Annotated Bibliography

Summary of Research
Assessing the Impacts of Artificial Turf and Tire Crumb Exposure
Washington Alliance for Nontoxic Play and Athletic Fields

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Health: The impacts of inhalation or ingestion of chemicals continues to be a concern for those installing, playing on, or working near artificial turf. The toxicity of crumb rubber is unknown and the toxicities of the vast majority of its components are unknown. Exposure is largely unmeasured. Models to estimate total risk are so uncertain that they are worthless. However, models that look at risk from one component, or a small subset of components, may demonstrate unacceptably high risk.. Additionally, there are concerns about injury risk and the increased risk of life-threatening bacterial infections precipitated by turf abrasions and turf burns.

SOCCER

1. Washington State Department of Health. (2017). Investigation of Reported Cancer Among Soccer Players in Washington State. http://www.doh.wa.gov/Portals/1/Documents/Pubs/210-091.pdf
    a. "This investigation was also not designed to add to our understanding of the risks or benefits of crumb rubber fields."
    b. "Assurances of the safety of artificial turf, however, are limited by lack of adequate information on potential toxicity and exposure. "
    c. The investigation examined whether playing soccer was associated with an increased risk of cancer, not whether exposure to the toxic chemicals from pulverized tire crumb was associated with an increased risk of cancer.
        i. Cancer cases were taken from the soccer players on Coach Amy Griffin's list of cancer victims who have been exposed to tire crumb.
        ii. The study noted, "For example, a person who began playing as a six-year-old in 1983, played for three years, and was diagnosed with cancer before their 25th birthday in 2002 could be included as an observed case in this study." Crumb rubber was introduced as an infill for synthetic turf in 1997, so the exemplar would not have been exposed and would not be on a list of cancer patients exposed to crumb rubber.
        iii. The soccer players from Coach Griffin's list come almost exclusively from a small subset of athletes. The vast majority of soccer players on Coach Griffin's list had spent hundreds to thousands of hours playing soccer on artificial turf fields. By hiding this small subset of soccer players in the larger soccer playing population WA DOH eliminated the possibility of finding the relationship between playing soccer on artificial turf and developing leukemia or lymphoma
    d. The scholarship of the research underlying the literature review portion of the paper is sloppy.
        i. There are missing references for five of the seven studies mentioned in Table 6.

ii. The OEHHA study was funded by the Integrated Waste Management Board, but this was not noted as a possible conflict of interest even though another possible conflict of interest was noted.
iii. The study performed by Gradient is listed as having been published for Lynnwood School District in 2015. Gradient completed a study by that name for the Verdant Health Commission in 2015. There is no citation for the study itself in the references. Earlier in the paper, there is a citation for a personal conversation with Recycled Rubber Council scientific advisor Michael Peterson, the Gradient toxicologist who co-authored the study.

CHEMICAL

1. Agency for Toxic Substances and Disease Registry at the National Centers for Disease Control and Prevention. (2008). Letter Health Consultation: Ironbound Athletic Field B. Retrieved from http://www.state.nj.us/health/ceohs/documents/eohap/haz_sites/essex/newark/ironbound_athletic_field/ironbound_hc_9_08.pdf

    a. ATSDR investigation of a field in NJ. There were concerns about the field after an adjacent industrial site was found to be contaminated with PCBs and heavy metals.

    b. "Based on review of lead loading and concentration data observed in dust samples from the Ironbound Athletic Field B and the potential for exposure to area residents, mainly children under 7 years old, the recreational use of the athletic field represents a ***Public Health Hazard***. The results indicate that the source of the lead contamination in surface dust originates from the synthetic turf fibers."

    c. Unlike other studies, in this study risk was based solely on the risk arising from inhalation or accidental ingestion of the lead in the **dust** on the field. "Incidental ingestion of lead contaminated dust would occur via hand-to-mouth activity after making hand contact with the surface of this field. Inhalation exposure is potentially present if lead contaminated dust is disturbed and becomes airborne through recreational activity occurring on the field."

    d. Analysis of the turf fibers and crumb indicated that the lead in the dust came from deteriorated turf fibers, not contaminated soil from the nearby site.

    e. Researchers used the USEPA's integrated exposure uptake biokinetic model, and assumed that a child visited the field five times a week for six months out of the year to calculated the probability that field exposure would cause the child's blood lead level to rise above 10 µg/dl. The estimated probabilities ranged from 17% for a 72 to 84-month-old child up to 59% for a 12 to 24-month-old child.

    f. The researchers calculated that the average blood lead level for a 72 to-84 month old child would be 6.34 ug/dl. The CDC currently warns that permanent neurological damage or behavioral disorders area associated with blood lead levels at or below 5ug/dl.

