby source, not coming from the fields themselves.

- The criteria used to determine which concentrations in samples were considered to be above background concentrations should be clearly defined. Even though average concentrations in samples were somewhat higher than background concentrations, the differences did not appear to be real given the variability frequently associated with analysis of background concentrations and analysis of samples containing concentrations close to background concentrations. For example, in Table 7 (page 15) of the UCHC Report, concentrations of vinyl acetate in samples were 1.23 and 1.13 μg/m^3 and were considered to be higher than the background concentration, which was 1.02 μg/m^3. Dichlorodifluoromethane is another example where an average of 2.28 μg/m^3 to 2.47 μg/m^3 was detected compared to the background of 2.23 μg/m^3. Also in Table 7, the background concentration for halocarbon 11 (1.96 μg/m^3) is higher than the sample concentrations (1.85 and 1.79 μg/m^3), but the sample concentrations are still bolded as if they were higher. The same issues are found in Tables 8 through 11.

It is suggested that qualifiers should be included for the VOC (and SVOC) data reported as above background by at least showing how far above background (e.g., 2x, 3x) or use the standard deviations from the results.

Semivolatile Organic Compound (SVOC) Results

The PRC suggests leaving out most of the hexanoic, decanoic, etc., compounds that were reported in Tables 17, 19, and 21 of the UCHC Report, since it appears that few, if any, of these "miscellaneous SVOCs" pertain to crumb rubber or artificial turf. For example, most of the acids reported in Table 17 are stearic and humic acids, which result from the decomposition of organic matter. They are commonly found in the natural environment and are usually non-toxic. For completeness, the PRC suggests putting these data into an appendix.

Off-Gas Findings

The question was posed to the state agencies as to whether these fields were representative of the majority of artificial turf fields. The answer to this question was that there may be variation in the manufacturing process and the raw recycled materials composing the crumb rubber. However, regardless of the source, the SVOC air contaminants off-gassed above the field are consistent between fields in the current report, and they are also consistent with the air contaminants reported in other similar studies. If this is correct, it would be a good idea to emphasize the consistency of these findings, so that the present report has greater impact as public entities evaluate the actions they should appropriately take with their own artificial turf fields. For instance, they would not need to have them individually tested if the fields consistently off-gas the same contaminants.

Reference Lead Levels

With respect to a reference level for lead in the UCHC Report (Table 6, page 12), it is suggested that the following Consumer Product Safety Commission standard for products intended for use by children 12 years of age or less (300 µg/g until 2011, then 100 µg/g) should be used as a benchmark (Consumer Product Safety Improvement Act, Section 101(a): http://www.cpsc.gov/businfo/frnotices/fr09/leadcontent.html). While the federal Environmental Protection Agency's (EPA) lead in soil standard (400 µg/g) likely governs the regulatory requirement for lead in artificial turf, the PRC prefers a lower or more conservative standard when it comes to the ingestion of lead.

HUMAN HEALTH RISK ASSESSMENT OF ARTIFICIAL TURF FIELDS BASED UPON RESULTS FROM FIVE FIELDS IN CONNECTICUT BY CT DPH

Human Health Risk Assessment - Benzene

As discussed in the primary findings, the benzene exposure data are suspect and probably invalid. This is problematic because DPH's conclusions are driven by the inclusion of benzene in the risk assessment. For example,

> *"… benzene is the leading contributor to cancer risk … contributing 51 to 73% of the total risk…"* (p. 19).

DPH acknowledges these limitations, but then ignores them. The following are references that support the conclusion that the benzene data are suspect.

a. Benzene was detected in some personal samples, but not in any field samples in the UCHC study. DPH proposed that this might represent sample contamination:

> *"the main contributors to cancer risk, benzene and methylene chloride, were found in personal monitors only and may not be field-related."* (p. 18)
>
> *"the major contributors to cancer risk are not clearly field-related…"* (p. 19)
>
> *"Benzene was only detected in personal monitoring samples and not in stationary field samples suggesting that a substantial portion of the personal monitoring detections comes from the sampling equipment or host and not from the field."* (p. 19)
>
> *"The level of benzene found in personal monitoring samples … is often considered the background range for ambient benzene …"* (p. 20)

b. DPH included benzene in the risk assessment despite the concerns expressed above because benzene was reported in some of the rubber crumb off-gassing studies performed by WOHL:

> *"These analytes were included at [sic] COPCs because of their detection in WOHL crumb rubber off-gas studies. Benzene was detected in the head space from two of the five crumb rubber samples …"* (p. 20)

However, WOHL also reported that benzene was found in laboratory background samples. The data were provided in the UCHC report (Table 4, p. 10; section 3.3.1, p. 9):

