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Comprehensive multipathway risk assessment of chemicals associated with recycled ("crumb") rubber in synthetic turf fields

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ABSTRACT

Background: Thousands of synthetic turf fields in the US are regularly used by millions of individuals (particularly children and adolescents). Although many safety assessments have concluded that there are low or negligible risks related to exposure to chemicals found in the recycled rubber used to make these fields, concerns remain about the safety of this product. Existing studies of recycled rubber's potential health risks have limitations such as small sample sizes and limited evaluation of relevant exposure pathways and scenarios.

Objective: Conduct a comprehensive multipathway human health risk assessment (HHRA) of exposure to chemicals found in recycled rubber.

Methods: All available North American data on the chemical composition of recycled rubber, as well as air sampling data collected on or near synthetic turf fields, were identified *via* a literature search. Ingestion, dermal contact, and inhalation pathways were evaluated according to US Environmental Protection Agency (US EPA) guidance, and exposure scenarios for adults, adolescents, and children were considered.

Results: Estimated non-cancer hazards and cancer risks for all the evaluated scenarios were within US EPA guidelines. In addition, cancer risk levels for users of synthetic turf field were comparable to or lower than those associated with natural soil fields.

Conclusions: This HHRA's results add to the growing body of literature that suggests recycled rubber infill in synthetic turf poses negligible risks to human health. This comprehensive assessment provides data that allow stakeholders to make informed decisions about installing and using these fields.

1. Introduction

Synthetic turf fields containing recycled rubber (also called "crumb rubber") infill have been in use for decades. These fields typically consist of bottom backing layers composed of polypropylene, polyurethane, or latex, with polyethylene, nylon, or polypropylene blades woven into the material (Synthetic Turf Council, 2011). After the field is laid down, infill is added to soften the field and allow the individual turf blades to stand up (Fig. 1). One of the most common types of infill is recycled rubber, often mixed with sand (Synthetic Turf Council, 2011). Recycled rubber infill is typically made from recycled automobile and light truck tires, which are ground, shredded, and sorted into uniformly sized pieces (Synthetic Turf Council, 2011).

In the mid-2000s, a US Environmental Protection Agency (US EPA)[1] investigation identified the presence of lead in a synthetic turf field in New Jersey, and it was eventually determined that the source of the lead was a yellow pigment used on the synthetic turf's blades (US EPA, 2017a). This finding resulted in the initiation of multiple regulatory

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[1] US EPA, US Environmental Protection Agency; CalOEHHA, California Office of Environmental Health Hazard Assessment; ATSDR, Agency for Toxic Substances and Disease Registry; COI, Chemical of Interest; HHRA, Human Health Risk Assessment; COPC, Chemical of Potential Concern; RSL, Regional Screening Level; HQ, Hazard Quotient; RME, Reasonable Maximum Exposure; TTC, Threshold of Toxicological Concern; US FDA, US Food and Drug Administration; JRC, Joint Research Centre; PAH, Polycyclic Aromatic Hydrocarbon; UCL, Upper Confidence Limit; USGS, US Geological Survey; EPC, Exposure Point Concentration; UCLM, Upper Confidence Limit on the Mean; RAGS, Risk Assessment Guidance for Superfund; RIVM, Netherlands National Institute of Public Health and the Environment; ECHA, European Chemicals Agency; PCB, Polychlorinated Biphenyl; SVOC, Semivolatile Organic Compound; IRIS, Integrated Risk Information System; PPRTV, Provisional Peer-Reviewed Toxicity Value; HEAST, Health Effects Assessment Summary Tables; CalEPA, California Environmental Protection Agency; CSF, Cancer Slope Factor; RfD, Reference Dose; TEF, Toxicity Equivalency Factor; IUR, Inhalation Unit Risk; RfC, Reference Concentration; ELCR, Excess Lifetime Cancer Risk; HI, Hazard Index; TOSHI, Target-organ-specific Hazard Index; VOC, Volatile Organic Compound; IARC, International Agency for Research on Cancer; EFSA, European Food Safety Authority; $PM_{2.5}$, Particulate Matter with Particles 2.5 μm or Less in Diameter; PM_{10}, Particulate Matter with Particles 10 μm or Less in Diameter; NAAQS, National Ambient Air Quality Standards.