2. American Lung Association. (2015). State of the Air 2015: Particle Pollution. Retrieved from http://www.stateoftheair.org/2015/health-risks/health-risks-particle.html

    a. This article explains health risks associated with PM10 and PM2.5 and carbon black (Particulate matter of size 10 microns, or 2.5 microns and smaller, is abbreviated as PM10 and PM2.5.)

    b. Short-term exposure risks include increased severity of asthma attacks in children; increased hospitalizations for asthma in children; death from respiratory and cardiovascular disease, including stroke; and increased numbers of heart attacks.

3. Ariana Eunjung Cha, The Washington Post. (2015, June 17). Startling link between pregnant mother's exposure to DDT and daughter's risk of breast cancer. Retrieved from https://www.washingtonpost.com/news/to-your-health/wp/2015/06/16/ddts-breast-cancer-legacy-pregnant-mothers-exposure-linked-to-four-fold-increase-in-daughters-risk/ and http://press.endocrine.org/doi/10.1210/jc.2015-1841)
    a. The true impact of a chemical exposure could take decades to be measured.
4. Bosma, R. (2016, November 4). Dangerous Play. Retrieved from Zembla. Retrieved from http://zembla.vara.nl/dossier/uitzending/dangerous-play
    a. Documentary on various health risks associated with artificial turf and crumb rubber.
5. Brown, D.R. (2007). Artificial Turf: Exposures to Ground-up Rubber Tires. Environment & Human Health, Inc. (EHHI). Retrieved from http://www.ehhi.org/reports/turf/turf_report07.pdf
    a. Author is toxicologist Dr. David Brown, a former Deputy Director of The Public Health Practice Group of Agency for Toxic Substances and Disease Registry at the National Centers for Disease Control and Prevention
    b. "Given the complexity of the exposures, the limited research information on the actual toxic actions of these chemicals, and the limited experience with human exposures at sites other than tire fabrication facilities, identification of maximal safe exposure levels is not scientifically possible."
    c. "There is enough information now concerning the potential health effects from chemicals emanating from rubber tire crumbs to place a moratorium on installing any new fields or playgrounds that use ground-up rubber tires until additional research is undertaken."
    d. "Exposures to already installed synthetic turf fields that contain ground-up rubber tire crumbs should be limited, pending the development of additional human exposure information."
6. California Office of Environmental Health Hazard Assessment (OEHHA) (2007). Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products. Report prepared for the Integrated Waste Management Board. Retrieved from http://www.calrecycle.ca.gov/publications/Documents/Tires%5C62206013.pdf
    a. OEHHA calculated an excess cancer risk of 1.2 in 10 million based on a one-time ingestion of 10 g of tire crumb rubber over a lifetime. This is an unrealistic assumption based on how soccer players interact with turf.
    b. Norwegian Institute of Public Health (2006) estimated that soccer players may ingest as much as 1 g of rubber crumb per practice/ match. They assumed 4 practices and one game per week, for six months out of the year. If a player played 10 years, she could consume 1,300 grams of crumb rubber, or 130 times as much as OEHHA assumed. This would dramatically affect the excess risk calculation.
    c. OEHHA did the gastric leaching study on tire shred, not tire crumbs and dust which have a much greater surface area per gram of tire. Since all chemical reactions take place at the surface, greater surface area would lead to higher levels of toxics in leachate. Using tire shreds would lead to an underestimation of risk in crumbs and dust.

d. Risk of lead poisoning was also likely grossly underestimated. For example, in the OEHHA study, the highest level of lead found in the leachate was 0.7µg/g (0.7 mg/kg). In contrast, the Pavilonis 2013 study, lead was found in gastric leachates of tire crumbs at levels ranging from 2.5 to 250 mg/kg. A 15 kg child who consumed 10 g of tire crumb that contained 250 mg/kg of lead would receive a dose 167 µg/kg, well above the acute toxicity threshold of 2.7 µg/kg.

e. Assuming daily use of a tire shred playground from age 1 until age 12, the estimated excess risk from Chrysene alone was estimated to be 2.9 cancers per million children. This fails to consider the likely synergistic effects of the other PAHs present. It also does not consider how the other toxics, like lead, in the crumb rubber may interact to affect total risk, nor how they may add to the total body burden of low dose exposures.

f. Only 31% of the tested playground surfaces made of recycled tires met state regulations to prevent head injuries during falls. All the tested playground surfaces with wood chips passed.

