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MICROPLASTICS, PFAS, AND RUBBER-DERIVED POLLUTANTS FROM ARTIFICIAL TURF: IMPLICATIONS FOR ATHLETE HEALTH AND SPORT-FACILITY MANAGEMENT

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Abstract

Background. Artificial turf is widely used in sport facilities, but concerns persist about artificial-turf-derived microplastics, PFAS, and rubber-derived pollutants. **Aim.** This narrative review synthesizes gathered evidence on pollutant sources, exposure pathways, health-risk interpretation, and sport-facility management. **Material and methods.** Twenty-three publications were analyzed using a hazard-exposure-risk framework linking turf components, pollutant classes, athlete exposure routes, bioaccessibility, and management responses. **Results.** Artificial turf is a multi-component exposure system. Crumb-rubber particles may contain tire-derived organic chemicals, metals, PAHs, VOCs, 6PPD-related transformation products, and other additives, while fibers and backing may contribute fluorinated compounds. Exposure through dermal contact, incidental ingestion, inhalation, and environmental runoff is plausible, particularly for frequent users, youth athletes, goalkeepers, and indoor-facility users. Long-term athlete disease causation remains unproven based on the reviewed publications. **Conclusions.** Artificial turf pollutants should be managed as a potential sport-health and facility-governance concern through material transparency, infill evaluation, ventilation, particle containment, monitoring, runoff control, and end-of-life planning.

Keywords: artificial turf, crumb rubber, microplastics, PFAS, athlete health, sport-facility management, rubber-derived pollutants, exposure assessment, risk management

Content

1. Introduction

Artificial turf has become an important component of contemporary sport infrastructure because it offers durability, predictable playing conditions, and the possibility of year-round use. These advantages are particularly relevant for schools, municipalities, sport clubs, and high-use facilities where natural grass may be difficult to maintain. However, from a sports-medicine and environmental-health perspective, artificial turf should not be evaluated only as a playing surface. It is a layered synthetic system composed of turf fibers, backing materials, infill, and supporting structural layers. These components may contain or release chemical and particle pollutants relevant to athletes, coaches, maintenance workers, and nearby environments.

The main pollutant groups discussed in the current literature include crumb-rubber particles, polycyclic aromatic hydrocarbons (PAHs), phthalates, per- and polyfluoroalkyl substances (PFAS), metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), volatile methylsiloxanes, rubber additives, and antioxidant transformation products (Murphy and Warner 2022; Mayer et al. 2024; Ryan-Ndegwa et al. 2024; Karatela et al. 2025). This creates a dual challenge. On one hand, artificial turf provides practical benefits for sport-facility operation. On the other hand, it introduces synthetic and recycled materials into environments where athletes experience repeated skin contact, elevated ventilation during exercise, incidental ingestion of particles, and transfer of material to clothing, footwear, gloves, water bottles, and equipment.

The current evidence does not justify deterministic claims that artificial turf exposure causes specific diseases in athletes. Human-health evidence remains limited, and several risk-assessment studies have estimated low or negligible risk under defined exposure assumptions (Pavilonis et al. 2014; Peterson et al. 2018). At the same time, repeated identification of chemical classes of concern in turf components means that absence of definitive epidemiological proof should not be interpreted as absence of exposure relevance. The issue is therefore not only toxicological, but also managerial: sport organizations must make decisions under conditions of incomplete and evolving evidence.

Research Objective. The objective of this narrative review is to synthesize gathered evidence on microplastics, PFAS, and rubber-derived pollutants associated with artificial turf systems and to translate this evidence into practical implications for athlete-health protection and sport-facility management.

Research Problem. What do current studies suggest about pollutant exposure from artificial turf systems, and how can this evidence guide safer sport-facility management?

Research Hypotheses. Not applicable. This article is a narrative review and does not test statistical hypotheses.