> "*The following VOC compounds were reported in the laboratory background sample: … benzene (18 ppb)…*" (UCHC, p. 9)

At standard pressure and room temperature, 18 ppb benzene is equivalent to about 57.5 $\mu g/m^3$. In other words, the background benzene levels at the WOHL labs were nearly 50-fold greater than those reported in any of the ATF personal samplers.

c. The DPH report recognized the problem posed by background contamination of the WOHL laboratory, but chose to ignore it:

> *"… laboratory blank analyses from those WOHL headspace analyses found 6 VOCs in the lab blanks including, benzene, methylene chloride and acetone. This creates additional uncertainty regarding the field-related nature of these VOC detects, but they were still considered as COPCs for the purposes of the current risk assessment."* (p. 20)

d. In addition to the concerns described above regarding the benzene samples, there is also inconsistency in the benzene findings reported in the UCHC and DPH reports. That is seen in the following table, which categorizes the reported data as "ND" = non-detect and "+" = positive detection. It can be seen that fields with positive UCHC personal samples yielded non-detect results at WOHL, while fields with positive results at WOHL yielded non-detect results in the UCHC personal samples.

Sample	Field A	Field B	Field C	Field D
6" Stationary	ND	ND	ND	ND
3' Stationary	ND	ND	ND	ND
Personal	ND	+ [1]	+ [2]	ND
WOHL	+ [3]	ND	ND	+ [3]

[1] One of two samples was positive

[2] The "positive" sample was only 66.3% of the measured outdoor background level

[3] Benzene was also detected in laboratory background samples

In other words, the results present no consistent pattern. To the contrary, these results appear to reflect background contamination and random noise. DPH uses ventilation rate corrections that appear to exaggerate the assessment of exposure to all volatile toxicants considered by DPH, including benzene. DPH should give better documentation as to the basis for their ventilation correction factor with specific references to the EPA's revised exposure handbook (2009).

Human Health Risk – Benzothiazole

DPH notes that benzothiazole, a vulcanizing chemical found in crumb rubber, is found in the atmosphere, both in a gaseous and particulate form, as a result of the wearing down of rubber tires, and that analysis of field leachates found benzothiazole levels as high as 6.1 ppb. New York, in their studies of crumb rubber (NY State Dept of Health, 2009), found leachates of crumb rubber could contain up to 526 ppb benzothiazole. In their risk assessment of benzothiazole, DPH uses an analogy with formaldehyde for their acute inhalation risk assessment to protect against respiratory irritation and potential inhalation sensitization. There is no scientific justification for making this analogy. The current regulatory status (http://ntp.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/Benzothiazole.pdf) from EPA is

- NIOSH or OSHA have not set standard or guidelines for occupational exposure to or workplace allowable levels
- American Conference of Governmental Industrial Hygienists (ACGIH) has not recommended a threshold limit value (TLV) or biological exposure index (BEI) for benzothiazole
- Flavor and Extract Manufacturers Association considers that benzothiazole is "generally recognized as safe" as a flavor ingredient

However, benzothiazole is an allergen and contact exposure has been associated with contact dermatitis (Sfia, et al, 2007). Solubility in salt solutions (such as sweat) is similar to that seen in water (Bogert & Husted, 1932). The authors of the latter study noted that brief contact to 25 mg of this chemical produced a poison ivy-like contact dermatitis in 39% of exposed subjects after a single contact, including one of the authors. DPH did not address this known risk of sensitization reactions to benzothiazole from direct skin contact. With sensitization at a dose of 12,500 mcg/cm^2, benzothiazole would be considered at least a moderate sensitizer equivalent to some known fragrance sensitizers. The PRC suggests that DPH address allergenic risks of benzothiazole exposures from direct contact with crumb rubber or from inhalation of this chemical when playing on indoor fields in their risk assessment of this chemical.

Human Health Risk – Lead Findings

Past studies have reported the presence of lead in the artificial turf in concentrations ranging from 0.09% lead by weight to 0.96% (http://www.cpsc.gov/library/foia/foia08/os/turfassessment.pdf). If artificial turf fields were primarily produced for use by children age 12 or under (such as in grade schools), then there would be a question of whether or not such fields could even be used in such settings and still comply with federal lead regulations. Therefore, human exposure to lead dust released from these fibers as they weather and deteriorate over time has been the subject of substantial health concern, and has been addressed by authoritative sources of public health information such as the CDC, CPSC, and the New Jersey Department of Health and Senior Services. The fact that the present study looked for lead in green artificial turf fibers and failed to find lead at any level of concern is a significant finding that the PRC believes deserves greater emphasis than it currently receives in the report.

Human Health Risk Assessment – Metals

The following are the committee's concerns related to the risk assessment performed based on the metal data.