7. California Office of Environmental Health Hazard Assessment (OEHHA) (2009). Chemicals and particulates in the air above the new generation of artificial turf playing fields, and artificial turf as a risk factor for infection by methicillin-resistant Staphylococcus aureus (MRSA): Literature review and data gap identification. Retrieved from http://www.calrecycle.ca.gov/tires/products/Health/TurfStudy/LitReview.htm

a. This is a literature review.

b. It contains a component-based health risk assessment using literature-based exposure estimates. The lack of validity of this type of risk assessment for a complex mixture such as crumb rubber can clearly be seen in the EPA guidance on risk assessments for chemical mixtures.

8. California Office of Environmental Health Hazard Assessment (OEHHA) (2010). Safety Study of Artificial Turf Containing Crumb Rubber Infill Made From Recycled Tires: Measurements of Chemicals and Particulates in Air, Particulates in the Turf, and Skin Abrasions Caused by Contact with the Surface. Retrieved from http://www.calrecycle.ca.gov/publications/Documents/Tires%5C2010009.pdf

a. This study examined the temperature at four artificial turf fields. It measured the VOCs in the air above the air at the four fields. Air for the VOC samples was collected from stationary monitors placed beneath galvanized steel garbage cans for 45 minutes. PM 2.5 samples were also collected from three fields, however, the results from two fields were below the limit of detection. The results from the third field were inconsistent.

b. The study also looked at MRSA risk. While artificial turf has not been shown to harbor or transmit the MRSA virus, its abrasiveness significantly increases the risk of epidermal injuries that could result in a MRSA infection.

9. Center for Disease Control and Prevention. (2008, June 18). CDC Health Advisory. Potential exposures to lead in artificial turf: Public health issues, actions, and recommendations. Retrieved from http://www.dhhr.wv.gov/oeps/disease/Documents/Advisory_00275.pdf

c. Artificial turf made of nylon or nylon/polyethylene blend fibers contain lead and pose a potential public health concern.

d. The risk for lead exposure is higher for artificial fields that are old, dusty, heavily used, exposed to the weather, or have abraded, faded, or broken fibers. The turf disintegrates into lead containing dust as it ages. This dust could then be ingested or inhaled.

e. The CDC cannot estimate the risk associated with lead exposure from artificial turf but states:

i. After playing on the field, individuals are encouraged to perform aggressive hand and body washing for at least 20 seconds using soap and warm water.

ii. Clothes worn on the field should be taken off and turned inside out as soon as possible after using the field to avoid tracking contaminated dust to other places. In vehicles, people can sit on a large towel or blanket if it is not feasible to remove their clothes. These clothes, towels, and blankets should be washed separately and shoes worn on the field should be kept outside of the home.

iii. Eating while on the field or turf product is discouraged.

iv. Avoid contaminating drinking containers with dust and fibers from the field. When not drinking, close them and keep them in a bag, cooler, or other covered container on the side of the field

9. Crain, W. and Zhang, J. (2006, September 21). Rachel's Democracy & Health News #873: Hazardous Chemicals in Synthetic Turf (Revised). Retrieved from http://www.precaution.org/lib/06/prn_toxins_in_synthetic_turf_rev.060921.htm

a. Both rounds of testing of the crumb rubber pellets at Manhattan's Riverside Park revealed levels of six hazardous PAHs, all possible or possible human carcinogens, at levels above New York DEC cleanup limits.

b. The PAHs found at hazardous levels were: Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k)fluoranthene, and Dibenzo(a,h)anthracene.