2. Research materials and methods

2.1. Literature selection

This narrative review was based on 23 publications selected for their relevance to artificial turf, crumb-rubber infill, artificial-turf-derived microplastics, PFAS or fluorinated compounds, rubber-derived pollutants, athlete or human exposure pathways, health-risk assessment, and regulation or facility-management implications. The evidence base includes the original 10 sources, 10 additional publications from 2020 to 2025, and three further publications from 2024 to 2026 to strengthen the currency of the review and address tire-wear particle chemistry, recycled tire-rubber hazardous substances, and stormwater release from artificial turf fields.

The included publications were grouped into five analytical categories. The first category included general toxicological and human-health reviews of artificial turf. The second focused on PFAS, fluorinated compounds, and analytical uncertainty in turf components. The third examined crumb-rubber particles and tire-derived pollutants. The fourth addressed exposure pathways, bioaccessibility, and risk assessment. The fifth focused on policy and facility-management implications.

Because the included publications differed in study design, sampled materials, exposure metrics, chemical targets, and outcome measures, quantitative synthesis or meta-analysis was not appropriate. Instead, the review used a structured narrative approach designed to synthesize findings across material characterization, exposure assessment, risk interpretation, and facility-management relevance.

2.2. Narrative synthesis framework

The review was organized using the following conceptual sequence:

artificial turf component -> pollutant class -> release or transfer pathway -> athlete exposure route -> bioaccessibility and dose -> health-risk interpretation -> facility-management response.

This framework was used to distinguish chemical detection from clinically meaningful exposure. The presence of a substance in turf material was treated as evidence of potential hazard, not as direct evidence of disease causation.

2.3. Data collection and analysis

This narrative review did not involve original data collection, participant recruitment, laboratory testing, or statistical data analysis. Evidence was extracted conceptually from the 23 predefined publications and organized according to pollutant source, exposure route, health-risk interpretation, and facility-management relevance.

2.3.1. Statistical Software

Not applicable. No statistical software was used because this article is a narrative review and no quantitative synthesis or statistical testing was performed.

2.3.2. AI

AI-assisted tools were used for language editing, structural organization, and academic style refinement. All scientific content, source selection, interpretation of evidence, citations, and conclusions were reviewed and verified by the authors. AI tools were used strictly as assistive instruments under human supervision and did not replace authorial judgment, critical interpretation, or responsibility for the final manuscript.

2.3.3. Statistical Methods

Not applicable. No statistical testing, hypothesis testing, or quantitative meta-analysis was performed. The manuscript uses narrative synthesis to integrate evidence from heterogeneous study designs.

3. Research results

3.1. Artificial turf components, pollutant sources, and risk interpretation

Artificial turf is best understood as a multi-component exposure system. Earlier scientific and public discussions often focused on crumb-rubber infill because of its origin from recycled tires. This focus remains justified because crumb-rubber particles may contain complex mixtures of tire-derived chemicals. However, recent PFAS-related research indicates that turf fibers and backing materials also require attention (Lauria et al. 2022; Zuccaro et al. 2023). Therefore, the central question is not simply whether crumb rubber is safe, but which components of the artificial turf system contain which pollutants, under what conditions these pollutants may be released or transferred, and what level of exposure is plausible for athletes and facility users.

The term microplastics requires precision. In this review, artificial-turf-derived microplastics refers broadly to small synthetic or rubber-based particles generated from, or used within, artificial turf systems. This includes crumb-rubber particles derived from end-of-life tires, degraded polymer fragments from turf fibers, and particles released from backing or infill materials. Within the present evidence base, the strongest support concerns crumb-rubber particles as downcycled tire-derived microplastics, while broader tire-wear particle literature reinforces the importance of particle size, environmental mobility, chemical leaching, and mixture toxicity (Xie et al. 2022; Mayer et al. 2024; Ferreira et al. 2024; Wang et al. 2024).

This distinction is important because crumb-rubber particles are not chemically identical to plastic turf fibers. Tire-derived particles may contain rubber-specific additives, vulcanization-related compounds, antioxidants, metals, PAHs, 6PPD-related compounds, and p-phenylenediamine transformation products. For this reason, the manuscript avoids treating all microplastics as one toxicological category. Instead, crumb-rubber particles are interpreted as particle-based exposure sources that may also act as carriers of rubber-derived chemical mixtures.