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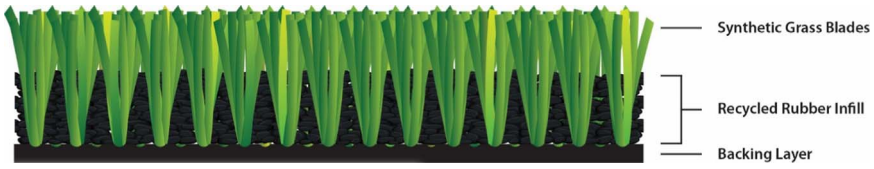

Fig. 1. Typical synthetic turf structure.

agency risk assessments, as well as a variety of peer-reviewed investigations, of various aspects of the potential risks of exposure to synthetic turf. Collectively, these investigations evaluated ingestion, inhalation, and dermal routes of exposure for chemicals in synthetic turf, as well as the mutagenicity of those chemicals and the impact of temperature on those chemical exposures. These assessments considered exposures to more than 100 different chemicals and have almost universally found that risks from exposure to chemicals in synthetic turf fields are low or below regulatory guideline levels. However, recent media coverage of cancer cases potentially associated with playing on synthetic turf fields, as well as studies that have identified carcinogens in recycled rubber, have reignited the debate surrounding the safety of synthetic turf. As a result, the California Office of Environmental Health Hazard Assessment (CalOEHHA) and a joint federal agency group (which includes the US EPA, the Agency for Toxic Substances and Disease Registry [ATSDR], and the Consumer Product Safety Commission) have initiated additional investigations of synthetic turf. Although these evaluations will likely assess the potential health risks from exposure to all of the components of synthetic turf, recycled rubber is currently the component of most concern. Some preliminary results of these assessments may be released in the coming year, but complete evaluations will likely take many years (*e.g.*, California's investigation is currently slated for completion in 2019).

One of the primary issues with the existing investigations of recycled rubber is that they do not include a comprehensive, multi-pathway risk assessment that is inclusive of all potential exposure pathways and all chemicals of interest (COIs). In order to provide additional information to stakeholders, our investigation intends to fill these data gaps by combining publically available data on the concentrations of chemicals in recycled rubber and air sampling data that have been collected to date, as well as by evaluating ingestion, inhalation, and dermal exposure pathways for the chemicals in recycled rubber used in synthetic turf fields in a comprehensive human health risk assessment (HHRA). While many previous studies of recycled rubber are limited by small sample sizes or have evaluated only one or two pathways, integrating all of the data available into one comprehensive evaluation will provide stronger evidence for any potential risks associated with exposure to the chemicals in recycled rubber.

2. Methods

2.1. Data identification and selection

We conducted a comprehensive review of the literature to identify studies containing information about the concentrations of chemicals in recycled rubber or air sampling data that could be used in our risk assessment. Because recent European evaluations of recycled rubber have been published (RIVM, 2017; ECHA, 2017a), we focused on data collected from North American rubber recyclers or synthetic turf fields. Searches conducted included:

PubMed:

- ("artificial turf" OR "synthetic turf" OR "crumb rubber" OR ""recycled rubber") AND (chemical OR risk)

Scopus:

- (TITLE-ABS-KEY ("artificial turf " OR "synthetic turf " OR "crumb rubber " OR "recycled rubber") AND TITLE-ABS-KEY (chemical OR risk)) AND NOT INDEX (medline)

Google Scholar Search Terms & Strategies:

- Search terms: "artificial turf" chemical risk
- Search terms: "synthetic turf" chemical risk
- Search terms: "crumb rubber" chemical risk
- Search terms: "recycled rubber" chemical risk

Google Internet Searches (evaluated the first 100 results for each search)

- "artificial turf chemical" "artificial turf risk," "synthetic turf chemical" "synthetic turf risk," "crumb rubber chemical," crumb rubber risk," "recycled rubber chemical, "recycled rubber risk"

In addition, we reviewed reference lists related to recycled rubber or synthetic turf compiled by various organizations (US EPA, 2016a; Synthetic Turf Council, 2017). We searched abstracts for relevance and obtained studies that evaluated either the chemical composition of recycled rubber, potential air emissions from recycled rubber, or the bioaccessibility of chemicals from recycled rubber. With one exception (discussed later), we only considered North American studies. In addition to literature sources, we contacted companies involved in the recycled rubber or the synthetic turf industries to request their testing data. Two of the companies we contacted provided data from independent laboratories for use in our evaluation. The sample data provided by these companies is provided in the Supplemental Materials (Supplemental Table S1). Because most of these data are for different lots (and sources) sampled over a number of years, each sample is designated as a separate study for the purposes of Table 1.

We compiled the raw data from all the above sources into a database that also included brief descriptions of the analytical methods used and/or field sampling conditions reported in the studies. The data included were representative of many of the different environmental conditions present during the use of synthetic turf fields. The data we used in the risk evaluation included recycled rubber composition data from both virgin and aged synthetic turf fields, as well as indoor and outdoor fields, and air samples collected at indoor and outdoor fields. Table 1 provides the numbers of studies and samples that we compiled into the database.

Table 1
Summary of Information Sources Used.

Data Evaluated	Recycled Rubber Composition Studies	Outdoor Air Studies	Indoor Air Studies
Number of Studies with Data	37	7	2
Number of Samples	103	76	17
Number of Chemicals Evaluated	139	213	172