10. Crain, W. and Zhang, J. (2007, April 12). Rachel's Democracy and Health News #992: Hazardous Chemicals in Synthetic Turf, Follow-up Analyses. Retrieved from http://www.precaution.org/lib/07/prn_synthetic_turf.070405.htm

a. Testing at the Parade Ground in Brooklyn and the Sara D. Roosevelt Park in Manhattan found Dibenzo (a.h)anthracene was found at hazardous levels. Two other PAHs, Chrysene and Benzo(b)fluoranthene, were found at hazardous levels at the Parade Ground site.

11. Connecticut Department of Public Health (2010). Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut. Retrieved from http://www.ct.gov/deep/lib/deep/artificialturf/dph_artificial_turf_report.pdf

a. One of total of five documents from five different agencies comprising the State of Connecticut's study of artificial turf fields.

b. Of the dozens of chemicals found to be contained in crumb rubber, twenty-seven chemicals of potential concern were identified by the CT Department of Public Health for the risk assessment portion of the study.

c. **Thirteen compounds** were included in the cancer risk assessment. Cancer unit risks were obtained from standard toxicology databases for four of those, **two of those**

included human epidemiologic data. Unit risk estimates for the other nine carcinogens were estimated, assumed or obtained from nonstandard sources.

d. As per EPA risk assessment guidelines for chemical mixtures, this study lacks necessary toxicity information to do a quantitative risk assessment and uses an inappropriate risk assessment methodology.

12. Environment and Human Health Inc. (2015). Artificial Turf- Chemical Analysis. Retrieved from http://www.ehhi.org/chemicals

a. EHHI's study done at Yale University found 96 chemicals in the synthetic turf and rubber tire mulch used as surfacing in toddler playgrounds. Of the 96 chemicals detected — a little under a half have had never had toxicity assessments for their health effects. Of the rest, 20% are probable carcinogens.

13. EPA Risk Assessment Forum Technical Panel (2000). Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. Retrieved from http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=4486

Thus far, risk assessments on crumb rubber, a complex chemical mixture, have not been done in a manner consistent with these guidelines.

a. The guidelines define a complex mixture: "A mixture containing so many components that any estimation of its toxicity based on its components' toxicities contains too much uncertainty and error to be useful. …. Risk assessments of complex mixtures are preferably based on toxicity and exposure data on the complete mixture..." Appendix B p.2

b. "Approaches based on the mixture's chemical components are recommended for relatively simple, identified mixtures with approximately a dozen or fewer chemical constituents." p.76

c. There are guidelines for determining the quality of health effects data.

d. Poor: "A lack of health effects information on the mixture and its components in the mixture precludes a quantitative risk assessment."

e. Fair: "Full health effects data are available, but extensive extrapolation is required for route or duration of exposure or for species differences. These extrapolations are not directly supported by the information available. Certain important health effects data are lacking and extensive extrapolations are required for route or duration of exposure or for species differences."

f. Good: "Full health effects data are available and relatively minor extrapolation is required. Full health effects data are available but extensive extrapolation is required for route or duration of exposure or for species differences. These extrapolations are supported by pharmacokinetic considerations, empirical observations, or other relevant information."

14. Goodson, W. H., Lowe, L., & al, e. (2015). Assessing the carcinogenic potential of low-dose exposures to chemical mixtures in the environment: the challenge ahead. Carcinogenesis, S254-S296. Retrieved from http://carcin.oxfordjournals.org/content/36/Suppl_1/S254.full.pdf

a. This paper reports that the World Health Organization and the International Agency for Research on Cancer (IARC) suggest that the fraction of cancers attributable to toxic

environmental exposures is between 7% and 19% of all cancers; other sources suggest the proportion of cancers due to unknown causes may be much higher.

b. Supported by over 500 references, this paper presents evidence of physiologic mechanisms that predict/explain how chemicals that are not carcinogens when acting alone (heavy metals, endocrine disruptors, and others) can collectively work through different pathways (such as immune suppression) at different points in time to ultimately induce cancer.

c. This paper is relevant because it addresses how a complex chemical mixture such as crumb rubber could be much more carcinogenic than a simple analysis of its components would indicate.