A critical interpretive distinction is required between hazard, exposure, and risk. Hazard refers to the intrinsic potential of a substance to cause harm. Exposure refers to contact with that substance through a biologically relevant route. Risk depends on dose, frequency, duration, bioaccessibility, route of exposure, and susceptibility of the exposed population. Artificial turf studies provide credible evidence of potential hazard because multiple pollutant classes have been identified in turf systems (Massey et al. 2020; Murphy and Warner 2022; Armada et al. 2022; Duque-Villaverde et al. 2024). However, chemical detection does not automatically demonstrate clinically meaningful exposure or adverse health outcomes.

This distinction explains why apparently different conclusions in the literature are not necessarily contradictory. Peterson et al. conducted a comprehensive multipathway risk assessment of chemicals associated with recycled crumb rubber and concluded that assessed risks were negligible under modeled exposure assumptions (Peterson et al. 2018). In contrast, Ryan-Ndegwa et al. emphasized that definitive conclusions regarding real-world human-health risks remain difficult because the broader evidence base is limited and heterogeneous (Ryan-Ndegwa et al. 2024). These conclusions address different levels of inference: one concerns modeled risk under defined assumptions, while the other concerns uncertainty across the available literature.

3.2. PFAS and fluorinated compounds in artificial turf

PFAS-related evidence represents one of the most important emerging areas in artificial turf research. However, this evidence must be interpreted carefully because different analytical methods measure different fluorinated fractions. Total fluorine is a broad screening signal. Extractable organic fluorine reflects a more mobile or extractable fraction. Target PFAS analysis identifies specific compounds. Fluorotelomer alcohol analysis focuses on a narrower class of PFAS-related substances.

Lauria et al. reported widespread total fluorine in artificial turf samples from Stockholm, but extractable organic fluorine and target PFAS were less frequently identified than total fluorine signals (Lauria et al. 2022). This suggests that some fluorine may be present in forms that are not readily extractable or may be associated with polymeric fluorinated materials. Therefore, total fluorine should not be interpreted automatically as proof of bioavailable PFAS exposure.

Zuccaro et al. provide a complementary perspective by assessing extraction-analysis methodology for detecting fluorotelomer alcohols in artificial turf fibers and crumb-rubber infill (Zuccaro et al. 2023). Their work supports the view that specific PFAS-related compounds can be investigated in turf materials and that analytical method strongly influences what is detected.

The synthesis of these findings is that PFAS should be included in artificial turf risk governance, but conclusions must remain methodologically precise. It would be scientifically inappropriate to state simply that artificial turf contains PFAS without specifying whether the evidence refers to total fluorine, extractable organic fluorine, target PFAS, polymer-associated fluorine, or fluorotelomer alcohols. For sport-facility managers, the appropriate response is not immediate assumption of harm, but procurement transparency, supplier documentation, and standardized chemical reporting.

3.3. Crumb-rubber particles and rubber-derived chemical mixtures

Crumb rubber is the most developed area of artificial turf pollutant research because of its origin from recycled tires. Tires are chemically complex products, and when processed into infill, they may retain or release mixtures of organic chemicals, metals, PAHs, VOCs, rubber additives, antioxidants, and transformation products. Comparative chemical work on artificial turf infill demonstrates that material choice matters, because different infill types can differ in chemical content and potential exposure relevance (Massey et al. 2020).

Armada et al. evaluated recycled tire crumb rubber used on synthetic turf football pitches and identified it as a chemically heterogeneous material relevant to artificial turf hazard assessment (Armada et al. 2022). More recent analytical work on recycled tire rubber has strengthened this interpretation by targeting hazardous substances such as antiozonants, vulcanization agents, crosslinking compounds, and related tire-rubber chemicals, thereby reinforcing the need for compound-specific material documentation (Duque-Villaverde et al. 2024).