- Metals other than lead which may be of concern in crumb rubber, such as chromium and zinc, should be included in the risk assessment. For example, relatively high levels of chromium leached from the alternate infill products are shown in Table 10 in CAES Report (page 12). It would be good to see those results addressed in the Human Health Risk Assessment, especially if the chromium is due to the material used to dye the artificial turf green.
- The major concern is not for the children > 10 and adults playing on the field, but for the younger players ≤ 10, who are still growing rapidly, and younger sibling toddlers who are sitting on the field during practice and during games. For example, many families bring the younger siblings who sit on the ATF. They are closer to the ground and therefore have a greater possibility of inhalation exposure, especially during the hot weather months. Also, they are more likely to pick things up and put them in their mouths and they may be crawling around on the turf, resulting in a greater chance of exposure to the high levels of chromium and zinc found in the ATF/crumb rubber.

Human Health Risk Assessment – Indoor Air Sampling Findings

The effect of the indoor air samples may have a biasing effect on the conclusions of the study, raising the following issues:

- Would the study still come to the conclusion of "cancer risks slightly above de minimis levels" if the indoor samples were not included?
- The report finds that the Hazard Index for acute risk was close to 1 for children playing on the indoor fields. Would a corollary conclusion then also be that the same index was NOT approaching 1 for children on outdoor fields?
- Are the indoor air samples truly accurate in reporting that air contaminants come from the artificial turf, as opposed to coming from a separate source within the building?
- Is there any difference in the manufacture or installation of indoor product that might also account for the greater indoor elevation?
- Finally, since the building exhaust system was not operating during the sampling period, is this representative of the conditions when the field is in use during a game or practice?

Artificial Turf Study: Leachate and Stormwater Characteristics by CT DEP

From the laboratory leachate and stormwater results it would seem that metals such as zinc, manganese, and chromium from crumb rubber and/or alternative infill materials would result in the greatest environmental contamination. The PRC suggests that the impact of field runoff contribution to a watershed may require treatment of runoff using alternate draining methods such as perforated drainage pipe.

2009 Study of Crumb Rubber Derived from Recycle Tires by CAES

The following are comments and suggestions on the CAES Report:

- In Table 4 (page 6), the percent relative standard deviation is given for the concentrations listed in Table 2 (page 5). While statistically "valid," they have little meaning for two analyses per sample. It is suggested that a standard deviation be shown, as in Table 3 (page 5), for two replicates.
- In the principal component analysis (PCA) graphic (Figure 2, page 7), there are also clusters around some of the A samples. If PCA is going to be used, the other relationships as shown in the graphic should be examined. For example, it is suggested that the commonalities of A1005 and A1008 (e.g., are they from the same field?), as well as the other groupings of A's should be examined.

Analytical Results – CAES versus WOHL

The committee is concerned about the differences in the analytical results found in off-gassing studies performed by the CAES Analytical Laboratory and WOHL. The primary issue that needs to be addressed is the presence or absence of benzene. Below is a summary of the differences found between the two labs and how the interpretation of the data has a significant impact on the results of the risk analysis.

- CAES reported that benzene was not detected in the head space of crumb rubber fill. There were 14 samples tested, all provided by Connecticut DEP. It is assumed that they correctly represented samples of virgin crumb rubber fill of the type used in the fields tested by UCHC, and also that the 14 represented multiple independent sources of rubber crumb.
- If the correct samples were provided by DEP and if analyses were correctly performed, then these results strongly argue that significant amounts of benzene do not volatilize from rubber crumb.
- CAES also reported relatively rapid VOC off-gassing and weathering of virgin rubber crumb.
- If the correct samples were provided by DEP and if analyses were correctly performed, then these results strongly argue that volatile compounds not detected in the off-gassing of virgin rubber crumb would not be expected to off-gas from weathered rubber crumb fill.
- WOHL detected benzene in the head space from 2 of 11 crumb rubber samples, from Fields A and D which had been in service for two years.
- The committee is unable to determine the composition and manufacturer(s) of Fields A and D, and cannot determine whether the rubber crumb samples provided to CAES were the same or similar to the rubber crumb used for those two fields.
- If the samples provided by DEP were the same or similar to the rubber crumb used for Fields A and D, then the WOHL results can not be seen as supporting inclusion of benzene in the risk assessment unless it is also determined that the CAES lab was incorrect in both its analyses of off-gassing from and its analyses of weathering of virgin crumb samples.

Before accepting the conclusion, based on the WOHL results, that benzene is a primary concern for ATF risk assessment, it is important that the results of the CAES lab be validated. One possibility is to have the CAES lab and at least one other well-recognized analytical lab perform repeated analyses of samples of virgin crumb rubber. If neither lab finds benzene in the off-gas, then benzene should be deleted from the risk assessment.