15. Highsmith, R., Thomas, K., & Williams, R. (2009). A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds. National Exposure Research Laboratory, U.S. Environmental Protection Agency.

a. This study was readily available on the EPA's servers during the summer of 2015, **along with warnings that the results could not be generalized beyond the four sites sampled in the study.** However, that page was removed and access to the study from the EPA website was temporarily not possible. Now there is a link to the study from the EPA's Tire Crumb and Synthetic Turf Field Literature and Report list. **All warnings about the limitations of the study have been removed.**

b. This study included three outdoor sites with artificial turf fields and one two playgrounds. One playground had rubber shreds, which are larger than rubber crumbs, and the other had tire crumb that had been formed to resemble brown and green bark pieces.

c. This study examined airborne PM 10 and VOCs. The more dangerous PM 2.5 levels were not measured. Heavy metals from surface wipes, the crumb rubber and the turf blades from each location were also measured.

d. Bioaccessibility of the lead in the crumb rubber was estimated using the protocols for assessing the bioaccessibility of lead in soil. At the three sites where turf blades were assessed, the highest lead level for each site were 389 ug/g, 2.8 ug/g, and 701 ug/g. None of the fields had high levels of lead in the crumb rubber.

e. Bioaccessibility estimates for lead in turf blades ranged from 0.2% to 86.8% with the blades with highest lead levels having the lowest bioaccessibility rates. The bioaccessibility methods were designed for use with soil and have not been validated for use with plastic grass. Additionally, the extreme variability in rates leaves little confidence in the methodology.

f. One of the two playgrounds had a high level of extractable lead 443 ug/g in one of its samples of rubber shreds. Here too, there was a significant variability in the estimates of the bioavailability of the lead in the rubber shreds ranging from 0.3% to 10.7% with the shred with the highest lead levels having the lowest bioavailability. It should be noted that lead in shreds would be expected to be significantly less bioavailable than lead in crumbs. See Kim 2012 and Pavilonis 2013.

g. Thus, at three of the five sites, there was at least one sample of an easily ingested material that contains lead at a level significantly greater than is what allowed in children's products.

h. The study protocols for air sampling on the turf fields did not mimic real world conditions because the air monitors were located on the sidelines away from active play. This severely limits the conclusions that can be drawn about PM10 exposure for field users.

i. PM10 levels on the playground were approximately twice the background rate. It is unclear where the air monitors were in relation to children on the playground.

16. Kim, S., Yang, J.-Y., Kim, H.-H., Yeo, I.-Y., Shin, D.-C., & Lim, Y.-W. (2012). Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability. Environmental Health and Toxicology. Retrieved from http://doi.org/10.5620/eht.2012.27.e2012005.

a. This study showed that lead leached out of smaller sized EPDM rubber pellets more readily than larger sized ones. However, none of their risk calculations are directly relevant because the U.S. crumb rubber is SBR not EPDM.

17. Labosport. (2014, November 5). Technical Report: Toxicological Analysis of performance infill for synthetic turf fields according to EN71-3 standard - Safety of toys Part 3: Migration of certain Elements. Lower Canada College. Retrieved from Synthetic Turf Council: https://c.ymcdn.com/sites/syntheticturfcouncil.site-ym.com/resource/resmgr/Files/R14525CAN-B1_-_EN.pdf

a. Based on the description of the test material, it is likely that tire crumb was washed prior to testing to remove all dust and small particulates. This would have significantly reduced the amount of lead in the leachate.

b. The wrong standards from the EU guidelines were used. Tire crumb would best be classified as a "dry, brittle, or powder like" material given its known dusty nature. Therefore, the limits for category 1 materials rather than category 3 materials should have been applied.

18. Li, X., Berger, W., Musante, C., & Mattina, M. J. (2009). 2009 Study of Crumb Rubber Derived from Recycled Tires Final Report. New Haven: Department of Agricultural Chemistry, The Connecticut Agricultural Experimental Station.

a. This was the portion of the Connecticut study that initially identified the chemicals in crumb rubber. Off-gassing, leaching and the effects of weathering were studied.