Complementary studies from Japan further disaggregate this chemical profile: Sakai et al. characterized VOCs in synthetic turf rubber granule infill, Kawakami et al. analyzed rubber additives and related compounds, Nishi et al. examined PAHs and related compounds, and Kubota et al. assessed total metal content and migration into simulated biofluids (Sakai et al. 2022; Kawakami et al. 2022; Nishi et al. 2022; Kubota et al. 2022). Together, these studies support a component-specific approach to facility management rather than a generic assumption about all infills.

Ferreira et al. broadened this pollutant profile by evaluating volatile methylsiloxanes in downcycled tire microplastics from synthetic turf football fields (Ferreira et al. 2024). This is important because volatile methylsiloxanes are not always central in traditional crumb-rubber discussions, which have often focused more heavily on PAHs, metals, phthalates, and SVOCs. Their inclusion reinforces the need to evaluate artificial turf as a mixture-exposure system rather than as a single-chemical exposure scenario.

Recent work on antioxidant p-phenylenediamines and their quinones in recycled rubber particles from artificial turf adds a further layer of concern because it links artificial turf infill with emerging tire-derived contaminants that are also discussed in broader tire-wear particle research (Zhao et al. 2024; Wang et al. 2024; Mayer et al. 2024). This does not imply that artificial turf users experience clinically meaningful exposure to every detected chemical, but it strengthens the rationale for targeted chemical documentation, aging studies, and leachate testing.

The mixture dimension is especially relevant to sports medicine. Athletes may encounter multiple low-level exposures repeatedly over time. Current risk assessments provide important reassurance under defined assumptions, but they may not fully capture repeated exposure to combinations of particles, VOCs, SVOCs, PFAS-related substances, metals, antioxidant transformation products, and rubber additives during high-intensity sport. This does not prove harm, but it supports precautionary monitoring and improved exposure characterization.

3.4. Athlete-specific exposure pathways and modifiers

Artificial turf exposure is sport-specific because athletes interact with the surface differently from occasional recreational users. The main relevant pathways are dermal contact, accidental ingestion, and inhalation.

Dermal exposure may occur through sliding, falling, tackling, stretching, goalkeeping, and direct skin contact with infill particles. Skin abrasions may increase concern because they can alter the normal barrier between the athlete and the playing surface. However, the provided evidence does not directly quantify how abrasions modify systemic uptake of artificial turf pollutants. Abrasions should therefore be treated as a plausible exposure modifier rather than a proven risk amplifier.

Accidental ingestion may occur through hand-to-mouth contact, transfer of particles to mouthguards, water bottles, gloves, clothing, or equipment, and incidental ingestion of crumb-rubber particles. Children and youth athletes may be especially relevant because of lower body mass and potentially greater hand-to-mouth behavior. Peterson et al. explicitly considered multipathway exposure, including ingestion, in their human-health risk assessment of recycled crumb rubber in synthetic turf fields (Peterson et al. 2018).

Inhalation is also relevant because exercise increases ventilation rate. Simcox et al. investigated VOCs, SVOCs, rubber-related chemicals, and PM10 in synthetic turf field environments, including active field use (Simcox et al. 2011). More recent in vitro and particle-aging evidence shows that turf-related materials can produce biologically active extracts or aged fragments, reinforcing the need to distinguish contact with bulk materials from contact with weathered, fragmented, or leached materials (Xie et al. 2022; Siegel et al. 2024).

Table 1. Sport-specific exposure modifiers relevant to artificial turf pollutant exposure.

Modifier	Relevance to Exposure Interpretation	Evidence Status Within the 23-Source Base
Age group	Children may have different exposure patterns and lower body mass	Supported indirectly through risk-assessment logic
Playing position	Goalkeepers and sliding or tackling athletes may have higher surface contact	Plausible sports-medicine inference
Training frequency	Repeated use may increase cumulative contact	Plausible inference; insufficient long-term athlete data
Indoor versus outdoor setting	Indoor environments may influence VOC and SVOC accumulation	Directly supported by field-investigation logic
Skin abrasions	May affect barrier function	Plausible but not directly quantified
Heat, weathering, and field aging	May influence chemical release, particle fragmentation, leachate bioactivity, and runoff chemistry	Supported by aging, weathering, and stormwater-oriented studies but not fully resolved in athletes

Source: Own synthesis.