REFERENCES

Bogert, M. T., Husted, H. "Contribution to the pharmacology of the benzothiazoles." *Journal of Pharmaceutical Experimental Therapy*. 1932; 45: 189-207.

Dye, C., Bjerke, A., Schmidbauer, N., Mano, S. "Measurement of air pollution in indoor artificial turf halls." Norwegian Pollution Control Authority. 2006

Miguel, A. G., Cass, G. R., Weiss, J, Glovsky, M. M. "Latex allergens in tire dust and airborne particles." *Environmental Health Perspectives.* 1996 Nov;104(11):1180-6

Sfia, M., Dhaoui, M. A., Doss, N. "Consort allergic dermatitis to cosmetic agents in a 10-year-old young girl." *Contact Dermatitis*. 2007 Jul;57(1):56-7.

Vandenplas. O., Larbanois, A., Vanassche, F., François, S., Jamart, J., Vandeweerdt, M., Thimpont, J. "Latex-induced occupational asthma: time trend in incidence and relationship with hospital glove policies." *Allergy*. 2009

MAJOR STUDIES OF THE ACADEMY

2009

- A Study of the Feasibility of Utilizing Waste Heat from Central Electric Power Generating Stations and Potential Applications
- Independent Monitor Report: Implementation of the UCHC Study Recommendations

2008

- Preparing for Connecticut's Energy Future
- Applying Transportation Asset Management in Connecticut
- A Study of Weigh and Inspection Station Technologies
- A Needs-Based Analysis of the University of Connecticut Health Center Facilities Plan

2007

- A Study of the Feasibility of Utilizing Fuel Cells to Generate Power for the New Haven Rail Line
- Guidelines for Developing a Strategic Plan for Connecticut's Stem Cell Research Program

2006

- Energy Alternatives and Conservation
- Evaluating the Impact of Supplementary Science, Technology, Engineering and Mathematics Educational Programs
- Advanced Communications Technologies
- Preparing for the Hydrogen Economy: Transportation
- Improving Winter Highway Maintenance: Case Studies for Connecticut's Consideration
- Information Technology Systems for Use in Incident Management and Work Zones
- An Evaluation of the Geotechnical Engineering and Limited Environmental Assessment of the Beverly Hills Development, New Haven, Connecticut

2005

- Assessment of a Connecticut Technology Seed Capital Fund/Program
- Demonstration and Evaluation of Hybrid Diesel-Electric Transit Buses
- An Evaluation of Asbestos Exposures in Occupied Spaces

2004

- Long Island Sound Symposium: A Study of Benthic Habitats
- A Study of Railcar Lavatories and Waste Management Systems

2003

- An Analysis of Energy Available from Agricultural Byproducts, Phase II: Assessing the Energy Production Processes
- Study Update: Bus Propulsion Technologies Available in Connecticut

2002

- A Study of Fuel Cell Systems
- Transportation Investment Evaluation Methods and Tools
- An Analysis of Energy Available from Agricultural Byproducts, Phase 1: Defining the Latent Energy Available

2001

- A Study of Bus Propulsion Technologies in Connecticut

2000

- Efficacy of the Connecticut Motor Vehicle Emissions Testing Program
- Indoor Air Quality in Connecticut Schools
- Study of Radiation Exposure from the Connecticut Yankee Nuclear Power Plant

CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING
179 Allyn Street, Suite 512, Hartford, CT 06103
Phone or Fax: 860-527-2161
e-mail: acad@ctcase.org
web: www.ctcase.org

Connecticut Academy of Science and Engineering

The Connecticut Academy is a non-profit institution patterned after the National Academy of Sciences to identify and study issues and technological advancements that are or should be of concern to the state of Connecticut. It was founded in 1976 by Special Act of the Connecticut General Assembly.

Vision

The Connecticut Academy will foster an environment in Connecticut where scientific and technological creativity can thrive and contribute to Connecticut becoming a leading place in the country to live, work and produce for all its citizens, who will continue to enjoy economic well- being and a high quality of life.

Mission Statement

The Connecticut Academy will provide expert guidance on science and technology to the people and to the State of Connecticut, and promote its application to human welfare and economic well being.

Goals

- Provide information and advice on science and technology to the government, industry and people of Connecticut.
- Initiate activities that foster science and engineering education of the highest quality, and promote interest in science and engineering on the part of the public, especially young people.
- Provide opportunities for both specialized and interdisciplinary discourse among its own members, members of the broader technical community, and the community at large.

Connecticut Academy of Science and Engineering
179 Allyn Street, Suite 512, Hartford, CT 06103
Phone or Fax: 860-527-2161
e-mail: acad@ctcase.org
web: www.ctcase.org