19. Llompart, M., Sanchez-Prado, L., Lamas, J. P., Garcia-Jares, C., Roca, E., & Dagnac, T. (2013). Hazardous organic chemicals in rubber recycled tire playgrounds and pavers. Chemosphere, 90(2), 423-431. Retrieved from http://www.elcorreodelsol.com/sites/default/files/chemosphere_maria_llompart.pdf

a. Samples were taken from 9 urban playgrounds in Spain and 7 new commercial rubber puzzle pavers. All samples were originally in mats rather than loose crumbs.

b. When discussing the levels of carcinogenic PAHs found in the samples, the authors stated, "Considering that these compounds are priority POPs regulated at lower levels in agricultural and even industrial soils, the use of this kind of materials on fields or playgrounds for children should be reconsidered."

c. While most of the VOCs and SVOCs examined were detected in the headspace above the samples at 25°C, some were only detected at 60°C. This demonstrates that while a few of the compounds only off gas at significant rates when heated such as on warm, sunny days, most can off gas indoors at room temperature.

d. It should be noted that is not feasible to separate out the chemical contribution of the binders from that of the crumb. Nonetheless, the mats are clearly a health risk.

20. Marsili, L. C. (2016). Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes. Environmental & Analytical Toxicology. Retrieved from https://www.omicsonline.org/open-access/release-of-polycyclic-aromatic-hydrocarbons-and-heavy-metals-from-rubber-crumb-in-synthetic-turf-fields-2161-0525.1000265.php?aid=39265

a. This study clearly demonstrated that both the temperature at which off gassing is measured and the model which is used to assess risk dramatically affect the conclusions of a risk assessment.

b. When a risk assessment was done at 25 degrees Celsius, using the Lifetime Average Daily Dose to calculate cumulative excess cancer risk lead to estimates well below the de minimus level.

c. However, when the risk assessment was conducted with the crumb rubber heated to 60 degrees, and a toxic equivalent quotient model was used, the exposure was up to 1,000 times the virtually safe dose of B(a)P in food.

d. The authors noted that the model likely overestimates the risk because it overestimates the percentage of inhaled dust that comes from the field rather than the environment. However, if even 10% of inhaled dust comes from the field, their model would still predict exposure up to 100 times the virtually safe dose.

21. New York State Department of Environmental Conservation, New York State Department of Health. (2009). An Assessment of Chemical Leaching, Releases to Air and Temperature at Crumb-Rubber Infilled Synthetic Turf Fields. Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

a. This study involved two artificial turf fields, both located in downtown New York City.

b. PM 10 and PM 2.5 were measured, but the measurements at Thomas Jefferson Field were deemed unreliable due to the implausible relationship between the PM 2.5 and PM 10 readings.

c. The cause of the implausible PM readings at the Thomas Jefferson field was not determined and the same equipment was used at the second field.

d. PM studies were based on upwind, on-field and downwind measurements taken while sampling staff simulated play with a soccer ball.

e. The temperature readings on the fields clearly demonstrated that once the ambient temperature reached the 80°F, the turf temperatures generally climbed above 120°F, and sometimes above 160°F. These temperatures are high enough to cause first to third degree burns, depending on temperature, and may increase the likelihood of heat-related illnesses.

f. VOC readings on the fields were not significantly different than off field readings, however, there may have been a signal vs. noise problem given the location of the fields. Additionally, although sampling was scheduled for days in which light to moderate to winds were predicted, no wind speed data was found in the report. Thus, there is no way to determine the degree to which winds may have diluted any off gassing from the field.

g. However, the results may indicate that at least under moderately windy circumstances, the air pollution on a turf field in downtown New York City is indistinguishable from the air pollution in the rest of the city. These findings may prove relevant to other fields located adjacent to highways or busy streets in urban areas.

22. Norwegian Institute for Air Pollution. (2005). Measurement of Air Pollutions in Indoor Turf Halls. Norwegian Pollution Control Authority. Retrieved from http://www.isss-sportsurfacescience.org/downloads/documents/SI1HPZNZPS_NILUEngelsk.pdf

a. Indoor turf halls with crumb rubber infill had significant amounts of airborne rubber particulate matter in the form of PM 10 and PM 2.5.

b. The authors noted that one of the two turf halls had levels of PM 10 that exceeded national targets and levels of PM 2.5 that approached the national recommendations while it was operating under optimal conditions. Under normal conditions, the authors believe the PM 2.5 and PM 10 levels would likely be double the national targets.

c. The air in the second hall had lower levels of airborne rubber particulate matter. The authors attributed this to the coating that was on the crumb at the second hall. The authors hypothesized that when the coating dried out in a few years the levels of airborne rubber dust particulates would rise.

d. The authors indicated that much of the carbon black in the PM 2.5 and PM 10 in air in these halls originated from the crumb rubber.

e. "The airborne dusts… contain large quantities of rubber from the granulate… the proportion of organic material is considerable. The airborne dust contains polycyclic aromatic hydrocarbons (PAH), phthalates, semi-volatile organic compounds, benzothiazoles and aromatic amines. It also contains organic and inorganic pollutants which are not specified in this study."

f. Total VOC levels in the indoor halls with crumb rubber were considered high to very high. However, the risk associated with the elevated levels was not assessed.