These modifiers do not prove that artificial turf causes harm. Rather, they identify the types of sport-specific variables that should be considered in future exposure studies and facility-management decisions.

3.5. Health-risk interpretation

The current evidence supports a cautious but non-alarmist interpretation. Artificial turf materials may contain multiple pollutant classes, and athlete exposure pathways are plausible. However, direct evidence linking artificial turf pollutant exposure to specific long-term diseases in athletes remains limited. Murphy and Warner emphasized the need for further toxicological and epidemiological research, while Ryan-Ndegwa et al. concluded that definitive conclusions on real-world human-health risks remain difficult (Murphy and Warner 2022; Ryan-Ndegwa et al. 2024).

At the same time, risk-assessment studies should not be dismissed. Peterson et al. concluded that recycled rubber infill posed negligible risks under their multipathway assessment (Peterson et al. 2018). Pavilonis et al. also contributed to risk interpretation by evaluating bioaccessibility and exposure risk related to metals and SVOCs in artificial turf fill materials and fibers (Pavilonis et al. 2014). These studies help prevent the review from overstating risk based only on chemical detection.

The newer health-outcomes review by Karatela et al. further supports the interpretation that evidence of adverse health outcomes associated with rubber crumb infill remains limited and inconclusive, while also underscoring continued uncertainty around PAHs and metalloids (Karatela et al. 2025). In parallel, Siegel et al. demonstrated potential endocrine and cardiometabolic bioactivity in vitro from artificial turf material extracts, suggesting that biological plausibility requires further exposure-centered investigation rather than dismissal (Siegel et al. 2024).

The most scientifically defensible conclusion is that artificial turf pollutants represent a potential health-management issue, not a proven athlete-disease pathway. This distinction should guide both medical interpretation and facility policy. Sport clinicians, coaches, and facility managers should avoid categorical claims of either safety or danger. Instead, artificial turf should be managed as a complex material system requiring transparent procurement, exposure-aware operation, and periodic reassessment.

4. Discussion

4.1. Sport-facility management implications

The strongest practical contribution of this review is its translation of environmental-health evidence into sport-facility decision-making. Artificial turf management should be organized across the facility life cycle: planning, procurement, installation, daily operation, maintenance, monitoring, replacement, and disposal.

Several management measures are directly supported by the included evidence. First, procurement transparency should be required. Because pollutants may be associated with crumb-rubber infill, turf fibers, and backing materials, facility managers should request chemical documentation from suppliers. PFAS-related evidence supports including fluorinated compounds in procurement discussions, while crumb-rubber studies support scrutiny of tire-derived chemical profiles, VOCs, PAHs, metals, rubber additives, 6PPD-related compounds, and antioxidant transformation products (Massey et al. 2020; Lauria et al. 2022; Sakai et al. 2022; Kawakami et al. 2022; Nishi et al. 2022; Kubota et al. 2022; Zuccaro et al. 2023; Duque-Villaverde et al. 2024; Zhao et al. 2024).

Second, indoor ventilation should be treated as a sport-health management issue. Simcox et al. investigated air-related pollutants in synthetic turf field environments, including active-use conditions, supporting the relevance of air-quality management where indoor artificial turf facilities are used (Simcox et al. 2011). This recommendation should be framed as risk management rather than proof of clinical harm, because available studies do not yet establish disease outcomes in athletes.

Third, regulatory, runoff, and end-of-life planning should be integrated into artificial turf governance. Zuccaro et al. reviewed international policies concerning artificial turf and crumb-rubber infill, demonstrating variation in regulatory approaches and supporting the need for facility managers to consider compliance, surveillance, and disposal at the planning stage rather than only at replacement (Zuccaro et al. 2022). Broader tire-wear particle literature also supports source-process-end thinking, including source reduction, material substitution, runoff interception, and environmental control strategies (Wang et al. 2024; Mayer et al. 2024). Recent stormwater research adds field-level relevance by showing that artificial turf fields can act as recurring point sources of metals and emerging tire-derived contaminants, including 6PPD-quinone, in runoff pathways (Moloney et al. 2026).