23. Norwegian Institution for Public Health and the Radium Hospital. (2006). Artificial turf pitches – an assessment of the health risks for football players. Retrieved from http://www.isss-sportsurfacescience.org/downloads/documents/74wa3x7e22_fhiengelsk.pdf

a. Assumed up to 1g of crumb rubber ingestion per practice session or soccer match

b. Calculated the risk from inhaled and ingested VOCs in 9 different scenarios.

c. The risk from each VOC was assessed and deemed negligible or tolerable.

d. The risks from heavy metals were not assessed.

24. Pavilonis, B., Weisel, C., Buckley, B., & Lioy, P. (2013). Bioaccessibility and Risk Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers. Risk Analysis. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666/

- **a.** Based on their findings, the authors stated that, "Since it is possible that children may be exposed to potentially high concentrations of lead while using artificial turf fields we recommend, at a minimum, all infill and fibers should be certified for low or no lead content prior to purchase and installation."
- **b.** It was very concerning that extremely high levels of lead and chromium were found in some of the samples of the tire crumb, the plastic turf and the biofluid extracts of these materials. The authors also noted the extreme variability of lead and chromium in the samples.
- **c.** "Lead was detected in almost all field samples for digestive, sweat, and total extraction fluids with digestive fluid extract of one field sample as high as 260 mg/kg. Metal concentrations were not markedly different across the three different sample types (new infill, new turf fiber, tire crumb field sample). However, one of the new turf fiber samples contained relatively large concentrations of chromium (820 mg/kg) and lead (4,400 mg/kg) compared to the other samples tested...the variability of lead contained in the infill material is large and can span more than two orders of magnitude. One field [tire crumb] sample did contain a high lead level (260 mg/kg) which was on the same order of magnitude as the NJ DEP cleanup value (400 mg/kg)."
- **d.** Other toxicants were also detected at low levels. However, this study likely significantly underestimated the levels of bioaccessibility of toxicants in the crumb rubber and turf. The study did not use biologically relevant crumb rubber particle sizes or incubation times when determining the bioaccessibility of SVOCs and metals in simulated biofluids. The dust and tiny particulates less than 10 microns in diameter that are most relevant, not the relatively large crumbs. Athletes are inhaling particulate matter often only a few microns in diameter and the particulate matter may stay lodged in the lungs for months, not 24 hours. Dust particles stick to the skin far more effectively than crumbs and are much harder to spit out when they accidentally get into the mouth. Surface area is a key factor in determining bioavailability. The toxicants in dust are far more bioavailable than those in crumbs. The initial study on the Ironbound Athletic Fields in New Jersey by the New Jersey Department of Health, the EPA, and the ASTDR analyzed the dust on the fields for lead content.

25. Schiliro T., Travers, D., Degan, R., Pignata, P., Alessandria, L., Scozia, L., Bono, R., Gilli, G. (2013). Artificial Turf Football Fields: Environmental and Mutagenicity Assessment. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23007896

- **a.** The control data for this study came from two atmospheric meteorological-chemical control stations.
- **b.** PM 10 control data was collected from a monitor located 6 meters (18 feet) above ground in a central limited traffic zone. PM 2.5 control data was collected from a monitor two meters (6 feet) above ground, "sandwiched" between two busy streets.
- **c.** The authors stated, "No significant differences were found between artificial football fields and urban sites." The authors also found no difference between a clay field and artificial fields. Grass fields were not included.

d. Using air pollution levels from a busy street as a comparator is not reassuring since road traffic pollution has been shown to have a variety of negative effects on cardiovascular, respiratory, and neurological health.

e. If Italian children must choose between playing soccer on the medians of busy streets or on artificial turf fields, this study may reassure those who play in the medians.