Other recommendations are reasonable precautionary inferences from the evidence but should not be presented as proven interventions. These include particle-containment strategies, cleaning protocols, infill-migration control, shoe and equipment cleaning, runoff management, and targeted reassessment of heavily used fields. These actions follow logically from evidence that crumb-rubber particles can function as tire-derived pollutant sources, but the selected studies do not directly test each intervention’s effectiveness in sport facilities.

Accordingly, these actions should be framed as precautionary exposure-reduction principles, not as validated clinical prevention strategies. This distinction improves scientific credibility and prevents overstatement. Some possible management actions require further evidence before they can be strongly recommended. These include choosing specific alternative infills, implementing routine athlete biomonitoring, or defining universal exposure thresholds for artificial turf users. The current source base supports the need for comparative research but does not provide sufficient evidence to declare a single alternative material universally safer.

4.2. Proposed facility-management framework

The following framework translates the reviewed evidence into a practical decision model for sport facilities.

Table 2. Facility-management framework for artificial turf pollutant risk management.

Management Stage	**Key Question**	**Evidence Interpretation**	**Recommendation Strength**
Planning	What turf system is being considered?	Artificial turf is a multi-component system, not a single material	Evidence-supported
Procurement	Are chemical profiles available for fibers, backing, and infill?	PFAS-related compounds, rubber additives, metals, PAHs, VOCs, and crumb-rubber pollutants may occur in multiple components	Evidence-supported
Infill selection	Is crumb rubber being used?	Crumb rubber is a tire-derived particle material with chemical complexity	Evidence-supported
Indoor operation	Is ventilation adequate during active sport use?	VOCs, SVOCs, and rubber-related chemicals are relevant to air-quality management	Evidence-supported
Maintenance	Are loose particles and dust controlled?	Particle transfer is plausible, but intervention evidence is limited	Precautionary

Management Stage	Key Question	Evidence Interpretation	Recommendation Strength
Runoff and drainage	Are drainage pathways designed to reduce contaminant export?	Stormwater may mobilize metals and emerging tire-derived contaminants from artificial turf fields	Evidence-supported
Athlete hygiene	Are athletes encouraged to reduce particle transfer?	Ingestion and dermal contact are plausible pathways	Precautionary
Monitoring	Are high-use fields periodically reassessed?	Field-specific exposure may vary by use, age, weathering, and operating conditions	Precautionary
Replacement and disposal	Is end-of-life handling planned?	Policy evidence highlights regulatory variation and disposal concerns	Evidence-supported
Alternative materials	Is an alternative infill demonstrably safer?	Comparative evidence is insufficient and substitution should not rely on marketing claims alone	Research-dependent

Source: Own synthesis.

This framework should be interpreted as a synthesis generated from the reviewed literature, not as a guideline formally validated by any single included study.

4.3. Evidence gaps and future research directions

The most important evidence gap is the lack of long-term athlete-centered epidemiological research. Existing studies provide material characterization, exposure modeling, field investigation, systematic review evidence, in vitro toxicology, and policy analysis, but they do not adequately establish whether repeated artificial turf exposure contributes to specific long-term health outcomes in athletes. This gap is emphasized in the toxicological and systematic-review literature (Murphy and Warner 2022; Ryan-Ndegwa et al. 2024; Karatela et al. 2025).

Future research should prioritize real-world sport exposure. Laboratory extraction studies and modeled risk assessments are valuable, but athlete exposure depends on field age, temperature, ventilation, maintenance, infill type, athlete position, duration of play, and frequency of use. Particular attention should be given to children, adolescent athletes, goalkeepers, indoor-facility users, and athletes with frequent surface contact. Studies that compare new, weathered, and aged materials are especially important because artificial turf materials change chemically and physically over time (Xie et al. 2022; Siegel et al. 2024).

Mixture toxicity also requires further investigation. Artificial turf users may be exposed not to one pollutant but to combinations of crumb-rubber particles, PAHs, phthalates, metals, VOCs, SVOCs, PFAS-related substances, volatile methylsiloxanes, p-phenylenediamine antioxidants, quinones, 6PPD-related transformation products, and other rubber-derived additives. Current risk assessments are useful, but they may not fully capture repeated low-level mixture exposure in high-frequency sport settings. The broader tire-wear particle literature supports this concern by highlighting co-exposure, environmental mobility, and joint toxicity as unresolved issues (Mayer et al. 2024; Wang et al. 2024).

PFAS research requires further standardization. Lauria et al. and Zuccaro et al. show that conclusions depend strongly on analytical method and chemical fraction (Lauria et al. 2022; Zuccaro et al. 2023). Future studies should distinguish total fluorine, extractable organic fluorine, target PFAS, polymer-associated fluorinated materials, and fluorotelomer alcohols. Without this distinction, PFAS discussion risks becoming scientifically imprecise.

Finally, policy research should examine how regulatory differences influence real sport-facility practice. Zuccaro et al. demonstrate that artificial turf and crumb-rubber regulations vary across jurisdictions, creating uneven guidance for municipalities, schools, clubs, and facility operators (Zuccaro et al. 2022). Future work should connect chemical surveillance, procurement standards, field maintenance, runoff management, ventilation design, and disposal requirements into a coherent governance model. Stormwater-oriented field studies also indicate that environmental export from artificial turf fields should be evaluated alongside athlete exposure when defining facility responsibilities (Moloney et al. 2026).

4.4. Limitations

This narrative review has several limitations. First, it was restricted to 23 selected publications. This improves source discipline but limits the breadth of the review. Second, the included studies are heterogeneous in design, including toxicological review, systematic review, analytical chemistry, field investigation, in vitro toxicology, risk assessment, and policy analysis. This heterogeneity prevents quantitative synthesis. Third, the available literature contains limited athlete-specific epidemiological evidence, particularly regarding long-term outcomes after repeated exposure. Fourth, several management recommendations are precautionary inferences rather than interventions directly tested in the included studies. These limitations should be considered when interpreting the practical recommendations.

5. Conclusions

Artificial turf should be interpreted as a chemically complex, multi-component sport-surface system. The reviewed evidence identifies potential pollutant sources in crumb-rubber infill, turf fibers, and backing materials. Relevant pollutant groups include artificial-turf-derived microplastics, PFAS or fluorinated compounds, metals, VOCs, SVOCs, volatile methylsiloxanes, PAHs, 6PPD-related compounds, p-phenylenediamine antioxidants and quinones, and other rubber-derived chemicals. However, the presence of these substances does not automatically establish athlete harm.

Current evidence supports exposure plausibility and management concern, but not definitive causal claims linking artificial turf pollutant exposure to specific long-term diseases in athletes. Human-health risk assessments often suggest low or negligible risk under modeled assumptions, while systematic, toxicological, and material-characterization studies emphasize uncertainty regarding real-world exposure, repeated use, mixture toxicity, weathering, runoff, and long-term outcomes. Therefore, the most scientifically appropriate response is structured risk management rather than alarmism.

For sport-facility managers, practical implications include material transparency, chemical documentation, careful infill evaluation, ventilation management in indoor facilities, maintenance to reduce particle migration, periodic reassessment of heavily used fields, runoff control, and end-of-life planning. This approach aligns athlete-health protection with responsible sport-facility governance while remaining faithful to the current limits of the evidence.

Disclosure

This article is a narrative review based exclusively on previously published literature. No original experimental, clinical, or observational data were collected.

Supplementary Materials

Not applicable.

Author Contributions

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Institutional Review Board Statement

Not applicable. This article is a narrative review and did not involve human participants, animals, or original clinical data collection.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data sharing is not applicable to this article because no new data were created or analyzed. All sources used in this review are listed in the References section.

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Conflicts of Interest

The authors declare no conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing process

In preparing this work, the authors used ChatGPT for language editing, structural organization, formatting support, and verification of bibliographic style. After using this tool, the authors reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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