26. SGS Consumer Testing Services. (2013, June). CEN Publishes New Toy Safety Standard EN 71-3:2013 For Soluble Elements. Retrieved from SAFEGUARDS SGS Consumer Testing Services. www.sgs.com/-/media/global/documents/brochures/sgssafeguards11113cenpublishesnewtoysafetystarden7132013ed13.pdf?la=en

a. This is a listing of the migration limits for heavy metals in children's products in Europe.

b. Leachable lead in dry, brittle, or powder like items such as compressed paint tablets, the cores of coloring pencils, chalk, or crayons may not exceed 13.5 mg/kg.

27. Shalat, S.L. (2011). An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields, Final Report. Retrieved from http://www.nj.gov/dep/dsr/publications/artificialturf-report.pdf

a. The research compared the levels of inhalable particulate matter and inhalable lead particulates measured by

i. a stationary air monitor away from active play
ii. a mobile air monitor attached to a 10 kg remote controlled robotic vehicle driving in rectangular patterns.
iii. a mobile air monitor attached to a 12-year-old child who ran, dribbled, and kicked a soccer ball as if in practice

b. Inhalable lead particulates and inhalable total particulates were highest for the air monitor attached to the child, lowest for the stationary air monitor and intermediate for the air monitor attached to the robot.

c. The research indicates that stationary air monitors may significantly underestimate the levels of airborne particulate matter and dust to which field and playground users are exposed.

28. Van Ulirsch, G. et al. (2010). Evaluating and regulating lead in synthetic turf. Environmental health perspectives, 118(10), 1345. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2957910/pdf/ehp-118-1345.pdf

a. Lead author from Agency for Toxic Substances and Disease Registry at the National Centers for Disease Control and Prevention, co-authors from NY Dept. of Health, NJ Dept. of Health & Senior Services.

b. Recommended all synthetic turf fields be tested for lead. Fields that tested above the CPSC limit for children's products should then be tested with wipe-testing.

c. If wipe-testing revealed lead at levels greater than 40 $\mu g/ft^2$, access to the field should be limited to less sensitive individuals, and the field should be replaced as soon as possible.

d. Recommended that fields with lead levels above CPSC limit for consumer products but that passed the wipe test be closely monitored because fields degrade and dust levels can be expected to increase.

e. At the time of the article, CPSC limit on lead in children's products was 300 mg/kg. It has since been lowered to 100 mg/kg.

29. Ward, T. (2014, November 25). New Independent Lab Testing of Synthetic Turf Crumb Rubber Infill Re-confirms Health and Safety. Retrieved from Synthetic Turf Council: http://www.syntheticturfcouncil.org/news/204292/New-Independent-Lab-Testing-of-Synthetic-Turf-Crumb-Rubber-Infill-Re-confirms-Health-and-Safety.htm

a. In this document, Marketing and Education Director for the STC claims crumb rubber meets EU toy safety guidelines, indicating a belief that EU guidelines are relevant and achievable. Ward refers to EU's guidelines as the "most advanced in the world."

30. Zhang J., Han, I. K., Zhang, L., & Crain, W. (2008). Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids. Journal of Exposure Science and Environmental Epidemiology, 18(6), 600-607. Retrieved from http://www.nature.com/jes/journal/v18/n6/pdf/jes200855a.pdf

a. Related to Crain 2006 and Crain 2007

b. Samples crumb rubber taken from four fields at different times and analyzed for PAH content and bioaccessibility in synthetic digestive fluids. **All the fields had at least one PAH above NY DEC cleanup limits.** PAHs were not highly bioavailable in digestive fluid. However, PAHs are SVOCs and inhalation is likely the main route of exposure.

c. The crumbs and turf samples were also analyzed for heavy metals. Except for zinc, heavy metals were found at low levels.

d. Although lead was found at levels below 100 mg/kg, the two extractions in gastric acid found it to be 44.2% and 24.7% bioavailable. The authors note that these estimates are lower than the estimates of the bioavailability of lead in household dust from a 2006 study done by Yu et al. This is likely due to particle size, as demonstrated in the Kim 2012 study.

e. The authors theorized that the levels of PAHs in the crumb rubber decreased over time due to off gassing, but the levels on a field were complex due to the constant need to backfill fields to replace crumb rubber losses.